Energetic materials are chemical compounds such as explosives, propellants, pyrotechnics that have exothermic heats of decomposition (positive heats of formation). Energetic materials also include mixtures of materials that can react to produce high-energy releases. Explosive or high-energy releases typically are initiated by detonative or mechanical impact, friction, or runaway reaction that causes high temperature. The consequences of high-energy release can be explosive generation of gases, high pressure resulting from rapid heating of decomposition or reaction gases, growth to detonation due to high pressure growth, or equipment rupture from high pressure and/or high temperature.

Examples of high-energy materials and events include:

- Chemical compounds that contain triple bonds (acetylenic compounds) or double bonds (unsaturated compounds) and some nitrogen-containing compounds (such as “azo” chemicals).
- Mixtures of fuels and oxidizers.
- Molten metals in contact with water (rapid phase transitions).
- Reactive metals (such as Sodium) and water (generating hydrogen gas and heat).

The difference between chemical explosions and explosive rupture of an air tank is that the first generates energy and the second releases the energy stored in the compressed air.
Energetic events can be characterized in the following manner:

<table>
<thead>
<tr>
<th>Event</th>
<th>Mechanism</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical-energy explosion</td>
<td>Pressure/Volume Bursts</td>
</tr>
<tr>
<td>Chemical-energy explosion</td>
<td>Runaway Reaction</td>
</tr>
<tr>
<td>Fuel-oxidizer fire or explosion</td>
<td>Vapor/air combustion; Dust/air combustion; Metal/oxidizer reaction</td>
</tr>
<tr>
<td>Steam explosion</td>
<td>Rapid phase transition</td>
</tr>
</tbody>
</table>

Energetic materials can be in the form of gases, vapors, liquids, solids mix or mixtures of them which rapidly release energy in the above mechanisms.

Explosive reactions have been studied extensively, and computer models have been developed to quantify the energy release, based on the likely reactions and the physical and chemical properties of the materials involved. Such computations can yield the maximum energy output but cannot determine the rate of reaction.

To determine the reaction rate, laboratory testing and studies are required, using one of several testing methods. The types of testing equipment that can be used include the Accelerating Rate Calorimeter [ARC], the Carius tube, the Differential Scanning Calorimeter [DSC], and the RC1 reactor, pressure-time test, closed bomb testing, and strand burn testing.

For violently-reactive materials, the Heavy Confined Cap (flier plate) test can be used to determine the relative energy-release rate for a sample as compared to reference energetic materials. The setup is shown in Figure 1 and utilizes a heavy plate on top of a steel block that contains a test tube. If the sample explodes when the blasting cap is fired, the height of flier plate launch gives an estimate of the combination of energy-release rate and total energy for the sample material.

From the testing, a relative ranking of the material output can be obtained, as follows:

<table>
<thead>
<tr>
<th>Material</th>
<th>Height of flier plate above ground</th>
</tr>
</thead>
<tbody>
<tr>
<td>#8 Blasting cap alone</td>
<td>4ft.</td>
</tr>
<tr>
<td>#8 cap with gasoline and air</td>
<td>6ft.</td>
</tr>
<tr>
<td>#8 cap with Ammonium Nitrate</td>
<td>25ft.</td>
</tr>
<tr>
<td>#8 cap with shot shell powder</td>
<td>55ft.</td>
</tr>
<tr>
<td>#8 cap with Nitromethane</td>
<td>120ft.</td>
</tr>
</tbody>
</table>
Safety Consulting Engineers has conducted extensive testing on many chemicals, fuel/oxidizer mixes, propellants, detonable mixes, and explosives over the past 30 years. Other test methods that are utilized to evaluate the energy released in chemicals and materials in gaseous, liquid, and solid forms are underwater bubble-energy tests, shock sensitivity, detonation velocity, explosion-pressure measurements, thermal stability, and initiation-safety testing. Other test methods used at Safety Consulting Engineers are as follows:

• Shock sensitivity [Mil-STD and UN 1.1.2]
• Heavy confinement small scale shock sensitivity test [SCE method]
• High pressure strand burn testing [MIL Spec]
• High pressure small scale strand burn testing [SCE test]
• Detonation velocity and pressure tests [US Bureau of Mines test]
• Pressure DSC testing [SCE test]
• Plate dent test [Mill spec]
• Small scale underwater bubble pulse test [MIL spec]
ABOUT DEKRA INSIGHT

DEKRA Insight is the global leader in safety at work. We specialize in helping clients evolve both their organizational culture and their operational environment, empowering them to reduce injuries, save lives, protect assets—and in the process, achieve higher performance. Our integrated solutions have been honed over decades and are proven to reduce risk and enhance organizational cultures:

• Safety strategy – Building your roadmap for long-term safety improvement
• Culture & leadership – Building high-performance teams
• Behavioral reliability – Assuring unwavering execution of safety systems and processes
• Governance & capabilities – Providing the framework for safety execution and results
• Safety Resource Optimization – Putting your resources to work for safety
• Management Systems – Developing and aligning the systems that drive safety excellence
• Data Analytics & Metrics – Information and insight that drive results
• Process Safety Lab Testing – Precise data, analysis and tools for process safety decision and action
• Process Safety Engineering – Engineering and advice for process safety excellence everywhere

DEKRA Insight represents the collective expertise of our legacy businesses and partners, each an institution in safety: BST, Chilworth, Optimus Seventh Generation, RCI Safety, RoundTheClock Resources, and Russell Consulting.

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