SAND2020-8678R

Occurrence Causal Analysis Report
Inadvertent Reaction During the Pressing of Energetic Material

Occurrence Number: NA--SS-SNL-2000-2020-0002
Event Date: 6-30-2020
SAND No.: SAND2020-1184957

REPORT DATE: 08-14-2020

Sandia National Laboratories

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1. Event Summary

On June 30, 2020, an inadvertent reaction occurred during pressing of the energetic material pentaerythritol tetranitrate (PETN). The location of the event was the energetic component Rapid Prototype Facility (RPF), where similar operations performed on a variety of energetic materials are routinely provided for customers throughout Sandia National Laboratories (SNL). A background on pressing of energetic materials is provided to enhance clarity in the description of the event. This background includes a description of the equipment, materials, and tooling present during the event:

- Press: pneumatic press manufactured by SCHMIDT Technologies that extends a piston vertically down with a force of 10,000 lbf.
- Acceptor: customer-provided piece part into which the energetic material was to be consolidated
- Energetic Material: PETN, a crystalline powder with a consistency similar to powdered sugar
- Press tooling: A set of tools consisting of a base, funnel, ram, and shims:
    - The base mates with the press to ensure proper alignment of the press and tooling. The base also enables the operator to align and secure into place the acceptor and funnel.
    - The funnel is a tube with the same inner diameter as the acceptor and a tight tolerance to the ram. If pressing a freestanding pellet rather than into an acceptor, the funnel is often referred to as a die.
    - The ram is a smooth-surface finish rod that contacts the energetic material, transferring the force from the press. The ram is slightly longer than the funnel and will extend slightly beyond the funnel for alignment.
    - The shims compensate for the excess length of the ram during the pressing operation to control the relative height of the consolidated energetic material into the acceptor.

There are two common methods for pressing; pressure loading and dead-stop loading. Pressure loading relies on the force applied to the energetic material to control the final consolidated density, which is typical for pressings of high-density (approaching the theoretical maximum density) of the energetic material. Dead-stop loading relies on the mass of powder and a fixed volume to control the final consolidated density. The tool design limits the stroke of the pressing operation. The full force applied by the press is supported by the tooling and the energetic material. Dead-stop loading is typical for pressing to low-density or for maintaining tight dimensional tolerances on the final product. In both dead-stop and pressure loading, a dwell ranging from 30 seconds to several minutes is performed; this is the press continuing to apply force after reaching the final pressure (for pressure loading) or position (for dead-stop loading). During the event, the acceptor piece part was placed into the base. The ram was inserted without shims into the funnel, and the ram protruded from the bottom of the funnel by approximately 0.010 in. The extended ram allows precision of the funnel to the acceptor. After alignment the base is tightened to maintain alignment of the funnel and the acceptor.

The PETN was weighed (approximately 0.8 g) and poured into the funnel. This mass of powder was to produce a low-density pressing of PETN. The powder loosely filled the acceptor and up into the funnel above. The ram was inserted into the funnel and came into contact with the PETN. Shims were placed around the ram to limit the ram stroke during the pressing. The tooling assembly – base, acceptor, power, ram, and shims – was placed in the alignment interface under the press. The press was remotely operated with the press piston moving at approximately 0.25 in. per second until the funnel and shims prevented further extension, which is the dead-stop position. At the beginning of the dwell portion of the operation, the operator heard an audible metallic sound quickly followed by flash of light. There was no injury to the operator as a result of the event. There was no visible damage to equipment beyond the destruction of portions of the pressing tooling. The tooling did not produce fragments, and all remnants were contained within the assembly. The tooling was segregated for further

technical evaluation and the press was removed from commission until absence of non-visual damage was verified.

The pressing operation included a request to produce 8 pellet pressings: 4 pressings of one lot of PETN (Lot 1) and an additional 4 pressings from a second lot of PETN (Lot 2). The event occurred on the fifth operation, which was the second pressing using the PETN from Lot 2. The operations performed were consistent with the applicable operating procedure and the employed hazard mitigations were consistent with those outlined in the Work Authorization Form (WAF) that serves as a portion of the organization's Work Planning and Control (WP&C) process. The activity has been paused pending completion of a readiness review evaluation to glean insight as to why this powder reacted during the operation.

A causal analysis was conducted July 14, 2020. The causal analysis team included representation from Occurrence Management (reporting specialist and causal analyst), Safety and Security Regulatory Support (SSRSP), Sandia Field Office (SFO), the ES&H Coordinator, Safety Engineering Subject Matter Expert (Explosive Safety SME), workers, and a manager from Department 2554, EM Dynamic & Reactive Science. During the causal analysis, the team conducted a barrier analysis and discussed proposed corrective actions and potential forensic investigation topics. It is evident that the barriers in place provide defense in depth for Department 2554 operations. There are barriers in place to mitigate a reaction and to mitigate the effects of a reaction.

As the mitigations were demonstrated as successful the event is communicated primarily to inform the community at large with openness to continual improvement through feedback.

Two issues and one cause (applicable to both issues) were identified and addressed:

Issue 1. Inadvertent reaction occurred during the pressing of PETN.

Issue 2. Sensitivity of energetic materials is application dependent. The complexity of the pressing operation, which must include the tooling and acceptor piece parts, further complicates understanding the potential insults to PETN.

Cause 1. Pressing of PETN is not consistent in its response.

Due to the nature of the event, Department 2554 has established a technical team of subject matter experts (SMEs) to forensically assess what may have contributed to the inadvertent reaction during the pressing of PETN. The team will evaluate all aspects of the operation to include contributions due to the energetic material (two different lots of PETN), the press and its function, and the specific pressing process used during the full operation. However, this evaluation does not a guarantee finding a direct cause for this event but will contribute to the learning of the energetics community.

Report Number: NA--SS-SNL-2000-2020-0002

Title of Report: Inadvertent Reaction from Pressing Energetic Material

Categorization Criteria and Reporting Level: Informational Report Level Occurrence Report, according to DOE Order 232.2A reporting criterion 10.1 - An event, condition, or series of events that does not meet any of the other reporting criteria, but is determined by the Facility Manager or line management to be of safety significance or of concern for that facility or other facilities or activities in the DOE complex.

- Discovery date and time: 6-30-2020 at 3:45 p.m. (All times are MT)
- Categorization date and time: 6-30-2020 at 5 p.m.
- SFO courtesy contact date and time: 6-30-2020 at 6:26 p.m.

Location of Event: SNL/NM, Tech Area II, Building 905, Room 1315

Responsible Manager (RM): Leanna Minier, Department 2554

Causal Analysis Information:

- Date of fact-finding meeting: 7-02-2020
- Name and level of causal analysis lead: Brittni Romero, Senior Causal Analyst – High
- Type(s) of analysis performed: Barrier Analysis (Table 1).
- Date(s) of causal analysis meeting: 7-14-2020 (via Skype)

Causal Analysis Team

Role	Invited	Attended
Responsible Manager	☒	☒
Causal Analysis Facilitator	☒	☒
Individuals Involved in the Event	☒	☒
Center 600 ES&H Coordinator	☒	☐
Division Integration Manager	☒	☐
Center 600 ES&H SME Cognizant of the Hazards Involved in the Event	☒	☒
SFO Representative or Occurrence Program Manager	☒	☒
Member of Safeguards and Security Regulatory Support Program	☒	☒
Department 635 Performance Assurance Reporting Specialist	☒	☒
Others at the Discretion of the Responsible Manager or Reporting Specialist	☒	☒

2. Event Details

Problem Statement: An inadvertent reaction occurred during the pressing of energetic material.

Operating Conditions of Facility at Time of Event: Normal operations.

Immediate Actions: The equipment was secured, and the activity was paused until further evaluation.

3. Causal Analysis Results

The WP&C performed is for pressing operations covering a variety of energetic materials, including materials which are more sensitive than PETN. As such, there are mitigations identified in the table for which the effectiveness cannot be evaluated for this event because the PETN material was not susceptible to the hazard that drives the barrier. The example is Electro-Static Discharge (ESD). PETN is not sensitive to ESD generated by personnel and the event did not occur during an operation in which a discharge was possible, such as picking up material when at a different electrical potential.

Table 1. Barriers in Place Proving Defense in Depth.

Barrier/Control	Effectiveness	Additional Information
Administrative and Engineering Controls		
Potential gradient for Building 905	Not applicable to the event	Even if inclement weather was present it would not have impacted the event; work is performed indoors to protect from stray electrical events.
Shielded workstations with 2.5 g trinitrotoluene (TNT) equivalent limit	Effective	Prevented the reaction from reaching the worker during the inadvertent reaction. Mitigated the effects of the reaction.
Grounded tables, powder balances, and height gage	Not applicable to the event	All tables and balances are electrostatic discharge(ESD) rated.
ESD chairs on grounded conductive floor mats	Not applicable to the event	
Humidity control and monitoring	Not applicable to the event	
Two-hand remote operation	Effective	Controls are in a fixed location and cannot be moved. System setup itself is an engineering control; two hands must be outside of the box.
Ionizers	Not applicable to the event	
Splitting working quantities in assembly room	Effective	By performing preliminary operation in a room appropriate for handling larger quantities of material the event

		did not exceed either the operational room limits or the blast rating for the safety shielding.
Non-sparking metal tools	Effective	
Personal Protective Equipment		
Safety glasses with shields	Effective	Provided defense in depth in combination with the effective blast shielding.
Grounding wrist straps (with daily checks)	Not applicable to the event	Not in contact with the powder during press operations. Taken off while operating press. Powder is not ESD sensitive.
Conductive steel-toed safety shoes (with daily checks)	Not applicable to the event	Conductive steel-toed safety shoes not worn at the time of the event.
65 % minimum cotton clothing	Effective	Cotton lab coat was not worn because cotton clothing was being worn. Barrier is associated with ESD hazard which is not applicable to this event.
Gloves	Not applicable to the event	Not used/not in contact with powder while operating press.
Barriers/Controls in place during Pressing Operations		
During pressing operations two hands are required	Effective	Engineered control – hands outside the pressing box during pressing by the design of the press.
Usage of shims to prevent over-pressing	Effective	Process control – stainless steel; never in touch with the powder (not a material compatibility issue).
Visual inspections – tooling used for pressing shall be reviewed by pressing SME prior to use	Effective	Process control – visual inspection looking for discoloration/fatigue/cracks/damage done before the job starts. Note: visual examination is only what can be seen by the naked eye.
Cleaning process – Kimberly-Clark Kimtech Science Wipes (Kimwipes) and lint-free cloth	Effective	Visual inspection confirmed that wiping cleaning removed all residual powder from previous operations. Process control – lint-free cloth and

		brush to clean inside the tool between each pressing and clean ram with lint-free cloth.
Buddy system	Effective	Administrative control – another operator was nearby and responded immediately. No action was required as no injury to personnel resulted from event

Evidentiary Support:

A review of the following documents was performed –

- ETG-GP-0108 Work Planning and Control Process for the Explosives Technologies Group (2550) Rev f
- ETG-OP-0431 Process Hazards Analysis for Explosives Testing Revision E-1
- 54-0172P ESD & Non-ESD Energetic Material Pressing WAF
- ETG-OP-0257 Energetic Powder Pressing Operations Rev K-1

4. Corrective Action Plan

See Table 2.

Table 2. Corrective Action Plan

Problem Statement: An inadvertent reaction occurred during the pressing of energetic material.

Fact(s)	Issue	(C#) Cause and Cause Code	(CM#) Compensatory Measure Action	CM Action Owner & Due Date	(LT#) Long Term Corrective Action	LT Action Owner & Due Date
F1. On June 30, 2020 an inadvertent reaction during pressing of energetic materials occurred. F2. Approximately 800 mg of (0.8 gram) pentaerythritol tetranitrate (PETN) was being pressed. F3. PETN is a non-electrostatic sensitive explosive. F4. A steel die is used for this operation (with a diameter of approximately 3 in and a height of 4.5 in). The pressing operation occurs with the lowering of the aligned steel ram into the die containing the powder (ram was aligned to the die prior to addition of PETN powder). F5. The operation being performed is "dead-stop loading," meaning the ram is mechanically blocked by a shim atop the die in operation prior to powder reaching maximum pressed density. F6. A pneumatic press is used for this operation; operating pressure is from house air at 120 pounds per square inch (psi), which produces up to a 10,000-pound force. The pressure-limiting factor is the house air pressure limit. F7. The press was operated by the simultaneous pressing of two buttons outside the Lexan shield box containing the press (engineering control: each button requires a hand to press, buttons require simultaneous depression to activate press assuring hands are outside of box). F8. During the pressing of the powder into the die, there was an acceptor cup and alignment operation between the pressing ram and acceptor for axial alignment. F9. Shims were used to control a pressed powder flush condition. F10. The pneumatic press ram was at the end of its stroke when initiated. The ram lowered at its usual slow speed and pushed down the pressing ram on the tool set. The reaction happened at the end of that process. The technician heard a "tink" sound and the reaction produced a quick flash of white light and a loud sound. F11. Single customer request – this was an eight-part job (required eight PETN pressed pellets) and required a switch of PETN powder lots halfway through the pressing operation. PETN powder lot was changed after the fourth consecutive pressing of the day. F12. The inadvertent reaction happened on the sixth consecutive pressing operation of the day, which was the second consecutive pressing of the second PETN lot being pressed.	I1. Inadvertent reaction occurred during the pressing of PETN. I2. Sensitivity of energetic materials is application dependent. The complexity of the pressing operation, which must include the tooling and acceptor piece parts, further complicates understanding the potential insults to PETN.	C1. Pressing of PETN is not consistent in its response. *A2B6C02 Defective or failed material*	Not applicable.	Not applicable.	LT1. The die that was in use during the inadvertent reaction will be taken out of service. LT2. Department 2554 will form a technical team to forensically investigate the contributing factors of the inadvertent reaction. Investigation results and any necessary improvements will be documented. Topics to be reviewed include, but are not limited to – ▪ Evaluation of the materials that were pressed. ▪ The press and its functional operation. ▪ The pressing process itself.	R&D S&E Material Science Department 2554 8/14/2020 Manager Department 2554 9/18/2020

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F13. Post-event, the shield was intact showing no visible damage. F14. The die involved in the inadvertent reaction has not been taken apart, pending establishment of technical assessment team. F15. The pressing operation with this press has been successfully accomplished multiple times in the past years (nothing abnormal; last job was performed in April). F16. Per standard process, the tooling was visually inspected before work. F17. Discoloration/cracks/fatigue/smooth operation/good fit are features that were visually inspected. F18. A standard cleaning process was performed between each operation (cloth to remove any residual powder). F19. Mitigations that were in place provided adequate protection. • The tooling looks like it was in the middle of the job, it didn't look like it was subject to a reaction. • Two-hand button operation; Lexan box protection; eye protection; distance from the press to shield; grounded tables and chairs; cotton clothing. • Weighing and tool seal – no gloves for that scenario; no physical contact between hands and powder. • Grounded bench; building ground bar along the lab that was routinely checked by facilities or when any changes were made. No changes to workstation had occurred since previous scheduled inspection.						

5. Occurrence Report Approval

Signature(s) confirm approval of the completed occurrence report and the corrective action plan.

Responsible Manager: Leanna Minier, Department 2554

Signature: Leanna Minier Date[1]: 14 August 2020

[1] Report was signed on time (7-30-2020) per MN471022, *ES&H Manual Chapter*, "ES&H Reporting". Amendments were made to the report on 8-10-2020.