DEFENSE NUCLEAR FACILITIES SAFETY BOARD

Washington, DC 20004-2901

October 17, 2018

The Honorable James Richard Perry
Secretary of Energy
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585-1000

Dear Secretary Perry:

In September 2017, the Defense Nuclear Facilities Safety Board reviewed the special tooling program at the Pantex Plant. We identified five deficiencies within the special tooling program: (1) application of the *Special Tooling Design Manual*, (2) weld quality and application of non-destructive evaluation techniques, (3) pedigree of preventive maintenance and in-service inspection programs, (4) performance criteria within safety basis documentation, and (5) special tooling loading conditions. These deficiencies continue to exist within the special tooling program. Further information on each is provided in the enclosure.

Yours truly,

Bruce Hamilton
Chairman

Enclosure

c: Mr. Joe Olencz

Enclosure

Pantex Plant Special Tooling Program Review

This report details the deficiencies that the Defense Nuclear Facilities Safety Board's (Board) staff review team found within the special tooling program. Deficiencies exist in the application of the Pantex Plant (Pantex) *Special Tooling Design Manual* [1], assurance of weld quality and application of non-destructive evaluation (NDE) techniques, pedigree of preventive maintenance and in-service inspection (ISI) programs, utilization of performance criteria within safety basis documentation, and special tooling loading conditions. Based on these deficiencies, the National Nuclear Security Administration (NNSA) Production Office (NPO) and Consolidated Nuclear Security, LLC (CNS), have not demonstrated that the currently implemented process for design, fabrication, production usage, and maintenance of special tooling at Pantex assures that all special tooling can meet its required safety-related functions.

Background. Pantex utilizes special tooling to support and manipulate nuclear explosive components during operations at the plant. Special tooling functions as a passive design feature managed through the special tooling program, and is credited within the Pantex safety basis to meet minimum factors of safety. Adherence to these design criteria assures special tooling does not fail during normal and abnormal loading conditions. Failure of special tooling to meet its credited safety functions could lead to impacts to sensitive components of the nuclear explosive (e.g., dropping of unit or equipment impacts onto the unit), potentially resulting in high order consequence events. The requirements for the special tooling program are identified in the NPO-approved Pantex *Sitewide Safety Analysis Report* [2], and specifics are flowed down into the contractor-established *Special Tooling Design Manual*, the *General Requirements for Tooling Fabrication & Inspection* [3], and the *Special Tooling Operations* [4] manual.

During the onsite review and follow-up teleconference, the staff review team evaluated various aspects of the Pantex special tooling program, including safety basis integration; flow down of functional requirements; technical support documentation and analyses; preventive maintenance and ISI of special tooling; quality assurance requirements and processes; and corrective actions resulting from nuclear explosive safety (NES) evaluations, the CNS Special Tooling Top-Down Review [5], and the 2015 NPO Special Tooling Assessment [6].

The staff review team evaluated the special tooling program and its ability to ensure that credited pieces of special tooling are adequately designed, fabricated, and inspected, ensuring their ability to perform safety significant and/or safety class functions. During this review, the staff review team evaluated more than 75 special tooling designs, including a vertical slice of special tooling for the B61 program and a horizontal slice of common special tooling designs across weapon programs (e.g., vacuum lifting fixtures, lifting and rotating fixtures, and workstands). Evaluation of the B61 special tooling allowed the staff review team to examine some of the oldest and newest tooling designs that are currently authorized for use. The staff review team noted deficiencies, opportunities for improvement, and noteworthy practices, which will be described in further detail in the remainder of this report.

Content and Application of *Special Tooling Design Manual*. No consensus or industry standards currently govern the design, fabrication, inspection, and maintenance of special tooling, including factors of safety, weld inspections, and quality assurance practices. Because there are no standards specifically applicable to these aspects of special tooling, the guidance and requirements provided in the *Special Tooling Design Manual* frequently do not have documented or cited bases.

Deviations from Manual Guidance—The staff review team identified multiple instances where Pantex did not meet the requirements and guidance in the *Special Tooling Design Manual*. For example, Pantex currently does not perform NDE for special tooling welds with low factors of safety, which appears to be in direct conflict with the *Special Tooling Design Manual* (see following sections). In addition, the *Special Tooling Design Manual* specifies a minimum of 3:1 factor of safety to yield or 5:1 factor of safety to ultimate strength, as well as the 1.25:1 factor of safety to yield for rare events (i.e., seismic or falling man loads). The staff review team noted instances in which tooling does not meet the minimum factors of safety specified in the *Special Tooling Design Manual*:

- Workstand (061-2-0815) pieces 64 and 65 did not meet the 1.25:1 factor of safety at yield for rare events.

- Penetrator case sleeve (061-2-0738) did not meet the 3:1 factor of safety at yield.

- Assembly press (061-2-0841) did not meet the 3:1 factor of safety at yield.

Pantex personnel stated that designs that deviate from the *Special Tooling Design Manual* only require the same approval process as those designs adhering to the manual. As the *Special Tooling Design Manual* provides the means to satisfy the programmatic requirements set forth in the *Sitewide Safety Analysis Report*, the staff review team suggests elevating deviations for additional review and approval beyond the typical process.

Ambiguous Guidance—The *Special Tooling Design Manual* contains imprecise guidance and requirements allowing for multiple interpretations of certain sections. This has the unintended consequence of allowing deviations when implementing the manual. For instance, the section on weld inspection requirements recommends NDE for welds with a factor of safety less than 10:1 [1]. However, the manual does not clarify whether this is a factor of safety to ultimate or yield strength, and does not specify whether this stress analysis must be done for both yield and ultimate strength. The staff review noted instances in which Pantex personnel did not implement special tooling NDE because there was no analysis of the factor of safety to ultimate strength. Similarly, the special tooling engineer has latitude to evaluate for either 3:1 at yield or 5:1 at ultimate strength for normal loads at his or her discretion.

Basis for Rare Events Factors of Safety—The staff review team identified a concern with the minimum factors of safety for rare events, as recommended in the *Special Tooling Design Manual*. The choice of factors of safety for rare events (1.25:1 at yield strength and 1.5:1 at ultimate strength) does not represent the level of uncertainty in the tooling construction and abnormal loading parameters. For instance, welds in special tooling are currently not subject to NDE beyond visual inspection. The lack of NDE of welds introduces uncertainty regarding the material properties of special tooling. Moreover, as discussed in the 2013 Approved Equipment

Program Volume II NES Master Study (AEP Vol. II NESMS) [7], factors of safety from 1.25 to 1.5 are typically used in weight-sensitive applications and are appropriate only if there is a strong degree of certainty in the material properties, loads, and resultant stresses. The special tooling program does not include measures to provide additional assurance for the performance of tooling with low factors of safety, such as load testing to failure or higher maintenance frequency.

The closure package that Pantex submitted for the 2013 AEP Vol. II NESMS finding "Factor of Safety for Special Tooling Rare Event Analysis" discusses the level of uncertainty present in design and materials for special tooling. However, the closure package focuses on several key areas where uncertainty may be present without comprehensively analyzing all sources of uncertainty and variability in design, fabrication, and operation of special tooling [8]. For instance, weld quality, lack of in-house material certification, and damage (including material fatigue, wear, and handling damage) during operations may all introduce uncertainty and variability in performance. Moreover, the closure package provides only a qualitative assessment of uncertainty in the determination of factors of safety, and does not present a quantitative uncertainty analysis to demonstrate that the safety margins for rare event loading are appropriate.

Special Tooling Design–Ductile Versus Non-Ductile Systems—Due in part to the perceived low frequency of seismic events and falling man events—assumed to be analogous to seismic events in the *Special Tooling Design Manual*—Pantex employs less conservative factors of safety for rare event loads. Factors of safety for rare event loading are developed in the *Technical Basis for Safety Factors* [9], which supports the *Special Tooling Design Manual* and *Special Tooling Seismic Analysis* [10]. This technical basis document states that "criteria for tooling design packages are equivalent or more conservative" [9] than DOE Standard 1020-2002, *Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities* [11]. Part of this justification specifically focuses on not crediting the ability to use energy absorption factors to reduce seismic loads for ductile structural systems similar to building structures.

While the justification for rare event load paths states that ductile systems will use the factor of safety of 1.25:1 to yield, and non-ductile systems will use a 1.5:1 factor of safety to ultimate strength, there is no guidance in the *Special Tooling Design Manual* for what is classified as ductile behavior or materials to avoid in the design of ductile systems. The manual also does not incorporate the principles of capacity-based design or overstrength of critical elements of a load path that consensus seismic standards use. Furthermore, the *Special Tooling Materials Database* [12] employed by special tooling engineers contains examples of permitted materials with little or no ductility, such as plastics and high-performance alloys (where yield and ultimate strength can be within a few percent of each other). Without guidance for determining when systems can be considered ductile, special tooling engineers determine independently which safety factor should be used as an acceptance criterion and which materials are suitable for tooling subject to rare event loads. This use of engineering judgement could lead to variability in selected factors of safety and potentially result in a non-conservative special tooling design.

Special Tooling Design–Failure Probability—The ultimate goal of seismic design methods that meet DOE Standard 1020 is to achieve a certain probabilistic performance for structures, systems, and components (SSC). An SSC designed for PC-3 design loads using this standard has an input ground motion with an annual probability of exceedance of $4x10^{-4}$ but is designed with enough margin to have an annual probability of failure of less than 10^{-4}. In order to meet this performance, consensus standards such as American Society of Civil Engineers Standard 43-05, *Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities* [13], restrict certain types of materials, designs, or analysis techniques to ensure adequate ductility and quality. Lower performance SSCs, in turn, have smaller input forces and higher annual probabilities of failure, and are permitted to use less rigorous design methods and employ a wider variety of materials or structural types. The *Special Tooling Design Manual*, however, does not incorporate these principles, relying entirely on its rare event loading factors of safety.

Neither the *Special Tooling Design Manual* nor the *Special Tooling Seismic Analysis* address how the 10^{-4} annual probability of failure expected of PC-3 SSCs is ensured through their selection of safety factors. DOE Standard 1020 ensures this performance through the use of consensus standards built around estimates of SSCs' statistical margin to failure. Because special tooling is a class of custom-made design features, there is not the same statistical basis for their beyond design basis performance like other SSCs that DOE Standard 1020 was meant to address. Typically for seismic design, the approach to non-standard designs or structures is to <u>not</u> credit ductility and use the most conservative design factors to bound the uncertainty in a structure's beyond design basis performance, or to use overstrength factors to ensure the controlling failure modes are well-understood, ductile failures [14].

During the 2013 AEP Vol. II NESMS, a NES Study Group evaluated Pantex's special tooling program and noted this issue in a statistical analysis of performance for special tooling under rare-event loads. As described in section 3.3.2 of the Master Study report, the NES Study Group highlighted that probabilistic margin requires understanding not just the deterministic safety factors of the special tooling, but the hazard curves that determine the probability of exceedance for various intensities of ground motion [7]. In order to have sufficient design margin, the overstrength of special tooling (defined in this case by its factor of safety) has to be combined with the probability of both design basis and beyond design basis ground motions, as well as uncertainties in these two values. The NES Study Group also observed that factors of safety this low are normally associated with designs with high degrees of certainty in not just design and fabrication, but operating environment, rather than abnormal conditions such as a falling man or seismic event.

Pantex developed a white paper justifying its rare event loading approach that was formalized into the submitted closure package for the 2013 AEP Vol. II NESMS finding "Factor of Safety for Special Tooling Rare Event Analysis," and documented within the *Special Tooling Design Manual* [8]. The closure package qualitatively states that the conservative design practices, low probability of earthquakes, known material properties and operational environment for tooling, and the maintenance of special tooling create a conservative framework for use of these safety factors. In addition, this closure package states that "loads and resultant stresses are known with a high degree of certainty" [8] citing the *Special Tooling Seismic*

Analysis. However, this document provides only a high-level discussion and does not cite a probabilistic goal for tooling performance, relying instead on the tooling program as a whole to provide sufficient performance. The high degree of certainty in the demands to which tools are evaluated does not translate to low variability of potential seismic demands. There is no quantitative basis that the safety factors and other aspects of the special tooling program provide seismic margins comparable to equivalent safety SSCs.

Weld Quality and NDE of Welds. The *Special Tooling Design Manual* requires NDE of welds for the fabrication or modification of tooling in high-stress applications with factors of safety less than 10:1. Pantex personnel do not implement NDE beyond visual inspections done by a qualified weld inspector. However, per the Metals Handbook Volume 10, *Failure Analysis and Prevention* [15], while visual inspection can identify visible features such as cracks, weld mismatch, and bead convexity or concavity, the following subsurface features would not be identified through visual inspection, but may be identified through additional NDE: underbead crack, gas porosity, inclusions (slags, oxides, or tungsten impurities), incomplete fusion, and inadequate penetration. These subsurface features can result in a weld with lower strength or ductility. During the review, the staff review team identified three concerns:

- *Weld Performance*—As discussed previously and shown in Table 1 of Appendix A, the *Special Tooling Design Manual* specifies a minimum factor of safety to yield strength of 1.25:1 and a factor of safety to ultimate strength of 1.5:1 for rare event loadings, such as seismic and falling man loads. Special tooling engineers do not consider any reduction of weld performance due to poor weld quality through either joint efficiency factors (per American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code Section VIII [16] and American Petroleum Institute Standard 653 [17]) or more conservative safety factors (such as phi-factors used for American Institute of Steel Constructors (AISC) 360-10, *Specification for Structural Steel Buildings* [18]). Due to the low minimum factors of safety allowed by the *Special Tooling Design Manual* for rare event scenarios, a reduction in weld performance may challenge the special tooling's ability to perform its credited safety function. For example, ASME Boiler and Pressure Vessel Code Section VIII assumes a joint efficiency factor of 0.7 for a double welded butt joint without radiography or equivalent NDE. Applying the 0.7 joint efficiency factor to tooling designed to the minimum 1.25:1 factor of safety to yield strength (for rare event loading) results in a factor of safety of 0.875:1. Thus the tooling would be expected to yield during rare event loading.

- *Plastic Deformation*—There are instances where special tooling is anticipated to deform plastically in the course of meeting its design function during abnormal events (i.e., a deflection limit for dynamic load), rather than meeting more conservative factors of safety specified in the *Special Tooling Design Manual*. In cases of plastically deforming structures, higher weld quality and performance are necessary to ensure the structure performs as expected, as exemplified by demand-critical welds defined in AISC 341-10, *Seismic Provisions for Structural Steel Buildings* [14]. However, Pantex personnel do not perform NDE of welds subject to plastic deformation, such as the W76 swing arm (000-2-0831). Upon a dynamic impact, the

W76 swing arm is credited to deform no more than a certain distance vertically, such that the unit underneath will not be impacted. Without NDE verification of weld integrity, Pantex cannot ensure that such special tooling will meet its safety critical design function.

- *Vendor Quality Issues*—Pantex personnel provided the staff review team with vendor performance reports for past and present special tooling vendors [19]. The staff review team noted that several of these reports included instances of receipt refusal of procured tooling due to weld quality issues. Pantex personnel identified these quality issues during receipt quality control visual inspections. The staff review team noted that due to the nature of weld quality issues (e.g., weld penetration depth, heat-affected areas, pores, cracks, inclusions), visually identified weld quality issues could indicate the presence of additional weld quality concerns that cannot be identified through visual inspection alone, and may go undetected.

As part of the submitted closure package for the 2013 AEP Vol. II NESMS finding "Preventative Maintenance," Pantex personnel included additional information in the *Special Tooling Design Manual* detailing different types of NDE [20]. While this information includes the advantages and limitations of different techniques, it does not specify any NDE requirements, and thus does not address the concerns noted above.

Pedigree of Special Tooling Preventive Maintenance and ISIs. The staff review team noted three methods that Pantex used to ensure that special tooling—credited design features in the safety basis—can continue to meet its safety functions throughout its time in service: (1) as-built designs (e.g., inherently conductive special tooling fabricated out of stainless steel), (2) production technician inspections for damage prior to use, and (3) special tooling preventive maintenance and ISIs.

Based on observed preventive maintenance activities and subsequent discussions, the special tooling preventive maintenance and ISI programs lack the rigor expected for maintenance on and inspection of equipment with safety class and/or safety significant functions. For instance, in contrast to other safety-related SSCs, preventive maintenance and ISIs on special tooling are not performed per detailed written procedures. As a specific example of maintenance performed with sufficient rigor, during review of the maintenance and cognizant system engineering programs at Pantex in December 2017, the Board's staff observed preventive maintenance of ESD flooring—a design feature—in two nuclear explosive facilities. Workers conducted the preventive maintenance according to a detailed, written procedure (i.e., Technical Procedure TP-MN-06291, *ESD Flooring Resistance Measurements, Annual, Plant* [21]) and with an appropriate level-of-use (e.g., reader-worker practices). In contrast, the staff review team observed that for special tooling maintenance, Pantex relies heavily on worker knowledge and the skill of the craft to meet specifications that the special tooling engineer provides in the supporting data sheets. This practice could compromise the reproducibility of test results and prevent reliable testing of important features, given the potential variability in results.

Performance Criteria Assurance. The performance criteria for meeting the functional requirements for safety class and/or safety significant special tooling are absent from the safety basis and reside in supporting documents (i.e., design requirements documents, supporting data sheets, and analyses). Although the requirements for the special tooling program are governed by the NPO-approved *Sitewide Safety Analysis Report*, the performance criteria for program-specific special tooling are neither within Pantex safety basis documentation nor reviewed and approved by NPO. DOE Standard 3009-1994, Change Notice 3, *Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Documented Safety Analyses*, delineates expectations that the safety basis chapter on SSCs include "[i]dentification of the performance criteria necessary to provide reasonable assurance that the functional requirements will be met" [22]. The lack of NPO approval of the specific performance criteria conflicts with DOE Standard 3009-1994 expectations.

Special Tooling Loading Conditions. During its review, the staff review team noted the following deficiencies regarding special tooling loading conditions:

W76 Swing Arm—Pantex relies on the test results of a single (prototype) W76 swing arm [23] to validate that it will perform its safety basis function under analyzed loads. The staff review team identified several concerns with this testing, including the following:

- The test assessed whether the swing arm would perform its safety function in the case of dynamic loading (i.e., the special tooling would vertically deflect less than a certain distance during an impact scenario). However, Pantex performed only a single test, and Pantex personnel informed the staff review team that it was not performed with a high quality pedigree, such as in accordance with the quality assurance requirements of ASME NQA-1, *Quality Assurance Requirements for Nuclear Facility Applications* [24]. When coupled with the weld quality concerns and weld manufacturing variances noted above, it is unclear to the staff review team how Pantex can ensure that all swing arm copies will be able to perform their safety functions during an impact scenario (i.e., they will not deflect beyond the specified limit and potentially impact the unit).

- The staff review team identified an additional falling man scenario with the W76 swing arm that Pantex had not previously analyzed. As this impact scenario applies a load on a longer lever arm, there exists the possibility for a larger deflection of the swing arm than previously postulated, which would potentially defeat its safety function. Pantex personnel stated that they do not consider the scenario to be credible. However, the staff review team contends that during transient movements of the swing arm, production technicians have a direct pathway to apply load on the longer lever arm.

Falling Man Rare Event Loading—The staff review team noted non-conservative assumptions regarding placement and distribution of falling man rare event loading. Per the reviewed analyses, special tooling engineers typically apply the falling man loading to the center of gravity of the components supported by special tooling. This usually results in a symmetric distribution of loads. The staff review team questioned the appropriateness of this approach, postulating that it may be more conservative and bounding to assume an uneven distribution of loads, such as primarily loading one beam of a two-beam system rather than applying equal loading across both beams.

Specifically, for the B61 program, the staff review team identified non-conservative assumptions with the placement and distribution of falling man rare event loads involving a configuration between the support beam (061-2-0730) and support and alignment fixture (061-2-0860). In this configuration, the staff review team noted that falling man horizontal loads could impart a torsional load component to the support beam that Pantex had not analyzed. While this may be a robust piece of special tooling with respect to vertical loading, Pantex did not evaluate the factor of safety for torsional load. As justification, special tooling engineers noted that the angles from which production technicians can approach this configuration preclude this torsional loading. However, nuclear explosive operating procedures do not restrict approach angles to protect this assumption, and subsequent staff review team observations of B61 nuclear explosive operations revealed that a falling production technician could approach at the angles of concern and could impact this configuration to generate out-of-plane loadings not currently evaluated.

Loss of Special Tooling Design Function during Impacts—Functional requirements for special tooling include factors of safety based on static loading conditions. However, as observed during falling man studies performed at Virginia Polytechnic Institute and State University [25], special tooling, such as tooling employing a banjo plate configuration, had considerable elastic deformation during certain dynamic impact scenarios. Pantex does not typically consider how deformations under loading could render the special tooling incapable of performing its safety function throughout the loading cycle (e.g., a holding fixture deforming under impact and allowing a held component to be dropped).

Opportunities for Improvement. The staff review team identified several opportunities for improvement in the special tooling program.

- *Periodic Reevaluation of Analyses*—The staff review team noted that there currently is no requirement or guidance to Pantex personnel that requires the periodic reevaluation of special tooling engineering analyses. Such a program would allow opportunities for Pantex to self-identify incomplete or deficient conclusions, bolster the analysis methodology to include modern methods (e.g., finite element analysis software), and provide additional assurance in the conclusions of the special tooling analysis.

- *NES Study Concerns*—NNSA does not currently have near-term plans to redesign or upgrade B61, W76, and W87 special tooling to address outstanding NES Study concerns, including reducing the size of gas cylinder carts to eliminate/minimize hazards and discontinuing an electrical tester cart (i.e., for the PT3746) that is susceptible to toppling. NES Study Groups have identified aspects of special tooling associated with these weapon programs that do not meet the intent of Seamless Safety for the 21st Century, including the W76 program's continued use of a swing arm and the absence of an engineered control for potentially cracked high explosive and unnecessary unit lifts on the W87 program. Furthermore, the staff review team noted that when a NES Study Group identifies potential deficiencies in the special tooling design or implementation on one weapon program (e.g., elimination of a similar swing arm on the W78 program by introduction of a transfer cart), NNSA and the Pantex contractor do not consistently address the deficiency on other applicable weapon programs.

- *Validation Testing*—The staff review team identified that Pantex only performs limited testing of special tooling to validate engineering calculations. For example, the first destructive test of a piece of special tooling (i.e., the B61 support beam) was conducted in July 2017. This destructive test was used to confirm the conclusions of the associated engineering analysis. In case of special tooling with factors of safety lower than required by the *Special Tooling Design Manual*, additional testing would be valuable to eliminate uncertainty regarding whether the tooling will perform its design function.

- *Safety Catches*—The staff review team evaluated the use of W76 vacuum lifting fixtures and the 2015 issue in which cracks were identified in vacuum lifting fixture safety catches (see Figure 1). The safety catches are a secondary feature to prevent a drop of high explosive charges should vacuum fail on the lifting fixture. The staff review team is concerned that actions taken to-date may not prevent recurrence of cracking of safety catches. Pantex continues to rely on production technicians to identify cracking during routine prior-to-use inspections. The staff review team believes that application of an ISI or introduction of a specific step within the nuclear explosive operating procedure to check for safety catch damage prior to use would bolster the reliability of this check. Alternatively, the safety catches could be redesigned, substituting a material with a lower likelihood of cracking (e.g., appropriately coated metal).

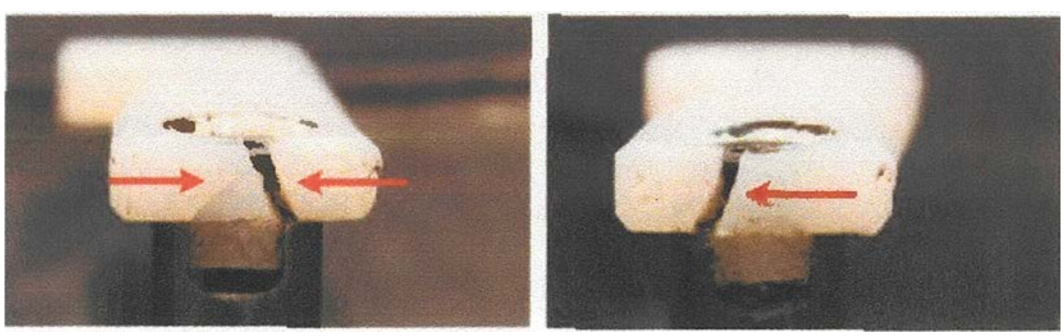

Figure 1. *Cracked Safety Catches in the W76 Aft Disassembly Fixture, 076-2-0382* [26].

- *Special Tooling Acceptance Process*—As discussed onsite, in one instance, Pantex delivered an incorrectly fabricated W88 lifting and rotating fixture (088-2-0377) to production for use, and technicians subsequently installed it in the facility and began operations. On this specific piece of special tooling, a component used to mate the tooling to the stand was out-of-tolerance. The component is designed with a slight bend; however, the bend angle was out-of-tolerance by approximately 10 degrees, preventing the component from interfacing properly with other special tooling during the operation. The bend angle is neither part of the receipt inspection for subcontracted tooling (as a recordable feature), nor part of the quality assurance inspections required before the tooling is released for production use. A NES Change Evaluation was ultimately required to authorize the use of a temporary procedure to remove the special tooling and continue operations. In light of this occurrence and other instances of special tooling used without all necessary reviews and approvals [27], the staff review team encourages improvements to the special tooling acceptance process.

Noteworthy Practices and Updates. The staff review team identified a number of noteworthy practices that Pantex has implemented that contribute to the improvement of the overall safety posture of special tooling program. In addition, the staff review team noted several ongoing initiatives.

Noteworthy Practices—The staff review team noted several practices that contribute to the safety posture of the special tooling program.

- **Sharing Lessons Learned.** Pantex has established methods for sharing lessons learned among special tooling engineers (e.g., use of "Design Tips" documentation). The staff review team specifically noted an example with the B61 presray plate (061-2-0761). Given incidents with this special tooling (e.g., loss of air pressure due to intrusion of foreign material through the supply air), Pantex took appropriate actions to apply in-line air filters to all special tooling requiring air pressure to perform its required functions.

- **Quality Assurance Consensus Standard Implementation.** As part of its 2016 approval of the combined Y-12 and Pantex *Quality Assurance Program Description* [28], NPO required Pantex to apply the quality assurance requirements of NQA-1 to the special tooling program [24, 29]. Historically, special tooling quality assurance has been governed by the NNSA Weapon Quality Policy (i.e., NAP-24), which establishes specific weapon and weapon-related product-focused quality requirements for designing, producing, and surveilling weapon products.

  As part of its extent of condition review, Pantex identified a large number (between 5,000 and 10,000) of special tooling designs that will require additional evidence to meet the commercial grade dedication requirements of NQA-1. Pantex is conducting a pilot study on six pieces of special tooling in order to inform NPO of the potential cost and timeframe for complete implementation of NQA-1 for special tooling. The tooling selected for the pilot study includes an assembly cart (000-2-1230), W76 lifting & rotating fixture (076-2-0365), assembly stand (000-2-0832), and a B83 vacuum fixture (083-2-0460).

- **Supplier Quality Control Improvements.** The staff review team identified some noteworthy practices by Pantex Supplier Quality. First, Pantex uses a risk-informed process to determine whether a given supplier requires additional Pantex oversight to ensure that the special tooling received from the supplier meets Pantex quality requirements. The staff review team notes that these risk-based surveillances occur in addition to the triennial Pantex re-evaluation. Second, Pantex has developed a *Supplier Quality Handbook for Special Tooling Suppliers* [30] that will help inform special tooling suppliers of many of the pitfalls encountered by Supplier Quality. Third, Pantex has demonstrated its willingness to remove suppliers who are routinely at risk from the Qualified and Approved Suppliers List until the supplier demonstrates compliance with Pantex Supplier Quality requirements.

Ongoing Initiatives—Pantex plans to make improvements to the *Special Tooling Design Manual*, as well as special tooling engineering analyses, including the following:

- **Clarification of Design Manual.** Pantex has revised the *Special Tooling Design Manual* to include clarifications and additional language to provide guidance on factors-of-safety requirements for special tooling and the use of backup features with friction-based special tooling. However, Pantex has not provided sufficient additional guidance for factors of safety for press assemblies. Pantex has clarified that either the factor of safety of 3:1 at yield or 5:1 at ultimate strength can be used in analysis, but does not provide guidance on the appropriateness of one value or the other.

- **Guidance for Deviations from Design Manual.** Pantex has updated the *Special Tooling Design Manual* to provide additional guidance regarding the approval process for special tooling designs that deviate from manual requirements. However, the approval process for deviations from the design manual does not require elevation beyond the normal approval chain.

- **Engineering Mentors.** Pantex has updated the *Special Tooling Design Manual* to implement a mentor system, in which senior special tooling engineers will be tasked with providing clarification and improvements to the design manual.

- **Updates to Special Tooling Analyses.** Pantex is updating several special tooling engineering analyses that were discussed during the staff review team's onsite review (e.g., the W76 swing arm (000-2-0831), B83 belly band (083-2-0476), W87 primary lifting fixture (087-2-0400), and B61 penetrator case sleeve (061-2-0738) analyses).

  Specifically for the W76 swing arm, the staff review team questioned whether the single dynamic loading test would bound the impact of a falling man scenario, as was indicated in the *W76 Hazard Analysis Report* [31]. Pantex personnel have updated the tooling analysis to defend its safety basis assumption that dynamic testing bounds the falling man scenario. Pantex personnel have updated their swing arm calculation to demonstrate that forces from the test exceed the current falling man load.

Appendix A
Special Tooling Safety Factors

The *Special Tooling Design Manual* presents factors of safety for custom special tooling within the anticipated load paths. These values do not apply to off-the-shelf components, such as casters or pressurized tubing. Non-pressurized off-the-shelf components are held to a factor of safety of 1:1 to working load or 5:1 to vendor-stated failure load. Pressurized off-the-shelf components are held to a factor of safety of 1:1 to working load or 4:1 to vendor-stated burst pressure. In addition, the *Special Tooling Design Manual* includes minimum factors of safety for several other types of special tooling, such as systems relying on vacuum or acting to restrain compressed air hoses; however, these are not discussed further in this report.

The factors of safety most relevant to this report are stated below:

Design Case	To Yield Strength		To Ultimate Strength
Minimum allowable design factors of safety for normal loading (e.g., weight of components, anticipated pressures)[1]	3:1	or	5:1
Minimum allowable design factors of safety for rare events (falling man and seismic)	1.25:1	or	1.5:1
Minimum factor of safety that does not require non-destructive evaluation of welds	N/A		10:1[2]

Table A-1. *Factor of Safety Requirements for Custom Special Tooling Components [1].*

Of note, special tooling does not require redundancy of load path elements in design [1]. As noted in the report, based on analyses reviewed by the staff review team, special tooling engineers typically apply the loading to the center of gravity of the components supported by special tooling. This usually results in a symmetric distribution of loads.

1. Pantex personnel do not currently apply these minimum factor of safety requirements to special tooling that includes high-pressure press components; Pantex personnel plan to update the *Special Tooling Design Manual* to reflect slightly less conservative factor of safety requirements for this special tooling type.

2. The current revision of the *Special Tooling Design Manual* does not state whether this factor of safety requirement is to yield strength or to ultimate strength; Pantex personnel indicated that it is intended to be to ultimate strength.

References

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