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The LLNL Heavy Element Facility -- Facility Management, Authorization Basis, and Readiness Assessment Lessons Learned in the Heavy Element Facility (B251) Transition from Category II Nuclear Facility to Radiological Facility

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The LLNL Heavy Element Facility -- Facility Management, Authorization Basis, and Readiness Assessment Lessons Learned in the Heavy Element Facility (B251) Transition from Category II Nuclear Facility to Radiological Facility

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ABSTRACT

This paper presents Facility Management, Readiness Assessment, and Authorization Basis experience gained and lessons learned during the Heavy Element Facility Risk Reduction Program (RRP). The RRP was tasked with removing contaminated glove boxes, radioactive inventory, and contaminated ventilation systems from the Heavy Element Facility (B251) at Lawrence Livermore National Laboratory (LLNL). The RRP was successful in its goal in April 2005 with the successful downgrade of B251 from a Category II Nuclear Facility to a Radiological Facility. The expertise gained and the lessons learned during the planning and conduct of the RRP included development of unique approaches in work planning/work control ("*Expect the unexpected and confirm the expected"*) and facility management. These approaches minimized worker dose and resulted in significant safety improvements and operational efficiencies. These lessons learned can help similar operational and management activities at other sites, including facilities restarting operations or new facility startup.

B251 was constructed at LLNL to provide research areas for conducting experiments in radiochemistry using transuranic elements. Activities at B251 once included the preparation of tracer sets associated with the underground testing of nuclear devices and basic research devoted to a better understanding of the chemical and nuclear behavior of the transuranic elements. Due to the age of the facility, even with preventative maintenance, facility safety and experimental systems were deteriorating. A variety of seismic standards were used in the facility design and construction, which encompassed eight building increments constructed over a period of 26 years. The cost to bring the facility into compliance with the current seismic and other requirements was prohibitive, and simply maintaining B251 as a Category II nuclear facility posed serious cost considerations under a changing regulatory environment. Considering the high cost of maintenance and seismic upgrades, the RRP was created to mitigate the risk of dispersal of radioactive material during an earthquake by removing the radioactive materials inventory and glove box contamination. LLNL adopted the goal of reducing the hazard categorization of the Facility from a Category II Nuclear Facility to a Radiological Facility.

To support the RRP, B251 transitioned from a standby to a fully operational Category II Nuclear Facility, compliant with current regulations. A work control process was developed, procedures were developed, Authorization Basis Documents were created, work plans were written, off-normal drills practiced, a large number of USQ reviews were conducted, and a "Type II" Readiness Assessment (RA) was conducted to restart operations. Subsequent RA's focused on specific operations. Finally, a four-step process was followed to reach Radiological Status: (1) Inventory Reduction and D&D activities reduced the inventory and radiological contamination of the facility below the Category III threshold (DOE-STD-1027), (2) Radiological Safety Basis Document (SBD aka HAR) was approved by NNSA, (3) the inventory control system for a Radiological Facility was implemented, and (4) verification by NNSA of radiological status was completed.

Figure 1. The LLNL Heavy Element Facility

[1] For referral to the appropriate author, contact to whom questions should be addressed.

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Key to this success is the RRP philosophy in a schedule driven paradigm.

- *"Expect the unexpected and confirm the expected"*
- Recognize when you reach the point of diminishing returns,
- Develop robust processes that anticipate and can handle surprises,
- Plan, plan, and re-plan *"Measure twice, cut once"*

Staff from multiple organizations played significant roles in downgrading B251 from Nuclear Category 2 to Radiological

Impressive safety accomplishment
No one had decontaminated facilities with this level and variety of high specific activity isotopes (e.g. ^{244}Cm, ^{238}Pu)
Dramatic cost savings, $250 million under current regulations

1.0 INTRODUCTION

The Risk Reduction Program (RRP) successfully downgraded the LLNL Heavy Element Facility (B251) from a Category II Nuclear Facility to a Radiological Facility. The expertise gained and the lessons learned during the planning and conduction of the RRP included development of unique approaches in work planning/work control ("*Expect the unexpected and confirm the expected"*) and facility management. These approaches minimized worker dose and resulted in significant safety improvements and operational efficiencies. These lessons learned can help similar operational and management activities at other sites, including facilities restarting operations or new facilities starting new operations. To support the RRP, B251 transitioned from a standby to a fully operational Category II Nuclear Facility, compliant with current regulations. A work control process was developed, procedures were developed, Authorization Basis Documents were created, work plans were written, off-normal drills practiced, a large number of USQ reviews were conducted, and a "Type II" Readiness Assessment (RA) was conducted to start up operations. Subsequent RA's focused on specific operations. Finally, a four-step process was followed to reach Radiological Status. Best management practices for Facility Management, Authorization Basis, and Readiness Assessments were a key factor in this success.

2.0 HISTORY

B251 was constructed at LLNL to provide research areas for conducting experiments in radiochemistry using transuranic elements. B251 activities once included the preparation of tracer sets associated with the underground testing of nuclear devices and basic research devoted to a better understanding of the chemical and nuclear behavior of the transuranic elements. Highlights of B251's history include:

- Approximately 20 nuclides discovered using B251 fabricated accelerator targets.

- B251 prepared accelerator target contributed to 1974 discovery of Element-106, subsequently named seaborgium.
- B251 developed capabilities to separate and purify exotic isotopes, e.g., ^{242m}Am.
- B251 conducted research on quantitative use of gamma spectroscopy to measure concentrations of fissile isotopes. This work aided development of safeguards systems for nuclear materials accountability.

The B251 Facility safety systems and experimental systems were deteriorating with age, even with preventative maintenance. A variety of seismic standards were used in the facility design and construction, which encompassed eight building increments constructed over a period of 26 years. In 1993, the high cost to meet new regulatory requirements (e.g. seismic upgrade) drove LLNL to discontinue programmatic operations. In 1995, B251moved from Operational to Standby mode.

The RRP was created to mitigate the risk of dispersal of radioactive material during an earthquake by removing the radioactive material inventory and glove box contamination. The cost to bring the facility into compliance with the current seismic and other requirements was prohibitive, and simply maintaining B251 as a Category II nuclear facility posed serious cost considerations under a changing regulatory environment. LLNL therefore adopted the goal of reaching Radiological Facility status. In 2002, the RRP began establishing an integrated plan to de-inventory and decontaminate the facility to Radiological Status. DOE granted B251 a two-year schedule exemption from 10 CFR 830 to conduct the RRP. RRP activities were motivated by a schedule driven paradigm.

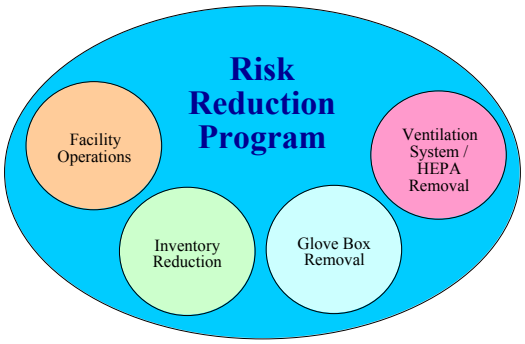
The RRP inherited a contaminated and aging facility. Anticipating return of funding and operations, researchers had left experiments in glove boxes, blue caves, hot cells, etc. This posed a unique challenge for facility management and the RRP. Facility management began to restart B251 as a Category II nuclear facility under the current regulatory environment, while the RRP searched for new homes for rare, and useful, materials. This included contacting the Inventory Disposition Path Development–Nonactinide Isotope and Sealed Source Management Group (NISSMG), Inactive Actinides Working Group (AIWG), and conducting presentations at meetings & personal contacts within LLNL, DOE Complex, and industry.

B251 successfully completed a Readiness Assessment (RA) to Restart Operations, an RA to perform source encapsulation, and two subsequent RAs to conduct D&D activities. The RRP transferred rare and useful radioactive materials to other sites, decontaminated and decommissioned (D&D) glove boxes and ventilation systems, and packaged and shipped waste offsite. By November 2003, inventory was reduced to 20% of the initial inventory and on April 8, 2005, B251 achieved Radiological Status. Subsequently, unique and large equipment, such as an isotope separator and the blue caves (large shielded gloveboxes with manipulators), were decontaminated and dispositioned, and the RRP was completed.

Figure 3. Isotope Separator

3.0 RRP ACTIVITIES

The RRP was composed of facility management and three projects: Inventory Reduction, Glovebox Removal (D&D), and Ventilation System Removal. These projects are discussed in several publications, for more information, see the References section.



4.0 RESTART: TRANSITIONING FROM STANDBY TO OPERATING CATEGORY II NUCLEAR FACILITY

The facility restart required B251 to develop staff, work processes/facility, and regulatory infrastructure within the safety basis (e.g. ES&H, AB, USQ, CM, QA, CAPs) as a fully operational Category II nuclear facility.

4.1 Staffing

To accomplish its goals within schedule required recruitment of experienced individuals in key positions, and consult with facility retirees who provided a knowledge base on operations dormant for the past decade was vital. During Standby, B251 was staffed with three people. The RPP needed sufficient staffing for multiple teams to conduct concurrent operations. We recruited staff with the required training and who had experience with high specific activity alpha emitting isotopes. Most staff required training in the current regulatory environment. Most staff required training for the RRP's unique work practices, including:

- Open air transfers, pass in/pass out
- Blue cave manipulator operations

Hazards Control staff was essential for safe operations; the RPP found that an in-house Health Physicist and at least 3 hazard control technicians were required to conduct concurrent operations.

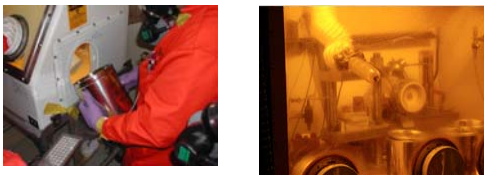


Figure 4. Open air transfer and legacy enclosure

4.2 Develop Work Processes

B251 developed work processes for a fully operational Category II nuclear facility. This rapid transition occurred in months. The RPP developed a large variety of procedures and work plans for doing diverse and unique operations. Facility management developed robust processes that could handle surprises from legacy unknowns:

- a characterization process involving several techniques, including radiography and gamma spectroscopy;
- a work planning process including Hazards Control review; and
- strategic Authorization Basis documents.

Key lessons learned include:

- develop procedures and training for off-normal conditions, develop flexibility in work plans,
- maintain a prudent margin below regulatory inventory limits (e.g., potentially exposed material (PEM) and material at risk (MAR)) during operations in case legacy inventory items were found or determined to be of higher activity than records indicate, and
- develop work planning process to ensure controls are in place to do work safely.

A noteworthy, and often overlooked, lesson learned is that an effective Document Control Center (DCC) greatly increases efficiency of engineering staff and is essential in a schedule driven paradigm.

5.0 RISK REDUCTION PHILOSOPHY IN SCHEDULE PARADIGM

B251's success resulted from a guiding philosophy that carefully balanced key factors:

- Regulatory Compliance
- Schedule
- Dose
  - Dose exposure during decontamination for D&D activities;
  - Dose exposure during handling/repackaging for inventory activities;
- Cost
  - Decontamination cost for D&D activities (LLW vs. TRU);
  - Repackaging cost for inventory activities;
  - Waste disposal cost (LLW vs. TRU).

Adapting to a schedule driven paradigm in the current regulatory environment can be challenging. The RRP operated compliant within the current regulatory environment. B251 was held and audited to similar regulatory standards (DNFSB, NNSA, OA, USQ, CM, ALARA, DOE-HQ Training, etc…) as NNSA's Plutonium Facilities. New personnel were often frustrated by the complex and bureaucratic rules of nuclear facility operations. Staff often take time to transition to the DOE Complex's current regulatory environment. Several approaches helped smooth this transition: the strong guidance of the RRP management's *"safety first"* philosophy, teaming of less experienced personnel with more experienced personnel, and a strong team *"can do"* attitude. The knowledge that the RPP was of significant importance to LLNL and NNSA, combined with strong upper management support, spurred the team to be extra diligent, pay greater attention to safety, and put in the extra effort to make the RPP a success.

Schedule driven paradigm requires foresight and planning. Key schedule lessons learned include:

- Recognize what you control and what you don't (e.g. NNSA approval of RAs, positive USQDs, Safety Basis Amendments, shipping).
- Prepare for changes in regulator interpretations of requirements (e.g. DOE-STD-1027).
- Foresight in preparation for changing regulatory environment is critical to meeting schedule, preventing delays from audits, corrective action plans, being shutdown.

- Plan for potential delays during interactions with regulators (e.g. waiting for regulator approval of RA's, positive USQDs, and Safety Basis Amendments).
- Direct/line item funding essential to match regulator expectations with funding and schedule. Proper budgeting critical to ensure proper staffing levels.
- "*One person deep*" creates failure points and stress in schedule driven paradigm. Recognizing these failure points, cross training of personnel and having backup signatory authorities is critical for schedule. Understand connection between productivity and happiness. Positive reinforcement. Match skills and needs.
- Overshoot inventory reduction goals because shipping delays, container issues, and other work delays will occur and regulatory expectations/ interpretations may change.
- Schedule based upon current regulations – not upon "old rules" in force at time facility operational.
- Add contingency for changing regulatory environment
  - do not assume Readiness Assessments successfully completed and approvals received in timely manner,
  - do not assume outside audits & rule changes kept to minimum, and will not impact schedule, and
  - do not assume Authorization Basis reviews and approvals received in timely manner.
- Add contingency for project considerations (e.g. accidents, responding to accidents, shipping delays, delays in receiver site identification and shipment approvals obtained).
- *"Better to be Radiological than to be Right!"* A successful general knows which battles to lose and which battles to win in order to win the war, i.e. assess when it is best to stop fighting regulators' unusual interpretations and instead perform the work they request.
- *"How clean is clean enough?"* In a schedule driven paradigm for D&D, first determine the endpoint. This is especially important when there are significant uncertainties concerning inventory or contamination. At the beginning of a D&D project, it is important to establish attainable goals for decontamination, determine stopping point for decontamination (diminishing returns), and when to instead explore alternative options (shipping or waste disposal).

6.0 FACILITY MANAGEMENT APPROACHES

B251 Facility Management found that transparent business practices and building trust with the regulators was essential for successful operations and meeting schedule. Several best practices for facility management were observed.

"*Clear goals and interpretations"* It is important to obtain clear, defined goals formally approved by NNSA *in writing.* An example of such goals is the objectives to reach Radiological status:

1) Reduce inventory to below the Category III threshold (DOE-STD-1027),
2) Obtain approval for a Radiological Safety Basis Document (SBD aka HAR),
3) Demonstrate a Radiological inventory system,
4) NNSA verification step .

"We don't always think alike" recognize that NNSA field offices may interpret requirements differently than the contractor.

"Keep an ear to the ground" to determine expectations to ease transitions and not be surprised; recognize regulatory priorities and conservative interpretations.

"Bite the bullet" recognize the impact of audit findings on schedule driven projects. It is very difficult to cope with audit findings and still make schedule. As the regulatory environment continues to get stricter, it is better to do work right the first time rather than later under even more strict interpretations. Pace yourself with workload balancing – assess rules and proactively respond at a time of your choosing as you won't have time to react later.

"Keep upper management in the loop" as upper management's backing and interpersonal interactions are critical.

"Good relationships are good business practices" LLNL's Chemistry and Environmental Services (CES) increased characterization throughput by factor of 20. Good relationships with numerous organizations across the DOE Complex helped facilitate timely response at receiving sites (onsite and offsite) via shipping agreements. In 3 weeks, one organization achieved an equivalent of 1 year of normal waste throughput. Personal interactions are critical to finding new homes for items and facilitating shipments in a timely manner. It is

important to work with receiving facilities early in the process, to ensure container and shipping issues are resolved in a timely fashion. This also helps minimize unnecessary repackaging activities.

"Embrace the Matrix" the matrix organizational approach to staffing helped supply necessary manpower from multiple organizations (e.g. Transportation, Materials Management, Hazards Control, Chemistry, Engineering, Waste Management). The matrix organization structure allows for rapid staffing across diverse technical skill sets. To be successful with this approach, it is important to have prioritization on staff and budget.

7.0 REGULATORY AND FACILITY INFRASTRUCTURE

Facility management developed facility & regulatory infrastructure (e.g. AB, USQ, CM, QA, ES&H, CAPs) and conducted 364 USQ reviews over the course of the RRP, coordinated 15 major Authorization Basis documents, developed a new TSR and Facility Safety Plan (FSP), and obtained approval for a Radiological Safety Basis Document (SBD) – the first of its kind under new institutional requirements. Although a "graded approach" was originally planned under the Risk Reduction Plan, B251 ended up paving new ground in unexplored regulatory arenas, with first of a kind documents. The following sections address Authorization Basis strategies, best practices, and organizational structure; Facility Infrastructure strategies, and Readiness Assessment strategies.

7.1 Authorization Basis Strategies

An overall authorization basis strategy is to anticipate the full scope of work at the beginning of a program. Submit positive USQDs/Safety Basis Amendments early in project, recognizing the time required for the DOE approval process. Anticipate issues with legacy equipment, like-for-like replacements simply may not exist; assess these legacy issues early as this may result in program delays while equivalent parts are analyzed and USQDs prepared. Delay for resolving AB issues is not acceptable in an aggressive schedule, so anticipate potential positive USQDs and tackle the problems early. Plan for adequate implementation time for completing NNSA commitments (e.g. SAR/TSR implementation, TSR Verification, FSP training, annual updates). Utilizing conservative assumptions in USQDs will *increase* productivity. Assume conservative, bounding values for legacy radioactive inventory, don't assume precise values to the last significant digit (e.g. assume 20 Ci instead of 11.1 Ci), as you may find surprises. Be aware that process impurities may be a bigger concern than daughter products for some isotopes. Assume conservative impact on equipment important to safety (EITS) given legacy equipment and wide variations possible in D&D.

An effective overall AB strategy considers the Safety Basis and planned work. Strategic DSA preparation increases USQD efficiency and can assume issues at system level for legacy/D&D environment. A strategic, conservative hazard analysis/accident analysis is essential to allowing work to proceed. Minimize credited controls and develop clear system boundaries. Whenever possible, base accident analysis on inventory assumptions (e.g. PEM vs. MAR) instead of crediting mitigating controls (e.g. facility systems). It is important to understand a system's or SSC's safety function. Lack of understanding can inappropriately increase USQD workload. Staff may not recognize legacy issues with infrastructure and may not address potential D&D activities. Specific Limiting Conditions of Operations (LCOs) for specific systems and rooms may be utilized instead of facility-wide MODE change. Realistically anticipate potential conditions. Ensure that the time for TSR Required Actions is realistic given the infrastructure conditions. Replacement parts may not be available to bring systems back on line as soon as desired. Develop Required Actions such as the use of portable generators, portable CAMs, and other equipment in a legacy, D&D environment. These strategies were essential in the RRP achieving its objective.

7.2 AB Best Practices

Several best practices for Authorization Basis (AB) strategies were observed.

"Keep an open mind" Feedback & lessons learned are important, either as opportunity for improvement or alternative pathway to keep in your back pocket. Plan for the unexpected so work can proceed on schedule when surprises occur – and they will occur.

"Assess & Adhere" Assess the relevant regulations and strictly adhere to them; no less and no more unless benefits outweigh the costs. Adhering to regulations is essential in a schedule driven paradigm; there is no time to do the work twice.

"Feedback Mechanisms" Develop, disseminate and implement feedback via monthly meetings with NNSA, biweekly with institutional AB management, feedback distributed to staff (e.g. completed USQDs,

audit findings), discuss key points, emphasize need to meet NNSA expectations.

"In the loop" Recognize the potential impact of frequently changing NNSA and auditor expectations. It is essential to provide feedback mechanisms for safety analysts so they can continue to meet regulator expectations. A best practice is to, when possible, use safety analysts to perform all aspects of the USQ process and keep them *"in the loop."* Staff who perform USQ reviews infrequently may not be able to keep up with frequent regulatory changes or may not be receiving the necessary feedback on changing expectations. This approach allows workers to focus on conducting their work and safety analysts to focus on safety analysis.

"Consistency" Centralized USQ process promotes consistency and higher quality USQDs meeting expectations.

"Templates" Develop strong USQDs for each type of work (e.g. key facility SSC maintenance, inventory operations, D&D operations, ventilation D&D) and boilerplate reminders of NNSA expectations (e.g., answer the questions, address interim hazards and worker safety issues, provide the appropriate level of detail, and use clear DSA/TSR citations).

"Do it right the first time" Better to produce good work the first time – it will survive audits and can be re-used. Do not rush, redo, and then fight the auditors.

7.3 AB Organizational Structure

An effective facility management organization can greatly enhance the productivity of projects conducting work in the facility. Organization of facility staff requires foresight and is developed over time in response to lessons learned and best management practices. This organizational structure was extremely efficient and very responsive while maintaining the necessary focused expertise in their respective areas. B251 organized AB staff into 3 focused teams: the USQ Review Team, the AB Document Team, and the Special Projects Team.

The USQ Review Team organized safety analyst staff based along the lines of the projects, dedicating specific staff to the inventory reduction project, the D&D project (i.e., glove boxes), the ventilation project, and facility operations. One primary safety analyst was assigned to each project as the USQD preparer. Each project prioritized their safety analyst's work. This approach eliminated inherent inefficiencies with staffing reassignments, aka "Robbing Peter to pay Paul." A few safety analysts were kept in reserve. USQDs were prepared by dedicated safety analysts who maintained knowledge of the frequently changing NNSA and auditor expectations, lessons learned, and other feedback issues. The senior safety analyst reviewed the USQDs and served as the mentor and trainer, but did *not* have to manage the safety analysts' workload. Finally, the USQD approver served as the final quality check of USQDs and consistency of USQDs across projects. The USQD approver also served as the technical and communication link between the USQ Review Team and the AB Document Team, while providing the common interface with regulatory organizations (e.g. NNSA and auditors) as well as other facilities and the central institutional AB organization. The benefits of this approach:

- increased efficiency in USQ reviews by enforcing discipline in priorities, minimizing staff reassignment fluctuations and work balancing by AB management, and increased productivity while minimizing conflict;
- resulted in positive project/system engineer/safety analyst interfaces; and
- staff came up to speed faster on technical and applicable USQD issues.

The AB Document Team focused staff on key regulatory documents such as DSA/TSR, SBD/HAR, and FSP. In a schedule driven paradigm, it is essential to preserve the focus of the USQ review team and utilize another team for document production. This team developed and maintained expertise in specific regulatory issues, e.g. DOE-STD-3009, DOE-STD-3011, and DOE-STD-1186. The team had three priorities:

- Serve as "Plan B", the contingency for 10CFR830 Compliance if the Risk Reduction Program did not accomplish it's objectives. The contingency was development of a 10CFR830 Compliant DSA and TSR.
- Produce the large documents, e.g. SAR/TSR annual updates, Radiological Safety Basis Document (SBD aka HAR) and Facility Safety Plans.
- Serve as the Reserve for the USQ team, filling in when needed on rushes.

The Special Projects Team staff focused on particular objectives, the special projects pertaining to authorization basis and facility management issues. This included conducting TSR Implementation, performing assessments, verifying compliance with DOE-STD-3011 and 10CFR830, supporting activities pertaining to DOE-STD-1027, responding to DNFSB

issues and results of DNFSB Recommendations, and planning and performing Radiological Verification activities. They developed expertise in very specific areas involving local NNSA interpretations.

7.4 Facility Infrastructure Strategies

Keeping a legacy facility operational in a challenging and changing regulatory environment is crucial for meeting schedule and a significant challenge.

Good configuration management is an essential starting point. Facility engineers must know the safety function of each system and its critical components, integrate configuration management into work control processes, and understand the relationship with the Safety Basis. Early on, B251's system engineers developed system design descriptions for equipment important to safety. These efforts increased efficiency and effectiveness of work control for inventory reduction operations, D&D, and facility operations, including maintenance. Auditor scrutiny verified the effectiveness of these efforts.

Several best practices for facility infrastructure strategies are noted below.

- *"Expect the unexpected and confirm the expected"* Recognize that legacy systems were not designed for optimal D&D and include legacy hazards such as inaccurate as-built drawings, hard wiring of equipment, "abandoned" in place systems, electrocution hazards, and component degradation issues (e.g. bags, window gasket seals, fan motors, bearings).
- *"Infrastructure Contingencies"* It is important to proactively prepare for legacy system issues. Understand the safety function for equipment important to safety. Recognize that legacy components such as seals and exhaust fans can fail. Facility maintenance to support the RRP was far higher than anticipated; many systems unexpectedly required maintenance or replacement. Recognize legacy facility equipment may be at end of their operational life.
  - Perform proactive like-in-kind determinations for legacy systems and develop an Approved Equivalent Parts List as like-for-like components may be difficult or impossible to obtain for some legacy equipment.
  - Pre-purchase replacement parts for long lead time items (e.g. SS/SC systems, particularly exhaust fans). A few extra dollars to buy or refurbish spare parts may save significant down time in the future.
  - When a trend is identified, act on it. Proactive replacement of key components reaching end-of-service life is critical to minimizing impacts of failure during operations (e.g. exhaust fan motors). After several exhaust fan motors failed, as a precaution 100% of fumehood exhaust fans were replaced during the RRP's preplanned maintenance windows.
- *"Spill happens"* so prepare standing contingency practices
  - decontamination carts containing tools, spare parts, spill decontamination kits, bags, glove box gloves, extra meters, Radiac wash, Stripcoat, tape, extra respirators;
  - include spill clean up procedure in every work plan;
  - conduct extensive dry runs, then work on lower level D&D before moving up to higher level D&D and then finally $^{244}Cm/^{238}Pu$ in complicated equipment.
- *"Escalating Contingencies"* There are a number of legacy issues that can result in operational issues escalating, e.g. legacy containers may not be in the state anticipated due to degradation. It is important to have contingency infrastructure operational prior to starting work activities. If conducting work in a room, have a fumehood pre-approved as operational with canners ready. If doing work in a fumehood, have a glove box pre-approved as operational.
- *"How we know what we know"* In a legacy facility with multiple concurrent operations, it is important to institute procedures for periodic walkdowns of work areas by ES&H safety disciplines and facility staff. Develop effective communication tools including paging procedures, information centers, and on-going verification of system operability. On the longer term, conduct Configuration Management reviews and implement effective mechanisms for ensuring and confirming TSR Implementation.
- *"Use existing facility infrastructure"* Carefully assess the facility to determine what can be used. In a schedule driven paradigm, this is crucial – you simply don't have time to install new major systems. For example, hot cells can be used for safely conducting radiography and staging for shipment, low background areas can be used for gamma spectroscopy, and existing glove boxes, enclosures, and fumehoods can be used for repackaging, solidification, and contingency work areas.
- *"Ask why and look at the big picture"* Carefully assess all aspects of the work activity and

evaluate the entire worker safety envelope - don't fall into the trap of listening to one reviewer who may have a myopic view and is unaware of other issues, solving one problem only to create a different safety hazard or waste disposal problem.
    - It is important to assess infrastructure and spatial parameters. Several glove boxes were relocated and seismically stabilized to support Inventory Reduction and D&D, thereby creating free work space important for improving safety of operations.
    - Scaffolding was required for elevated work above enclosures. It is important to recognize solutions to fall protection may cause secondary problems, e.g. hindering safe response to CAM alarms, scaffolding hitting glove boxes/ventilation, or harnesses inappropriately being connected to equipment important to safety.
    - Tenting is not always the solution; it may not be necessary and may get in the way, causing worker safety issues.
- *"Open air transfers are safe!!!"* The RRP successfully conducted hundreds of open air transfers. This is the result of extensive planning and drills, including preparation for off-normal events.

7.5 Readiness Assessment (RA) Strategies

B251's strategies resulted in significant safety improvements and operational efficiencies. As a result of robust processes and application of lessons learned, B251 successfully completed a Facility Startup Readiness Assessment (RA) [with NNSA] as well as three operational RAs [institutional with NNSA oversight].

B251's success with the four RAs was a direct result of extensive proactive preparation. Best practices for RAs include:

- Develop facility processes, project documentation and procedures, personnel interfaces.
- Develop presentations that demonstrate the facility and project's response for each CRAD; clearly show the assessors why the CRAD is satisfied. Involve appropriate personnel and proactively anticipate RA questions
- Conduct extensive dry runs as training
    - Dress rehearsals with PPE in operational glove boxes are very helpful for simulating the real work, use techniques such as talcum powder and black lights to mimic contamination during material handling and repackaging.
    - Demonstrate D&D activities with cold glove boxes and mock-ups.
    - Conduct off normal event drills and testing (e.g. contamination, component failure, personnel issue such as heart attack).
- Obtain pre-approval of all possible requirements (e.g. USQDs, environmental monitoring, NEPA, BAAQMB, Criticality).
- Front load the schedule, do not delay work until the end. Do the legwork initially prior to the RA to minimize findings and under your schedule, rather than responding to NNSA and DNFSB afterwards during schedule crunch time.

8.0 OPERATIONAL STRATEGIES: ROBUST PROCESSES THAT "*EXPECT THE UNEXPECTED*"

B251 developed safe work control processes. The success of these processes is demonstrated by an excellent safety record and the successful completion of a Facility Startup Readiness Assessment (RA) [with NNSA] as well as three operational RAs [institutional]. Robust processes significantly improved safety and contributed to the RRP's success by supporting:

- Facility Management (Work Planning, Work Control, ALARA, and Safety Analyses).
- Inventory Reduction,
- D&D process development, and
- D&D activities.

8.1 "Building Block" Work Plan Process

B251 utilized a "building block" work plan process. Such a process provides flexibility, ease of use, and is best suited for situations where performing the same operation may be required for a multitude of activities. Once the initial effort to write the procedures is complete, creating a work plan is relatively simple in comparison to other facility's work control process used around the DOE Complex. Another important benefit of the building block approach is that employees are trained to each procedure, and can effectively perform each individual task, whereas giant work plans that do not follow this approach are difficult to train to and effectively implement.

The following discussion describes how the "building block" work plan process functions. A project leader identifies what needs to be done and determines how

they would like to perform that activity. The overall order of the process is as follows:

1. Assembles procedures for an overall activity from a selection of previously approved procedures for specific operations that make up that activity. For example, to repackage an item in a glove box, select procedures for checking infrastructure functionality (e.g. room ventilation, glove box ventilation, continuous air monitors), entering specific locations and retrieving items, and open air transfers into and out of a glove box.
2. "Plug in" results from Characterization (e.g. gamma spectroscopy) about the specific items in question.
3. Conduct a standing meeting with reviewers to assess the proposed work package. Reviewers may include: ES&H safety disciplines (e.g. health physics, industrial hygiene, industrial safety, fire protection, environmental analysts), safety analysts (USQ), facility engineering (Configuration Management), and facility management. The reviewers assess and assimilate the reviewer's comments and develop a completed, *final* work package.

This approach minimizes review time as reviewers already understand each operation and focus their assessment on the integrated activity and specific hazards. This approach allows reviewers to assess each inventory item individually, which is important when radiation levels may vary greatly for the same operation depending on isotope (e.g. from a few mRem/hr to 5 Rem/hr). Thus ALARA controls may vary between items, and these details are discussed in pre-start meetings.

Additionally, the "building block" work plan process provides operational flexibility so you don't have to stop work to re-enter the paperwork processes. The project leader and reviewers consider possible issues and builds in contingency plans with previously approved procedures (e.g. glove changes, filter changes, spill plans). They expect the unexpected, and take steps to anticipate potential surprises when conducting the work, such as by monitoring for both neutrons and α/β/γ and establishing hold points for radiation levels and contamination. These hold points are based upon input from characterization (e.g. gamma spectroscopy) that helps the project leader to better understand the work environment.

Several best practices of the building block work plan process are:

- Assemble procedures for an activity from a selection of previously approved procedures for specific operations (e.g. facility operating procedures, OSPs, numerous IWSs, surveillance procedures).
- Conduct standing meetings with reviewers (e.g. ES&H, safety disciplines, USQ, CM, facility management) to assess proposed activities and then completed, *final* work package.
    - This approach minimizes review time as reviewers already understand each operation and focus their assessment on the integrated activity and specific hazards.
    - Assess each inventory item individually, radiation levels may very greatly for the same operation depending on isotope. ALARA controls may vary, discuss in pre-start.
    - Assures each sub-task is considered and procedure is up to date.
- *"Expect the unexpected and confirm the expected"* add steps to verify infrastructure operability, continue to verify status, and perform radiation and contamination checks.
- Build in operational flexibility so you don't have to stop work to re-enter paperwork processes unnecessarily. Contingency plans and procedures may include:
    - glove changes, filter changes, spill plans
    - hold points for radiation levels and contamination
    - Bullets vs. numbering - carefully consider order of steps – is ordering important?
- The project leader assembles the initial information and shepherds it through the entire regulatory process and then conducts the work. The project leader is the most knowledgeable individual on the activity and assimilates all relevant aspects of the work.

8.2 Work Control and Continuous Batch Processing

The RRP utilized a continuous batch process where the current activity was conducted while planning the next activity. These activities involved coordinating multiple organizations. Characterization was pivotal in work planning. The overall order of operations was as follows:

1. Plan the work, prepare the work plan, facilitate safety and regulatory reviews, and obtain approval to do work.
2. Characterize the material (e.g. inventory item or contaminated equipment).
3. Plan the work using characterization results; update the work plan as required.
4. Conduct the work.

a. Repackage and stage the material, and obtain appropriate documentation.
b. Plan the shipment, develop shipper/ receiver agreement, facilitate shipment.
c. Ship in batches.
d. Conduct a Lessons Learned to facilitate improvements for the next batch.

Figure 5. Application of Integrated Safety Management (ISM)

The guiding motto of the Risk Reduction Program (RRP) was to "*Expect the unexpected and confirm the expected.*" The RRP utilized a variety of characterization tools, including: Gamma spectroscopy; Radiography; Alpha/Beta/Gamma (α/β/γ) measurements; Neutron measurements; Entry and concurrent radiation (during job) surveys; Pre-job, post-job, and concurrent contamination surveys. This selection of characterization tools resulted from lessons learned during Risk Reduction activities. Monitoring progress in a continuous batch process requires careful consideration of incremental progress. As inventory reduction reflects progress as a step function, it does not show incremental progress of steps prior to the inventory leaving the facility. It is important to monitor the progress of preliminary steps such as characterization, solidification, and repackaging. Simply monitoring inventory is insufficient for monitoring overall project progress.

8.3 Work Control Key Lessons Learned

Several best management practices for work control are noted below:

- Meetings can be very beneficial.
  - Pre-start meetings with staff, management, and safety personnel ensure awareness of planned work activities.
  - Transition to tailgate meetings only after sufficient expertise is demonstrated.
  - Standing safety meetings for ES&H team review & approval (e.g. Health Physics, Industrial Hygiene, Fire).
- Monitor the state of the facility using:
  - pre-job surveys for contamination,
  - post-job surveys for contamination,
  - infrastructure checks (e.g. CAMs, glove box exhaust, room exhaust, contingency workstations),
  - facility status information centers communicating which systems are operable and available for programmatic use,
  - *"How-we-know-what-we-know"* procedures and processes, in event of facility issues during operations, and
  - training on how equipment works, e.g. potential issues for false alarms when Radon is not pre-eliminated when working with ^{244}Cm and less common isotopes.
- Radiation monitoring for unknowns, not just anticipated radiation:
  - when entering legacy areas,
  - when accessing legacy items,
  - use neutron and alpha/beta instruments,
  - use hold points for radiation levels and contamination.
- Active communication is important!
  - Facility Manager, Health Physicist, and the Responsible Individuals actively communicate.

8.3 Work Control Improves Safety

B251 developed a unique work control process that increased operational efficiency and safety. The two-step work control process (ALARA review/dose prediction) utilized gamma spectroscopy for ALARA and operational efficiency. First, RRP staff reviewed historical and process records to better understand the material in question (inventory item or contaminated equipment). Particular attention was paid to sister isotopes, process impurities, and daughter products, which often weren't considered by the original researchers working with the materials. This information provided the input to the 1st ALARA Review, which estimated conservative doses and planned the initial characterization. The RRP conducted the work with survey measurements and hold points from the ALARA review. Second, RRP staff characterized the material in question and compared the results with historical and process records. This information provided the input to the 2nd ALARA Review, which used characterization results as input to dose calculation codes (e.g. Microshield) for developing more accurate dose estimates and planning the hands-on work. RRP conducted hands-on work (e.g. repackaging, neutralization/solidification, special form encapsulation, decontamination). Finally, the parcel

was assayed for shipper/receiver documentation (for reuse in other programs or as waste).

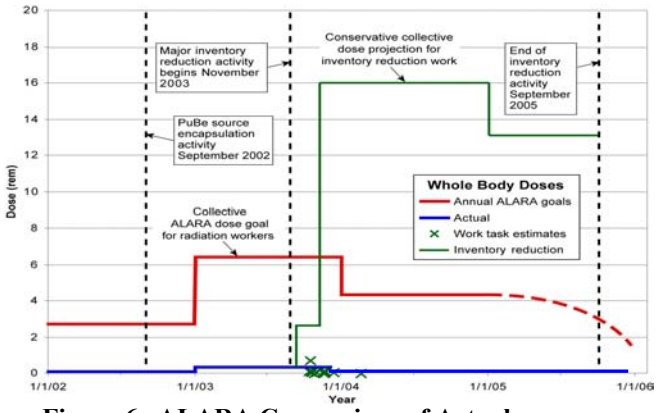


Figure 6. ALARA Comparison of Actual vs. Predicted Dose Demonstrates Success of Work Control Practices

There was little experience in the DOE complex in decontaminating facilities with this level and variety of high specific activity, alpha emitting isotopes (e.g. ^{244}Cm, ^{238}Pu). As a result of the B251 work control process, the RRP maintained an excellent safety record. There were no major contamination incidents, no radiation over-exposures (in fact, doses were far lower than dose predictions), and no major injuries. Individual and collective doses were maintained ALARA. The success of B251 work control processes was demonstrated by the excellent safety record (Fig. 6). Collective annual whole body doses were at least three times lower than ALARA goals and more than 10 times lower than conservation dose projections. Individual annual external whole body doses were less than 150 mrem.

8.4 Characterization

In a legacy facility, it is critical to develop robust processes that can handle surprises from legacy unknowns. B251's inventory control and work control processes resulted in significant safety improvements and operational efficiencies. The RRP followed a formal, rigorous process utilizing an independent, state certified, peer-reviewed gamma spectroscopy program in conjunction with other characterization techniques (e.g. radiography, α/β/neutron measurements), process knowledge, and historical records. This provided information for:

- Work planning, work prioritization, work control and safety analyses (e.g. development of stop work points and bounding hazard analysis);
- Helps define operational approaches to achieve ALARA, e.g. hold points, stop work points, appropriate engineering controls, PPE, workstations, and time/distance/shielding.

De-inventorying and decontaminating a legacy facility that had not been operated for almost a decade presented unusual challenges. Some items dated back over 40 years and were stored in a variety of conditions, including underground storage vaults (USVs), Mosler safes, hot cells, and rooms in variety of engineered containers (e.g. centrifuge cones, slip-lid cans, dog bones, and USV containers).

Figure 7. Legacy Inventory

Characterization facilitated efficiently and safely packaging legacy items for reuse onsite and shipment offsite, and disposition to waste. Characterization helped the RRP reduce the number of items requiring handling and opening down to the source level, allowing simpler repackaging operations and thereby minimizing dose. Furthermore, characterization facilitated efficient repackaging of co-located items, reducing the number of repackaging steps and avoiding severe schedule implications that otherwise be required to repackage a large number of co-located items.

8.5 Self-checking Inventory Control Process

The RRP utilized a self-checking process for inventory control that followed the guiding principle of *"Expect the unexpected and confirm the expected."* Records had been kept to requirements of the times, and often did not meet modern standards; many records included cryptic hand-written entries. There was a large risk of unknown legacy items. The RRP characterized each stored inventory item and each repackaged parcel. Inventory both increased and decreased due to characterization results. The RRP created a robust system for examining process knowledge in combination with characterization (Fig. 8). This systematic approach was a fundamental key to the success of B251.

Figure 8. Self-checking Inventory Control Process

The first part of the inventory control process was to review records and conduct interviews. RRP staff reviewed hand-written process notebooks, Materials Management records, interviewed previous facility managers and numerous previous facility residents, and contacted legacy offsite suppliers. In the time since legacy items originated with offsite suppliers, numerous changes occurred at those suppliers (name changes, mergers, out-of-business, etc.). These corporate changes at legacy suppliers required investigation, i.e. many supplier records were not as easily retrieved as anticipated. The second part of the inventory control process was characterization. Characterization included: gamma spectroscopy, X-ray radiography, alpha spectroscopy, visual examination, and Alpha/Beta/Gamma ($\alpha/\beta/\gamma$) measurements.

8.6 X-ray Radiography in Hot Cell

Radiography was essential for safe and efficient inventory reduction. Used in conjunction with other characterization tools such as gamma spectroscopy, radiography was a very powerful tool in inventory reduction. Radiography helped determine the condition of unknown legacy packaging, understand shielding issues with respect to gamma spectroscopy, minimize required repackaging and dose, helped plan repackaging operations efficiently and safely, facilitated shipments, and supported shipping documentation.

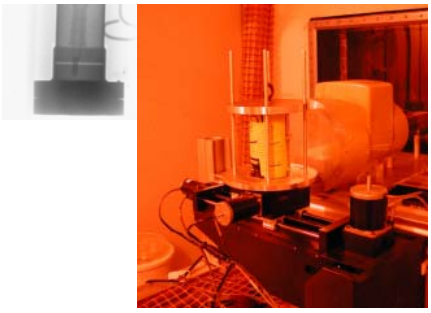


Figure 9. Radiography Increases Safety and Efficiency

8.7 Shipping

Shipping was important to RRP's success. Key lessons learned include the need to recognize package availability and shipping constraints; develop shipper/receiver agreements (which often required a great deal of lead time and was important to tackle early in the planning process); develop clear, agreed upon expectations for known issues; schedule for waste characterization, paperwork processing, acceptance, and transportation; and be aware that a large number of parcels can swamp characterization programs and transportation. Multiple paths are important because unanticipated events can occur at receiving facilities, e.g. for mixed LLW disposition. Furthermore, it is critical to select and obtain correct containers dependent on the receiving site:

- Pipe Overpack Container (POC) for high dose items,
- Standard Waste Box (SWB) for TRU glove boxes not decontaminated to LLW,
- 10 Drum Overpack for blue cave enclosures,
- Custom Type A Containers for special contaminated enclosures (glove boxes), and
- Special Form Container for sealed sources.

9.0 RESULTS

The Risk Reduction Program was an impressive success! No one had decontaminated facilities with this level and variety of high specific activity isotopes (e.g. ^{244}Cm, ^{238}Pu). All enclosures were characterized (gamma spectroscopy, alpha-swipe tab sampling). The RRP completed D&D of 40 of 49 Enclosures in 1 year and completed the rest shortly thereafter. Details include:

- 37 lower-contaminated glove boxes through D&D and shipped as LLW,
- 2 highly-contaminated Blue Cave enclosures emptied with little or no contamination
- 2 fume hoods carefully disconnected and relocated for new programmatic use

The RRP generated over 800 waste parcels, 84 TRU drums, and numerous LLW drums. Contaminants included: ^{166m}Ho, ^{232}U, ^{233}U, ^{235}U, ^{237}Np, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu, ^{242}Pu, ^{241}Am, ^{242m}Am, ^{243}Am, ^{243}Cm, ^{244}Cm, ^{246}Cm, ^{248}Cm, ^{249}Cf. Special packaging included:

- 1 high activity glove box transferred as TRU Waste in a Standard Waste Box (SWB),
- 1 transferred as TRU Waste in a Type A Box

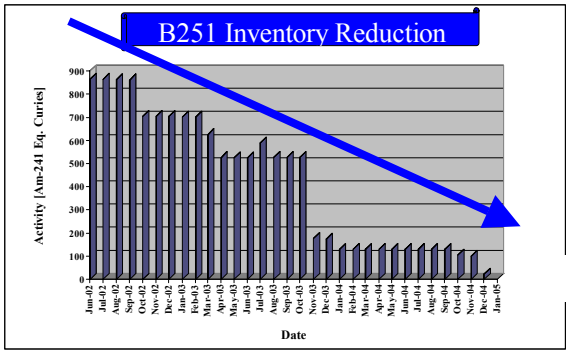


Figure 10. Dramatic inventory reduction

10.0 CONCLUSIONS

During the program, key lessons were learned. The Facility Management, Readiness Assessment, and Authorization Basis lessons learned during the Risk Reduction Program (RRP) can improve upon similar activities at other facilities. Key to this success is the RRP philosophy in a schedule driven paradigm.

- *"Expect the unexpected and confirm the expected"*
- Recognize when you reach the point of diminishing returns,
- Develop robust processes that anticipate and can handle surprises,
- Plan, plan, and re-plan *"Measure twice, cut once"*

Key Contributors to B251's Success

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NOTE: Figures 11 – 13 are located on subsequent pages.

Preparing, emptying, decontaminating, disconnecting, packaging, characterizing, and shipping enclosures

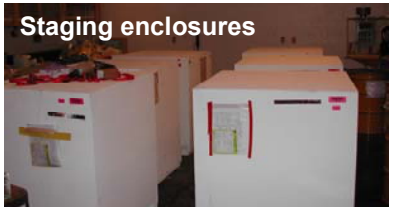

Figure 11. Examples of D&D Activities

Enclosure D&D: Conditions of Legacy Equipment

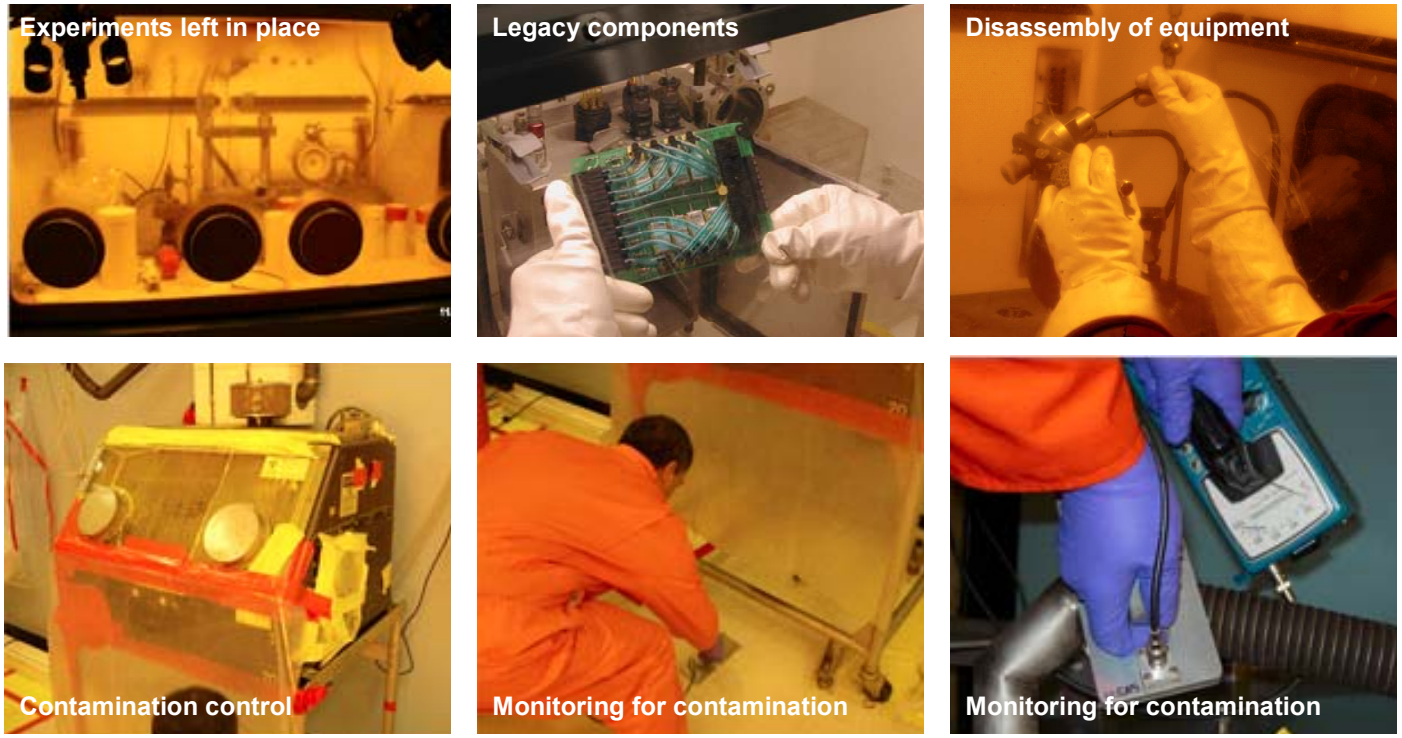

Figure 12. Examples of Legacy Equipment and Contamination

Enclosure D&D: Before and After

B251 Experimental Decontamination Results:

- Emptying removes large fraction of activity.
- One or two passes of Strip Coat removes bulk of loose activity. Scrubbing surface with acidic solution loosens remainder of surface activity. Material removed by another pass of strip coat.
- Additional passes of acid wash and Strip Coat remove less and less residual activity because residual material embedded under metal surface.

Figure 13. Before and After D&D