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John W. Crawford, Jr.  
Joseph J. DiNunno  
Herbert John Cecil Kouts

# DEFENSE NUCLEAR FACILITIES SAFETY BOARD

625 Indiana Avenue, NW, Suite 700, Washington, D.C. 20004  
(202) 208-6400



October 25, 1993

The Honorable Thomas P. Grumbly  
Assistant Secretary for  
Environmental Restoration and Waste  
Department of Energy  
Washington, DC 20585

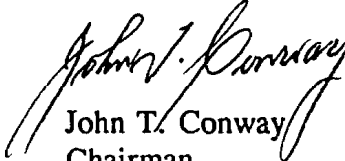
Dear Mr. Grumbly:

Enclosed for your consideration and action, where appropriate, are a number of observations contained in two separate trip reports concerning packaging, storage, and inspection of special nuclear materials at the Rocky Flats Plant. These observations were developed by members of the Defense Nuclear Facilities Safety Board (DNFSB) staff and outside experts. These observations are based on reviews of available documents, and discussions with Department of Energy (DOE) staff and contractor personnel at Rocky Flats on July 19-22, 1993 and September 22-23, 1993, with subsequent discussions involving Board members, staff, and outside experts.

The Board wishes to call your attention to the large number of metal plutonium items stored in plastic bags, the plutonium solutions, and some categories of residues. The status of the metal evaluation and repackaging program, the solution stabilization program, and studies apparently being conducted to assess the immediacy of hazards posed by the various residues will continue to be of extreme interest to the Board in the near future. The Board requests that DOE provide their plans and priority for dealing with these issues.

If you need further information, please let me know.

Sincerely,



John T. Conway  
Chairman

c: Dr. Tara O'Toole, EH-1  
Mark Whitaker, Acting EH-6  
Dr. Victor H. Reis, DP-1

Enclosure: (1) Trip Report for the DNFSB Staff Review of Special Nuclear Material Issues  
at the Rocky Flats Plant  
(2) Report on Plutonium Storage

## DEFENSE NUCLEAR FACILITIES SAFETY BOARD

September 9, 1993

**MEMORANDUM FOR:** Technical Director

**COPY TO:** Board Members

**FROM:** R. E. Kasdorf

**SUBJECT:** Rocky Flats Plant - Trip Report for the DNFSB Staff Review of Special Nuclear Material Issues

1. **Purpose:** This memorandum provides a summary report of the trip by the DNFSB staff (Stadnik, DeLaPaz, Bamdad, Tontodonato, Kasdorf and outside expert Leary) from July 19 - 22, 1993 to review special nuclear material issues at the Rocky Flats Plant (RFP).
2. **Summary:**
  - a. The RFP contractor, EG&G, has a good understanding of the types of items, quantities of plutonium and uranium and the general forms of special nuclear material (SNM) stored at Rocky Flats. However, the actual composition of much of the material, especially scrap and residues, is not known.
  - b. The staff believes that the safety controls for movement of SNM between material access areas at Rocky Flats are adequate for Category I and II material as defined by DOE Order 5633.3A, *Control and Accountability of Nuclear Materials*. Site procedures require a safety screening per the intent of DOE Order 5480.21, *Unreviewed Safety Questions*, by the Facility Safety Engineering (FSE) group which is intended to prevent movement of materials which would violate the safety basis of the receiving location. Similar controls for Category III and IV material did not exist; however, the staff was told a procedure was in draft and would include FSE group review.
  - c. The packaging and storage requirements for many different forms of SNM established by RFP are apparently based on past practices when the plant was in production. There appears to be little additional technical justification for the current storage requirements. SNM has not always been stored in a consistent configuration, nor are the requirements for the storage location such as atmospheric controls and engineered safety features consistent among the various storage locations. As such, the current storage requirements do not appear to address the health and safety concerns that arise from long-term storage of SNM that will likely occur with the new RFP mission.
  - d. RFP is planning a disciplined process to inspect and repackage about 1800 SNM items which have not been periodically inspected in accordance with RFP requirements. The

process includes an initial inspection of about 10% of the items to better understand the storage issues. However, inspection of many of the items will not be performed until the buildings in which they are stored are prepared to perform the repackaging evolution, which could be a year or two away.

- e. Apparently there are no requirements (e.g., periodic sampling, periodic containment integrity evaluation) for actinide solutions stored in tanks and bottles. Actinide solutions in tanks have not been sampled and raschig rings have not been inspected since curtailment of operations in 1989. Extended curtailment of operations at RFP has left potentially unstable actinide solutions in bottles, tanks and process systems in Buildings 771 and 371. Only limited tank surveillances (i.e., look for leaks) have been performed since curtailment. Bottles are being inspected and sampled as part of the Building 771 Phase I solution stabilization program. EG&G states that there are no imminent safety hazards with these solutions and is preparing a plan to address stabilization of these solutions. The Los Alamos Technology Office (LATO) has reviewed the conditions at RFP and in a draft report concluded that the most severe hazard would be an increased frequency of leaks from the tanks and piping.
- f. There are numerous plans and programs under preparation by RFP. These plans and programs did not appear to be well coordinated and disciplined. RFP is currently developing an integrated program with a risk-based ranking and prioritization of planned work. This integrated program will be used initially to prioritize about 1400 work items currently identified for FY 1994. The staff will be following this effort to ensure safety items are not inadvertently deferred.

### 3. Background:

- a. In May 1993, RFP reported that they were not in compliance with their site requirements for storage of SNM. Approximately 1800 items had not been inspected within the periodicity specified in site procedures (Health and Safety Practices Manual HSP 31.11, *Transfer and Storage of Pyrophoric Plutonium for Fire Safety*). In June 1993, the Board reviewed this non-compliance and other SNM issues at Rocky Flats. RFP did not adequately respond to Board questions concerning SNM stored at RFP such as:
  - 1. What is stored (form, quantity, condition, accuracy of the data),
  - 2. How is SNM movement controlled to ensure safety assumptions are met,
  - 3. What is the basis for the priority for processing the SNM,
  - 4. What is the basis for the final stored condition of the material, and
  - 5. Is there an integrated plan for transition including processing and elimination of SNM.
- b. The staff considered that additional action was necessary to better understand the SNM issues that exist at the RFP.

#### 4. Discussion:

- a. What is stored: RFP uses the Safeguards Accountability Network (SAN) system to provide an inventory of the items stored at RFP. SAN is a secret database which makes working with it difficult. SAN provides a detailed listing of each individual item stored which includes the Item Description Code (IDC), the mass of the item, the mass of plutonium, uranium or beryllium in the item, and the storage location (material balance area). Each IDC can be related to a general form of material. There are about 325 individual IDC's. For some items, such as pits, the data may also provide the actual chemical composition.

For finished components, parts and pure metal the data is expected to be complete and accurate. For other material, such as residues and scrap, the actual composition is generally not known. Only the quantity of certain materials (i.e., plutonium and uranium) are provided since they are required for safeguards purposes, which was the original purpose for maintaining the database. Where and how the residue or scrap was generated is generally known from the IDC. RFP assumes that the material is "typical" of that process. There are large quantities of actinide solutions (about 17,000 liters containing about 100 kg of plutonium) stored, most of which has not been sampled since the curtailment of operation in 1989.

The current packaging configuration for the items stored is not known with certainty for much of the material. Of particular concern is whether plastic was used in direct contact with plutonium metal or oxide, which is undesirable from the standpoint of radiolytic decay products from the plastic. When there is any doubt, RFP conservatively assumes that the material is in plastic. On this basis, as much as half of the non-compliant items may have been packaged in plastic.

RFP has provided the staff with a brief description of each of the IDC's. The staff is reviewing these descriptions to better understand the various types of materials being stored at RFP and their safety significance. The items that the staff believes may present a health and safety concern will be the subject of future reviews at RFP.

- b. Basis for the final condition: The storage practices for SNM are the same as historically used when RFP was in production. During the production era at RFP, SNM was not typically stored for extended periods. The DOE-RFO root cause analysis report concluded, in part, that there was a lack of a technical basis for making decisions on issues concerning SNM packaging and storage. The report also noted that a comprehensive technical analysis was not completed to provide a safety basis for SNM storage, packaging and inspection. The EG&G root cause analysis concluded a contributing cause of the non-compliance was the lack of DOE-wide standards for storage of plutonium. As such, the current RFP storage requirements may not address the health and safety concerns that arise from long-term storage of plutonium that is expected with the new RFP mission.

The primary DOE order for plutonium packaging and storage, DOE Order 5480.5, *Safety of Nuclear Facilities*, is, in general, not specific and leaves the individual sites to develop their own specific, detailed packaging and storage requirements.

There are other DOE orders which provide transportation, and safeguard and security requirements concerning SNM. The staff does not believe that these requirements adequately address health and safety concerns with long-term storage of SNM. The design requirements of DOE Order 6430.1A, *General Design Criteria*, in general, do not apply to existing facilities, and, furthermore, do not offer significant insight into the packaging and storage of SNM.

Material considered to be potentially pyrophoric, such as plutonium oxides, will be thermally stabilized in Building 707 at a temperature of about 550 °C. Prior to the public meeting concerning resumption of Building 707 operations, RFP provided the staff with information that indicated that this temperature had been selected based on ignition studies and processing experience which had proven to provide satisfactory stabilization of the material. The staff believes that most material thermally stabilized at RFP will be adequately stabilized for interim storage (5 to 10 years); however, there is little technical data concerning long-term storage of plutonium in the various forms existing at RFP.

For other SNM metal and oxides, the storage requirements for RFP are contained in their procedure HSP 31.11. As indicated above, this procedure is based on past production practices and there appears to be little technical basis for the requirements. EG&G is planning a disciplined process to repackage the 1800 items that RFP has identified as not being in compliance with the inspection periodicity in this procedure. The process will address the standards to be used, plutonium holdup in exhaust ducts for the gloveboxes to be used for inspection and repackaging, and fire protection requirements. Prior to repackaging the non-compliant items, a readiness evaluation will be conducted by DOE-RFO to address equipment, personnel, and management and administrative system readiness. While EG&G admits that there may be more important material in other buildings, the personnel, procedures, training, and equipment needed to conduct the repackaging in Buildings 779 and 707 are the closest to being ready. Materials stored in these buildings will be repackaged first. Other buildings are proceeding in parallel but some could be more than a year away from being ready.

EG&G categorized the 1800 items into 55 groups with similar properties or conditions and then ranked the groups with respect to hazard based on packaging, age, type of plutonium and material form. A statistical sample of about 200 of the higher hazard items were selected to be taken out of storage and inspected (including thermogravimetric analysis and infrared spectroscopy of oxides collected from the items) in an effort to better understand the severity of the storage issue and whether repackaging of the remaining items is warranted. These samples will be inspected when the building where the items are stored has had its readiness review by DOE-RFO. As noted above, Buildings 779 and 707 are the closest to being ready; other buildings could be a year away from being ready to perform this inspection.

At Rocky Flats several packaging configurations have been used in the past. RFP has proposed standard packaging configurations for future storage of SNM metal and oxides. The proposed configuration for plutonium metal is a can with a crimped seal, which is packaged while in an "inert" environment (less than 5% oxygen), and an outer can with a crimped seal. For stabilized plutonium oxides, Rocky Flats proposes an inner can with a taped lid, a plastic bag around this can, and an outer can with a locking lid that has been taped. Non-stabilized oxides would be placed in a can with a taped lid, and stored in an "inert" atmosphere or on a heat detector.

Apparently there are no requirements (e.g., periodic sampling, periodic tank integrity evaluation) for actinide solutions stored in tanks and bottles (i.e., RFP does not have requirements for liquids which are equivalent to HSP 31.11 requirements for metal and oxides). Extended curtailment of operations at RFP has left potentially unstable actinide solutions in bottles, tanks and process systems in Buildings 771 and 371. Actinide solutions in tanks have not been sampled and raschig rings have not been inspected as specified in ANSI/ANS-8.5 since the curtailment of operations in 1989. Only limited tank surveillances (i.e., look for leaks) have been performed since curtailment. Bottles with low concentration solutions (less than 1.5 g/l plutonium) are being inspected and sampled as part of the Building 771 Phase I solution stabilization program. EG&G states that there are no imminent safety hazards with the actinide solutions and is preparing a plan, the Actinide Solution Disposal Study, to address stabilization of these solutions. The Los Alamos Technology Office (LATO) has reviewed the conditions at RFP and in a draft report concluded that the most severe hazard would be an increased frequency of leaks from the tanks and piping.

The staff considers that the DOE needs to develop a standard to provide clear and consistent requirements for the storage of special nuclear materials. The staff will provide the Board an issue paper addressing the need for DOE to determine storage requirements that provide for adequate protection of the public and worker health and safety. A standard needs to be developed and issued which specifies:

1. Material forms and conditions that are acceptable for long term storage,
  2. Acceptable intermediate storage periods for other material forms and conditions,
  3. The type of environment to be established during packaging and the packaging configuration for storage,
  4. Requirements for the storage facilities such as atmospheric controls and engineered safety features, and
  5. Requirements for periodic inspection and surveillance of the stored material.
- c. How is SNM movement controlled to ensure that safety assumptions are met: RFP has developed a procedure for controlling transfer of certain types of SNM between material access areas (MAA). This procedure, 1-63200-NMT-001, *Transfer of Nuclear Material Between Material Access Areas*, is intended to prevent movement of Category I and II SNM (as defined by DOE Order 5633.3A) which would violate the safety basis of the receiving location. The procedure requires that Facility Safety Engineering (FSE)

perform a safety screen or unresolved safety question determination (USQD) prior to the material movement.

EG&G told the staff that a similar procedure for Category III and IV materials was being prepared and that the procedure would also include a FSE review prior to the material movement.

Material movement between material balance areas (e.g., a vault) within a MAA would be controlled by criticality safety operating limits (CSOL) or Nuclear Material Safety Limits (NMSL).

The staff believes that RFP will have adequate safety controls on SNM movement between MAA's once the procedure for Category III and IV is issued and implemented.

- d. What is the priority: The current efforts at RFP have focused on: thermal stabilization in Building 707; processing actinide solutions in Buildings 771 and 371; consolidation of SNM into Building 371; conducting inspections of SNM and bringing SNM storage back into compliance with local HSP requirements; and compliance with the numerous state and federal requirements.

The priority for work in FY 1994 and beyond is being evaluated and established using a risk-based assessment as part of an integrated planning program discussed below.

- e. Is there integrated site program planning: There are numerous plans being prepared and studies being conducted at RFP. There appears to be little coordination and discipline to these efforts. EG&G indicated that this was in part true, and that greater integration was needed. EG&G stated that current program plans and efforts are not prepared in a unified manner and that there is no risk-based ranking in the planning process. EG&G identified that they are trying to get all of their efforts pulled together into an integrated site-wide program plan. The process is called the Integrated Planning Process (IPP). This process is a pilot project which when fully implemented (plans are in three years) would provide a picture of all the activities going on at RFP from environmental monitoring to specific upgrades or clean-out projects needed to put the site in the condition desired for future uses. It is intended to provide a near-term and long-range planning tool to define and prioritize projects needed to achieve a final condition (not yet defined for RFP), and to provide input for future funding requirements. The IPP is currently focusing on organizing, unifying, and prioritizing the efforts identified for FY 1994 which represents about 1400 individual project plans.

EG&G has yet to complete the first round of integration, and complete their review of the risks and priorities before finalizing the activities that will be conducted during FY 1994 and beyond. Since these tools are still being prepared, the staff will be following up on this process in September 1993 as the first integrated program plan is completed to ensure that health and safety items are given a rational priority.


## 5. Future Actions:

- a. The staff believes that DOE needs to develop a standard to provide clear and consistent requirements for the storage of special nuclear materials that ensure public and worker health and safety. The staff will provide the Board with an issue paper on this subject.
- b. The staff believes that DOE-RFO and EG&G need to evaluate the risk-benefit of inspecting SNM samples that have a relatively high risk ranking in buildings that are ready to conduct this inspection rather than waiting for the individual buildings to be prepared. EG&G has verbally agreed that inspecting the samples as soon as possible would be prudent. The staff will continue to follow RFP actions in this area.
- c. The staff believes that although the actinide solutions in tanks may not pose an imminent hazard to the public, the lack of a surveillance program which assesses the containment boundary for the solution process system (including tanks) may expose the workers to a risk of contamination due to leaks or possible rupture of the boundary. These solutions need to be disposed of to mitigate this concern. The staff has been informed that RFP intends to process these solutions for disposal starting in FY 1994. The staff will continue to follow RFP efforts on this project and will review EG&G's basis for considering safety issues other than leakage incredible.
- d. The staff will complete its evaluation of the list of descriptions of individual IDC's to identify the material forms that appear to have the greatest health and safety concern, and review the actions being taken by RFP to mitigate these concerns.
- e. The staff will follow-up on the EG&G efforts to integrate and prioritize the identified work at RFP to ensure that health and safety items are given a rational priority.



**DEFENSE NUCLEAR FACILITIES SAFETY BOARD**

October 22, 1993

**MEMORANDUM FOR:** Technical Director  
**COPY TO:** Board Members  
**FROM:** Davis Hurt   
**SUBJECT:** Rocky Flats Plant - Report on Plutonium Storage

1. **Purpose:** This memorandum is a report by the DNFSB staff (Davis Hurt and outside experts Joseph Leary, Jesse Cleveland, and Homer Lowenberg) on a visit to the Rocky Flats Plant from September 22-23, 1993. The visit had three purposes:
  - a. to inquire into the state of knowledge at Rocky Flats of long-term plutonium storage properties;
  - b. to improve our understanding of the current plutonium storage situation at Rocky Flats; and
  - c. to collect information useful to the Board on the question of which chemical forms and packaging methods would be most suitable for long-term plutonium storage.
2. **Summary:** Based on information obtained during this visit the staff has come to believe that there are immediate safety issues related to the storage of plutonium-bearing scrap materials (locally called "residues") at Rocky Flats. In the course of general inquiries into plutonium storage experience, the staff spoke with a senior plutonium scientist at Rocky Flats who has written a report on safety issues associated with the large number of 55-gallon scrap drums stored at the site. The report's findings were paraphrased to the staff during the site visit, and formed the basis for bringing this issue to the Board's immediate attention. The actual report ("Evaluation of Residue Drum Storage Safety Risks", William V. Connor, September 27, 1993) has been obtained since then, and has confirmed the impression formed by the staff in speaking with its author.

The DNFSB staff and outside experts believe that there are several categories of scrap that are of immediate concern. In general, they are materials that combine fairly high radiation fields with reactive chemical environments. Some examples are

electrorefining salts, unpulverized extraction salts, and combustible items soaked with nitric acid. Hydrogen generation, overpressurization of containers, and accumulation of pyrophoric substances are the most serious issues. Some of the drums may contain ignition sources in the form of reactive metals, pyrophoric plutonium compounds, and unstable peroxides.

3. **Background:** The DNFSB has been aware for some time of potential safety issues related to the storage of plutonium and other special nuclear materials at Rocky Flats. The DNFSB staff first made inquiries into this subject in early 1992 in connection with Building 991. Later in 1992 the staff made further inquiries in connection with Building 779 and Building 371. In both cases, the staff concluded that plutonium materials were being stored in unsuitable environments. In the case of Building 779, it was clear that many of the Rocky Flats technical personnel involved were aware of the problem but felt constrained in their ability to address it by the plutonium operations suspension that affected the whole site.

Rocky Flats management appears not to have recognized that there were serious problems with plutonium materials in storage until a specific compliance issue came into prominence in early 1993. It emerged that inspection of plutonium metals and oxides in storage had not been performed as required by the local health and safety manual (HSP 31.11). The manual was not intended to apply to many of the types of materials now in storage, such as residues, nor was it intended to cover the long storage periods now in effect. It is not clear that full compliance would resolve most of the safety problems.

4. **Discussion:**

- a. Plutonium scrap

Many of the problematic plutonium materials stored at Rocky Flats are intermediate forms (such as solutions) or scrap (locally called "residue"). Many of these materials, particularly the ones with high plutonium content, were never intended for anything but very short-term storage. Because of the sudden shutdown at Rocky Flats, they have all been stored at least 4 years, and some of them pose significant dangers. There is a credible program at Rocky Flats to stabilize solutions, but the unstable scrap materials seem to have been somewhat neglected.

An experienced plutonium chemist at Rocky Flats - EG&G has recently been assigned to analyze the scrap stability issue. He has written a report that discusses the safety hazards posed by the various scrap materials and proposes a ranking system for the categories. The DNFSB staff and outside experts met with him and found his oral summary of the report compelling. Since the trip, the DNFSB staff has obtained a copy of the report which confirmed the initial impressions.

The DNFSB staff and outside experts believe that there are several categories of scrap that are of immediate concern. Examples are electrorefining salts, unpulverized extraction salts, and combustible items soaked with nitric acid. The EG&G author identified several specific processes that could lead to the accumulation of hydrogen gas and has cited a substantial amount of actual data on hydrogen gas accumulation in similar drums. Some categories of scrap may contain ignition sources in the form of inclusions of reactive metal, pyrophoric forms of plutonium or americium, or unstable peroxides. He also identified categories of drums that may be susceptible to spontaneous combustion of flammable solids.

There is a possibility that some of these materials could explode if the drums are dropped, punctured, or otherwise roughly handled. There is also the possibility of spontaneous reactions in some of the drums. The report's author has defined five risk categories. The number of 55-gallon drums in the highest risk category is 1,095 and the number of drums in the second highest is 1,037.

The potential reactions in these drums pose a significant immediate safety issue. Somewhat longer term, there is also a serious scrap characterization issue. Many of the scrap materials are not well characterized. The DNFSB staff and outside experts believe it is important to start characterizing the unknown ones as soon as possible. It may not be wise, though, to wait for extensive characterization before taking steps to deal with the drums in the dangerous categories.

b. Improperly packaged line items

In response to a safeguards directive in late 1991, many of the plutonium items in the glove box lines, mostly metal, were packaged hastily and placed in vaults. The engineers supervising the packaging were compelled by pressure of time to package most items directly in plastic bags because there was not time to use the downdraft tables, which would normally have been the way to remove metal items from the glove boxes without using plastic. According to the people with whom the DNFSB staff spoke, it was perfectly well understood that plutonium items should not be packaged in direct contact with plastic if they are to be stored for more than a short time.

Unsafe packaging methods were used because of the overriding emphasis on getting the plutonium into the vaults by a deadline. The engineers responsible had to hope there would be opportunity to re-package the items in the near future. It seems that the dangerous situation exists today not because of inadequacies in established practice, but because established practice was not followed.

It is not correct to make a general conclusion that there was no sound "technical basis" for storage practices at Rocky Flats. The engineers responsible for storage had sound reasons for doing what they normally did. For the short-term storage with which they normally dealt, their practices were usually successful. Some of the practices were not

codified to any great extent, but that is not the same as having no technical basis. The problem in the view of the DNFSB staff and outside experts is that practices that were safe for the short term are not safe for the long term.

c. Standards for Long-Term Plutonium Storage

There are apparently no complex-wide standards for long-term storage of plutonium-bearing materials. This deficiency has undoubtedly contributed to the present unsafe situation. It is useful to think about the issue in terms of two types of plutonium materials: materials that are already in a form roughly suitable for long-term storage, and materials that are not. There seems to be general agreement among the experts that metals and oxides, properly processed and packaged, are suitable forms, and that most other things are not. Rocky Flats has a great many materials in the "not potentially suitable" category.

The Department of Energy (DOE) is developing a new interim storage standard for metals and oxides. The DNFSB staff and outside experts believe DOE has made a good start. DOE has put together a particularly comprehensive technical background document ("Assessment of Plutonium Storage Issues at DOE Facilities", still in draft form). The DNFSB staff believes it is important that this work continue.

For scrap and intermediate plutonium materials, the need is less for the development of storage standards than for prompt action to stabilize the materials themselves. Everyone with whom the DNFSB staff spoke agrees that these materials should not be stored any longer than necessary. Ideally, they should be stabilized in a way that makes them as suitable as possible for long-term storage. But there is an urgent need to start stabilizing the worst items, if only to an interim form. It is unfortunate that DOE did not foresee years ago the need for interim storage standards for some of these materials. Stopping all work now to develop a new standard does not make sense, and runs the risk of distracting key people from the actual stabilization work. The DNFSB staff believes an aggressive parallel effort needs to be pursued by DOE.

d. State of Knowledge

The body of knowledge at Rocky Flats of the properties of plutonium metal is still very extensive, even with all of the recent retirements. A great deal is known about the long-term (10-20 year) behavior of metal in two or three specific environments. The pit interior environment is by far the best understood, both theoretically and practically. There is somewhat less experience, but still a significant amount, with one or two other storage environments involving metal sealed in atmospheres different from the pits. Long-term behavior in adverse environments (wet ones, for example) is less well known, although a few important particulars are understood based on individual experiments or incidents.

Local knowledge of oxides is much more casual. Judging from the people with whom the DNFSB staff spoke, there has been relatively little systematic thought given to understanding how oxides interact with packaging and environment, even short term. There may be a great deal more knowledge at some of the other sites.

As far as the DNFSB staff could tell there is little local knowledge of the storage behavior of scrap and intermediate materials. Process chemistry of these materials is, of course, well understood. But, with few exceptions, little thought seems to have gone into their storage properties.