Lessons Learned from a Tc-99 Glovebox Deflagration at a Chemical Laboratory

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In June 1999, a glovebox in the Chemical and Metallurgical Research (CMR) facility over-pressurized, bursting a glove and releasing high levels of Tc-99 contamination into a laboratory room. Fortunately, this particular room was unoccupied at the time, and no personnel contamination or injuries occurred.

At the time of the incident, CMR personnel were evaporating approximately 5L of aqueous waste that was highly contaminated with Tc-99. The waste also contained ammonium ions, nitrates, hydrogen peroxide, sulfates, potassium, fluorides, and quantities of various metals. RCRA metals in excess of regulatory limits were also discovered after the incident.

During lunch, a deflagration burst a glove and released contamination throughout the room. Investigators later hypothesized that as the solution evaporated, the ammonium nitrate in solution concentrated and then rapidly decomposed to N2, NOX and water vapor. Normally, this decomposition reaction would occur at temperatures higher than the 80 C used to evaporate the waste solution. However, we believe that the presence of transition metal ions catalyzed the decomposition reaction at a much lower temperature producing a deflagration.

Investigation revealed a number of deficiencies in the work control process, the most serious being that the work was performed outside of the established review and approval process. For example, this resulted in a lack of adequate review and authorization prior to accepting the work at CMR. In addition, the change control process was not used when unanticipated hazards were identified.

The lessons learned form this incident has been incorporated into CMR facility operations. As a result, the CMR Laboratory has steadily improved their operations.

Background

As part of the uranium enrichment operations at the Portsmouth Gaseous Diffusion Plant (PORTS) in Ohio, some highly enriched uranium (HEU) became mixed waste (MW). Much of the uranium feed material used in the gaseous diffusion process was reclaimed or recycled from processed reactor fuel. The chemical process to purify recycled uranium leaves trace amounts of transuranic elements, e.g. Np and Pu, and fission products, principally Tc-99. Because PORTS lacked the capability to process the generated waste, they issued a call for proposals to process the materials by recovering the HEU and separating the RCRA materials.

In September 1996 PORTS and the Los Alamos National Laboratory (LANL) agreed to conduct a treatability study at the Chemical and Metallurgical Research Laboratory (CMR). Approximately 100 kg of waste was to be processed containing HEU and RCRA materials. LANL was to recover and return the HEU, separate and properly discard the RCRA materials. The PORTS study involved three discrete waste streams:

- X-710 – this waste was generated in the X-710 uranium analysis laboratory as a result of analytical operations.
- Oil Leak Gunk – this waste was generated in the X-326 facility as a result of a 1973 lubrication oil leak into the process waste stream.
- Freon Degrader – this waste was generated in the X-326 facility and originated from the freon degrader system.

PORTS provided the LANL research team leader with elemental analysis data that demonstrated the presence of RCRA constituents such as arsenic, chromium, silver, lead, and selenium. The oil leak gunk and freon degrader waste streams contained relatively high levels of Tc-99, ranging from 1.76E7 to 4.65E8 pCi/gram.

LANL notified the DOE Los Alamos Area Office (DOE-LAAO) of the treatability study; who then in turn notified the New Mexico Environmental Dept. (NMED). The notification included a process description, but no mention was made of the Tc-99 content in the wastes and little detail was provided on the proposed methods to separate the RCRA metals from the waste streams. In November 1996 NMED approved the treatability study of approximately 100 kg of PORTS MW at LANL. The NMED granted LANL 1 year to complete the study that LANL understood was to commence the day the PORTS waste samples arrived.

In August 1997 CMR staff prepared an Unreviewed Safety Question Determination (USQD) and What-If Hazard Analysis (HA). The USQD was "negative", indicating that it was within the bounds of the existing CMR Authorization Basis (AB). The USQD incorrectly noted that "trace" quantities of TC-99 on the order of 1 pCi/gram of material. On the contrary, the PORTS elemental data analysis, which had already been provided to LANL, indicated that the waste samples ranged from 1.76E7 to 4.65E8 pCi/gram. The PORTS research team leader apparently overlooked this data. Neither the USQD nor the What-If HA contained specific details regarding possible interactions between process/waste materials or the possible impacts of these interactions on engineering controls (e.g. glovebox ventilation, HEPA filters). In addition, neither the USQD or HA stated that the work was to be performed in enclosures that did not provide HEPA filtration (i.e. the radiological hoods in the Wing 4 basement). Lastly, no mention was made of the directional airflow requirements. After the incident, the Incident Investigation Team noted positive airflow from Room 4064 to adjacent uncontaminated areas. Interviews with facility personnel indicated that directional airflow problems in this area of CMR were long standing and well recognized.

Treatability Study

The process, as originally envisioned, commenced with dissolving the PORTS waste, which was in solid form, in nitric acid. The solution was filtered, with the solid residue being separated as mixed waste. Ammonium hydroxide was then added to the nitric acid solution containing the HEU until the pH was 2.5. Hydrogen peroxide was then added to precipitate the HEU as a yellow cake (UO4). The solution was filtered to remove the yellow cake, which was then calcined at 900C for 6 hours to produce UO3 powder. The remaining solution had its pH adjusted to $\leq$ 1with nitric acid. Potassium hydroxide was then added to adjust the pH to 10. This precipitated the remaining RCRA metals.

On 25 August 1997 the first shipment of 20 drums arrived at CMR, starting the one-year study granted by NMED. On 2 Sept. 1997, CMR management suspended all operations due to several incidents involving poor conduct of operations (unrelated to the PORTS study). Before normal operations were allowed to resume, all CMR activities, including the PORTS treatability study, were to be reviewed and formally authorized. During the standown, the CMR research team leader became concerned that a prolonged standown would hinder the completion of the study within the one-year time limit. CMR wrote to DOE-LAAO proposing that the waste materials would be properly stored until operations resumed. The letter proposed delaying the start date for the one year time limit until the formal resumption of CMR operations. The letter stated that unless informed otherwise, the Laboratory would assume that NMED found this delay acceptable. The letter was forwarded to NMED and when NMED did not formally respond the CMR research team leader assumed the modification in the start date was "authorized".

During the standown, the CMR research team leader prepared a Work Authorization Package (WAP). The PORTS WAP was deficient in the following respects:

- It did not include or reference the PORTS elemental analysis data, which clearly identified significant Tc-99 contamination.
- The radiation protection checklists did not list U-234, the principal alpha emitter within the HEU, or Tc-99, the principal beta emitter. The only isotope listed was U-235. The WAP also stated that the PORTS work required no air sampling, air monitoring, or personnel contamination monitoring. Alpha contamination monitors, an alpha continuous air monitor (CAM) and fixed head air sampling units were already in place and were left as a precaution.

- The WAP specified that the final products and waste generated from the treatability study would be recovered HEU, solid MW, low-level waste (LLW) and aqueous LLW solutions. The HEU was to be returned to PORTS, the RCRA materials disposed off-site, the LLW discarded at the Laboratory, and the solutions poured down the radioactive waste drain to TA-50. The research team leader overlooked the high levels of TC-99 contamination and assumed the resulting LLW solutions would meet the TA-50 WAC.
- The procedures contained in the WAP were incomplete and did not address the Tc-99 content in the waste streams.

CMR commenced the PORTS treatability study on 4 June 1998. In late July 1998, processing of the X-710 waste stream was completed. The CMR team successfully recovered the HEU from the X-710 waste stream. All liquid effluents were collected for RCRA analysis. Work then commenced on the freon degrader waste.

On 5 August 1998 one team member became contaminated with a beta emitter while opening a PORTS container of freon degrader waste. It was discovered that the team member and a small area in the room had become contaminated with Tc-99. CMR subsequently stood down the PORTS work. Through investigation into the incident it was discovered that the PORTS elemental analysis showed the oil leak gunk and the freon degrader wastes were highly contaminated with Tc-99. Reviews of the uranium good practices manual also indicated that these levels of Tc-99 should have been anticipated.

On 15 October 1998 the stand-down on the PORTS work was lifted and the treatability study resumed. However, no path forward was developed to address the handling of solutions that were now known to be highly contaminated with Tc-99. It was now clear that the high Tc-99 content would prevent the solutions from meeting the WAC for TA-50 disposal.

In November 1998, the PORTS research team began noticing the formation of white “fumes” in a glovebox while they were performing uranium precipitation. At the same time, they noticed a drop in the magnahelic gauge reading on the glovebox. This gauge measured the differential pressure between the glovebox and the room. Normally the gauge read between 0.5 to 1.0 inches of water. When the fumes began forming, the gauge dropped to below 0.7 inches. The team periodically adjusted the air inlet valves to maintain a “normal” reading on the gauge.

Beginning in November 1998 the team dramatically increased the pace of operations to meet the assumed NMED deadline of 4 June 1999. Because of the increased volume of work, more problems were noted with the magnahelic gauge readings. In addition, the quantities of Tc-99 contaminated solutions began to increase. Because the solutions did not meet the WAC for TA-50, they could not be poured down the radioactive waste drain. At this point the PORTS research team leader decided to develop a method to handle the Tc-99 contaminated solutions.

In December the team leader conducted a literature search and found a process that used ferrous ammonium sulfate (FAS) to precipitate the Tc-99. Small-scale experiments were then conducted with the FAS process on the Tc-99 contaminated solutions. Although the treated solutions still did not meet the WAC for release at TA-50, the small-scale results appeared promising. Therefore, the team leader decided to try the FAS process on a larger scale. No change control analysis (e.g. USQD) was developed for this process.

The FAS process involved adding nitric acid to the solution to bring the pH down to 1. FAS was then added to reduce the Tc(VII) to Tc(IV). Potassium hydroxide was then added to precipitate the Fe2O3 and the TcO2.

In early January 1999 problems with the magnahelic gauge reading continued. The team also began to notice white powder accumulating on the surfaces of the HEPA filter. Ammonium hydroxide and nitric acid were among the chemicals used to precipitate HEU. The team leader assumed that the ammonia and nitric acid vapors had combined to form white ammonium nitrate fumes and that these fumes had condensed as a white powder on the HEPA filter. None of the PORTS hazard analyses or any other PORTS documentation had ever addressed the formation of ammonium nitrate or the possibility that this material could clog the glovebox filter media.

Also in January, the team began large scale FAS treatment on the Tc-99 contaminated solutions. The team found that even after repeated treatments with FAS, the solutions still contained high levels of Tc-99 and did not meet the WAC for TA-50. However, the team continued FAS treatment of solutions, hoping to obtain better results.

The FAS process was not described in the NMED approved treatability study. The research team leader assumed, based on knowledge of process, that all the RCRA metals had been removed from the liquid effluents during the potassium hydroxide precipitation process. However, this assumption was not verified by any analysis. The research team leader did not notify ESH-19 or the Waste Management and Environmental Compliance Group (NMT-7) before beginning the FAS treatment. In essence, the team was treating RCRA waste without a permit.

In February, a measurable, but well below any regulatory limits, release of Tc-99 occurred from the CMR Wing 4 exhaust stack. The release was caused by the calcining operation of the uranium oxide solid residues by the PORTS team. The team performed the 900 C degree calcining in this non-HEPA filtered hood because they assumed that no Tc-99 was present in the solid uranium oxide compounds.

Because of the Tc-99 release, the team leader moved the calcining furnace from the hood into a glovebox. Because of the possibility of a fire in the outlet HEPA filter, the team leader decided to install fire screens on the upstream side of the outlet HEPA filters in the gloveboxes. These fire screens affected the operation of the glovebox magnahelic gauges. The low-pressure sides of the gauges were connected just upstream of the glovebox outlet HEPA filters to measure the dp between the boxes and the room. After the fire screens were installed, the gauges measured the dp between the narrow space between the screens and the outlet HEPA filters. With the screens completely clean, this arrangement would make little difference in the dp measurement. However, if the screens became partially or completely plugged, the gauges would not provide an accurate measure of the dp between the gloveboxes and the room.

A radiological work permit (RWP) and a safe work permit (SWP) were approved to authorize the placement of the fire screens in the gloveboxes. However, no USQD or hazard review analyzed or authorized the change to safety significant equipment and analyzed possible impacts on the CMR AB and facility engineering controls.

After the fire screens were installed, the team noted periodic changes in the magnahelic gauge readings on the gloveboxes and had to clean white powder from the screens approximately every two weeks.

In March 1999, the team leader noticed that the quantities of HEU in the freon degrader waste was nearly twice what was measured through previous PORTS and Laboratory uranium assay data for the PORTS waste. Before March, the team leader had limited the amount of HEU in each glovebox and hood to 200 grams to ensure that operations were conducted well within the criticality limit of 520 grams per enclosure. The team leader had based his knowledge of the amount of HEU in each sample on the PORTS and laboratory assays. Because the new March data suggested that nearly 400 grams of HEU had actually been present in each enclosure, the team leader reduced the amount of waste by half to stay well below the criticality limits. The team leader did not inform his CMR management of the discovery of the higher HEU content in the freon degrader waste. Consequently, no formal reviews, e.g. USQD, were performed to ensure that the higher HEU content was still within the bounds of the CMR AB. In addition, no reviews were performed of the specific hazards involved with the higher HEU content in the PORTS waste.

In April 1999 the team completed processing the freon degrader waste and began work on the oil leak gunk. Up to this point, although samples had been submitted, the team had not received any analytical data showing that the RCRA metals were successfully removed from the freon degrader liquid effluents. However, the research team leader assumed that the potassium hydroxide that was added to the liquids during both the RCRA precipitate and the FAS processes had removed the RCRA metals.

During one week in April 1999, the PORTS team had three radiological incidents involving either skin or area contamination. Nuclear Materials Technology (NMT) and CMR management reviewed the incidents. The observations included the following:

- Too many different operations being performed too quickly.
- Poor housekeeping.
- An apparent willingness to violate procedures.
- Poor laboratory practices.

Based on these observations and a growing concern over the viability of this work, NMT management decided to “phase-out” the treatability study. In May NMT management formally terminated the project. The PORTS research team leader was instructed that no new work was to be performed on the PORTS samples. The team leader was instructed to finish treating the current samples and to begin repackaging the remaining samples for transport back to PORTS.

On 3 June 1999 all unused/uncompleted samples were shipped back to PORTS. Of the 111 55-gallon drums of waste that had been shipped to LANL, 64 drums were returned to PORTS; 34 of the drums containing oil leak gunk were never opened.

Evaporation of Liquid Effluents

On 11 June 1999, the team voiced concerns to the team leader regarding the FAS process. Each time the team performed the process, more solution was generated, but the beta activity in the liquids was not significantly decreasing. Based on these concerns, the team leader and the team discussed how best to proceed with the Tc-99 contaminated solutions. They decided to slowly evaporate the liquid to reduce the volume, dry any solid residue, and then discard the residue as a solid MW.

On 14 June the team leader met discussed the evaporation process with the team. The team leader instructed the team that the Tc-99 contaminated solutions were to be poured into trays and then slowly heated on hot plates in the gloveboxes. The team leader informally provided the following precautions:

- Tie the glovebox gloves outside the boxes to prevent them from coming in contact with the hot plates.
- Maintain the liquid temperature in the trays to approximately 80C to prevent boil-over. Ensure that a liquid level is maintained in the trays to prevent evaporating to dryness.
- Periodically remove the slurry that accumulates in the trays and set it aside in the glovebox.
- Continually attend the process except during lunch breaks, and turn off the hot plates at the close of each day.

After these informal discussions, the team began evaporating the Tc-99 contaminated solutions. No written procedures were developed or considered necessary by the team leader. The team leader did not inform his management of the evaporation process nor was this process described in the NMED-approved treatability study. Furthermore, a fundamentally new process was implemented without using the activity approval process/change control. Consequently there was no USQD. The team leader also neglected to complete a Continuous Unattended Operations Permit. This document would have informed the CMR Operations Center on how to de-energize the hot plates.

During June, the team continued to evaporate the solutions using two trays, each one located in a separate glovebox. The two gloveboxes were connected. At the end of each day the team turned off the hot plates and ensured that the trays were filled with liquid. At the start of the following day, the team scraped the slurry out of the trays and placed it in large beakers within the gloveboxes. The trays were then filled with solution and the hot plates turned on. The process was repeated every day. The team evaporated approximate 2 L of fluid per day per tray.

On Friday, 18 June, at the end of the day, the team turned off the hot plates and secured the area as usual. The trays were not checked that weekend or the following Monday and Tuesday (21-22 June) because of a two-day Laboratory-wide security stand-down.

On Wednesday, 23 June, when the team returned to work, they noted that the trays were nearly empty of liquid and that the crystals had migrated out of the two trays and onto the hot plates in each box. They further noted that the hot plate in one of the gloveboxes had failed. The team then decided to use a smaller tray in that box because of safety concerns and the possibility of leaks from the over-sized tray.

By the end of the day on 24 June, the team had evaporated all but the contents of three 2L bottles. Up to this point, neither the team leader nor the team suspected that the increased concentration of the solution in the trays, combined with impaired glovebox airflow, might lead to problems.

Incident Description

On 25 June, at 0830, the team returned to work and started the evaporative process. They scraped the slurry from the trays and poured some of the liquid from the three remaining bottles. Work progressed as usual with the team monitoring the solution temperatures and keeping the trays as full of solution as possible. The team noted the usual rise in the magnahelic gauge readings on the two gloveboxes. Before breaking for lunch, the team verified that the temperatures of the liquids were approximately 80C and that the trays were about 75% full.

At approximately 1240, one of the team members returned from lunch, and while waiting for the other team members to return, proceeded to a computer in room next to the laboratory. As he walked to the computer, he glanced into the laboratory, which is separated from the adjacent room by a yellow laser safety curtain. Noting nothing unusual, e.g. glovebox gloves protruding out of the glovebox, he started the computer. Two or three minutes later, he heard a popping sound in the laboratory and he looked in to observe what had happened. At the entrance, he looked through the yellow curtain and saw what he believed to be brown smoke coming from one of the gloveboxes. He then evacuated the area and contacted the research team leader. Power was not secured to the gloveboxes, therefore the hot plates were still on and the evaporation process continued.

At 1253 the team leader informed the CMR operations center of the problem. Shortly thereafter emergency response was initiated.

At 1320, a CMR employee standing near the main floor entrance to Wing 4 smelled NOX gas. This employee had experience working with NOX gas. Another CMR employee in the same area also smelled an unusual odor.

Emergency Response

Between 1400 and 1430, the first responders in the PORTS work area, looking past the yellow laser curtain, noted that a low-lying white haze had filled the laboratory room. This haze also cleared during this time period. Later, the responders discovered that the left glove in the upper-middle set of gloves in one glovebox had "blown off" (Figure 1). Response personnel subsequently plugged this glove port (Figure 2).

Between 1300 and 1600, facility personnel attempted to shut off the hot plates in the gloveboxes. However, due to the absence of a Continuous Unattended Operations Permit in the CMR Operations Center and a knowledge of breaker locations, the source of power could not be determined. Eventually, facility personnel physically located the breaker panel for the glovebox power, and at approximately 1630 the hot plates were shut off.

At approximately 1930, response personnel entered the laboratory room and found that the floor, equipment, and surfaces of the room were highly contaminated with Tc-99. They also found that the slurry from the hot plates had splattered all over the insider surfaces of the gloveboxes.

Investigation

Samples were collected from the gloveboxes including liquid from the last 2L bottle of solution and solids from the trays, fire screens, glovebox floors, and the large beakers containing slurry.

The liquid sample from the 2L bottle contained high levels of ammonium nitrate, ppm quantities of organic compounds, hydrogen peroxide, nitrate, sulfate, many transition metals including, copper, nickel, zinc, Tc-99 in the form of pertechnetate (TcO4-), and ppm amounts of uranium. The pH of the liquid was between 8 and 9. The liquid also contained some RCRA metals; two of which were present in quantities above regulatory limits: chromium at 27.9 ppm versus the limit of 5.0 ppm and selenium at 6.5 ppm versus the limit of 1.0 ppm.

The materials on the two fire screens were analyzed and found to have molar ratios of nitrate to ammonium ion of 1.1 and 1.0 respectively, indicating the material was essentially ammonium nitrate, with a slight enrichment of nitrate. This ratio is slightly different than the 1.2 ratio that was found in the sample liquid.

All samples from the trays and the glovebox floors had enrichments of nitrate ion to ammonium ion ranging from 1.4 to > 48. This indicated the loss of some ammonium ion relative to the nitrate ion in the samples, possibly by formation of ammonia gas or by some other mechanism. The Tc-99 was depleted relative to the other trace metals in these samples, indicating a possible loss of Tc-99 during the evaporation process. Samples in the large beakers showed enrichment in the nitrate ion relative to the ammonium ions, again probably due to a release of ammonia gas during evaporation.

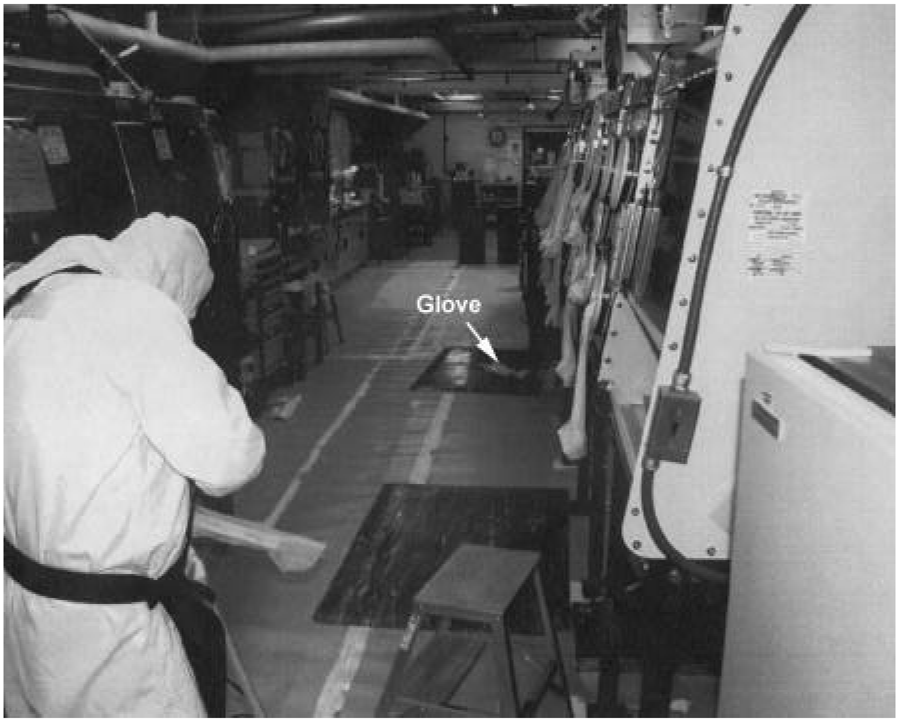

Figure 1, Laboratory Room showing the glove on the floor following the incident

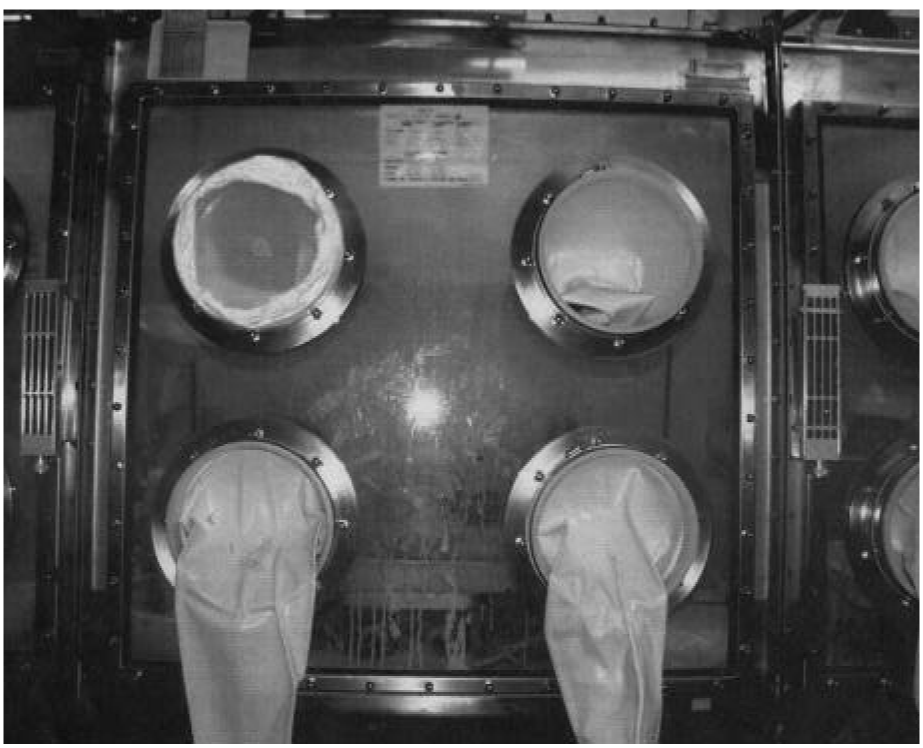

Figure 2, Glovebox with glove port plugged following the incident.

Based on the sample analyses and the observations during the incident, the following is presented as the probable pressure-producing chemical reaction in the glovebox. There was no evidence of an explosive event, e.g. charring, overturned containers etc. The solutions and residues contained significant amounts of ammonium nitrate and this compound can rapidly decompose into decomposition gasses such as NOX, N2, and water vapor. Generally, this rapid decomposition occurs at 210C when the ammonium nitrate is in solid form. However, the process of evaporation concentrates the transition metals and other impurities in the solution. Although at the time of the incident, it is believed that the trays were about 75% full and the liquids were at about 80C, the concentrated transition metals in solution could have catalyzed the decomposition reaction in the solution.

The following evidence supports the hypothesis of a rapid chemical decomposition leading to glovebox pressurization is:

- The team member returning from lunch did not notice the glovebox gloves "sticking out" minutes before the incident, thus indicating that this event was not the result of a slow buildup of evaporation vapors/gasses.
- Partial clogging of the fire screens and/or exhaust HEPA filters would facilitate the pressurization of the glovebox during a rapid generation of gasses. It is less likely that partial clogging would prevent the release of a slow buildup of pressure. The glovebox inlet HEPA filters were examined after the incident and found relatively free from residue buildup. Although some moisture buildup (from the evaporation process) may have impeded flow through these filters, they should have served to vent pressure unless there was a rapid generation of gasses in the glovebox.
- The team member returning from lunch heard a popping sound only two or three minutes after entering the adjacent room. He then saw, through a yellow plastic laser screen, brown smoke when he looked into the laboratory room immediately after hearing the popping sound. NOX gas is brown in color.
- Shortly after the incident, two employees at the main floor entrance to Wing 4 smelled an unusual odor. One of the employees was sure that the odor was consistent with that of NOX gas.
- After the glove was blown off, Tc-99 contamination was released into the laboratory and evenly distributed throughout the room.

The fire screens and outlet HEPA filters were removed from both gloveboxes. Inspection of the fire screens in both boxes revealed that the screens were almost completely clogged with solid residues. Inspection of the HEPA filters showed that the material in the upstream side of the filters was significantly deformed and thus allowed a significant flow of air through the filter media (Figures 3 and 4).

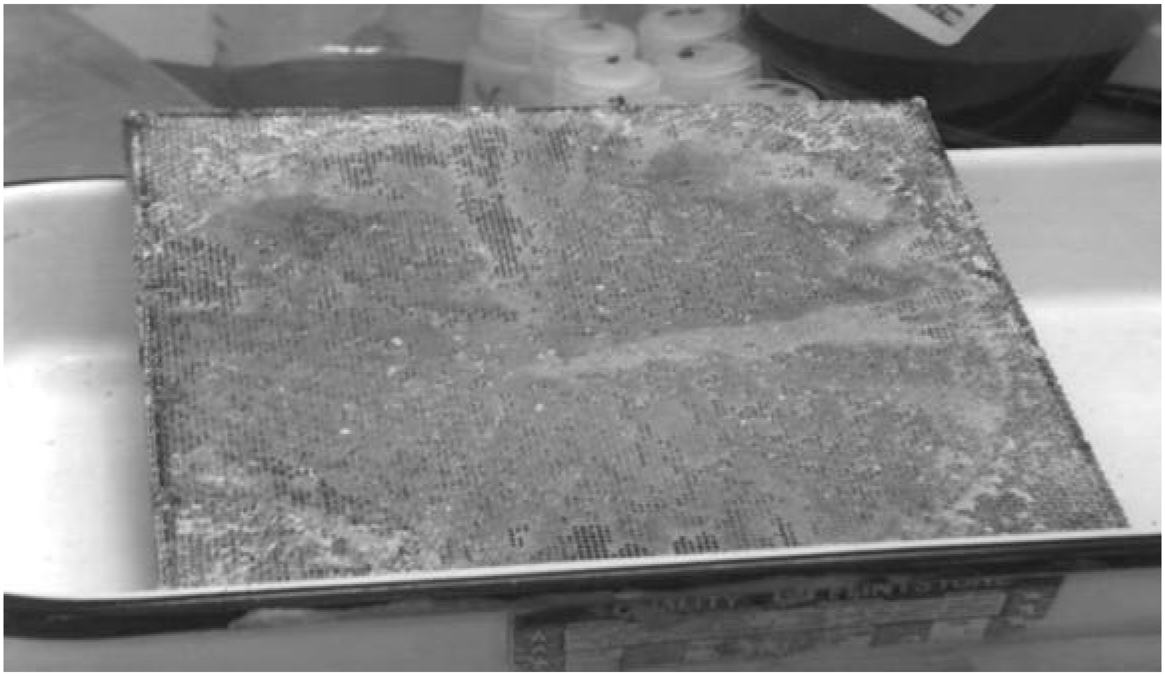

Figure 3 Glovebox fire screen following the incident.

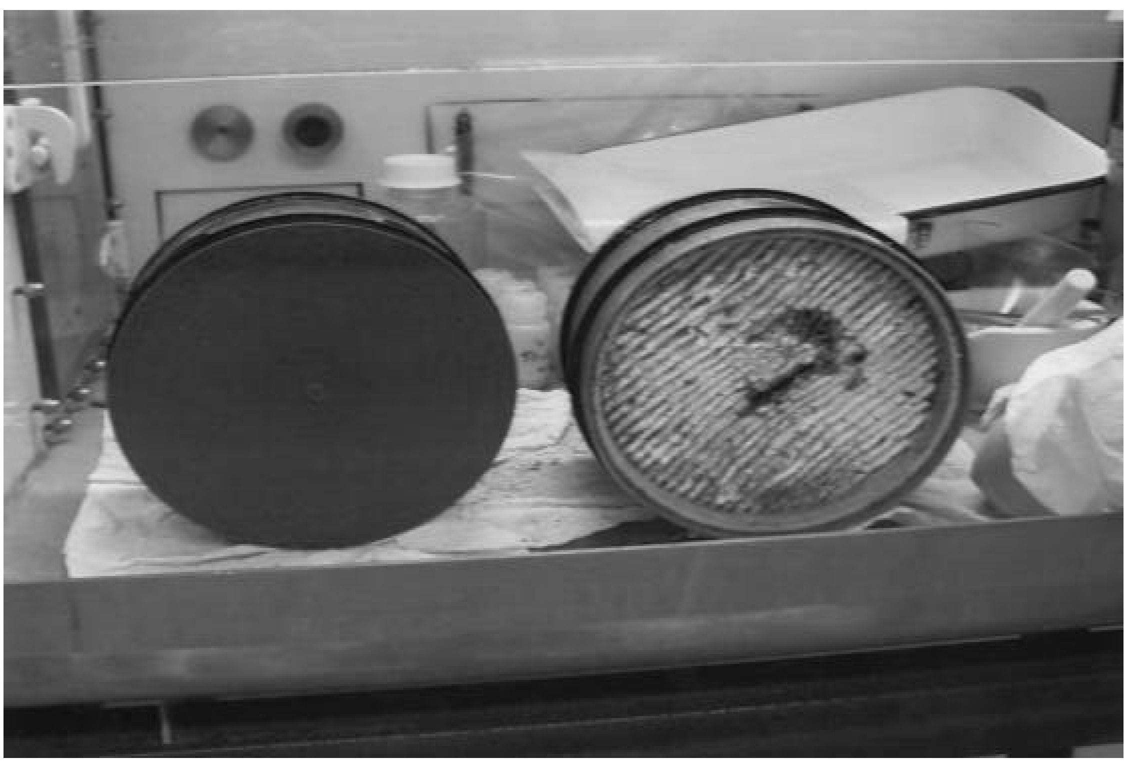

Figure 4 Glovebox HEPA following the incident

Lessons Learned and Corrective Actions

LANL management was aware of CMR's operational difficulties from other past incidents. Therefore, in February 1998 they reorganized CMR management replacing Chemical Science and Technology Division (CST) administration with management from Nuclear Materials Technology Division (NMT). Due to this reorganization, CMR conduct of operations noticeably improved. However, the PORTS Tc-99 contamination incident highlighted some remaining conduct of operations issues. It has provided LANL in general and CMR in particular with some valuable lessons learned that materially strengthened CMR conduct of operations.

Key issues raised by the investigation were:

- The commitment to perform the PORTS treatability study was made without sufficient consideration or line management knowledge of the work elements and related hazards.

- Routine and effective line management involvement was inadequate. Note that line management oversight markedly improved when NMT assumed responsibility for CMR. For example, In May 1999, management decided to terminate the PORTS project due to safety concerns.

- RCRA mixed waste was unknowingly treated by FAS and evaporation without a permit based on a flawed understanding of the chemical constituents and the lack of analytical data.

- The chemical composition of the waste was not properly considered during the project planning. For example, until a contamination incident occurred, Tc-99 was not identified as a significant constituent of the PORTS waste. Also, the amount of HEU actually found in the samples was twice that expected.

- Over 100 drums of mixed waste were accepted from PORTS, but only a fraction of this amount appeared necessary to perform the treatability study.

- The change control process was not used adequately. Examples include the installation of fire screens in the gloveboxes, the discovery of unanticipated high concentrations of Tc-99 in the samples and the discovery of higher than anticipated concentrations of HEU. When unanticipated hazards were identified, new controls were implemented, e.g. moving operations from hoods to gloveboxes. However, no formal review, i.e. USQD, was performed to ensure that new hazards were not introduced as a result of implementing these new controls.

The investigation report concluded that the direct cause of the incident was the overpressurization of a glovebox due to a rapid but non-explosive decomposition of chemical compounds while subjected to heat. Furthermore, the local root cause of the incident was a lack of adequate line and facility management involvement in the planning, review, approval and execution of all phases of the work. Finally, the systemic root cause of the incident was weaknesses in the implementation of Integrated Safety Management (ISM). Multiple systems were in place to evaluate and authorize work, but they failed to ensure that all hazards, controls and responsibilities for safety were clearly identified, understood and implemented.

Based on the above, LANL, NMT division and CMR management have adopted a number of actions to improve conduct of operations. From a LANL-wide basis:

- The lessons learned from this incident have been widely disseminated.
- All LANL Team Leaders are required to complete a one-day Team Leader Safety Training Course that is similar in content to the safety training required of group leaders.
- The LANL Audits and Assessments organization is currently conducting an assessment of the process by which LANL research projects are accepted. This assessment is not yet completed.

CMR facility management also undertook corrective actions:

- CMR has discontinued all laboratory operations laboratory room where the incident occurred. CMR management also plans to discontinue all operations in the Wing 4 basement.
- CMR walked down all electrical panels to ensure that the emergency shut off for all process equipment is correct. They have also ensured that all electrical prints are correct.
- CMR reviewed and updated all Continuous Operating Permits to ensure they accurately described how any process equipment could be de-energized both locally and in the area. These documents are maintained in the CMR Operations Center.

Conclusion

This incident has provided a valuable learning experience regarding the consequences of unanticipated chemical reactions during research. Because of the lessons learned from this incident and corrective actions taken, the safety at CMR has been materially strengthened.