# STATUS OF KNOWN VULNERABILITIES
# OAK RIDGE OPERATIONS

## SITE: OAK RIDGE NATIONAL LABORATORY


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# I. EXECUTIVE SUMMARY

This report reassesses the status of known vulnerabilities (chemical and radiological) at Oak Ridge National Laboratory (ORNL). ORNL is managed by Lockheed Martin Energy Research Corporation (LMER) for the U. S. Department of Energy (DOE). The ORNL site also includes facilities in DOE's Environmental Management program which are managed by Lockheed Martin Energy Systems (LMES). These facilities are included in this report. Additionally, ORNL operates certain facilities at the Y-12 site and these facilities are also included in the scope of this report.

Chemical and radiological vulnerabilities at the ORNL site have been identified in recent years by DOE, the Defense Nuclear Facilities Safety Board (DNFSB), and by contractor self-assessment. These vulnerabilities have been documented and entered into corrective action programs and implementation plans. Significant progress on the mitigation of the identified vulnerabilities has been made in many areas, notably the reduction of unneeded chemicals, the near-term removal of sodium and lithium hydride, progress on the plutonium vulnerability actions, shock-sensitive perchlorate removal, and major risk reduction achievements at the Molten Salt Reactor Experiment. In the interim as corrective actions are implemented for the vulnerabilities, appropriate surveillance, maintenance, and controls are applied such that the safety of the workers and public is ensured. Additionally, waste storage tanks were reviewed for possible chemical reactions. Integrity and safe operation of waste tanks is ensured by appropriate waste acceptance criteria and implementation of the Tank Compliance Program under the Federal Facility Agreement. Follow up reviews of waste tank reports have been identified for action.

ORNL was founded in 1942 during the Manhattan Project. It is the largest of the U.S. Department of Energy's five multiprogram energy laboratories and has a current annual budget of more than $500 million. ORNL has a staff of about 5000 employees, plus more than 4000 visiting researchers. Major programs exist in energy conservation, materials development, magnetic fusion energy, nuclear safety, robotics and computing, biomedical and environmental sciences, medical radioisotope development, and basic chemistry and physics. It is home to sixteen uniquely equipped research facilities open to researchers from industry and universities.

The mission of the ORNL is to conduct basic and applied research and development (R&D) in order to advance the nation's energy resources,

environmental quality, and scientific knowledge and to contribute to educational foundations and national economic competitiveness.

## II. STATUS OF CHEMICAL VULNERABILITY REPORTS

### A. Tomsk Reviews

On April 6, 1993, at the nuclear fuel reprocessing plant of the Siberian Chemical Combine at Tomsk-7, Russia, a sequence of events occurred that caused substantial physical damage to the facility. A runaway exothermic chemical reaction occurred in a large process vessel which contained a concentrated solution of uranyl nitrate along with nitric acid, plutonium nitrate, residual fission products totaling about 560 curies, and uncertain amounts of organic constituents derived from the solvent extraction process. In response to the Tomsk-7 incident, DOE initated a series of reviews at DOE sites to assure that similar conditions do not exist in DOE processing vessels. After survey of the ORNL site, the Tomsk review focused on a detailed review of the large scale development facility (the Integrated Process Demonstration Facility (IPD)), and a limited review of the Radiochemical Engineering Development Center (REDC). The review also considered a tank of thorium nitrate at building 3019. The conclusion of the reviews, as documented in the August 1993 DOE report, was that a nitrate-organic reaction at ORNL was extremely unlikely. In 1994, following that review, the scope was broadened somewhat for self-evaluation of all potential nitrate-organic safety hazards (Tomsk-II review). There were no nitrate or organic safety concerns identified in this followup review other than those previously evaluated. Three actions were taken at the IPD as a result of the Tomsk reviews.

Since the Tomsk evaluations, the IPD facility (building 7602) has been shutdown. All of the process chemicals were removed from the facility following flushing of the systems. The facility is currently in the EM-60 funded High Ranking Facilities Deactivation Project. No chemical process development/operations are permitted in the IPD facility. The Robotics and Process Systems Division is currently performing chemical separations development using depleted uranium and organic solvents in Laboratory 3, Building 7603. The relatively small quantities of material (tens of liters) are recycled without concentration (heating) of solutions. Also, the nitric acid solution concentrations used in the development program are less than those

that caused a problem at Tomsk-7. These operations are carried out in a walk-in hood and are closely monitored by an engineer or technician. Organic solutions are stripped of uranium using the solvent extraction equipment and recycled for testing. Any uranium solutions that have uranium concentrations within a range acceptable for future tests are stored and reused. Laboratory 3 does not have the process capability to boil down solutions. At either the conclusion of the testing program or when the solution storage capacity is reached, Y-12 has agreed to accept these solutions. Y-12 will, within their own processes, recycle these solutions or discard them as waste.

Since the Tomsk evaluations, the relevant operations and controls are basically unchanged at the REDC. That is, the REDC facility incorporates dissolution, solvent extraction, and ion exchange operations that recover and purify transuranic isotopes from targets irradiated in the High Flux Isotope Reactor. Only the solvent extraction step, along with its associated feed preparation and waste handling operations, is of concern for potential nitrate-organic reactions. Volumes of the reagents are low, with tankage limited to a few tens of liters, and the inventory in the contactors is small. Based on safety demands of the processes carried out and the highly limited quantities of materials in process at any time, it was concluded during the Tomsk review that the safety of these operations with respect to nitrate-organic reactions was clearly established. This conclusion remains valid.

The tank of thorium nitrate (approximately 15,000 liters) remains at building 3019. However, its disposal is now included in the scope of actions for the Defense Nuclear Facilities Safety Board (DNFSB) Recommendation 97-1. The implementation plan for this recommendation identifies planned disposal of excess material beginning in FY 1999. The planned disposal method is solidification or fixation of the material with a solid. The tank is periodically sampled and there is no evidence of organics. The tank is ventilated to the ORNL process off-gas system. The controls and monitoring are adequate precautions until disposal of the material.

## B. Chemical Vulnerability Report

The DOE Chemical Safety Vulnerability Working Group conducted a field assessment of the Oak Ridge Reservation in April 1994. The purpose was to review and identify chemical safety vulnerabilities that might result in (1) fires or explosions from uncontrolled chemical reactions, (2) exposure of workers or the public to hazardous chemicals, or (3) release of hazardous chemicals to the environment. The review identified five vulnerabilities for the Reservation. The September 1994 Management Response Plan addressed those vulnerabilities with near-term and short-term actions. At the time of the 1994 Response Plan, the open actions for ORNL were: (1) removal of radioactive sludge from a ventilation sump in building 3047 and (2) relocation of laboratory activities in building 3047 to a facility with proper handling and storage facilities and with proper eyewash and safety showers. These actions have since been completed. The relocation of the laboratory involved the removal for disposal of over 500 chemicals. A gamma counting facility associated with this laboratory remains in building 3047.

The more long-term and comprehensive response to the generic vulnerabilities were addressed in the Comprehensive Site Response Plan to the Chemical Safety Vulnerability Working Group Report published in June 1995. This response identified the programs, initiatives, and activities to address the generic concerns. In addressing the removal of excess or unneeded chemicals, the report identified the unneeded elemental sodium (62.5 tons) and lithium compounds (3.5 tons) stored at two ORNL facilities. These facilities are the Tower Shielding Facility (facility 7700) and building 9201-3 at Y-12. If changed from their solid state to a liquid state, these materials have the potential to react vigorously with oxygen and water and to generate fires and toxic releases. Controls are applied for water use and fire protection. An evaluation is underway for the removal of the sodium and lithium hydride shields from the Tower Shielding Facility. One possible option is to convert the metallic sodium into sodium hydroxide for waste water treatment. The proposed schedule is to complete the removal by the end of the first quarter of FY 1999. In the meantime, the containers are inspected on daily checks for leaks and any other abnormal conditions. The integrity of the containers is also inspected semi-annually by the Quality Office. Building 9201-3 has five shutdown alkali metal facilities. Workplans have been prepared and funding obtained for the metal removal which is expected to begin in 1997 and to be completed early in 1998.

The program and activities described in the Site Response Plan that address the generic vulnerabilities continue as they have evolved and matured. These programs will be described in the progress report to Secretary Pena at the end of 1997.

### C. Highly Hazardous Chemicals

The ORNL site does not have chemicals in process or inventory that exceed the threshold quantities in the OSHA rule for Process Safety Management of Highly Hazardous Chemicals (29 CFR 1910.119) or the Environmental Protection Agency Risk Management Plan rule (40 CFR 68). The ORNL site participated in the DOE assistance support visit for Process Safety Management in August 1996. There were no observations identified relative to ORNL during the visit.

## III. STATUS OF RADIOLOGICAL VULNERABILITY REPORTS

### A. Plutonium Vulnerability and Recommendation 94-1

In June 1994, a comprehensive assessment of the environmental, safety, and health vulnerabilities arising from the storage and handling of plutonium (Pu) holdings at the Oak Ridge site (ORNL and Y-12) was conducted. The Pu Vulnerability Management Plan (DNFSB Recommendation 94-1 Implementation Plan) identified one milestone item for ORNL. This milestone is IP-3.2.017, "Repackage all Pu metals and oxides to meet the metal and oxide storage standard." This standard addresses the long term storage of these materials. The completion of the 12 work breakdown structure activities in the preparation phase for this milestone resolves 11 of the 12 identified vulnerabilities. The actual repackaging and disposal remains open. ORNL has no long term storage facility or equipment to prepare material for long term storage. ORNL has identified in the Site Integrated Stabilization Management Plan (SISMP) the actions, schedule, and proposed destination for disposal of unneeded Pu material at ORNL.

Recommendation 94-1 also identified concern for the storage of Spent Nuclear Fuel (SNF), both in terms of integrity of the fuels and the integrity of the SNF storage facilities. The implementation plan was developed to assure the timely remediation of these vulnerabilities, provide for safe interim storage of stabilized inventories, and promote smooth transition to future dispositioning activities. The SNF at ORNL is primarily spent fuel

from research or experimental reactors that are operating or have operated at ORNL. The SNF at ORNL is currently stored in various types of facilities including underground retrievable dry storage units, above-grade building, hot cells, and wet storage basins. At Oak Ridge, the Spent Fuel Working Group Report identified six ES&H vulnerabilities. Four of these vulnerabilities have been resolved. The remaining two (MSRE and SWSA 5-N storage) are being addressed in the SISMP.

**Molten Salt Reactor Experiment (MSRE)**

The MSRE operated from 1965 through 1969 to investigate molten salt reactors for commercial power applications. The reactor used a fluoride salt mixture of lithium, beryllium, and zirconium fluorides with uranium tetrafluoride as the fuel component. The reactor was initially fueled with $^{235}U$, and then replaced with $^{233}U$ in 1968. An addition of less than 1 kg of Pu trifluoride was made in 1969. When the reactor was shut down, the fuel salt was drained into two fuel drain tanks in the drain tank cell where it cooled and solidified. Following a post-operation examination, the facility was placed under a program of surveillance and maintenance awaiting eventual decontamination and decommissioning. Radiolysis of the fuel salt was expected to slowly produce fluorine ($F_2$) gas after a latent period, and a procedure to annually anneal the salt to recombine free fluorine with the salt matrix was part of the Surveillance and Maintenance program.

In the late 1980s, radiological surveillance at the facility indicated elevated gamma radiation in the North Electric Service Area inside the facility in piping connected to drain tanks. A visible release of an unidentified gas was also observed from the off-gas system piping in the vent house during a maintenance operation. This evidence indicated that contamination associated with the stored fuel salt may have migrated from the drain tanks. Plans were developed and initiated to investigate the migration problem and to determine appropriate mitigative measures. Gas samples taken from the off-gas piping in the vent house indicated significant concentrations of $UF_6$ and $F_2$. Radiation readings in the adjacent charcoal cell also determined that a significant deposit of solid uranium exists in the inlet section of the auxiliary charcoal bed (ACB). As a result of the designed shutdown condition, the cell containing the ACB remained filled with water, and as a consequence, the ACB section containing the uranium deposit was surrounded by water. If water from the cell were to have entered the ACB

and migrated to the deposit, there was the potential for an accidental criticality.

The migration of uranium (83.9% $^{233}U$) from the drain tanks to other locations within the MSRE off-gas system was triggered by the unanticipated formation of $UF_6$ from the uranium tetrafluoride ($UF_4$) in the fuel salt. The $UF_6$ reacted in part with activated charcoal, occupied the off-gas volume, and formed solid, non-volatile deposits in other parts of the off-gas system. The fluorine in the off-gas system also reacted at low temperature with the activated charcoal in the ACB to form fluorides of carbon. These compounds, such as $C_2F$ or $C_3F$, are highly exothermic if subjected to elevated temperatures. Thus an additional consequence of the reactive gas migration is a chemical deflagration potential sufficient to expel the contained uranium from the bed and the charcoal bed cell directly to the environment. This migration caused a condition that was outside the original safety authorization basis for storage of the fuel salt in the MSRE.

A comprehensive plan was initiated in 1994 to implement interim corrective measures, remove the reactive gases, chemically passivate the fluorinated charcoal to eliminate the explosive potential, remove the uranium deposits, and convert these materials to stable oxide for interim storage. The interim corrective measures (IP-3.5-010) to mitigate criticality potential, stop continued uranium migration to the charcoal bed, and enhance the containment of the charcoal bed cell to prevent radionuclide releases from a potential explosion were completed in November 1995. Since then, the off-gas system piping, the flush tank, and one of the two drain tanks have been depressurized (the system had pressure buildup due to the reactive gases of uranium hexafluoride and fluorine) and removal of the reactive gases continues by chemical trapping. The traps with the absorbed uranium are being stored in building 3019. Non-volatile blockages in the piping system are being bypasses or unplugged by chemical gas treatment. Actions are underway in preparation for solid uranium deposit removal from the ACB and conversion of uranium compounds to stable oxides. The fuel salt in the drain tanks and flush tank is to be removed and stabilized. These remediation actions are a part of DNFSB Recommendation 94-1.

The corrective actions taken thus far have greatly reduced the risk associated with the MSRE vulnerability, and the additional actions now in preparation and planning will fully remediate the vulnerability.

## B. HEU Vulnerability

In February 1996, DOE initiated a comprehensive Environment, Safety, and Health (ES&H) assessment of its inventory of Highly Enriched Uranium (HEU). The HEU Vulnerability Assessment identified vulnerabilities at ORNL which are recorded in the HEU Working Group Report. The HEU Vulnerability Management Plan identifies action items and schedules to correct the identified vulnerabilities.

Building 3019 at ORNL was listed by the HEU Working Group as one of the most vulnerable facilities. The facility was found to have five facility-specific vulnerabilities, two of them significant, and three adverse institutional factors. The major issues of concern include facility damage from an earthquake or high winds, leakage of a solution storage tank, and failure of U-233 storage containers. Any of these events could result in worker and public exposure and contamination of the environment.

A comprehensive natural phenomena evaluation being performed as part of the facility's Safety Analysis Update program is scheduled for completion by September 1999. Facility weaknesses noted during that evaluation will be corrected at a later date. The solution storage tank - it contains 15,000 liters of thorium nitrate and 130 grams of U-233 - was analyzed to ensure proper leakage confinement during transfers via outdoor, singly contained pipelines. All tank transfers are being closely monitored by workers. Final corrective action will involve identifying an acceptable long-term storage/disposal alternative, converting the contained solution to an acceptable form, and preparing the converted material for long-term storage/disposal. A decision on the long-term storage/disposal alternative will be part of the DNFSB Recommendation 97-1 Implementation Plan.

Planning is also under way to ensure against the failure of the U-233 storage containers during their removal from the facility's tube vaults. The plans feature the design of a ventilated confinement system for use while removing the (possibly degraded) containers. In addition, the facility's ventilation and building confinement system is to be evaluated to determine the necessary upgrades for reduction of the extrafacility impacts of container failure.

Approximately 200,000 grams of HEU has been identified as unneeded at ORNL and is being included in the SISMP for disposal as unneeded

material. DOE has concurred with including this unneeded material in the SISMP.

### C. Safe Storage of Uranium-233 and Recommendation 97-1

DNFSB Recommendation 97-1 addresses the need to safely store the existing inventories of unirradiated uranium-233 (U-233) bearing materials. A significant portion of the DOE inventory of U-233 is in storage at building 3019 at ORNL. An implementation plan has been recently submitted by DOE to the Board. The primary safety issue being addressed with the implementation plan is the lack of material characterization and uncertainty of storage conditions for U-233. The implementation process is being accomplished in the shortest possible time consistent with a graded approach, available funding, and safety of the personnel involved. At the same time, the safety of existing U-233 storage is ensured through near-term risk assessments, surveillance activities, and safety assurance actions. The U-233 associated with MSRE is addressed under the implementation plan for DNFSB Recommendation 94-1, and is therefore outside the scope of 97-1. However, once the U-233 material is removed from MSRE and stabilized, it will enter the scope of 97-1.

## IV. OTHER VULNERABILITY REVIEWS

### A. Seismic Evaluation

Executive Order (EO) 12941, *Seismic Safety of Existing Federally Owned or Leased Buildings*, was prepared to reduce the vulnerability to buildings owned or leased by agencies or departments for Federal use. The goals of EO 12941 are to develop listings of Federally owned buildings, identify vulnerable buildings within the listings, and prepare cost estimates for rehabilitating these buildings. The inventory and cost estimate information collected will be used to develop reliable information for developing future national public policy for mitigating seismic risk of vulnerable buildings within the Federal inventory.

The ORNL building scope includes buildings that are physically located at ORNL, East Tennessee Technology Park (formerly K-25), and the Oak Ridge Y-12 Plant. The ORNL report addresses buildings physically located at the ORNL plant site. ORNL buildings located at ETTP and Y-12 plant sites will be included in the EO 12941 implementation reports for those

sites. At ORNL, there are six contractor (LMER) leased buildings and 513 DOE owned buildings. Of the 513 owned buildings, 355 were determined, through a screening process, to be exempt from the requirements of EO 12941. One hundred fifty-eight owned buildings were found to be non-exempt. Of the 158 non-exempt buildings, one building was identified as "Definitely Needing Rehabilitation" and two were identified as "Exceptionally High Risk." Thirty-five buildings were found to be seismically vulnerable. Programs to fully mitigate the identified vulnerable buildings will be developed by the Federal Emergency Management Agency and Congress after December 2000. The total estimated cost for rehabilitating ORNL buildings is approximately $31 million.

## B. Fire Protection Assessment

Fire protection was one of the four areas selected in the DOE ES&H Assessment of ORNL in August 1997. The assessment identified four "concerns" in the fire protection area that should be corrected to enhance the program's effectiveness. These concerns are under evaluation by ORNL for possible corrective actions.

## C. Waste Drum Over-Pressurization

As a result of the recent drum over-pressurization event at the Paducah site, the potential for similar events at ORNL is being evaluated. The Waste Management and Remedial Action Division (WMRAD) at ORNL has reviewed data on their Hazardous Waste Operations Corrosive Drum Inventory and is performing these actions: 1) inspection of mixed and hazardous waste inventory including daily inspections. (As an example of effectiveness, the walkdown revealed one drum that was beginning to bulge, and it was removed and remotely punctured. The drum contained absorbent used in a cleanup of potassium hydroxide.); 2) inventory review of corrosive waste (this inventory consists of 177 drums plus other bottles and packages totaling approximately 2000 items); 3) inventory review of TRU drums which have been classified as mixed waste to determine if there is concern; and 4) provide recommendations and guidance for inspection criteria to other ORNL divisions with drums of hazardous material.

Drum overpacks for corrosive waste does not appear to be a problem at ORNL. Daily inspection is being performed on drums with nitric acid in the contents. Offsite shipment and repackaging is planned for some

corrosive waste drums. In the last year, a significant number of hazardous waste drums were repackaged, processed, or put in new containers by WMRAD that have reduced the vulnerability of waste drum over-pressurization. Previously 100% verification of Low-Level Waste and TRU waste was performed at the Waste Examination and Assay Facility; this has been reduced to 10% verification due to funding limitations, and the implications of this action are not yet known.

### D. Perchlorate Hood Contamination

In the 50 years that ORNL has conducted research, numerous operations involved the use of hot perchloric acid in chemical fume hoods. Salts from these operations, when deposited in ductwork, present a potential to cause fires and explosive reactions, placing hood users and maintenance personnel at risk. Considering this, ORNL initiated a Perchloric Acid Contaminated Hood Decontamination and Deconstruction Team and Committee comprised of multi-divisional representatives. Their efforts resulted in the development of an improved NFPA testing method and a unique sampling and decontamination procedure. The group, during 1993 to 1996, planned and executed decontamination and deconstruction of 40 perchlorate contaminated ventilation systems in a safe, environmentally correct and cost effective method. This procedures resulted in transfer of technology to Los Alamos National Laboratory, Brookhaven National Laboratory, ETTP, Y-12, and over 500 commercial businesses. It has been highlighted in the *DOE Safety Connection*, the *ORNL Review*, a peer reviewed national publication and eight national scientific conferences. All known contaminated hoods have been remediated and the team continues to enhance ORNL research operations and safety compliance through review of the use of perchloric acid. High concentration levels of perchlorates located in the exhaust ductwork of the shutdown hot cells in building 3019B have been identified in the past year. This is a shock-sensitive, explosive vulnerability. Remediation of this vulnerability awaits funding and the ductwork has been posted to prevent disturbance in the meantime. Also, the building is unoccupied and access is controlled.

## V. WASTE TANK REVIEW

Waste storage tanks and ancillary equipment at ORNL were reviewed to ensure that they were identified, characterized, and considered for possible chemical

reactions. ORNL WMRAD assures integrity and safe operation of waste storage tanks through two methods: 1) Waste Acceptance Criteria (WAC) for the liquid waste systems and 2) implementation of the Federal Facility Agreement (FFA) Tank Compliance Program.

The WAC, and approved variances, places restrictions on types of chemicals that can be introduced and provides all active tanks and their ancillary systems protection from active waste streams creating chemical incompatibilities or damage to system structure. The WAC includes criteria to minimize the addition of nitrate bearing wastes, no addition of specified RCRA-regulated solvents, restrictions on concentration of soluble and non-soluble organic solvents, and prevention of explosive or pyrophobic material.

Inactive tank systems controlled under the FFA program are scheduled for waste and risk characterization, obtaining information on liquid low-level sludge, repairing tank systems, monitoring and maintenance, evaluation of tank contents removal, removal from service of systems not meeting requirements, and transfer of inactive tanks from Waste Management to the Environmental Restoration (ER) program, for remediation by their Inactive Tanks Program Team. WMRAD and ER are now implementing an integrated approach to the isolation and remediation activities. The Tennessee Department of Environment and Conservation and the U.S. Environmental Protection Agency has approved the combined isolation and remediation activities. Each tank (with piping) is successfully isolated, and remediation activities immediately follow using techniques chosen for each individual tank (i.e., close-in-place or remove). Remediation activities include emptying the tank and “triple” rinsing the interior prior to being taken out of service.

Waste Characterization data has been collected and an associated risk assessment has been performed on the data for inactive tanks. This information is contained in the *Waste Characterization Data Manual for the Inactive Liquid Low-Level Waste Tank Systems at Oak Ridge National Laboratory*, DOE/OR/01-1159&D1 (supercedes ES/ER-80), June 1993 and the *Risk Characterization Data Manual for the Inactive Liquid Low-Level Waste Tank Systems at Oak Ridge National Laboratory*. DOE/OR/01-1168&D1, July 1993. Follow up actions to this issue will include a review of these reports to ensure that 1) the risks specifically associated with chemical vulnerabilities in inactive waste tank systems have been adequately identified and 2) the waste characterization data will be

compared to the current WAC to assure that the waste contents will not compromise the integrity of the systems structure.