ACCIDENT ANALYSIS REPORT
FINAL DRAFT VERSION

GENERAL ELECTRIC
VALLECITOS NUCLEAR CENTER
PLEASANTON, CALIFORNIA

RELATED TO LICENSE RENEWAL OF
SPECIAL NUCLEAR MATERIALS
LICENSE NO. SNM-960

Division of Fuel Cycle
and Material Safety

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PLANT ACCIDENTS INVOLVING POTENTIAL RADIOACTIVE MATERIAL RELEASE

I. Introduction

This chapter presents the results of an analysis of postulated accidents at VNC that could release radioactive materials to the environment. An entire spectrum of accidents was analyzed to show what releases could occur for a range of circumstances. These postulated events cover the range from those that are quite probable to those that are highly unlikely, because they require that a series of improbable events occur in sequence. Guidance for selecting accidents to be analyzed comes principally from the historical record of past accidents.[1,2] Although this record provides a good basis for the selection of initiating events, past accidents have been terminated without serious consequence or exposure to the public. In this analysis, we forced the postulated accident to proceed to serious consequence to test the adequacy of backup and mitigatory systems. As part of the relicensing action, the operation and pertinent process safety features of the SNM-960 operations were reviewed to evaluate the safety of existing conditions. The plant operation history, reports of incidents involving control of radioactive materials, and inspection reports were reviewed to help establish conditions to be used for postulating accidents. In the 12 years that this plant has operated, there has been no release to the unrestricted area reportable to the NRC on the basis that it exceeded the specified concentration limits defined in 10 CFR 20.43.[3]

A key feature of any research and development facility accident analysis is a search for a mechanism that will disperse radioactive materials. Some agent such as uncontrolled chemical, nuclear, or mechanical energy must act on the radioactive material to cause it to become airborne in a form hazardous to man. Such a search was carried out for VNC using accident event tree analysis.[4] The results show that the accidents that should be considered are fire, explosion, criticality, mechanical disruption (spills), and external phenomena. The importance of the first four is also indicated by the historical accident record. To date, we know of no accidents or incidents involving plutonium in a research and development or fuel fabrication facility that were initiated by external events, such as earthquake, flood, tornado, airplane crash, or highway/railroad explosion. In the following section, both internal and external accident types are discussed in some detail.

II. Bounding Cases

A number of specific accident scenarios were examined for release potential. Many of these were discarded as trivial because it was determined early in the analysis that the releases would be insignificant. However, several cases were identified in which releases could be significant, and these were examined in considerable detail. These latter cases show the greatest potential for radioactive material release and therefore form the bounding upper-limit accident cases. These worst-case conditions dictate the building structural and process equipment design criteria required to effectively mitigate accident consequences and to "test" the adequacy of safety and backup systems. To conclude that the releases from a postulated accident exceed normally acceptable values (10 CFR 20), one must assume the failure of one or more safety systems. In most cases, multiple failures must be assumed.

The following presents specific bounding cases for fire, explosion, mechanical disruption, criticality, and natural phenomena.

A. Fire

Detailed fire scenarios were evaluated for five separate areas at VNC: the AFL, the PAL, the RML, the CMCL, and the CPEL. The most plutonium in dispersible form is located in the AFL. The PAL and CMCL have the most combustible material in contact with dispersible plutonium. The RML has within the cells the most radioactive material in the form of fission products. The CPEL contains the second largest amount of special nuclear material, and this material is in contract with solvents that could provide the dispersing mechanism.

1. AFL

The AFL, in the basement of Building 102, is the main area in which the plutonium is handled. Both wet chemical operations and dry powder operations take place here. Fuel contributing to the fire loading in this area includes rubber or plastic glove box gloves, plastic glove box windows, PVC bags and piping, and general laboratory equipment. The limited amounts of solvents allowed in the laboratory would not contribute greatly to the fire loading, but could provide a source for starting a fire. Burning plastics and PVC produce a sooty smoke that can plug the filters of the ventilation system and in turn reduce the air flow. Because the openings in glove boxes are closed by combustible materials (gloves and plastic windows), a fire that starts inside a glove box can burn its way out into the room and vice versa. The entire laboratory area is equipped with heat detection devices and automatic sprinklers.[5]

A fire that is quickly extinguished by VNC personnel or by the automatic sprinkler system will result in a trivial release of plutonium (0.1 mg). Even a glove box fire involving 30 kg of $Pu(NO_3)_4$ that burns out the glove box HEPA filter would result in only a nominal release (310 mg).

Only in the case of sprinkler system failure could a significant release occur. A major fire in the AFL was assumed to burn for 1 hour before the fire brigade could extinguish it. The quantity of plutonium made airborne in such a major fire could be as high as 150 g. The most probable course of events would be that the HEPA filters would plug from the sooty smoke and terminate the releases.[6] However, the intermediate filters located in the AFL exhaust could burn leaving the single stage of HEPAs in Building 102A as the only filtration before release. In this case the release could be as high as 56 milligrams (mg).

2. PAL

Analytical chemistry in support of research being carried out in AFL is performed in the PAL. The work is done mostly in hoods and glove boxes. Typical of chemical laboratories, the combustible loadings are high because of cleaning material such as Kimwipes, electrically powered analytical equipment, chemicals, and solvents. On the other hand, the plutonium at risk is small, being limited to 350 g for the whole laboratory. As with the AFL, heat detectors are provided in glove boxes, and the room is covered by automatic water sprinklers.

Small fires have trivial consequences in terms of plutonium release (38 mg). The release for a major fire (must assume sprinkler system failure) is limited by the material present. Under the very pessimistic assumptions of sprinkler system failure and failure of the intermediate filters, the release could be as high as 220 mg.

3. RML

The hot cells of the RML provide a place for remote handling of highly radioactive materials such as irradiated reactor fuel. Combustible loadings are not particularly high, but the cells themselves are not protected by a sprinkler system. The operating areas are sprinkler protected. The exhaust is filtered by an intermediate set of HEPA filters that have a CO_2 cool-down system and a final stage of HEPA filters in Building 102A that have a manual water spray cool-down system.

Because only small quantities of special nuclear material are used in the cells and because of the two banks of HEPA filters in addition to the local filter, releases of uranium or plutonium from a postulated fire are quite small. However, releases of fission products could be significant by comparison. In the postulated worst-case accidental release caused by a fire, the dissolver tank seals are broken and 3000 Ci of ^{131}I and 6500 Ci of ^{133}Xe are released to the cell atmosphere. Because the release must pass through charcoal beds, 0.5% of 15 Ci of iodine is released to the environment, and it is assumed that all of the xenon passes through the filtration system to the environment.

4. CMCL

The features of this laboratory that relate to potential accidental fires are very similar to those of the AFL discussed above. Presently the amount of plutonium in the building is somewhat less (10 g maximum) and is likely to remain less since Building 103 is not located in the safeguards area that surrounds Building 102. Because it is a research chemistry laboratory, the combustible loading and the number of ignition sources can be quite high at times. But it is fully covered by an automatic sprinkler system. Only in the case in which the sprinklers fail to function and the room filters fail as well do the releases come up to mg quantities (1.5 mg).

5. CPEL

Although this facility was examined in some detail because of the quantities of special nuclear material present, the radiological hazard presented by low-enriched uranium is thousands of times less per gram of material than plutonium. Even so, the building is fully protected by automatic sprinklers, and HEPA filters are provided both in room and hood exhausts and in a separate final stage located well away from the building itself. Because the gram quantities of ^{235}U (<1 kg) are less than the ^{239}Pu in the AFL (30 kg) and the radiological hazard is so very much less, the analysis was not carried further than to say the consequences would be far less than those analyzed for the AFL.

B. Explosion

Flammable gases, solvents, and IX resins are possible sources for explosions in the areas listed in Section 7.2.1. Such explosions might initially disperse radioactive materials and then develop into one of the fires described above. The consequences of an explosion would be comparable to those of a major fire in which the sprinklers fail. The amount of material made airborne will be limited by the amount that can be suspended in air. An explosion involving the nitrate conversion box in the AFL could lead to a release of 11 mg of plutonium. An explosion in the PAL could release 5.6 mg. The force of a postulated explosion was judged to be insufficient to demolish the building walls, although such an explosion might well damage them, as well as the glove box and local HEPA filters.

C. Mechanical Disruption

Several operations in the AFL and the RML could lead to a mechanical dispersion of plutonium. Machinery in the AFL includes mechanical blenders, slugging presses, granulators, and high-pressure pellet presses. This equipment could malfunction and disperse plutonium. Overhead cranes, forklifts, and grinding and polishing machinery are used in the RML. Operator error or equipment malfunction could cause containers or process equipment to be ruptured and to disperse plutonium or other radioactive material. An examination of the consequences of these events shows that they would be no worse than those for the explosions postulated above.

D. Criticality

Selby, et al.,[7] have estimated the probability of a fuel fabrication criticality accident at 9×10^{-3}/yr on the basis of four reported accidents and the number of years plants have operated. The reported accidents all occurred in wet systems. The probability of a criticality in dry systems was estimated[8] at less than 2.3×10^{-3}/yr. After a thorough review of the plutonium process system and controls in use at the plant, the staff has concluded that even under the two-contingency constraint they could not identify a credible situation that could produce a criticality. (See Section 4.1 for a complete discussion of Nuclear Criticality Safety.)

In spite of this, we have treated the criticality as a postulated design basis accident for this safety evaluation. The postulated criticality takes place inside the nitrate conversion line in the AFL. We assume that the glove box is breached, but the integrity of the building and ventilation system is maintained. The gaseous iodines and noble gases generated by $2 \times 10^{+18}$ fissions are transported through the ventilation system and out the stacks with no reduction in activity other than an assumed 50% reduction of iodine because of plate-out.

At a velocity of approximately 1.0 m/s, the gases take 7 minutes to reach the closest site boundary located 440 m downwind from the stack. A value for X/Q of 2.8×10^{-3} s/m^3 based on 5% meteorology is chosen. This accident results in a release of 470 Ci of iodine and 14,000 Ci of noble gases. The prompt radiation from this postulated excursion presents no significant hazard to the public at the fence line.

E. Natural Phenomena

Sections 70.22 and 70.23 of 10 CFR Part 70 requires that existing licensed plutonium fabrication plants be examined to determine their ability to withstand adverse natural phenomena. We have started an analysis of the effects of natural forces upon plant operation. The natural phenomena being considered are recurrent severe weather, earthquake, and flood.[9] The review will assess the likelihood that the plant will be damaged by one of these phenomena and the consequences to the public of that damage. It will also provide a basis for determining any necessary modifications to improve the plant's ability to withstand adverse natural phenomena.

III. Perspective

A. Historical Record

An in-depth review of accidents that have occurred in federal government facilities in the last 35 years shows that, although accidents such as those postulated above can occur, the resulting releases have never been as high as those described above. This is because protective systems have functioned as designed, thus mitigating releases. An excellent summary of the historical record has been presented by Selby, part of which is quoted below.

Loss-of-Control Incidents Involving Plutonium and Its Compounds

> "Various incidents have occurred involving plutonium and its compounds ranging from spread of contamination to major fires. In no case have hazardous quantities of plutonium been released to the environment. Three of the incidents were very serious in nature and involved different forms of plutonium.
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> "In November 1959, an estimated 500 mg of plutonium was blown through the open door and the operating holes of a cell during decontamination of an evaporator. The explosion was attributed to inadvertently using a nitrate organic cleaning agent. Although the nearby buildings, vehicles, roadway, and ground were contaminated, air samplers in the area did not indicate air concentrations above acceptable limits. Thus, although air concentrations near the contamination have exceeded

limits for a short period of time, air concentrations exceeding established limits could not leave the site boundaries even under these rigorous conditions.

"Detonation of nitrated exchange resin initiated a fire that destroyed a plutonium purification facility in Richland, Washington, in November 1963. Many kilograms of plutonium as nitrate were involved. The integrity of the vessel and glove box were destroyed, and material could escape through a partially open door. Although alpha contamination was widespread throughout the facility, air samplers located at the site boundaries within one-quarter mile did not indicate air concentrations exceeding established limits. The alpha contamination in this instance appeared to be associated with soot, and the great number of soot particles generated in this incident may have effectively removed a large part of any plutonium which was airborne.

"The most serious and significant incident involving plutonium to date was the fire in a major plutonium fabrication facility at Rocky Flats, Colorado, in May 1969. Products of a fire in one area clogged the exhaust filters of one of three exhaust systems. Flammable vapors passed into other areas. Ultimately, a significant portion of the facility was involved. The supply fans operated during the initial phase of the fire, and loss in negative pressure allowed back diffusion into office areas. Hundreds of kilograms of plutonium as metal and compounds was involved with a significant quantity in unknown form involved with the equipment Material Unaccounted For (MUF). Only 200 mCi of airborne material (0.003 g) was released through a damaged exhaust system. Based on the author's personal observation and data, a maximum of 0.5% of the plutonium may have been airborne within the facility. This value was derived by making the highly conservative assumption that all contamination measured on the ceiling, walls, and floors of all contaminated areas of the facility and all surfaces outside the enclosure was caused by airborne material. The estimate does not include the negligible amounts of plutonium found in the water collected from extinguishment nor the unknown quantities in the exhaust system. The vast majority of the plutonium used to obtain this estimate was measured as floor contamination in the immediate fire area and is probably debris that fell or was washed from the enclosure during extinguishment."

B. Comparison to VNC

VNC is not a new facility. In many respects, it is comparable to facilities for which data are available. Improvements, such as the automatic fire-suppression system, and procedures based on much more experience are available to VNC. These improvements significantly reduce the potential for a hazardous release. The most pertinent comparison would be between the major facility fire postulated above and the Rocky Flats fire in 1969. At Rocky Flats, plutonium metal, which is pyrophoric, was intimately involved in the burning material. The oxide or nitrate forms of plutonium at VNC would not likely be so intimately mixed with the burning materials because they cannot burn and are usually separated from combustible materials by steel canisters. There were water sprinklers in the exhaust filter plenum at Rocky Flats. The ventilation systems at VNC are comparable to those at Rocky Flats in 1969. If the ventilation system at VNC were to respond to a fire as did the system at Rocky Flats (that is, by partial plugging and continued operation), then the releases from a 1-hour fire would be comparable.

IV. Consequence Summary

The releases and the resulting doses for the limiting case accidents postulated above are summarized in Table 1. Filter efficiencies have been taken as 95% for local filters and 99.95% for testable final filters. The above discussion of accident scenarios together with filter efficiencies leads to estimated releases from the buildings. Before any effect on people can be assessed, the released material must move from the release point to the location of a person and then interact with the person. These steps are termed environmental transport and radiological dose. Transport of radioactive materials from the point of release to the point of uptake or inhalation by humans was calculated using the Gaussian plume model. Meteorological data from the site were used to determine the probability distribution of wind speeds and stability conditions. In each case, the atmospheric dispersion factor used is that value that will not be exceeded 95% of the time. The wind is assumed to be blowing in the direction of the receptor. Dilution in the turbulent wake of the building has been taken into account. The meteorological dispersion factors used in each case are also shown in Table 1.

Radiological doses from plutonium were computed using the Task Group Lung Model as described in the International Committee on Radiation Protection Publication Number 19 (ICRP 19). A one-particle size was assumed. The deposition fraction was conservatively taken to be 1/4. The mix of radionuclides present in the VNC process lines was used as the basis for dose computation. In the case of insoluble plutonium (PuO_2), the critical organs are the lung and bone. For soluble plutonium ($Pu(NO_3)_4$), the critical organ is the bone. In each case the 50-year dose commitment is reported. This means that for materials that are absorbed and retained in the organs of the body, the dose accumulated over a 50-year period is computed.

Doses from inhalation of iodine or immersion in a cloud of noble gases were computed using the dose conversion factors listed in RG 1.109. A breathing rate of 3.47×10^{-4} m^3/s was assumed in all cases.

REFERENCES

1. "Operational Accidents and Radiation Exposure Experience Within the United States Atomic Energy Commission, 1943-1975," WASH-1192 (Rev.), Division of Operational Safety, USAEC, Washington, DC (1975).

3. Letter from R. T. Kratzke, NRC, to J. M. Graf, July 17, 1978, available in Docket File 70-754, License SNM-960.

4. W. L. Delvin, "Procedure For Hazards Analysis of Plutonium Glove Boxes Used In Analytical Chemistry Operations," HEDL-TME report 76-98 (1977).

5. Applicant response indicating AFL sprinklers are operational.

6. "Hazards Control Progress Reports," Nos. 51 through 54, UCRL-500077-75-2, UCRL-50007-76-1, UCRL-50007-76-2, UCRL-50007-77-1, Lawrence Livermore Laboratory.

7. J. M. Selby, et al., "Considerations in the Assessment of the Consequences for Effluents from Mixed Oxide Fuel Fabrication Plants," BNWL report 1697 (Rev. 1) (June 1975).

8. Final Evironmental Statement Related to Operation of Mixed Oxide Fuel Fabrication Plant, Exxon Nuclear Company, June 1974, Docket Number 70-1257.

9. Ayer, J. E. and Burkhardt, W., "Analysis of the Effects of Abnormal Natural Phenomena on Existing Plutonium Fabrication Plants," ANS Topical Meeting on the Plutonium Fuel Cycle, Bal Harbour, FL, May 2-4, 1977.

10. Draft Environmental Impact Statement, ERDA-1545-D, Rocky Flats Plant Site, Golden, Colorado (September 1977).

11. The Metabolism of Compounds of Plutonium and Other Actinides, 1972, ICRP Publication 19, Pergamon Press.

Table 1

Summary of Postulated Accident Events

Scenario	Radioactive Material Involved	Release to Atmosphere	Site Boundary Dose[a] (rem)
<u>FIRE - AFL LAB AREA</u> - Fire in room; 65 lbs of contaminated materials burn; sprinklers douse fire.	1×10^{-4} kg $Pu(NO_3)_4$	1.1×10^{-7} g Pu-mix	9.8×10^{-5} [b]
<u>FIRE - AFL GLOVE BOX</u> - Fire in nitrate conversion and scrap recovery boxes; sprinklers fail; both local glove box and intermediate HEPA filters fail.	30 kg $Pu(NO_3)_4$	5.6×10^{-2} g Pu-mix	50[b]
<u>FIRE - PAL LAB AREA</u> - Fire burns entire lab, hoods and glove boxes; sprinklers fail; both local glove box and intermediate HEPA filters fail.	3×10^{-1} kg $Pu(NO_3)_4$	2.2×10^{-4} Pu-mix	2×10^{-1} [b]
<u>FIRE - RML HOT CELL</u> - Fire in cell 3 burns into dissolver tank containing fresh charge of irradiated ^{235}U.	3000 Ci - ^{131}I 6500 Ci - ^{133}Xe	15 Ci ^{131}I 6500 Ci ^{133}Xe	22[c] 1.7×10^{-1} [b]
<u>EXPLOSION - AFL GLOVE BOX</u> - Nonspecific explosion in nitrate conversion area loads room air to capacity; local and intermediate HEPAs fail.	30 kg $Pu(NO_3)_4$	1.1×10^{-2} g Pu-mix	9.8[b]
<u>EXPLOSION - CMCL LAB AREA</u> - Chemical reaction disperses 10% of building inventory; room HEPA filters fail.	1×10^{-3} kg $Pu(NO_3)_4$	4×10^{-4} Pu-mix	3.6×10^{-1} [b]
<u>CRITICALITY - AFL GLOVE BOX</u> - Postulated criticality in nitrate conversion area yields $2 \times 10^{+18}$ fissions	Fission Products	470 Ci I 14,000 Ci Xe, Kr	7.4[c] 2.2[d]

Notes: a. Site boundary taken as 440 m SSE. Relative annual dispersion factor at this location is 2.8×10^{-3} s/m^3 based on maximum 5% meteorology.

b. 50-yr commitment to bone. Thyroid dose co tment. Whole body dose commitment.