LA-SUB--95-225

SAFETY ASSESSMENT FOR TA-48 RADIOCHEMICAL OPERATIONS

Prepared by
H&R Technical Associates, Inc.
151 Lafayette Drive
Suite 220
Oak Ridge, Tennessee 37830

August 1994

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

Prepared for
Los Alamos National Laboratory

27
MASTER

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

**Portions of this document may be illegible
in electronic image products. Images are
produced from the best available original
document.**

TABLE OF CONTENTS

	<u>Page</u>
1. INTRODUCTION	1
2. SUMMARY AND CONCLUSIONS	2
2.1 INTRODUCTION	2
2.2 SCOPE OF ANALYSIS	2
2.3 METHODOLOGY	3
2.4 RESULTS OF ANALYSIS	3
2.4.1 Building RC-1 Dissolver Area	4
2.4.2 Building RC-1 Analytical Laboratories	4
2.4.3 Building RC-1 Alpha Facility	4
2.4.4 Building RC-1 Counting Room	5
2.4.5 Building RC-1 Hot Cells	5
2.4.6 Building RC-8	5
2.4.7 Building RC-28	6
2.4.8 Building RC-45	6
2.4.9 Building RC-46	6
2.5 SUMMARY AND CONCLUSIONS	6
3. SITE CHARACTERISTICS	8
3.1 LOCATION	8
3.2 GEOGRAPHY	8
3.3 LABORATORY FACILITIES NEARBY	10
3.4 DEMOGRAPHY	12
3.4.1 Size	12
3.4.2 Distribution	12
3.5 NEARBY INDUSTRIAL, TRANSPORTATION, AND MILITARY FACILITIES ...	12
3.6 METEOROLOGY	16
3.6.1 Observation Network	16
3.6.2 Wind	16
3.6.2.1 Speed, Direction, Stability Distributions	16
3.6.2.2 Dispersion Parameters	17
3.6.2.3 High Wind Probability Distribution	19
3.6.2.4 Tornado Probability	22
3.7 SEISMOLOGY	22
3.8 SUMMARY OF CHARACTERISTICS AFFECTING FACILITY OPERATING REQUIREMENTS	23
3.9 REFERENCES	25

TABLE OF CONTENTS (continued)

	<u>Page</u>
4. PROCESS/OPERATIONS DESCRIPTION	27
4.1 INTRODUCTION	27
4.2 BUILDING RC-1	27
4.2.1 Dissolution Area	27
4.2.2 Laboratories	31
4.2.3 Alpha Facility	38
4.2.4 Counting Room	41
4.2.5 Hot Cells	43
4.3 BUILDING RC-8	53
4.3.1 Isotope Separation Operations	53
4.3.2 Modification of Isotope Separation Equipment	55
4.4 BUILDING RC-28	55
4.4.1 Laser Laboratory Operations	55
4.4.2 Water Sample Analysis Operations	57
4.5 BUILDING RC-45	57
4.6 BUILDING RC-46	58
4.7 REFERENCES	59
5. FACILITY AND SUPPORT SYSTEM DESCRIPTION	60
5.1 INTRODUCTION	60
5.2 BUILDING RC-1	60
5.2.1 Dissolver Area	62
5.2.1.1 Main Floor	62
5.2.1.2 Basement	63
5.2.2 Laboratories	64
5.2.3 Alpha Facility	66
5.2.3.1 Main Floor	66
5.2.3.2 Basement	67
5.2.4 Counting Room	67
5.2.5 Hot Cells	69
5.3 BUILDING RC-8	70
5.3.1 Isotope Separator Area	70
5.3.2 Machine Shop Area	70
5.4 BUILDING RC-28	71
5.4.1 Building RC-28 Laser Laboratory	71
5.4.2 Building RC-28 Water Sample Laboratory	71
5.5 BUILDING RC-45	72
5.6 BUILDING RC-46	72

TABLE OF CONTENTS

	<u>Page</u>
6. RISK ASSESSMENT	74
6.1 INTRODUCTION AND METHODOLOGY	74
6.1.1 Hazard Identification and Screening	74
6.1.2 Accident Initiating Event Identification and Screening	85
6.2 BUILDING RC-1	90
6.2.1 Dissolver Area	90
6.2.2 Laboratories	98
6.2.3 Alpha Area	134
6.2.4 Counting Room	145
6.2.5 Hot Cells	145
6.3 BUILDING RC-8	150
6.4 BUILDING RC-28	154
6.5 BUILDING RC-45	154
6.6 BUILDING RC-46	160
6.7 REFERENCES	169
7. ACCIDENT ANALYSIS	174
7.1 TOXIC MATERIAL RELEASES	174
7.2 EXPOSURE TO RADIOACTIVE MATERIAL (ALPHA AREA)	180
7.3 EXPOSURE TO RADIOACTIVE MATERIAL (HOT CELLS)	184
7.3.1 Internal Exposure to Radioactive Material	184
7.3.2 External Exposure to Radioactive Material	191
7.4 REFERENCES	192

LIST OF FIGURES

	<u>Page</u>
Fig. 3.1. Location of TA-48 in relation to other Laboratory Technical Areas (TAs) and surrounding landholdings.	9
Fig. 3.2. Technical Area 48 site map.	11
Fig. 3.3. Technical sites.	13
Fig. 3.4. Calculated horizontal-dispersion coefficients (σ_y), based on TA-50 (12 m AGL) values.	20
Fig. 3.5. Calculated vertical-dispersion coefficients (σ_z), based on TA-50 (12 m AGL) values. . . .	21
Fig. 4.1. Building RC-1 main floor floor plan.	28
Fig. 5.1. Arrangement of typical two-work-area laboratory space.	65
Fig. 5.2. Floor plan for Buildings RC-46 and RC-47.	73

LIST OF TABLES

	<u>Page</u>
Table 3.1. Technical area populations	14
Table 3.2. 1990 Population within 80 km of Los Alamos	15
Table 3.3. Key to the P-G stability categories.	18
Table 4.1. Dissolution area inventory of significant hazardous chemicals	32
Table 4.2. Operations performed in the weapons testing laboratories	33
Table 4.3. Most significant inventories of hazardous chemicals for the weapons testing laboratories	37
Table 4.4. Most significant chemical inventories for the medical isotopes laboratories	39
Table 4.5. Current alpha facility SNM inventory	42
Table 4.6. Hot cell radionuclide inventory list	46
Table 4.7. Hot cell area pit inventory	52
Table 5.1. TA-48 data acquisition counter utility services requirements	68
Table 6.1. Hazard Identification Worksheet	75
Table 6.2. Chemical toxicity classes based on LI_{50}	77
Table 6.3. Limiting release amounts for "instantaneous" release scenarios: on-site exposures ...	81
Table 6.4. Limiting release amounts for "instantaneous" release scenarios: off-site exposures ...	82
Table 6.5. Dominant fission products and corresponding inhalation doses for weapons debris ...	84
Table 6.6. Limiting release amounts for "instantaneous" releases of radioactive materials for inhalation exposures	86
Table 6.7. Hazard classification scheme	87
Table 6.8. Release fractions for screening evaluations of material release events	89
Table 6.9. Hazard Identification Worksheet (dissolver area)	91
Table 6.10. Screening analysis for inventories of listed chemicals exceeding 1 lb (dissolver area)	93
Table 6.11. Identification and screening of accident initiating events (dissolver area)	95
Table 6.12. Accident initiating events (dissolver area)	99
Table 6.13. Hazard Identification Worksheet (analytical laboratories)	100
Table 6.14. Screening analysis for inventories of listed chemicals exceeding 1 lb (analytical laboratories)	103
Table 6.15. Identification and screening of accident initiating events (analytical laboratories) ...	122
Table 6.16. Accident initiating events (analytical laboratories)	135
Table 6.17. Hazard Identification Worksheet (alpha area)	137
Table 6.18. Screening analysis for inventories of radionuclides (alpha area)	139
Table 6.19. Screening analysis for physical form of radionuclides (alpha area)	140
Table 6.20. Identification and screening of accident initiating events (alpha area)	141
Table 6.21. Accident initiating events (alpha area)	144
Table 6.22. Hazard Identification Worksheet (counting room)	146
Table 6.23. Hazard Identification Worksheet (hot cells)	148
Table 6.24. Accident initiating events (hot cells)	151
Table 6.25. Hazard Identification Worksheet (RC-8)	152
Table 6.26. Hazard Identification Worksheet (RC-28)	155
Table 6.27. Hazard Identification Worksheet (RC-45)	157

LIST OF TABLES (continued)

	<u>Page</u>
Table 6.28. Screening analysis for inventories of listed chemicals exceeding 1 lb (RC-45)	159
Table 6.29. Identification and screening of accident initiating events (RC-45)	161
Table 6.30. Accident initiating events (RC-45)	164
Table 6.31. Hazard Identification Worksheet (RC-46)	165
Table 6.32. Screening analysis for inventories of listed chemicals exceeding 1 lb (RC-46)	168
Table 6.33. Identification and screening of accident initiating events (RC-46)	170
Table 6.34. Accident initiating events (RC-46)	172
Table 7.1. Postulated events involving the generation and/or release of toxic materials	175
Table 7.2. Key accidental release parameters for alpha area initiating events	181
Table 7.3. Radionuclide limiting inventories	186
Table 7.4. Dose (rem) resulting from external exposure to 100,000 rem/h (28 rem/s) source (100,000 rem/h @ 1 m)	193

1. INTRODUCTION

The purpose of this report is to document an assessment performed to evaluate the safety of the radiochemical operations conducted at the Los Alamos National Laboratory operations area designated as TA-48. This Safety Assessment for the TA-48 radiochemical operations was prepared to fulfill the requirements of U.S. Department of Energy (DOE) Order 5481.1B, "Safety Analysis and Review System" (1986). DOE/Albuquerque (AL) Order 5481.1B, "Safety Analysis and Review System" (1988), provided guidance for preparing this report.

The Los Alamos National Laboratory is owned by the United States government and is operated by the University of California as a prime contractor to the DOE. The laboratory is involved in a variety of research and development programs, many of them supporting nuclear weapons applications. The laboratory is one of several facilities administered by the DOE Albuquerque Field Office.

The area designated as TA-48 is operated by the Chemical Science and Technology (CST) Division and is involved with radiochemical operations associated with nuclear weapons testing, evaluation of samples collected from a variety of environmental sources, and nuclear medicine activities.

This report documents a systematic evaluation of the hazards associated with the radio-chemical operations that are conducted at TA-48. Buildings that are covered in this report include RC-1, RC-8, RC-28, RC-45, and RC-46.

Consistent with AL Order 5481.1B, the purpose of this document is to evaluate the magnitude of the hazards associated with the TA-48 radiochemical operations so that the need for a Safety Analysis Report (SAR) can be assessed. Accordingly, the accident analyses are limited to evaluation of the expected consequences associated with a few bounding accident scenarios that are selected as part of the hazard analysis.

Section 2 of this report presents an executive summary and conclusions, Section 3 presents pertinent information concerning the TA-48 site and surrounding area, Section 4 presents a description of the TA-48 radiochemical operations, and Section 5 presents a description of the individual facilities. Section 6 of the report presents an evaluation of the hazards that are associated with the TA-48 operations and Section 7 presents a detailed analysis of selected accident scenarios.

2. SUMMARY AND CONCLUSIONS

2.1 INTRODUCTION

The purpose of this section is to summarize the analysis of the TA-48 activities that is documented in this Safety Assessment. The primary goal of the analysis is to address the hazards associated with radiochemical operations. A variety of radiochemical activities are conducted at TA-48, including the chemical processing of small amounts of radioactive materials from weapons test activities, natural environmental sources, and medical radioisotope production operations. TA-48 radiochemical activities that are addressed in this analysis include those in Buildings RC-1, RC-8, RC-28, RC-45, and RC-46.

Building RC-1 activities include receiving weapon test shot debris into the dissolver area, manual separation of the material, chemical processing, and subsequent preparation of test samples for analysis. Most of the test sample preparation and testing is conducted in numerous individual laboratories throughout RC-1. Final analysis of the samples is performed in the counting area. The radioactive materials that are handled in these operations are beta and gamma radiation emitters.

Building RC-1 activities also include chemical research of high-alpha-activity materials in the alpha facility.

The production of a wide variety of radioisotopes for research and medical purposes is conducted in the hot cell area. Target materials that have been irradiated to produce the desired radionuclides are received and processed in the series of interconnected and highly shielded hot cells.

Buildings RC-8, RC-28, RC-45, and RC-46 are involved with small-scale analytical chemistry activities similar to those in Building RC-1.

2.2 SCOPE OF ANALYSIS

The analysis described in this report was performed to address the radiochemical operations that are conducted in the TA-48 complex. A number of buildings are located in TA-48. Radiochemical operations are conducted in those buildings mentioned in the preceding section. The remaining buildings are primarily devoted to administrative activities and are not included in this analysis.

This analysis focused on the hazards associated with the radioactive materials that are present at TA-48. In performing the analysis, it was necessary to evaluate other hazardous materials that could possibly initiate or worsen a release of or exposure to radioactive materials. Toxic or hazardous materials used in radiochemical operations that were present in sufficient quantity to potentially have adverse consequences were also examined.

2.3 METHODOLOGY

The analysis was performed by touring the TA-48 radiochemical operations and gathering information on the activities that are conducted in the facilities. Descriptions of the facilities and operations were prepared, and the hazards that are associated with the activities were identified. Next, the hazards were evaluated to determine if they might be routinely encountered and accepted by the public. Hazards such as electrical energy and mechanical hazards that could not have any adverse impact other than that normally encountered and accepted by the public were screened from further consideration.

Hazards that were identified as requiring further evaluation were subjected to a screening exercise that would determine if an exposure to the hazard could possibly result in significant adverse health effects. In the case of toxicological and radiological hazards, the quantities of materials that are present are considered. If quantities are sufficient to potentially cause adverse health effects, the materials were retained for more detailed analysis of the potential consequence of credible accident conditions. Possible accident initiators were identified, and the potential effects of bounding accident conditions were assessed. The purpose of this Safety Assessment is to evaluate the magnitude of potential adverse health effects on persons on-site and off-site from accident conditions so that the need for a SAR can be assessed. Therefore, no attempt was made in this analysis to evaluate the frequency of accidents that might occur, regardless of the potential consequence.

2.4 RESULTS OF ANALYSIS

The results of the analysis performed to evaluate the safety of the TA-48 radiochemical operations are summarized in the following subsections.

2.4.1 Building RC-1 Dissolver Area

The primary hazards of interest identified in the dissolver area are those resulting from the radioactive debris from nuclear weapons testing and the toxic chemicals used in processing the debris for further evaluation in other RC-1 operations. The radioactive material debris is present in small quantities and release of the material could not result in an exposure in excess of 100 mrem EDE from an internal exposure.

The bounding accident for RC-1 radiochemical operations using toxic materials was identified in the dissolver area. The hydrogen fluoride (HF) stored in the area represents one of the most hazardous materials in the facility, and it is present in sufficient quantity to potentially result in fatal exposure both on-site and off-site (see Section 7.1). The estimated peak concentration of HF at Pajarito Road (nearest point of public access) for this scenario is 2,710 mg/m³, which is more than 100 times the concentration that is immediately dangerous to life and health (IDLH).

2.4.2 Building RC-1 Analytical Laboratories

The analytical laboratories located throughout Building RC-1 are involved with a variety of analytic chemistry activities. Both radioactive materials and toxic materials are handled in the laboratories. The hazard resulting from the radioactive materials is of little concern because the quantities are very small.

A number of inventories of toxic materials that have been identified in the analytical laboratories could result in significant adverse health effects both on-site and off-site. Scenarios that could result in such releases were postulated but were not developed and analyzed in detail because they were clearly bounded by the HF release from the dissolver area.

2.4.3 Building RC-1 Alpha Facility

Activities in the alpha facility involve processing of alpha-emitting radioactive materials. This area is the only one in Building RC-1 where significant amounts of alpha-emitters are processed. Toxic materials are used in the processing activities and are present in quantities similar to those found in the dissolver area and the laboratories. The potential effects of the accidental exposure to toxic materials were

not considered in detail because such exposure scenarios were clearly bounded by postulated accidents for the other activities.

Postulated accidents that could result in the release of the alpha-emitting radioactive materials were examined; such accidents could possibly result in off-site doses as high as about 5 rem (see Section 7.2).

2.4.4 Building RC-1 Counting Room

Counting room activities involve the presence of both radioactive and toxic materials. Both types of materials are present in small quantities, and accidents that could involve the materials are either of no concern or were clearly bounded by postulated events in other areas.

2.4.5 Building RC-1 Hot Cells

Hot cell activities also involve the presence of both radioactive and toxic materials. The toxic materials are present in small quantities and are used in chemical processing activities in the hot cells; therefore, these materials are of little or no concern except for their possible involvement as initiators of other accidents that involve radioactive materials. Accidents that might involve the release of toxic materials are bounded by postulated events in other areas.

Radioactive materials in the hot cells present the potential for both internal and external radiation exposure. Radiation levels of freshly irradiated targets are very high, and even short exposures in close proximity to the source could result in potential fatalities (see Section 7.3.2).

Although a wide variety of radioisotopes may be processed in the hot cells, and a number of different radioisotopes may be present at one time, the inventories are small and any accidental internal radiation exposures would not be very high. Postulated events that would result in either on-site or off-site internal exposures would not result in doses in excess of 100 mrem EDE (see Section 7.3.1).

2.4.6 Building RC-8

Small amounts of radioactive and toxic materials are present in Building RC-8. The radioactive materials are present in very small quantities and do not present a significant hazard. Toxic materials are present in very small quantities; in addition, these materials are very common and are routinely encountered and accepted by the public.

2.4.7 Building RC-28

Small amounts of radioactive and toxic materials are present in Building RC-28. The radioactive materials are present in very small quantities and do not present a significant hazard. Toxic materials are present in very small quantities; in addition, they are very common and are routinely encountered and accepted by the public.

2.4.8 Building RC-45

Small amounts of radioactive materials and some larger quantities of toxic materials are present in Building RC-45. The radioactive materials are present in quantities that do not present a significant hazard. The toxic materials are present in quantities that, under accident conditions, could cause exposures resulting in adverse health effects on-site. However, the consequences of such accidents are bounded by those associated with the postulated HF release from the dissolver area.

2.4.9 Building RC-46

Toxic materials are present in Building RC-46 in quantities that, under accident conditions, could cause exposures resulting in adverse health effects on-site. The accidents that could result from Building RC-46 operations are bounded by those that might occur in Building RC-1 and that are analyzed as bounding events.

2.5 SUMMARY AND CONCLUSIONS

A variety of hazards are present in the TA-48 radiochemical operations. Many of the hazards are not unique to the radiochemical operations and are routinely encountered by the public. The TA-48 activities were examined to identify hazards associated with electrical energy, electromagnetic radiation, explosive materials, fissile materials, flammable materials, kinetic energy, potential energy, radioactive materials, reactive materials, thermal energy, toxic materials, and any other hazards that might not be routinely accepted by the public. The radioactive and toxic materials that are present in large quantities were identified as being the primary hazards of concern. Flammable/explosive materials, although

commonly used in industry, could result in the dispersion of the radioactive and toxic materials that are of more concern.

Toxic material inventories that could cause significant adverse health effects on-site or off-site were identified in Building RC-1, RC-45, and RC-46. The inventories in Building RC-1 were used to define bounding accident conditions involving toxic materials for the TA-48 radiochemical operations. An HF release from the dissolver area was identified as the bounding event and could result in potentially fatal off-site and on-site exposures.

The potential exists for accidents resulting in both external and internal radiation exposures to occur. Potentially fatal external exposures to radiation in the hot cell area can be postulated, but exposures of this magnitude could occur only on-site.

The bounding event for internal radiation exposure was identified for the RC-1 alpha facility operations. The predicted accident dose to an off-site receptor would not be expected to cause significant health effects, although it does exceed the public dose limit.

The RC-1 radiochemical operations are quite extensive. This analysis uses information made available during the short duration of the project to provide a cursory examination of those operations. Hazards were identified and accident events postulated that could potentially result in both on-site and off-site fatalities. Therefore, preparation of a SAR for these operations is indicated. Mitigation of the accident consequences could possibly be achieved by limiting hazardous material inventories, by modifying equipment, or by changing procedures. Increased analysis precision, especially if combined with reduced inventories and procedural/equipment changes, may show more acceptable results. A detailed accident scenario frequency analysis may also support risk acceptability and should be performed in preparing a SAR. Although the potential for external exposure to high levels of radiation will always exist as the result of the hot cell operations, the frequencies of postulated accidents may be sufficiently low as to cause little concern that such accidents will actually occur.

3. SITE CHARACTERISTICS

This chapter identifies pertinent regional and local site data necessary to characterize the Technical Area-48 (TA-48) site. Of particular interest is the potential for interaction of the TA-48 radiochemical operations with the surrounding area.

3.1 LOCATION

The Laboratory and associated residential areas of Los Alamos and White Rock are in and adjacent to Los Alamos County, in north-central New Mexico; about 60 miles north-northeast of Albuquerque; about 35 miles by highway from the state capital, Santa Fe (LASL 1978); and 25 miles northwest of Santa Fe by air (DOE 1979). Figure 3.1 is a map of the Laboratory in relation to surrounding landholdings.

The Laboratory was established in its present location during World War II in part because of the area's mild climate and relative isolation. The surrounding area, including most of Los Alamos County and portions of Sandoval, Rio Arriba, and Santa Fe counties, is largely undeveloped. Large tracts of land in the Jemez Mountains to the north, west, and south of the Laboratory site are held by the U.S. Forest Service and U.S. National Park Service.

3.2 GEOGRAPHY

The Laboratory is located between 7,500 and 8,000 ft above sea level (ASL) on the eastern slopes of the Jemez Mountains. The 27,500-acre Laboratory site and adjacent communities are situated on the Pajarito Plateau (DOE 1979), a shelf 10-15 miles wide and 45 miles long (LASL 1978) that stretches between the Jemez Mountains to the west and the Rio Grande Valley to the east (DOE 1979). Deep erosion of the plateau by runoff moving toward the Rio Grande has resulted in a series of mesas separated by canyons (LASL 1978) that trend east-southeast (DOE 1979). Most Laboratory and community development is confined to the mesa tops, which range in elevation from about 7,800 ft on the flank of the Jemez Mountains to about 6,200 ft above the Rio Grande Valley (LANL 1989).

Fig. 3.1. Location of TA-48 in relation to other Laboratory Technical Areas (TAs) and surrounding landholdings.

The Sangre de Cristo Mountains lie nearly 40 miles to the east. The Rio Grande Valley runs north-northeast to south-southwest between the two mountain ranges (Bowen 1990).

3.3 LABORATORY FACILITIES NEARBY

This discussion of facilities nearby is based on LANL (1989).

The Laboratory comprises 32 technical areas (TAs). The TA-48 site is located on DOE-controlled land south of the Los Alamos townsite. The site is situated along Pajarito Road. Figure 3.2 is a map of the TA-48 site.

Several DOE-controlled facilities border on the TA-48 site (see Figure 3.1).

- **TA-3:** In this main technical area of the Laboratory is the Administration Building that contains the Director's office and administrative offices and laboratories for several divisions. Other buildings house the central computing facility, administration offices, materials department, science museum, chemistry and materials science laboratories, physics laboratories, technical shops, cryogenics laboratories, Van de Graaff accelerator, and cafeteria.
- **TA-55:** Plutonium processing and metallurgy research are done here.
- **TA-59:** Occupational health and environmental science activities are conducted here.
- **TA-60:** This is an undeveloped technical area.
- **TA-64:** This is an undeveloped technical area.

TA-48

STRUCTURE NUMBER INDEX

STRUCTURE TA-NUMBER	STRUCTURE DESIGNATION	STRUCTURE NOMENCLATURE	STRUCTURE LOCATOR	SHEET MAP NO. REF
48- 1	48- 1	LABORATORY BUILDING	1 D-3	
48- 2	RC- 2	GUARD HOUSE	1 C-3	
48- 8	RC- 8	GENERAL STORAGE BLDG.	1 C-2	
48- 13	RC- 13	LAWN BUILDING	1 E-4	
48- 17	RC- 17	ASSEMBLY & CHECKOUT BLDG.	1 D-4	
48- 26	48- 26	OFFICE BUILDING	1 D-2	
48- 27	48- 27	OFFICE BUILDING	1 D-2	
48- 28	48- 28	INSTRUMENT DEV. BLDG.	1 F-2	
48- 29	RC- 29	TRANSPORTABLE OFFICE BLDG.	1 D-2	
48- 30	RC- 30	TRAILER, OFFICE	1 C-3	
48- 31	RC- 31	TRAILER, LAB & OFFICE	1 D-4	
48- 32	48- 32	TRANSPORTABLE	1 D-2	
48- 34	RC- 34	TRANSPORTABLE	1 A-2	
48- 35	RC- 35	RAILROAD BOXCAR, STORAGE	1 E-3	
48- 36	RC- 36	RAILROAD BOXCAR, STORAGE	1 E-4	
48- 37	RC- 37	STORAGE SHED	1 D-2	
48- 38	RC- 38	STORAGE SHED	1 D-2	
48- 39	RC- 39	STORAGE SHED	1 E-4	
48- 40	RC- 40	STORAGE SHED	1 E-4	
48- 41	RC- 41	STORAGE SHED	1 G-2	
48- 45	48- 45	A.R.M. DIAGNOSTIC BLDG.	1 C-3	
48- 46	RC- 46	TRANSPORTABLE OFFICE BLDG.	1 C-2	
48- 47	RC- 47	TRANSPORTABLE OFFICE BLDG.	1 B-3	
48- 56	RC- 56	TRANSPORTABLE OFFICE BLDG.	1 A-3	
48- 89	RC- 89	STORAGE SHED	1 E-4	
48- 90	RC- 90	STORAGE SHED	1 E-4	
48- 91	RC- 91	STORAGE SHED	1 F-2	
48-100	48-100	TRAILER, STORAGE	1 E-4	
48-101	48-101	TRAILER, STORAGE	1 E-4	
48-102	48-102	TRAILER, STORAGE	1 E-3	
48-103	48-103	BOTTLE TANK	1 E-3	
48-104	48-104	BOTTLE TANK	1 E-3	
48-105	48-105	BOTTLE TANK	1 E-3	
48-106	48-106	TRANSPORTAINER	1 E-3	

Fig. 3.2. Technical Area 48 site map.

3.4 DEMOGRAPHY

3.4.1 Size

According to LANL (1992) Los Alamos County has an estimated 1990 population of 18,200 (based on the 1990 census adjusted to July, 1990). The Los Alamos townsite (which includes residential areas of the Eastern and Western areas, North Community, and Barranca and North Mesas) has an estimated population of 11,400. The White Rock area (includes residential areas of White Rock, La Senda, and Pajarito Acres) has about 6,800 residents. See Figure 3.3 for a map.

3.4.2 Distribution

Within the geographic boundaries of the Laboratory, most of the population is in the technical areas (LANL 1992); see Table 3.1.

The distribution of the resident nonwork force is calculated with respect to the Los Alamos Meson Physics Facility's stack at TA-53. Population estimates for 1990 place about 213,000 persons within an 80-km (50-mile) radius of Los Alamos (Table 3.2).

3.5 NEARBY INDUSTRIAL, TRANSPORTATION, AND MILITARY FACILITIES

Besides the DOE-controlled facilities mentioned previously, the only other nearby industrial, transportation, or military facility is the Los Alamos Airport.

The airport, also controlled by DOE, has a single east/west runway, the west end of which is approximately 4,500 ft from the TA-48 site. All air traffic enters from and exits to the east. The west end of the strip is used only for run-ups or taxiing. The 7,150-ft altitude excludes some small aircraft. Airport officials estimate 350-400 scheduled and 500-600 private flights per month. Air traffic is limited because of the location of the field, necessity for traffic to enter from and exit to the east, and need for advance permission to land. Aircraft present minimal risk to facilities at the TA-48 site (Fuentes 1988).

Los Alamos

NATIONAL LABORATORY
Technical Area Locations

TA-0	Unassigned Land Reserve
TA-2	Omega Site
TA-3	South Mesa Site
TA-6	Two Mile Mesa Site
TA-8	Anchor Site West
TA-9	Anchor Site East
TA-11	K-Site
TA-14	Q-Site
TA-15	R-Site
TA-16	S-Site
TA-18	Pajarito Laboratory
TA-21	DP-Site
TA-22	TD-Site
TA-28	Magazine Area A
TA-33	HP-Site
TA-35	Ten Site
TA-36	Kappa Site
TA-37	Magazine Area C
TA-39	Ancho Canyon Site
TA-40	DF-Site
TA-41	W-Site
TA-43	Health Research Lab & DOE Headquarters
TA-46	WA-Site
TA-48	Radiochemistry Site
TA-49	Frijoles Mesa Site
TA-50	Waste Management Site
TA-51	Radiation Exposure Facility
TA-52	Reactor Development Site
TA-53	Meson Physics Facility
TA-54	Waste Disposal Site
TA-55	Plutonium Facility Site
TA-57	Fenton Hill Site
TA-59	OH-Site
TA-73	Airport

TA-60,61,64,66,68,72
(unnamed TAs)

Fig. 3.3. Technical sites.

Table 3.1. Technical area populations

Area	Population	Area	Population	Area	Population
0	549	21	242	46	371
2	24	22	76	48	193
3	6,495	28	N/A	49	0
6	6	33	73	50	71
8	61	35	591	51	38
9	58	36	52	52	199
10	12	37	9	53	1,125
14	0	39	80	54	22
15	121	40	38	55	605
16	493	41	136	57	18
18	80	43	212	59	273
TOTAL POPULATION: 12,359					

Table 3.2. 1990 Population within 80 km of Los Alamos

Direction	Distance from TA-53 (km)								
	1-2	2-4	4-8	8-15	15-20	20-30	30-40	40-60	60-80
N	1	0	0	0	0	0	1,136	0	368
NNE	0	0	0	565	0	542	1,730	7,797	221
NE	1	0	0	0	317	15,352	1,009	1,135	3,846
ENE	0	0	0	1,940	1,563	2,716	2,729	1,187	2,214
E	0	0	83	25	556	1,145	696	0	1,402
ESE	0	0	0	0	0	293	23,151	1,067	1,476
SE	0	0	6,757	0	0	0	53,520	2,443	8
SSE	0	0	0	0	0	0	426	4,347	95
S	0	0	0	50	0	318	614	6,775	0
SSW	0	0	0	20	0	817	201	2,238	33,485
SW	0	0	0	0	0	0	315	4,157	0
WSW	0	0	0	0	0	315	313	2,545	207
W	0	0	0	0	0	0	0	164	132
WNW	0	1,435	6,535	0	0	0	0	0	3,081
NW	0	523	1,721	0	0	0	0	1,438	0
NNW	0	578	579	0	0	0	0	64	62
1990 Pop. Distribution	2	2,536	15,675	2,600	2,436	21,497	85,838	35,357	46,597

Note: Total population within 80 km of Los Alamos is 213,000.

3.6 METEOROLOGY

The following sections describe aspects of the local meteorology and the measurement of meteorological variables that are important in evaluating potential accident conditions for the TA-48 radiochemical operations.

3.6.1 Observation Network

The Laboratory's Environmental Protection Group, Air Quality and Meteorology Section, maintains a meteorological tower and monitoring network. Measured meteorological variables include wind speed and direction, vertical wind speed, temperature, insolation, relative humidity, and precipitation. Measurements are taken at the six towers at ground level and at various heights (34-300 ft). Not all variables are measured at each tower, and some variables are measured at several tower levels.

Los Alamos weather data (temperature, precipitation, and snowfall) have been recorded at TA-59 since 1979. Temperature, humidity, and precipitation records have been kept for White Rock since 1964. Only precipitation is measured at three other locations.

Representative meteorological data have been measured at TA-53, TA-54, TA-59, East Gate, and Bandelier.

3.6.2 Wind

Wind conditions at LANL are described in the following sections.

3.6.2.1 Speed, Direction, Stability Distributions

Surface winds are quite light at Los Alamos; they average 7 mph. Winds are light because New Mexico lies at the southern edge of the band of westerly winds common over central North America. Winds speeds are strongest from March through June and weakest in December and January. Intense storms and associated cold fronts, occurring especially during the spring months, cause the strongest winds. Sustained winds exceeding 25 mph and peak wind gusts exceeding 50 mph are common during the spring. Frequency of wind greater than 11 mph ranges from 10% at TA-50 to 20% at the East Gate. Low wind speeds (< 5.5 mph) prevail about 45% of the time at TA-50.

Because of the complex terrain, Los Alamos surface winds often vary dramatically with time of day, location, and height above ground. When the sun is shining and winds are light and large-scale, a 600- to 1,000-ft-deep, thermally driven (convective) upslope wind develops over the Pajarito Plateau. Upslope winds are generally light, less than 6 mph. When the sky is clear and upper-level winds are light, these local winds reverse at night. A shallow drainage wind often forms; it flows down the plateau and can reach speeds of 6-8 mph.

Bowen (1990) reports that the frequencies of atmospheric stability conditions (estimates of the atmospheric dispersive capability), as defined by the Pasquill-Gifford (P-G) classification system (Table 3.3), are 52% unstable (A-C), 21% neutral (D), and 27% stable (E-F) during the winter at the TA-50 site. The frequencies are 44%, 22%, and 27%, respectively, during the summer. The stability category frequencies are based on vertical wind variations. Stability generally increases (less dispersive atmosphere) slightly toward the valley.

3.6.2.2 Dispersion Parameters

The irregular terrain at Los Alamos both favorably and unfavorably affects the atmospheric turbulence and dispersion. Increased dispersion promotes greater dilution of contaminants released into the atmosphere. The complex terrain and forests create an aerodynamically rough surface, forcing increased horizontal and vertical turbulence and dispersion. The dispersion generally decreases at lower elevations, where the terrain becomes smoother and less vegetated. The frequent clear skies and light winds cause good daytime vertical dispersion, especially during the warm season. The strong daytime heating during the summer can force strong vertical mixing up to 4,000-8,000 ft AGL.

Although the generally light winds enhance daytime vertical dispersion, they are limited in diluting contaminants horizontally. Furthermore, the same clear skies and light winds that promote dispersion during the day retard dispersion at night, causing strong, shallow surface inversions to form. These inversions can severely restrict near-surface vertical and, to a lesser extent, horizontal dispersion. The inversions are especially strong during the winter. Shallow drainage winds can fill lower areas with cold air, thereby creating deeper inversions. A deeper inversion is common toward the Rio Grande Valley (White Rock) on clear nights with light winds. Canyons can also limit dispersion by channeling air flow. Strong, large-scale inversions during the winter can limit vertical mixing to under 10,000 ft ASL.

Table 3.3. Key to the P-G stability categories.

Wind Speed (m/s)	Day			Night	
	Incoming Solar Radiation (ly/min) ^a				
	> 1.0	0.5 - 1.0	< 0.5	ΔT^b	
	(Strong)	(Moderate)	(Slight)	(Negative)	(Positive)
< 2	A	A	B	-	-
2-3	A	B	C	E	F
3-5	B	B	C	D	E
5-6	C	C	D	D	D
> 6	C	D	D	D	D

Note: Reference Turner (1970).

^aIncoming solar radiation (insolation) is usually measured in langley (1 ly/min $\approx$ 698 W/m²).

^bData on ΔT (change in temperature) were taken from ground level to heights 11-23 m AGL. Negative ΔT indicates temperature decreasing with height; positive ΔT indicates temperatures increasing with height.

Overall dispersion is generally the greatest during the spring when winds are strongest. Deep vertical mixing, however, is the greatest during summer afternoons when the atmosphere is unstable up to 5,000 ft AGL or more. Low-level dispersion is generally the least during summer and autumn evenings when winds are quite light. Even though low-level dispersion is generally greater in the winter, intense surface inversions can cause low-level dispersive conditions during the nights and early mornings.

The Gaussian model, using on-site turbulence data, is accurate (within a factor of 2) in predicting daily radioactive or nonradioactive levels up to 1 km or so downwind on mesa tops at the Laboratory (Bowen et al. 1987). Recent work shows that accurate predictions can be made to at least 3 km downwind on mesa tops (Bowen 1990). The predictions are dependent on accurate diffusion coefficients σ_y and σ_z . Calculations of σ_y and σ_z based on the Draxler (1976) method were made at TA-50 (12 m AGL) for six stability categories. Figures 3.4 and 3.5 show the σ_y and σ_z by downwind distance based on a 15-min averaging time. These dispersion coefficients are less conservative (greater in value) than values obtained from the widely used Pasquill-Gifford (P-G) curves, especially the σ_y . The increased values of σ_y and, to a lesser extent, σ_z represent the rough terrain at Los Alamos. The derived σ_y coefficients are 2 to 3 times larger than values obtained from P-G curves for the A and B categories and up to 4 times larger than those for the other categories. For the D and E stability categories, the derived σ_z coefficients are also larger than σ_z from the P-G curves by a factor of 2 to 3. For the most stable F category, the derived σ_z is only slightly larger than the P-G value for σ_z . However, for the unstable A and B categories, the derived σ_z is only slightly larger than the P-G value of σ_z very close downwind. At greater downwind distances, the P-G value for σ_z becomes much larger than the derived σ_z .

Note that σ_y and σ_z are calculated assuming a 3-m/s wind speed. These values may be adjusted for other wind speeds using models reported by Draxler (1976). For example, at a downwind distance of 10 km, the σ_y should be increased by 39% for a 10-m/s wind and decreased by 31% for a 1-m/s wind. Similarly, σ_z should be increased by 47% for a 10-m/s wind and decreased by 34% for a 1-m/s wind.

3.6.2.3 High Wind Probability Distribution

Kennedy et al. (1990) recommend that an extreme wind speed of 77 mph be used as the evaluation basis extreme wind event for low-hazard facilities at the Laboratory; this value is based on an annual probability of exceedance of 2×10^{-2} . An extreme wind speed of 93 mph is recommended as the evaluation basis extreme wind event for moderate-hazard facilities; this value is based on an annual probability of exceedance of 1×10^{-3} .

Fig. 3.4. Calculated horizontal-dispersion coefficients (σ_y), based on TA-50 (12 m AGL) values.

Fig. 3.5. Calculated vertical-dispersion coefficients (σ_z), based on TA-50 (12 m AGL) values.

3.6.2.4 Tornado Probability

No tornadoes have been reported to have touched down in Los Alamos in recent history. However, funnel-shaped clouds have been spotted nearby in White Rock and Santa Fe. Only weak tornadoes are possible in Los Alamos, but strong dust devils can produce winds up to 75 mph at isolated spots in the county, especially at lower elevations. Kennedy et al. (1990) recommend that no design basis tornado (DBT) be considered at Los Alamos because the annual hazard probability of exceedance is smaller than 2×10^{-5} .

3.7 SEISMOLOGY

This discussion of seismology is largely based on information reported by Dames and Moore (1972).

Over 230 earthquakes originating in New Mexico have been tabulated. This tabulation includes intensities as defined by the Modified Mercalli Intensity (Damage) Scale of 1931. A small number of additional shocks originating outside the boundaries of New Mexico have been felt within the state. Of the New Mexico events, Intensity VIII was reported 4 times, Intensity VII 6 times, Intensity VI 17 times, and Intensity V 40 times. Owing to incomplete records, no statistical significance is attached to reports of events less than Intensity V. The tabulation for Intensity V itself is probably far from complete, even for the time span considered, because many communities fail to report such events.

The moderate event that occurred closest to the Laboratory was the August 17, 1952, Intensity V Los Alamos earthquake. Its epicenter may have been about 10 miles east-southeast of the Plutonium Processing Facility. A tiny shock, Intensity II, was felt in Los Alamos during the evening of February 17, 1971. It was instrumentally recorded but not precisely located. This shock was probably directly under Los Alamos because it was unreported nearby.

The largest nearby earthquake was the May 28, 1918, Intensity VII to VIII Cerrillos earthquake, 35 miles southwest of the site. The intensity at Los Alamos for the Cerrillos event was inferred to be VI, which makes this the highest intensity the site has experienced in historic time. Several Intensity VII earthquakes occurred in 1893, about 85 miles south-southwest of the site, and at Dulce in 1966, 85 miles northwest of the site. Three Intensity VIII shocks were recorded about 140 miles south-southwest near Socorro in 1906, and one was recorded near Cerrillos in 1918. Other Intensity VIII shocks have occurred in the region, but none have been within 200 miles of the site.

Ground motion at the site caused by distant, large, out-of-state earthquakes is not considered a problem. West Texas (the area near Valentine, 350 miles south-southwest) is the nearest seismogenic zone capable of generating events larger than those already considered, and it is adequately distant from Los Alamos so that ground motions are attenuated to within acceptable levels.

The largest known earthquake for the New Mexico region was in Sonora, Mexico, in 1887 (375 miles south-southwest). Ground motions, however, from a similar Intensity VIII-IX future event in Sonora would be attenuated with distance to within acceptable levels at Los Alamos.

On the basis of an evaluation of the degree of ground motion that is remotely possible at Los Alamos, considering both seismic and tectonic history and geologic structure, Kennedy et al. (1990) recommended that an earthquake with peak ground acceleration of 0.22 g be used as the evaluation basis earthquake for low-hazard and moderate-hazard facilities located at the Laboratory. This best-estimate peak ground acceleration value is based on a hazard annual probability of exceedance of 1×10^{-3} , or a return period of 1,000 years. The acceleration value corresponds to the maximum acceleration that would be recorded by a three-axis, strong-motion instrument on a small foundation pad at the freeground surface.

The recommended value for vertical ground motion accelerations is two-thirds of the horizontal ground motion accelerations; that is, 0.15 g.

Ground response spectra indicate the dynamic amplification of the earthquake ground motion during linear, elastic seismic response of facilities. These spectra provide information about the frequency content of potential earthquake ground motion at the site.

Kennedy et al. (1990) recommended that the response spectrum be used as the design spectrum for facilities at the Laboratory.

3.8 SUMMARY OF CHARACTERISTICS AFFECTING FACILITY OPERATING REQUIREMENTS

The Laboratory is in and adjacent to Los Alamos County, north-central New Mexico, about 60 miles north-northeast of Albuquerque and 25 miles northwest of Santa Fe by air.

The surrounding area, including most of Los Alamos County and portions of Sandoval, Rio Arriba, and Santa Fe counties, is largely undeveloped. Large tracts of land in the Jemez Mountains to the north, west, and south of the Laboratory site are held by the U.S. Forest Service and U.S. National Park Service.

The 27,500-acre Laboratory site and adjacent communities are situated on the Pajarito Plateau. The plateau has been deeply eroded by runoff toward the Rio Grande, resulting in a series of mesas. Laboratory development is mainly confined to the mesa tops, which range in elevation from about 7,800 ft on the flank of the Jemez Mountains to about 6,200 ft above the Rio Grande Valley. Most of the Laboratory land provides isolation for security and safety and reserved capacity for the location of future structures.

The TA-48 site is located on DOE-controlled land south of the Los Alamos townsite. The site is situated along Pajarito Road (Figure 3.1).

Population estimates for 1990 place about 213,000 persons within an 80-km (50-mile) radius of Los Alamos. About 193 people work at facilities at TA-48.

The Los Alamos Airport, controlled by DOE, has a single east/west runway, the west end of which is approximately 4,500 ft from the TA-48 site. Aircraft present minimal risk to facilities at the TA-48 site.

Los Alamos has a semiarid, temperate mountain climate. This semiarid climate precludes using the area for extensive crop production. Sustained winds exceeding 25 mph and peak wind gusts exceeding 50 mph are common during the spring. Frequency of winds greater than 11 mph ranges from 10% at TA-50 to 20% at the East Gate. Light winds (< 5.5 mph) prevail about 45% of the time at TA-50.

Frequencies of various atmospheric stability conditions are approximately as follows:

	Winter	Summer
Unstable (good mixing)	52%	44%
Neutral (fair mixing)	21%	22%
Stable (poor mixing)	27%	34%

Kennedy et al. (1990) recommend that an extreme wind speed of 77 mph be used as the evaluation basis extreme wind event for low-hazard facilities at the Laboratory and that 93-mph winds be used to evaluate moderate-hazard facilities. Kennedy et al. (1990) recommended that no DBT be considered at Los Alamos because the annual hazard probability of exceedance is smaller than 2×10^{-5} .

The annual precipitation extremes range from 6.80-30.34 in. over a 69-year period. Lightning is sufficiently common over the Pajarito Plateau that lightning protection is an important design factor for most facilities at the Laboratory. Thundershowers occasionally generate flash floods in local canyons. These thundershowers can cause local flash flooding, especially in canyons, streams, and other low spots. Large-scale flooding is not common in New Mexico and has never been observed in Los Alamos. Most

of the Laboratory technical areas, including the TA-48 site, are located on top of the finger mesas near drainage divides.

The seismic history of the area indicates that the site will be subjected to only moderate levels of seismic ground motion during the life of the TA-48 facility. On the basis of an evaluation of the degree of ground motion that is remotely possible, considering both seismic and tectonic history and geologic structure, Kennedy et al. (1990) recommend that an earthquake with peak ground acceleration of 0.22 g be used as the evaluation basis earthquake for low-and moderate-hazard facilities located at the Laboratory. Kennedy et al. (1990) also recommend that the response spectrum be used as the design spectrum for facilities at the Laboratory.

3.9 REFERENCES

Bowen, B. M., *Los Alamos Climatology*, Los Alamos National Laboratory Report LA-11735-MS (May 1990).

Bowen, B. M. et al., *Measurements and Modeling of External Radiation from LAMPF Emissions*, LA-11150-MS, Los Alamos National Laboratory, Los Alamos, NM (November 1987).

Dames & Moore, *Report of Geologic, Foundation, Hydrologic, and Seismic Investigation, Plutonium Processing Facility, Los Alamos Scientific Laboratory, Los Alamos, New Mexico, for U. S. Atomic Energy Commission*, Dames & Moore, Los Angeles, CA (1972).

Draxler, R. R., "Determination of Atmospheric Diffusion Parameters," *Atmospheric Environment*, 10, pp. 99-105 (1976).

DOE, *Final Environmental Impact Statement: Los Alamos Scientific Laboratory Site, Los Alamos, New Mexico*, DOE/EIS-0018, U.S. Department of Energy, Washington, DC (December 1979).

Fuentes, M. K., *Probability of an Aircraft Crashing into the Special Nuclear Materials Building at Los Alamos National Laboratory*, memorandum, Sandia National Laboratories, Albuquerque, NM (August 19, 1988).

Kennedy, R. P. et al., *Design and Evaluation Guidelines for Department of Energy Facilities Subjected to Natural Phenomena Hazards*, UCRL-15910, U. S. Department of Energy, Washington, DC (June 1990).

LANL, *Environmental Surveillance at Los Alamos During 1988*, LA-11628-ENV, Los Alamos National Laboratory, Los Alamos, NM (June 1989).

LANL, *Environmental Surveillance at Los Alamos During 1990*, LA-12271-MS, Los Alamos National Laboratory, Los Alamos, NM (March 1992).

LASL, *Final Safety Analysis Report for the Plutonium Handling Facility TA-55*, LASL Document Group CMB-11, Los Alamos Scientific Laboratory, Los Alamos, NM (1978).

Turner, D. B., *Workbook of Atmospheric Dispersion Estimates*, NTIS No. PB191482, U. S. Department of Health, Education, and Welfare, Washington, DC (1970).

4. PROCESS/OPERATIONS DESCRIPTION

4.1 INTRODUCTION

The purpose of this section of the Safety Assessment is to describe the radiochemical processes and operations that are conducted at TA-48. The individual TA-48 buildings that are described include Buildings RC-1, RC-8, RC-28, RC-45, and RC-46. Included in the description is general information about the buildings as well as detailed information on the radiochemical operations.

4.2 BUILDING RC-1

Building RC-1 is involved with radiochemical operations associated with nuclear weapon testing, evaluation of samples collected from a variety of environmental sources, and nuclear medicine production activities. The activities are divided into the dissolver, laboratory, alpha room, counting room, and hot cell activities. Building RC-1 radiochemical operations are described in the following sections. A floor plan of the main floor of Building RC-1 is presented in Figure 4.1.

4.2.1 Dissolution Area

The south end of the building houses the test debris sample preparation area (Room 430) and the high-activity chemistry area (Room 423). Activities in these two rooms involve the largest amounts of beta-gamma radioactivity outside of the hot cells on the north end of the building.

When a nuclear device is exploded in the geologic formations at the Nevada Test Site (NTS), the device and some of the surrounding rock are vaporized. This material condenses and forms a black, glassy matrix containing fission products and activation products. Predominant radionuclides in the debris are ^{95}Zr , ^{99}Mo , ^{140}La , and ^{141}Ce . The debris is recovered and packaged for shipment from NTS to TA-48 in a U.S. Department of Transportation (DOT) Type B container. The activity level varies between 300 and 1500 mCi per container. The debris is damp dirt and up to gravel-size rock and is contained inside a plastic bag, which is sealed in a polyvinyl chloride (PVC) pipe that has a screw top. The PVC pipe is placed inside another plastic bag and inserted into the shipping container.

Personnel performing operations in Room 430 wear anti-contamination (anti-c) lab coats, gloves, booties, thermoluminescent dosimeter (TLD) badges, finger rings, pencil dosimeters, and chirper radiation alarms. Two health physics technicians are available in the building to take measurements. Rooms 430, 423, and 425 (shipping container loading and storage area) constitute a radiologically controlled area. An electric forklift is used to move the shipping container from the loading dock into Room 425 and subsequently into Room 430.

The forklift is used to move the unopened shipping container adjacent to the entry port of the glovebox line. The Type B shipping container is opened, and the inside container is opened. The radiation level typically is 0.5 to 4 R/h at contact. Tongs are used to transfer the plastic bag containing the PVC pipe to a sorting table at the end of the glovebox line. The time duration from opening the shipping container to placing the debris samples onto the sorting table is less than 2 min. The time of the transfer of debris from the container to the table is 3 to 5 s.

The individual debris sample bags are removed from the PVC pipe, and tongs are used to sort them on the shielded sorting table. Similar sample bags are placed inside a 1000-mL quartz beaker and transferred into the first glovebox. The bags are cut open and the contents, about 50 g, dumped into the beaker. The plastic bags accumulate in the box until the glovebox line is cleaned at the end of the shot processing campaign. The samples are washed in the second box; all liquid waste drains to the Radioactive Liquid Waste Treatment Facility (RLWTF) at TA-50. The high-grading operation in the third and fourth gloveboxes consists of using tweezers to remove the black, glassy debris from the native rock. From 30 g to 200 g of the high-graded debris is placed into a 1000-mL quartz beaker and transferred to gloveboxes five and six; the residue is stored in the gloveboxes until the end of the campaign. The damp debris is dried by placing the beaker on an electric hot plate in either glovebox five or six. Samples larger than 75 g are put into a paint can containing ball bearings and shaken in glovebox seven. Smaller samples are put into small containers containing ball bearings and shaken in glovebox eight. The pulverized debris sample is transferred to the glovebox nine (unshielded) and weighed into sample bottles for dissolution. Samples up to 20 g are put into a small polyethylene vial that has a press-fit top. Larger samples are put into a polyethylene bottle that has a screw top. Samples are usually stored in the first glovebox until needed. At the end of each campaign, the boxes are washed and a sand blank is sent through the process. If contamination is detected in the sand, the cleaning is repeated.

There are four hoods in Room 430. The first two hoods are used to prepare liquid samples for use throughout the building analytical laboratories. Operators wear lab coats, booties, and rubber gloves when working in the hoods. Sample solutions are prepared from pulverized debris by the same general technique used to convert silica and silicates to volatile silicon fluoride (SiF_4). The debris samples are hand-carried into the first hood and typically 10 g of dried, pulverized sample is placed into a Teflon vessel. Sample sizes can be up to 250 g, but usual maximums are 100 g for the rare earth extraction in Room 423. The exhaust duct washdown system is turned on, and fuming nitric acid (HNO_3), concentrated perchloric acid (HClO_4), and concentrated HF are added. The typical process involves repeated evaporation to fumes of HClO_4 in the Teflon vessel on a hot plate at a medium setting; followed by several cycles of fuming with concentrated HClO_4 in a Vycor beaker on a hot plate at a high setting and centrifuging to separate the residue. HCl is added to make the concentration of the original sample in solution 7.5 mg/mL. The typical sample solution contains less than 0.03 mCi/mL of mixed fission products, produces 150 to 500 mR/h at contact, and is stored behind lead bricks in Room 426.

The other two hoods are used for separating radionuclides, principally gold, silver, indium, zirconium, and bismuth, from liquid samples. The chemistry involves scavenging, precipitation, extraction, and so forth in a process similar to that just described.

Separation of the lanthanides lutetium and yttrium and of transplutonium actinides from the mixed fission products occurs in the high-activity chemistry area (Room 423). Personnel performing operations in Room 423 wear anti-c lab coats, gloves, sleeve protectors, booties, safety glasses, TLD badges, finger rings, pencil dosimeters, and chirper radiation alarms. Sample sizes can be up to 250 g with an associated high radioactivity level. To reduce exposures to levels as low as reasonably achievable (ALARA), sample sizes are generally kept in the 50 g - 100 g range (with a 1 to 2 R/h contact level), and some equipment is operated remotely. The procedure begins with preparation in Room 430 of a gel or slurry of debris in cold HClO_4 , which is hand carried (without a top) to hood three in Room 423. The sample is first salted with aluminum nitrate [$\text{Al}(\text{NO}_3)_3$] and the pH adjusted with lithium hydroxide (LiOH). The solution is hand-carried to hood one (walk in) and placed in the tributyl phosphate/di-2-ethylhexyl orthophosphoric acid (TBP/HDEHP) extraction apparatus, which is operated from a station about 6 ft away. The first extraction utilizes TBP and H_2O to back-extract the lanthanides and actinides. The aqueous phase is collected and transferred by hand (about 4 ft) to hood two, where a rotary flash evaporator is used to reduce the volume. The concentrated solution is hand-carried back to the extraction apparatus for the HDEHP extraction. The organic is first washed and then hand-carried to hood three, where it is boiled with decanol over a bunsen burner. The hot solution is back-extracted with HCl in two separatory funnels.

The aqueous phase is then passed through an anion-exchange resin column. The actinides, lutetium, and yttrium are separated in hood four by elution from a cation-exchange resin column with an HCl solution under 10 psi. A slowly rotating table collects small vials of the eluate, which are separated by measuring the alpha and the beta-gamma activity in hood five. The alpha activity can be as high as 800 counts/min, and the beta-gamma is in the range of 0.5 to 1 R/h. The desired samples are pooled in hood six and poured into counting vials containing about 2 cc. The vials are hand-carried to the counting room.

The inventories of significant hazardous chemicals in Rooms 423 and 430 required to perform the separation and purification are given in Table 4.1. Typically, a single 500-mL bottle is removed as needed from storage. Quantities screened out as described in Section 6 are omitted from the table. Materials are stored in Room 423 as follows: flammables in two flammable material cabinets, acids in cabinets under one set of fume hoods, bases in cabinets under another set of fume hoods, resins and other dry materials in cabinets over a work bench against one wall, waste organics (about 5 gal per shot) in an organic cabinet for later pickup and liquid radioactive waste in a safe for shielding purposes. Materials are stored in Room 430 as follows: flammables in a flammable material cabinet, acids in cabinets under fume hoods, bases in the same cabinets, and dry materials in cabinets over work bench areas.

4.2.2 Laboratories

The analytical laboratories at Building RC-1 are used to perform small-scale radiochemistry in support of either the weapons testing program or the medical isotopes production program.

Most of the laboratories dedicated to the weapons testing program are used to extract various elements from dissolved weapons debris or from environmental samples (rock, water, or ash) for further analysis in the counting area, the isotope separations facility (RC-8), or the mass spectrometry facility (RC-45). Different laboratories extract different elements from the sample materials. Table 4.2 lists the radiochemical operations performed in each weapons testing laboratory. The procedures controlling these operations are detailed in *Collected Radiochemical Procedures* (Kleinberg 1990). Note that no radioactive materials are handled in Rooms 302, 306, 310C, 402, and 415. These laboratories are used for analysis of "clean" materials.

Table 4.1. Dissolution area inventory of significant hazardous chemicals

Chemical	Room 423	Room 430	Room 421	Room 419
Hydrogen fluoride	-	80 L	-	-
Hydrochloric acid	-	2.5 L, 38%	-	-
Nitric acid	6.2 L	11.5 L, 90%, fuming	-	-
Perchloric acid	1 lb, 70%	11.5 L, 90%	6L	-
Sulfuric acid	9 lb	2.5 L	-	-
Bromine	-	-	-	2.2 lb
Hydrogen bromide	-	-	-	1.2 L
Hydrogen peroxide	-	-	-	2 L

Table 4.2. Operations performed in the weapons testing laboratories

Room No.	Operations
302	Analysis of nonradioactive materials
303	TBD
304	Sorption radiochemistry for characterizing partitioning of radionuclides between groundwater and geologic materials
305	Extraction of beryllium and yttrium from weapons debris
305B	Extraction of arsenic and tungsten from weapons debris
306	Analysis of trace elements in mercuric iodide (no radioactive materials)
306B	Extraction of lutetium and zirconium (^{95}Zr) from weapons debris
307/307B	Extraction of rare earth metals from weapons debris
308/308B	TBD
309/309A	Sorption radiochemistry for characterizing partitioning of radionuclides between groundwater and geologic materials
310	Sorption radiochemistry for characterizing partitioning of radionuclides between groundwater and geologic materials Extraction of lead, thorium, and uranium from samples of natural (unirradiated) rock
310C	Analysis of nonradioactive materials
311	Sorption radiochemistry to characterize radionuclide migration in crushed rock
311A	None
312/312A	TBD
339A	None

Table 4.2. (continued)

Room No.	Operations
339B	Concentration of actinides in environmental water samples from the Rocky Flats Plant (preparation of samples for spectrometric analysis)
339C	Extraction of plutonium from environmental samples for mass spectrometric analysis
339D	Preparation of silver iodide from unirradiated rock samples for off-site analysis of ^{36}Cl content Preparation of silver chloride from unirradiated rock samples for off-site analysis of ^{129}I content Extraction of technetium from environmental samples for mass spectrometric analysis
341B	Light-scattering measurements on plutonium colloids using autocorrelation photon spectrometer
402	Preparation of silver iodide from unirradiated rock samples for off-site analysis of ^{36}Cl content Preparation of silver chloride from unirradiated rock samples for off-site analysis of ^{129}I content
402B	Grinding of uranium ores
406	Comparison of weapons debris with unirradiated rock samples
407	Extraction of ruthenium, tantalum, and technetium from weapons debris
407B	Extraction of zirconium from weapons debris
408/408B	Extraction of ruthenium, tantalum, and technetium from weapons debris

Table 4.2. (continued)

Room No.	Operations
411/411A	Extraction of iridium, rhodium, and vanadium from weapons debris Extraction of gold, iridium, and osmium from rock samples irradiated in a reactor (sample preparation in dissolving area)
412/412B	Extraction of bismuth from weapons debris
413	Extraction of gold and silver from weapons debris
413C	Extraction of molybdenum and zirconium from weapons debris
414/414B	TBD
415	Dissolution of unirradiated rock samples with acids
416	Extraction of bismuth and thallium from weapons debris

The weapons debris sample solutions are prepared in the dissolving area as described in Section 4.2.1. Only small containers of dissolved weapons debris are handled in the analytical laboratories. Each sample contains, at most, 75 g of debris, and samples weighing 10-20 g are the norm. The containers of solution are carried to the laboratories from Room 426 in shielded carrying cases.

The environmental samples analyzed in some of these laboratories are not processed in the dissolving area; rather, they are brought directly to the laboratory, sometimes in dry form. The plutonium colloids that are analyzed in Room 341B are brought to Building RC-1 from TA-3 in sealed capsules. Each capsule contains only a few nanograms of plutonium, and the capsules are not opened as part of the experimental procedure.

The radiochemical procedures used to extract the various elements from samples differ somewhat, but most involve addition of reagents (mostly acids) to the material, drying of solutions (using either a bunsen burner or an electric oven), and centrifuging of solutions followed by decanting of supernate. Some procedures also involve ion exchange. Except for centrifuging and drying in ovens, these operations are conducted in HS-5-approved fume hoods. Chemists wear lab coats, safety glasses, and impermeable plastic or rubber gloves. Rooms 339A-D and 341B are clean rooms in which occupants must wear lintless paper coat and pants, paper skull caps, and special slippers.

The radiation levels in the laboratories vary, depending on the amount of sample solution handled, but typical levels are about 10-30 mR/h. When necessary, lead bricks are stacked inside fume hoods for personnel protection. All personnel wear dosimeter badges. The laboratory work areas where radioactive materials are handled or where radioactive contamination from earlier operations exists (all weapons laboratories except Rooms 302, 306 and 310C) are controlled for radiation protection purposes. Before exiting these work areas, personnel monitor themselves for radioactive contamination.

Table 4.3 lists the most significant inventories of hazardous chemicals found in the weapons testing laboratories. More information concerning the chemical inventories in these laboratories is presented in Section 6.2.2.

Rooms 409, 410, 314, 315, and 326 in Building RC-1 are laboratories dedicated to the medical isotopes production program.

**Table 4.3. Most significant inventories of hazardous chemicals
for the weapons testing laboratories**

Chemical	Laboratory Containing Largest Amount	Quantity (g)
Cellulose tetranitrate	309B	454
Chloroform	402 or 412	7,450
Hydrazine	414B	500
Hydrochloric acid	307	6,600
Hydrogen bromide	304	880
Hydrogen fluoride	339D	1,980
Hydrogen peroxide	311	5,600
Hydroquinone	408	500
Mercuric chloride	305	579
Mercuric oxide	408	570
Mercury	416	68,000
Nitric acid	402	9,000
Perchloric acid	305B	74,000
Sodium arsenate	407	500
Sodium arsenite	407	454
Sodium cyanide	402, 411, or 413	500
Sulfuric acid	312	8,200

Rooms 409 and 410 are used for small-scale synthesis of arsenic compounds for medical applications. Some work with selenium compounds is also performed in Room 410. Most work in these areas is performed inside HS-5-approved fume hoods. Lead bricks are used for personnel shielding as needed.

Room 314, located in the hot cell wing of the building, contains a DC plasma arc spectrometer. This instrument is used to analyze samples of mostly nonradioactive materials, although some radioactive samples are handled as well. Argon is supplied to the spectrometer from a standard DOT-approved cylinder mounted next to it. The spectrometer vents through a small HEPA filter into an adjacent fume hood. Both this fume hood and one other like it are used for preparation of samples for the spectrometer. Room 314 also contains a germanium gamma counter. This counter is identical to those used in the counting room (see Section 4.2.4). The counter has a 30-L liquid N₂ tank that is periodically filled from a portable dewar kept in the room.

Room 315 is currently not in use.

Room 326 is used for reagent preparation in support of the hot cell operations. Some experiments involving radioactive materials of low activity are also performed in the two HS-5-approved fume hoods in this area.

Chemists working in these laboratories wear lab coats, safety glasses, and impermeable plastic or rubber gloves. In addition, personnel entering these areas must wear dosimeter badges issued by HS-1. With the exception of Room 315, these areas are controlled for radiation protection purposes. Therefore, persons exiting these laboratories must monitor themselves for radioactive contamination.

Table 4.4 lists the most significant inventories of hazardous chemicals for the medical isotopes laboratories. More information concerning the chemical inventories in these laboratories is presented in Section 6.2.1.4.

4.2.3 Alpha Facility

The alpha facility is located in the northeast corner of the building and consists of four rooms in the controlled area (Rooms 606, 606A, 606B, and 606C) and other ancillary facilities and offices (Rooms 601 through 605). Activities in the controlled area involve the largest amounts of alpha radioactivity in the building.

Table 4.4. Most significant chemical inventories for the medical isotopes laboratories

Chemical	Laboratory Containing Largest Amount	Quantity (g)
Cadmium oxide	326	454
Chloroform	409	6,400
Hydrochloric acid	409	3,100
Hydrogen fluoride	410	908
Hydrogen peroxide	314	700
Mercury	326	4,500
Nickel	326	454
Nitric acid	410	1,510
Perchloric acid	314	580
Selenious acid	410	500
Sulfuric acid	314	4,600

The area was last used in 1990 and is currently being decontaminated and refurbished. Prior uses include (1) processing high-alpha-activity debris from weapons tests at the NTS, (2) fabricating high-enriched uranium targets for the Omega West Reactor (OWR), and (3) examining irradiated OWR targets. The major refurbishment activities remaining are replacement of the gloveboxes and possible improvements to the process ventilation system.

The minimum protective clothing required during normal room operations will be anti-c laboratory smocks, gloves, booties, and safety glasses. However, two pair of surgeon's gloves will be worn during hood or glovebox operations. Coveralls or surgeon's pants and lab coats will be required as a minimum for all work with test site debris; OWR irradiated samples; and plutonium, transplutonium elements, and enriched uranium above the 1-mg level. Hands will be monitored each time they are removed from the glovebox. Personal dosimeters (TLDs) will be worn in these rooms, as well as during transfer of radioactive material to and from other areas. Finger rings will be required as determined by the Radiation Control Technician (RCT).

Room 606 will be used for chemical research involving relatively long-lived alpha-emitting isotopes, including ^{231}Pa , $^{233,235}\text{U}$, ^{237}Np , $^{239,242}\text{Pu}$, $^{241,243}\text{Am}$, ^{249}Bk , $^{244,248}\text{Cm}$, and ^{252}Cf as well as mixed fission and activation products deriving from nuclear weapons testing and irradiations at the OWR. Experimentation will typically be on the multimilligram scale. Operations to be performed include syntheses under various conditions such as furnace temperatures up to $\sim 1,600^\circ\text{C}$, highly oxidizing conditions involving the use of acids such as HClO_4 , use of nonaqueous solvents, and other preparative conditions carried out in the glovebox trains and chemical fume hoods. Samples will be removed from the boxes and hoods for alpha- and gamma-counting analysis, spectroscopic characterization, and other forms of characterization, all of which will be carried out in Room 606A.

Room 606B is a combined corridor and storage room for a saw used to cut solid rock specimens. Room 606C is a storage room.

All dry materials having an alpha radioactivity of greater than 10^6 disintegrations per minute (dpm), materials in solution having an alpha radioactivity of greater than 10^7 dpm, and materials in solution having an alpha radioactivity of greater than 10^8 dpm in one source are required by administrative procedure to be processed in the alpha facility. Gloveboxes will contain multigram quantities, hoods will be used only for quantities very much less than multigram, and benchtops will be used only for nonradioactive processing. No powders are handled outside the gloveboxes. Prior uses have resulted in inventories in Room 600 on the order of 200 g of ^{239}Pu and ^{240}Pu , 300 to 500 g of ^{235}U , and up to 0.5 g

each of ^{252}Cf , ^{249}Bk , ^{241}Am , and ^{243}Am . Table 4.5 shows the current inventory, its physical form, and the containment for storage.

The four gloveboxes will contain process equipment for specific operations. One glovebox will contain dissolution equipment; another will contain grinding and weighing equipment. A third glovebox is for specialty operations. The function of the fourth glovebox has not yet been determined.

In all laboratory operations in which release of radioactivity is considered possible, such as placing material in and removing materials from the glovebox, red warning lights (once installed) will be activated outside the normal-access doors and the dock area emergency exit to keep out unsuspecting persons. The rooms are not to be entered while the red warning lights are activated, except by a knowledgeable individual wearing a full-face respirator, and after consultation with the RCT. A sign will be posted near the red lights detailing their purpose.

The chemical inventory currently in the alpha facility is not representative of future processing activities. The future inventories are assumed to be similar to those in the dissolution area and general laboratories. The current chemical inventory of significance is 17.5 L of HF, which is less than the 80 L in the dissolution area.

4.2.4 Counting Room

The counting room is located in the east wing of Building RC-1. A wide variety of low-level detectors and counting systems are utilized to quantitatively evaluate a wide array of radionuclides of importance in weapons design, weapons radiochemical diagnostics, medical, environmental, and other programs. Samples do not exceed nanocurie levels of activity.

Following radiochemical separation and purification of weapons debris in the dissolver area, the radiation counting systems are used to measure its activity. The counting room has a complete spectrum of counting systems to determine emissions of alpha, beta, gamma, and x-radiation and also has fission detectors. The emissions are energy resolved (except beta), counted, and normalized to absolute radionuclide standards.

The number of counters varies depending upon the needs of the radiochemical lab. Over 60 counters and detectors are currently operational in the counting room; these include 16 high-resolution germanium gamma-ray detectors, nine high-efficiency NaI(Tl) gamma ray detectors, 6 high-resolution solid state alpha detectors, 4 Frisch-grid alpha/fission counters, 3 internal $2\text{-}\pi$ gross alpha counters, 8 beta proportional counters, 2 trochoidal positron counters, and 2 x-ray proportional counters.

Table 4.5. Current alpha facility SNM inventory

Amount	Type	Physical form	Containment
147 g	93% $e^{235}\text{U}$	Metal foil	Can, 0.25 in.-thick, inside safe
74 g	99.7% $e^{235}\text{U}$	Oxide powder	Heavy-wall can inside safe
5 g	Pu	Metal chunks, 0.5 g	Glass vial, metal pipe, safe
1 g	Pu	Oxide powder	Glass bottle, heavy-wall can, safe
0.5 g	^{241}Am	Metal chunk	Glass vial, lead pig, heavy-wall can, safe
0.4 g	^{243}Am	Oxide powder	Glass vial, lead pig, heavy-wall can, safe
2 g	Pu	Nitric acid solution	Teflon bottle, 16-g metal box
2 g	^{242}Pu	Nitric acid solution	Teflon bottle, 16-g metal box
47 g	50% $e^{235}\text{U}$	Oxide powder	Glass bottle, 16-g metal box
1000 g	Natural thorium	Metal foil	Glass bottle
33,000 g	Depleted uranium	Ingots	Can, 0.25-in.-thick
7×10^{-6} g	^{249}Cf	Solid salt	Glass vial, metal pipe

Approximately 25,000 counts per year are performed by the data acquisition group. About 50% of these counts are of interest in the calibration and testing of the detectors, and the other 50% are themselves objects of the measurements. Sealed samples are received from the radiochemical labs in Building RC-1. The samples are received either mounted on planchets or in liquid form in small sealed plastic bottles. Ninety percent of the samples are gamma-emitting radioactive materials. Samples are mounted on a rotary mechanism found on each type of counter. The equipment is calibrated to align the sample with the actual counter or detector. On each counter, one sample is counted or detected at a time. After a preset period, the samples are automatically rotated so that the next sample is in place for counting or detecting. A combination of air and hydraulic actuators is used for sample changing. All counters are in-line with the Pulse Height Analyzer Read Out (PHARO) system, a computer-based data acquisition and analysis system. A more modern system, the Advanced Automated Readout and Operation Network (AARON), is being brought on line and will replace the PHARO system.

An extensive upgrade of the sample changer control and data readout systems for the beta counters is underway. Highlights of this upgraded system include local microprocessor control of each counter and sample changer, extensive error checking and self-testing, and a fully air-driven system for the sample changer mechanism.

The operating staff is made up of two TSMs, five technicians, and computer support personnel. The counting room is controlled for external radiation exposure purposes, rather than for contamination. The counting room contains only sealed sources of radioactive materials; thus, the potential for radioactive contamination is extremely low. Anti-c clothing is prohibited in the counting rooms to prevent any risk of inadvertent contamination from anti-c clothing to the counting room. General waste leaving the counting rooms is not considered suspect waste and may be disposed of as regular trash. If a radioactive sample were to leak in the counting room, the area would be immediately cordoned off and designated as controlled for potential contamination purposes.

Small amounts of chemicals are stored in a fire-safety-approved storage cabinet in Room 200. These chemicals include a few ounces of aluminum cutting fluid, various light instrument oils, ethyl alcohol, and 1-1-1 trichloromethane. Hydraulic oil is used in some of the counting machines for sample changer control.

4.2.5 Hot Cells

The TA-48 hot cells are primarily used in the small-scale production of selected radioisotopes for medical and research purposes. The process is accomplished by preparing target materials for irradiation

in the TA-48 hot cell machine shop (Room 343). The targets are transported to the Los Alamos Meson Physics Facility (LAMPF) where they are irradiated to generate the desired radioisotopes. The irradiated targets are extremely radioactive and typically emit beta particles and gamma rays. Materials with significant levels of alpha activity are not permitted in the hot cells at TA-48.

The highly radioactive targets are placed in approved transport packages at LAMPF and transported to TA-48 for chemical processing in the hot cells to recover the desired radioisotopes. The transport packages are designed to provide protection for the target and to provide radiation shielding. The targets may have radiation levels as high as 100,000 rem/h. The transport package reduces the radiation level at the surface of the package to not more than 200 mrem/h.

An irradiated target is transported from LAMPF in its protective pack to the TA-48 hot cell wing located in the northwest corner of the main floor of Building RC-1. An overhead hoist in Room 324 is used to remove the incoming targets from the transport vehicle. The packaged target is transported with the hoist into the hot cell warm corridor through the first set of shielding doors. The target is moved into the dispensary cell through the sliding shielding door at the back of the cell. Opening of the shielding doors is limited to times when radiation in the warm corridor and dispensary cells permit these operations to be performed safely.

Remote manipulators in the dispensary cell are used to unpack the target after the shielding door behind the cell has been closed. The package is stored in the cell. Scrap materials are packaged for disposal. Machining equipment in the cell is used for removing the target from its capsule. If the target has very high radiation levels, it may be stored in the dispensary cell for as long as two weeks to allow the decay of radioisotopes with short half lives. Radiation levels outside the hot cell can be as high as 5 mrem/h to 10 mrem/h when a new target is opened in the cell.

The remotely operated transport system is used to transfer the bare target to 1 of the 12 process hot cells for chemical processing. The actual processing steps are dependent upon what type of target is being processed. As many as 30 different radioisotopes may be processed in the cells. The processing is very much a batch-type activity, and what is actually in the cells at any given time is dependent upon what type of source materials have been irradiated. As many as 26 targets typically are processed in a year, and as many as 9 targets may be processed in a week, depending upon what particular target material was processed. Multiple radioisotopes are typically present in an individual target. The use of the individual cells varies to accommodate the processing requirements for a particular target.

Table 4.6 presents a list of the radionuclides that might be processed in the hot cells along with the dispersibility of the material and how much might be present.

The TA-48 hot cells and hot cell activities are located in the northwest wing of TA-48 Building RC-1. The hot cell corridor area is identified as Room 334 on Figure 4.1. The hot cell area consists of an area that is used for unloading incoming targets and for loading outgoing packages. Overhead cranes are used to unload and load packages from trucks. This area is identified as 324 on Figure 4.1. Room 322 is an open area that is used primarily for shipping and monitoring activities. Room 343 houses machine shop operations that are primarily associated with the preparation of targets for irradiation.

In addition to the shipping and monitoring activities, storage pits are in the floor in this area along the south wall. The pits are used for storage of radioactive material and have lids that are flush with the floor. The lids are constructed of steel and concrete and are approximately three feet thick to provide shielding. The inventory of the pits is presented in Table 4.7 along with the radiation level of the materials.

The hot cell corridor area, identified in Figure 4.1 as Room 334, is primarily used for bringing packaged irradiated targets into the dispensary cell for processing in the hot cells and for maintenance activities. Access to this area is limited to times when radiation is at safe levels and steps have been taken to ensure safety.

The primary use of the dispensary hot cell is for receiving and unpackaging irradiated targets into the hot cells for processing. Four remote manipulators enable the irradiated target to be removed from the transport over-pack and from the container in which it was irradiated. Storage allows radiation levels to decrease by allowing the decay of short-lived radioisotopes.

The process hot cells are used for the chemical processing of irradiated targets that have been unpacked and removed from their irradiation capsule. The operations within the cells are typically limited to distinct process steps, but because the radioisotopes that are being processed vary, the activities that take place in a cell are subject to change depending upon programmatic requirements. Operations in the hot cells include small-scale machining activities and chemical separation activities such as ion exchange, extraction, filtration, and other small-scale separation operations. The hot cells are also used to package the radioisotopes in solution to prepare them for shipping to medical establishments or universities.

The hot cell activities involve small quantities of toxic materials in addition to the radioactive materials that are present. The inventories of toxic materials that are in the hot cells are smaller than those in the dissolver area or the laboratories.

Table 4.6. Hot cell radionuclide inventory list

Radionuclide	Committed Dose Equivalent per Unit Intake (Sv/Bq) with Lung Clearance Class	Dose Conversion Factor (rem/ μ Ci)	Radioisotope Inventory (Ci)	Dispersibility of Material ^a	Total Inventory (Ci)
Be-7	8.67×10^{-11} Y	3.21×10^{-4}	0	High	31
			1	Moderate	
			30	Low	
Na-22	2.07×10^{-9} D	7.66×10^{-3}	0	High	100.3
			.3	Moderate	
			100	Low	
V-48	2.76×10^{-9} W	1.02×10^{-2}	0	High	3.9
			2.5	Moderate	
			1.4	Low	
Cr-51	9.03×10^{-11} Y	3.34×10^{-4}	0	High	1.8
			1.8	Moderate	
			0	Low	
Mn-52	1.54×10^{-9} W	5.70×10^{-3}	0	High	1.8
			1.8	Moderate	
			0	Low	
Mn-54	1.81×10^{-9} W	6.70×10^{-3}	0	High	62.4
			2.4	Moderate	
			60	Low	
Co-57	2.45×10^{-9} Y	9.06×10^{-3}	0	High	47.5
			.5	Moderate	
			47	Low	
Co-58	2.94×10^{-9} Y	1.09×10^{-2}	0	High	3.5
			2	Moderate	
			1.5	Low	

Table 4.6. (continued)

Radionuclide	Committed Dose Equivalent per Unit Intake (Sv/Bq) with Lung Clearance Class	Dose Conversion Factor (rem/ μ Ci)	Radioisotope Inventory (Ci)	Dispersibility of Material ^a	Total Inventory (Ci)
Co-60	5.91×10^{-8} Y	2.19×10^{-1}	0	High	59
			1	Moderate	
			58	Low	
Cu-64	7.48×10^{-11} Y	2.77×10^{-4}	0	High	1.5
			1.5	Moderate	
			0	Low	
Zn-65	5.51×10^{-9} Y	2.04×10^{-2}	0	High	6.3
			1	Moderate	
			5.3	Low	
Cu-67	3.32×10^{-10} Y	1.23×10^{-3}	0	High	6.6
			3.2	Moderate	
			3.4	Low	
Ga-67	1.51×10^{-10} W	5.59×10^{-2}	0	High	5.1
			1.7	Moderate	
			3.4	Low	
Ge-68	1.41×10^{-8} W	5.18×10^{-2}	0.5	High	1.5
			0	Moderate	
			1	Low	
Ge-69	2.27×10^{-10} W	8.40×10^{-4}	0.5	High	1.5
			0	Moderate	
			1	Low	
Se-72	1.1×10^{-9} (As-72)	4.07×10^{-3}	1.5	High	4.5
			0	Moderate	
			3	Low	

Table 4.6. (continued)

Radionuclide	Committed Dose Equivalent per Unit Intake (Sv/Bq) with Lung Clearance Class	Dose Conversion Factor (rem/ μ Ci)	Radioisotope Inventory (Ci)	Dispersibility of Material ^a	Total Inventory (Ci)
As-73	9.34×10^{-10} W	3.46×10^{-3}	4	High	40
			15	Moderate	
			21	Low	
As-74	2.15×10^{-9} W	7.96×10^{-3}	3	High	27
			9	Moderate	
			15	Low	
Se-75	2.29×10^{-9} W	8.47×10^{-3}	4	High	86
			39	Moderate	
			43	Low	
Br-82	4.13×10^{-10} W	1.53×10^{-2}	1	High	2.6
			0	Moderate	
			1.6	Low	
Sr-82	1.66×10^{-8} W	6.14×10^{-2}	0	High	24
			12	Moderate	
			12	Low	
Rb-83	1.33×10^{-9} D	4.92×10^{-3}	0	High	53
			26	Moderate	
			27	Low	
Rb-84	1.76×10^{-9} D	6.51×10^{-3}	0	High	42
			15	Moderate	
			27	Low	
Sr-85	1.36×10^{-9} D	5.03×10^{-3}	0	High	41
			21	Moderate	
			20	Low	

Table 4.6. (continued)

Radionuclide	Committed Dose Equivalent per Unit Intake (Sv/Bq) with Lung Clearance Class	Dose Conversion Factor (rem/ μ Ci)	Radioisotope Inventory (Ci)	Dispersibility of Material ^a	Total Inventory (Ci)
Rb-86	1.79×10^{-9} D	6.62×10^{-3}	0	High	39
			13	Moderate	
			26	Low	
Y-88	7.59×10^{-9} Y	2.81×10^{-2}	0	High	19
			9	Moderate	
			10	Low	
Nb-91m	7.90×10^{-9} (Nb-93m)	TBD	0	High	50
			25	Moderate	
			25	Low	
Zr-95	6.39×10^{-9} D	2.36×10^{-2}	0	High	20
			10	Moderate	
			10	Low	
Nb-95	1.57×10^{-9} Y	5.81×10^{-3}	0	High	160
			80	Moderate	
			80	Low	
Tc-95m	1.05×10^{-9} W	3.89×10^{-3}	0	High	8
			4	Moderate	
			4	Low	
Rh-101	1.07×10^{-8} Y	3.96×10^{-2}	0	High	11
			1	Moderate	
			10	Low	
Rh-102	3.24×10^{-8} Y	1.20×10^{-1}	0	High	3
			1	Moderate	
			2	Low	

Table 4.6. (continued)

Radionuclide	Committed Dose Equivalent per Unit Intake (Sv/Bq) with Lung Clearance Class	Dose Conversion Factor (rem/ μ Ci)	Radioisotope Inventory (Ci)	Dispersibility of Material ^a	Total Inventory (Ci)
Rh-102m	1.29×10^{-8} Y	4.77×10^{-2}	0	High	14.6
			1.6	Moderate	
			13	Low	
Ag-105	1.26×10^{-9} D	4.66×10^{-3}	0	High	4.2
			1	Moderate	
			3.2	Low	
Cd-109	3.09×10^{-8} D	1.14×10^{-1}	0	High	14
			4	Moderate	
			10	Low	
In-113m	1.11×10^{-11}	4.11×10^{-5}	0	High	4.2
			1	Moderate	
			3.2	Low	
Sn-113	2.88×10^{-9} W	1.07×10^{-2}	0	High	4.2
			1	Moderate	
			3.2	Low	
In-114m	2.40×10^{-8} D	8.88×10^{-2}	0	High	26
			6	Moderate	
			20	Low	
Sb-125	3.30×10^{-9} W	1.22×10^{-2}	0	High	5
			0	Moderate	
			5	Low	
Cs-134	1.25×10^{-8} D	4.63×10^{-2}	0	High	2
			1	Moderate	
			1	Low	

Table 4.6. (continued)

Radionuclide	Committed Dose Equivalent per Unit Intake (Sv/Bq) with Lung Clearance Class	Dose Conversion Factor (rem/ μ Ci)	Radioisotope Inventory (Ci)	Dispersibility of Material ^a	Total Inventory (Ci)
Pm-145	8.23×10^{-9} Y	3.05×10^{-2}	0	High	1
			1	Moderate	
			0	Low	

- ^a High dispersibility - Gases, vapors, volatile solids.
Moderate dispersibility - Mists, aerosols, spilled liquid or powder, powder or liquid under flammable or explosive conditions.
Low dispersibility - Bulky metal or sealed sources in flammable or explosive conditions.

Table 4.7. Hot cell area pit inventory

Pit Number	Content of Cell	Radiation level (/h)
1	Empty	N/A
2	94 MI separated ^{152}Eu	30 R
	1 g ^{244}Cm (oxide)	35 Mr
	Lead pig	15 mR
	5 gal ^{148}Gd	None
	4 mL ^{137}Cs	a
3	2 steel boxes ^{32}Si	a
4	1 mCi ^{90}Sr and 5 mCi ^{137}Cs	30 mR
5	Empty	N/A
6	Empty	N/A
7	^{252}Cf sources	a
8	^{60}Co shield	N/A
9	LAMPF beam stop in cylindrical shield	200 mR
10	LAMPF beam stop in lead-lined steel box	a
11	55-gal drum with Cf source	a
	Paint can with ^{232}U	a

^aNo data on radiation levels were available for this source.

4.3 BUILDING RC-8

The Isotope Separator Facility (RC-8) building operations take place in the one large room of the building in partitioned areas. These operations include isotope separations and modification of equipment used for the isotope separation operations. No special clothing or equipment (anti-c laboratory coats, etc.) is required to work in Building RC-8 other than the radiation-sensitive film badge that is required for all personnel entering the TA-48 secure area.

4.3.1 Isotope Separation Operations

Isotope separation operations (located in Building RC-8 and in Room 339 of Building RC-1) are grouped into two categories. The first category includes those operations designed to separate and collect radioactive isotopes of chemically prepared samples from weapons tests, and the second category includes operations in which isotopes from nonradioactive samples are separated and collected in support of ongoing LANL research programs.

The isotope separator uses four different types of ion sources. These include three sources of the gas-discharge/solid-sample type and one source of the surface-ionization/solid-sample type. The solid samples contain 10 mg or less and consist of almost any element in the periodic table in the form of oxides (rare-earth elements, yttrium, lanthanum, scandium, zirconium, hafnium, and tungsten), carbonates (alkali and alkaline earths), iodides (thallium), and elements (silver, gold, rhenium, osmium and lead). Since several different ion sources are used and many different samples are separated, the most common configuration (a surface-ionization-type source loaded with a rare-earth oxide sample) for a radioactive isotope separation operation will be described here.

Radiochemists initially prepare a sample (usually several milligrams) consisting of a stable carrier and chemically prepared test debris. The sample is fired to the oxide form and loaded into a tungsten crucible. After an RCT surveys and appropriately labels the sample box, separator personnel pick up the crucible containing the sample and install a tungsten-wire sample retainer and the crucible cap. The crucible is moved to the separator and installed into an ion source. The ion source is then installed on the separator accelerating-column, pumped to 10^{-6} Torr pressure, and helium leak-checked. When the source region is vacuum tight, ion source electrical connections are made, power supplies are activated, and the personnel safety cage is secured.

The accelerating and focusing power supplies are then energized, and the magnet power supply is activated and adjusted so that potassium ions (a sample contaminant) will reach the sample collection region.

Ion source power supplies are slowly raised in power over a 2- to 4-h period, outgassing the ion source and baking out contaminants.

When the contaminants are depleted, the ion source temperature is raised until the crucible cap is at 2,800-3,000 K. At these temperatures, the sample compound dissociates, leaving only sample metal. This metal slowly vaporizes at the high temperature and the metallic atoms reach the crucible opening where one electron is removed from each atom, leaving an ion. Each ion is then accelerated by the high-voltage accelerating column to a velocity of approximately 10^5 m/s.

These high-velocity ions pass through an electromagnet, where lower-mass ions are deflected more by the magnetic field than are the higher-mass ions. This magnetic field is designed so that it not only bends the path of the different mass ions but also focuses them as a camera focuses light.

A collection foil is located at the end of the separator at the point where the ions are focused. The ions hit the collection foil, which is electrically connected to a current integrator. The ion-beam current-integrator electronics is started to determine the total number of ions that reach the foil during the separation.

The separator is then put into computer control mode for continuous, unattended running. Approximately 3 days later, when the sample is exhausted, the computer senses loss of beam current and notifies the operator with an audible alarm. The operator de-energizes and deactivates all power supplies and closes vacuum isolation valves.

When the electrical shutdown is completed, the operator vents the collection tank using dry nitrogen gas, removes the collection foil, and replaces it with a fresh one. While the collection tank is being pumped down, the original collection foil is cut into sections.

The ion source is then removed from the separator and the used crucible is replaced with one containing another sample. Used crucibles are sorted for future examination.

When all elements from a particular NTS event have been separated, the ion source is returned to a fume hood (located Room 313 of Building RC-1), where any short-lived fission-product contaminants are allowed to decay. The ion source is later disassembled and cleaned. The cleaning is necessary to remove remaining longer-lived isotopes that might act as contaminants during future separations.

The isotope separators are also used to separate isotopes from nonradioactive samples. The procedure followed is exactly the same as just described except in the following details. The operator

loads the sample into the crucible from supplies of either commercially-prepared or CST-prepared oxides. The ion source does not require regular cleaning because no radioactive materials that might contaminate future samples are present.

The isotope separator area also contains a chemical storage cabinet, a fume hood, and a rack of lecture-sized gas cylinders. The chemical storage cabinet contains small amounts of solvents and other chemicals that are required for the isotope separator operations. The solvents and other chemicals are used in the fume hood for any necessary sample preparation work. The rack of gas cylinders contains the gas supplies that are required for use in the isotope separators. An isotope separator requires different gases depending on which ion source is being used.

4.3.2 Modification of Isotope Separation Equipment

Modifications to the isotope separation equipment (located in Building RC-8 and in Room 313 of Building RC-1) are done in the machine shop (located in the southeast corner of Building RC-8). The purpose of the machine shop is to provide operations support for the isotope separators. Frequently, components must be modified for repair, design upgrades, or testing of proof of principle in support of the laboratory's weapons program. The isotope separations equipment requires a separate machine shop to prevent contamination of the equipment when it is being modified.

4.4 BUILDING RC-28

The Weapons Diagnostic Instrumentation and Development Building (RC-28) houses a laser laboratory and another laboratory that is used to process water samples derived from the NTS and from other locations where radioactive contamination is present or suspected.

4.4.1 Laser Laboratory Operations

The laser laboratory contains five laser systems and two mass spectrometers. The mass spectrometers are used in resonance ionization, thermal ionization, and deuteromethane gas ionization analysis mass spectrometry. The laser systems in Building RC-28 are designed to provide both fixed-frequency and tunable laser radiation that is used in photoionization/ mass spectroscopy experiments in support of a variety of programs such as environmental research. The laser systems include two Class

IV CW argon ion lasers and four Class IV CW tunable dye lasers. The two argon ion lasers include one 30-W visible light laser (emitting laser radiation in the wavelength range of 458-515 nm) and one 5-W ultraviolet laser (emitting laser radiation in the wavelength range of 351-364 nm). Both of these argon ion lasers operate at a fixed frequency. The four tunable dye/Ti:SAP lasers (i.e., not operating at a fixed frequency) emit laser radiation in the wavelength range of 250-1400 nm. The maximum output for these tunable laser systems is dependent upon (and less than) the input radiation.

A sample (containing very low amounts of radioactivity and weighing only a few nanograms) from the radiochemical laboratories in Building RC-1 or Building RC-45 is prepared for analysis at a fume hood located in the laser laboratory (Room 107 of Building RC-28). An operator places the sample in one of the laser systems and then prepares the laser for operation.

For operations involving the argon ion laser systems, an operator ensures that the argon ion lasers are shuttered and/or blocked and that all the laser covers are properly in place. The operator also ensures that the status/warning panel is in the proper position. Then, cooling water to the argon ion laser system is turned on, and the power supplies to the argon ion laser are warmed up. Next, the operator presses the "START" button on the power supply and makes any necessary alignment adjustments. The solid sample is vaporized, and the laser beam then selectively excites certain atoms in the sample; which atoms are excited depends upon the wavelength at which the laser beam is operating. The excited ions will move through the magnetic field of the mass spectrometer, and the spectrometer will measure the amounts of materials present in the sample on the basis of the amount of deflection the ions experience in the magnetic field. The operator then shuts down the system by blocking and/or shuttering all the laser systems, turning off the argon ion laser power supplies, turning off the dye pumps, and setting the status/warning panel to "SAFE." The operator allows the argon ion laser to cool for 10 min and then turns off the cooling water flow.

For operations involving the dye/Ti:SAP tunable laser systems, an operator ensures that all the lasers are shuttered and/or blocked, that all laser covers are properly in place, and that the status/warning panel is set in the appropriate position. The operator ensures that the dye pump cooling water is turned on and that the dye pumps are turned on if necessary. The argon ion lasers are then unblocked, which allows the dye lasers to operate properly. Finally, the operator makes any alignment changes that may be necessary. The laser operation in relation to the mass spectrometer and the shutdown of the laser system by the operator is completed in the same manner as described previously.

4.4.2 Water Sample Analysis Operations

Water sample analysis is done in a laboratory located in Room 109 in Building RC-28. Water samples from the NTS and other locations in which radioactive contamination is present or suspected are processed in this laboratory. The levels of radioactivity in these samples varies from undetectable to tens of nCi/mL.

One of the two analytical procedures performed involves reducing by distillation the volume of a water sample from 206 L to 2 L. The second procedure involves treating the 2-L water sample on a vacuum line to remove and collect any dissolved ^{85}Kr .

DOT cylinders containing liquid nitrogen and liquid helium are located near the distillation equipment. (These materials are used as cryogenic materials for water traps in the vacuum line.) A chemical storage cabinet is also located in this laboratory. This cabinet contains solvents and other chemicals used in the distillation and vacuum collection operations (e.g., HCl used for cleaning the stills).

4.5 BUILDING RC-45

The Advanced Weapons Radiochemical Diagnostics Facility (RC-45) contains 11 chemistry laboratories and 7 instrument laboratories. These laboratories are clean-room areas that are designed to minimize the limitations that environmental factors place on the accuracy, precision, and sensitivity of isotope ratio measurements.

The operations that take place in the Advanced Radiochemical Weapons Diagnostics Facility (Building RC-45) cover a wide range of areas including measurements of isotope ratios from nuclear weapon test samples and experiments in solar physics, the geosciences, biology, and atmospheric science. For instance, in support of the weapons diagnostics program, CST personnel regularly perform isotopic analysis of actinides (e.g., thorium, uranium, plutonium, americium, and neptunium). As a part of this analysis, CST personnel regularly perform chemistry for sample clean-up and preparation and then analyze the actinide samples by thermal ionization mass spectrometry. The sample analysis procedure (developed by CST Division personnel) can detect as few as 10^5 atoms of certain nuclides and determine isotopes of particular elements by using no more than 10^8 atoms. During these procedures, the actinides are electroplated onto a rhenium thermal ionization filament and are coated with platinum. The platinum serves as a diffusion layer for the sample atoms and provides an increased ionization efficiency (atoms detected to atoms loaded) approaching 1%.

In the area of solar physics, CST personnel use a unique detector for solar neutrino production. In this experiment, CST scientists have been able to detect as few as 10^8 atoms of ^{98}Tc and ^{97}Tc in 107 kg of molybdenite ore. (The technetium isotopes are thought to have been formed by high-energy solar neutrinos over the past several million years.) These measurements are made possible by the use of a very efficient negative-ionization technique that takes advantage of a lanthanum oxide ionization enhancer and CST double-sector magnetic mass spectrometers. In addition, CST personnel perform technetium isotopic analysis for geochemical, environmental, and radionuclide migration projects.

Finally, CST personnel also are age-dating young (<350,000-year-old) volcanic rocks by a technique that employs the naturally occurring ^{238}U radioactive disequilibrium in rocks and minerals. Measured disequilibrium in rocks between secondary isotopes in the uranium series (^{234}U , ^{230}Th , and ^{226}Ra) indicates the length of time since fractionation during the magma generation processes. For example, although radium is a rare element in geologic samples, procedures developed by CST scientists allow the measurement of radium isotopic ratios and abundance with high precision (1% to 2% $2\sigma_m$) on as little as 1 to 10 fg (10^{-15} g) of total radium.

The general chemistry laboratories and the clean-room chemistry laboratories contain small quantities of solvents and other chemicals that are used in sample preparation. All of these chemical operations take place inside fume hoods located in the laboratories, and the chemicals are stored in chemical cabinets specifically designed to store solvents and other hazardous chemicals (i.e., flammable or toxic chemicals).

4.6 BUILDING RC-46

Rooms 101 and 102 of Building RC-46 are used for analysis of natural rock samples. Two types of experiments are performed in Room 101: x-ray diffraction experiments and hydrothermal experiments (heating of rock samples under high pressure in water or brine).

The x-ray diffraction experiments are carried out using a Philips XRD-3100 x-ray diffractometer. The x-ray diffractometer features a closed-beam x-ray source. The door to the sample chamber is interlocked with the beam shutter to prevent inadvertent operator exposures. An X-RAYS ON light on top of the unit warns personnel that x-rays are being produced. A smaller red light on the unit indicates that the beam shutter is open. Warning signs are also posted next to the instrument and at the entrance to the room. The diffractometer's internal power supply develops voltages on the order of several kV. Only specially trained personnel operate this unit. All personnel entering the area must wear a dosimeter

badge issued by HS-1. The internal power supply for this unit develops voltages on the order of 40 kV with current of 25 mA.

The hydrothermal experiments are conducted in six small tubular furnaces. Each furnace is heated by a bank of resistance heaters. Two of the furnaces operate on 220 V AC electric power; the others operate on 110 V AC power.

To prepare for a hydrothermal experiment, the sample is placed inside a small gold or titanium tube. This tube is inserted inside a 1-L pressure vessel equipped with a rupture disc, the pressure vessel is placed inside the furnace, and hydraulic tubing and a pressure sensor are attached to it. Then the furnace door is closed. A small diaphragm pump is used to add a small volume of water or brine to the pressure vessel. At this point, the furnace heaters are turned on to begin the experiment. Generally, the pressure vessel is heated to temperatures ranging from slightly above ambient temperature to 400 °C. The pressures attained inside the pressure vessel may reach 500 bar. Each furnace is equipped with its own dedicated control system. Power to the heaters is interrupted in the event of high pressure inside the pressure vessel or high temperature inside the furnace chamber or at the heater coils.

The pressure vessels used with the two larger furnaces each weigh about 100 lb. Therefore, a small hoist is used to load these furnaces. The other pressure vessels only weigh about 40 lb each; they are loaded manually.

Room 102 is used for preparation of rock samples to be analyzed in Room 101. This laboratory is equipped with two small electric ovens, a gas chromatograph, and a calorimeter. Three standard, DOT-approved gas cylinders supply methane, hydrogen, and nitrogen to the gas chromatograph.

Numerous small containers of chemical reagents are stored in Rooms 101 and 102. The most significant inventories are 16 L of chloroform, 4.7 L of sulfuric acid, and 1 L of HCl, all kept in Room 101. More information concerning the chemical inventories in these areas is provided in Section 6.6.

4.7 REFERENCES

Kleinberg, J., *Collected Radiochemical and Geochemical Procedures*, LA-1721, 5th ed., Los Alamos National Laboratory, Los Alamos, NM (May 1990).

5. FACILITY AND SUPPORT SYSTEM DESCRIPTION

5.1 INTRODUCTION

The purpose of this section of the Safety Assessment is to provide a description of the TA-48 radiochemical processing facilities and the associated support systems. The facilities and support systems that are described are those in Buildings RC-1, RC-8, RC-28, RC-45, and RC-46. Included in the description of the facility and support system is general information about the buildings as well as more detailed information on the radiochemical operations.

The Laboratory is supplied with electricity by a Los Alamos County/DOE power pool along with a 20-MW gas-fired generating plant in TA-3. Electricity is transmitted to the Laboratory over two 115-kV lines: one from Santa Fe (Norton Generating Station) and one from Albuquerque (Reeves Generating Station). Electricity is distributed throughout the Laboratory via 13.2-kV lines. Electrical power enters into the RC-1 basement to a substation in Room 226. Here the power is stepped down to 440 V. The entire building receives electrical power from the main switch gear in the basement, where it is then stepped-down to 220 V and 110 V and distributed to various locations in the building.

Water supply for the Laboratory comes primarily from three DOE-owned well fields and surface water from the Jemez Mountains. The system depends on gravity flow for distribution from high-elevation terminal storage facilities. Water is supplied to RC-1 from a water main that enters the building adjacent to Room 413A. The water main is valved to three separate supply lines for industrial, potable, and fire protection uses. The three lines are supplied with backflow preventers. The radioactive liquid waste from RC-1 is piped to the TA-50-1 RLWTF. The radioactive liquid treated at TA-50 is released to Mortandad Canyon.

Natural gas used by the Laboratory comes from the San Juan Basin in northwest New Mexico. The lines are owned by DOE but operated and maintained by the Gas Company of New Mexico under contract to DOE. Natural gas is supplied to the building for use in lab hoods, burners, and the main heating system.

5.2 BUILDING RC-1

Building RC-1 is a one-story structure with a basement. The building is of varied exterior construction and includes masonry, corrugated metal siding, cinder block, and stucco. The building roof

is primarily of built-up construction. Most of the building operations are located on the main level of the building. Limited radiochemical activities, chemical storage, and building utilities and support systems are located in the basement. Limited building utilities are also located on the roof.

The main utilities provided by the Laboratory are electricity, water, sanitary sewer, radioactive liquid waste lines, and natural gas.

The building is equipped with a suspended wet sprinkler system for fire suppression. The piping for the fire suppression system runs parallel to the main corridors and feeds into all process and lab areas except for the hot cells and computer rooms. A halon system is provided for the computer rooms. Currently, the hot cells have no fire suppression system in place. The hot cells were originally provided with a CO₂ system, but this system has been removed. A building fire alarm is connected to the Emergency Operations Center.

Two air compressor systems supply compressed air to RC-1 for lab processes and instruments. The compressors are located on a covered cement pad outside, adjacent to the south wall of the counting room. The compressors provide a discharge pressure of 125 psig with a capacity of 90 scfm free air delivery. The control equipment for each compressor is driven by 440 V electrical power. Each compressor is provided with a safety valve with lifting lever that is capable of relieving the full capacity of the compressor.

The ventilation for RC-1 includes a main system that was installed at the time of building construction and additional dedicated systems for the hot cell and dissolver areas, which were installed when these areas were later added to the building. All supply fans for normal ventilation are located in the mechanical room in the penthouse. Air is pulled in from outside and forced through the offices, labs, and corridors to provide a once-through system. Exhaust fans are located in the basement and exhaust through stacks through the roof of the building. The alpha wing and the hot cell areas ventilate through HEPA-filtered systems. The hot cells vent through a filtered exhaust stack. A redundant exhaust system is provided for the hot cells and hot cell room air.

A natural-gas-fired steam boiler located in the basement provides building heat. The boiler is fitted with a combined pressure gauge and thermometer, water temperature regulator, and pressure relief valve. The boiler is designed for a water working pressure of 30 psig and is supplied with an electric gas control valve.

Vacuum is provided to various laboratory operations for drying processes, counting equipment, and fixed-head air monitors. The vacuum pumps are single-stage, air-cooled, piston types driven by a 440-V, 3-phase, 60-cycle motor.

5.2.1 Dissolver Area

5.2.1.1 Main Floor

The primary process features of the dissolving room (Room 430) are a shielded glovebox line and four hoods for processing debris samples. The glovebox line consists of nine connected $3 \times 3 \times 3$ ft plexiglass gloveboxes, each of which has two gloves; all but the last are shielded by about 3 in. of lead encased in 12-gauge stainless steel. Each glovebox has a single lead-glass window. Each glovebox has two HEPA filters: one for incoming air and one for exhaust air. The flexible exhaust air hose passes through the wall behind the gloveboxes into the utility chase, drops down, passes through the floor, and enters the exhaust header for the dissolver area. Each glovebox exhaust line has a butterfly valve to adjust air flow. A single magnehelic gauge is mounted on the top of the middle glovebox. The HEPA filters are changed if the glovebox vacuum is too low.

Cold water is provided to each glovebox and is controlled by a handle on the front of the glovebox at a height of about 30 in. Other handles for natural gas, etc. are not connected to a gas supply. Each glovebox has a drain through the floor to a header; the process drains empty to the RLWTF at TA-50. Electrical switches for the hot plates in gloveboxes five and six are located just above the handles, in the bottom face of the steel benches supporting the gloveboxes.

A sorting table is located adjacent to the first glovebox. A lead window is supported by lead bricks, and access to the samples is achieved over a layer of lead bricks on either side of the window. Entry into the first glovebox (and exit from the last) is achieved through a plexiglass airlock.

The fume hoods are designed to handle HClO_4 processing by the inclusion of the capability for water washdown of each hood duct. The wash water is collected in the basement and routed to the RLWTF at TA-50. The exhaust is downward to the header in the basement (see Section 5.2.1.2). Lead bricks are stacked about 12 in. high along the front of each hood. Natural gas is provided to each hood. A status/alarm panel for the process air supply and exhaust is located on the wall opposite the hoods. The on or off status of each supply and exhaust fan is shown; if a fan fails, a light turns red, and a piercing alarm sounds in Room 430.

The electric forklift is stored in Room 425 along with empty and unopened Type B shipping containers. Two small rooms off Room 425 are used to store fabware. An electric monorail from Room 425 to Room 430 has been disabled at the motor and the hoisting mechanism removed.

The processing in the high-activity chemistry room (Room 423) is performed primarily in six fume hoods located along three of the four walls. A central island contains sinks for preparing process solutions and a remote operating station for the TBP/HDEHP extraction apparatus. The first fume hood extends from the floor to the ceiling; the others are standard. Each has downdraft exhaust to a header in the basement. All have natural gas service.

The first hood contains TBP/HDEHP extraction apparatus, which consists of TBP and HDEHP extraction vessels, each with a motor driven stirrer; a TBP and HDEHP transfer vessel; a feed solution vessel; and two vessels that can be used for waste or product solution. The apparatus has an air pressure line into the feed vessel and solenoid-operated valves to block flow to and from the extraction vessels. The feed vessels are connected by tubes to four 5-gal jugs of reagent as follows: HNO_3 , $\text{Al}(\text{NO}_3)_3$, NH_4NO_3 , and DI water. The apparatus is operated from a station on the central island about 6 ft away from the hood.

The second hood contains a rotary flush evaporator with up to 100 V power supply controlled by a rheostat. Lead bricks are stacked in the front of the hood. The third hood also has lead brick shielding in the working area. A bunsen burner is located in the hood and connected to a natural gas nozzle in the hood. The 10-psi ethanol-hydrochloric apparatus in hood four is enclosed in a plexiglass shield.

The rooms in the dissolver area have fire protection sprinkler heads.

5.2.1.2 Basement

All process exhaust from the dissolver area (Rooms 419, 421, 423, 425, and 426) flows to a common header in the basement. The wash water drains from the header to a line to the TA-50 RLWTF. The process exhaust exits the building in the southeast corner, enters parallel exhaust fans FE 45 and FE 46, and is released up a dedicated stack. An isokinetic sampler is located in the basement duct upstream of the fans.

The basement also contains a sample archive storage room and two gas-fired boilers. The combustion portions of the boilers are located in an isolated room that can be entered only from outside the building. Two blowout panels are located in the exterior wall of the boiler room.

5.2.2 Laboratories

The analytical laboratories described in this section are located in the following rooms on the main floor of Building RC-1: 302, 303, 304, 305, 305B, 306, 306B, 307, 307B, 308, 308B, 309, 309A, 310, 310C, 311, 311A, 312, 312A, 314, 315, 326, 339A-D, 341B, 402, 402B, 406, 407, 407B, 408, 408B, 409, 410, 411, 411A, 412, 412B, 413, 413C, 414, 414B, 415, and 416. With the exception of Rooms 314, 315, 326, 339A-D, and 341B (located in the hot cell wing of the building), all of the laboratory spaces are located along the main north-south corridor of Building RC-1, as shown in Figure 4.1.

Most of the laboratory spaces consist of two connected work areas, each with its own room number. For example, Room 408 has a door opening into the main corridor, and Room 408B is located directly behind Room 408, away from the main corridor. No door separates the two work areas. The back work area is in some cases bounded by an exterior wall with windows. Generally, each pair of laboratory work areas shares a small office, which is adjacent to one of the areas. Exceptions to this layout are Rooms 302, 303, 304, 406, 409, 410, 415, and 416, all of which consist of a single but larger work area opening into the main corridor. The laboratories in the hot cell area (Rooms 314, 315, 326, 339A-D, and 341B) also have different layouts. Room 315 is a single, enclosed work area that opens into the small corridor leading from the main north-south corridor into the hot cell area. Rooms 314 and 326, on the other hand, are open areas where development work is performed in support of the hot cell operations. Rooms 339A-D are clean rooms used for laboratory work requiring particulate-free conditions. Each of these laboratories consists of a single work area. Room 341B, the Light Scattering Laboratory, is also a clean room; it consists of a single, large work area.

Figure 5.1 shows the arrangement of a typical two-work-area laboratory space. The room is 24 ft long, 16 ft wide, and 8 ft high. Each work area occupies approximately half of the available space. In many cases, the work areas themselves are controlled for radiation protection purposes. However, the short walkway connecting the main corridor to the back work area is always outside the controlled areas. Each work area contains two workbenches and an approved fume hood. The fume hoods exhaust through roof vents. Generally, both the workbenches and the fume hood are equipped with natural gas outlets. The fume hoods also have outlets for water, steam, and vacuum. Cabinets and drawers under the workbenches and fume hood are used for storage of laboratory equipment and reagents. Most work spaces contain one small centrifuge and at least one small electric oven. Room 310C has a small magnetic separator.

Fig. 5.1. Arrangement of typical two-work-area laboratory space.

Room 314 in the hot cell area contains a DC plasma arc spectrometer that is used mostly for analysis of stable isotopes. However, this instrument is occasionally used to analyze samples of radioactive materials, so it is vented through a small HEPA filter into one of the two fume hoods in the room. The spectrometer uses argon gas, which is supplied from a standard, DOT-approved cylinder mounted next to it.

Rooms 339A-D and 341B, located adjacent to the hot cell area, are clean rooms. They are maintained at positive pressure with respect to surrounding areas to control particulate contamination. All air entering these rooms first passes through a HEPA filter. Rooms 339A-D are each equipped with a single, downdraft-type fume hood. Room 341B has two such hoods. No natural gas service is provided to these areas.

Room 341B contains an autocorrelation photon spectrometer. This device, used for dynamic light-scattering measurements on colloids, consists of a 3-W argon laser, a commercial goniometer with photomultiplier tube, and a computer (for data collection and manipulation). The laser has 12-16 in. of exposed beam.

The maximum supply voltage to any laboratory is 240 V AC. All laboratories are served by a sprinkler system.

5.2.3 Alpha Facility

5.2.3.1 Main Floor

The primary process features of the alpha facility are located in Room 606: three hoods, four gloveboxes, and tabletops. Two hoods are designed to handle HClO_4 by the inclusion of the capability for water washdown of the exhaust ducts. The hoods have a downdraft exhaust connecting to an exhaust fan (see Section 5.2.3.2).

The existing gloveboxes will be replaced with four new gloveboxes. The existing gloveboxes are not shielded. The inlet air and the exhaust air pass through HEPA filters. Magnehelic gauges are present on each glovebox. The glovebox exhaust header is located in the penthouse. The exhaust passes through two $24 \times 24 \times 20$ in. HEPA filters in parallel before being drawn into an exhaust fan and discharged to a stack that extends about 80 ft above grade. An isokinetic sampler is located near the air intake for the area. The pressure drop across the filters is measured and indicated locally. The alpha facility is maintained at a negative pressure with respect to the remainder of the building.

5.2.3.2 Basement

Process exhaust from the three hoods flows to a common header in the basement. The exhaust is filtered first in a prefilter plenum containing 12 $20 \times 20 \times 2$ in. metal filters and then in a filter house outside the basement. The filter house contains two stages, each having 10 $24 \times 24 \times 12$ in. HEPA filters in parallel. The exhaust is drawn into an exhaust fan and is discharged to a stack extending 75 ft above grade. The stack has an isokinetic sampler.

The basement also contains an exhaust system that has never been used. The system has a fume scrubber, HEPA filters, an exhaust fan, and a stack attached to the stack for FE-54.

5.2.4 Counting Room

Counting operations take place in the east wing of RC-1. This entire area is often referred to as the counting room.

The utility services provided to the counting room include electrical, water, compressed air, special gases, and ventilation. Table 5.1 gives counter and detector types with operating service requirements.

The counting room uses the building supply vacuum system for process needs. However, a backup pump for the counting room provides a dedicated vacuum supply should the main vacuum supply be lost. This backup system is provided for process convenience and serves no safety function.

Special gases supplied to the counting room include argon, argon-CO₂ mix, propane, methane, liquid nitrogen, and xenon. An argon-CO₂ mix is supplied in small cylinders for use with various counters. Liquid nitrogen is supplied from a 500-gal tank located outside RC-1, adjacent to the Room 211 wall. A feed line runs into the building at the end of the counting room corridor and is valved off at this point. As necessary, the liquid nitrogen is transferred from this line to a 200-gal dewar, which is then used to transfer the liquid nitrogen to smaller individual counter tanks.

A propane tank farm is located outside the building, east of the counting room wing and adjacent to the driveway. The tank farm consists of a tanker trailer and three standing 200-gal dewars. Currently the tanker supplies propane to the dewars that connect to a 1/2-in. 304 ss line. The line is directed up over the driveway to the roof of the counting room wing, along the building, and down to an enclosure that opens through the wall of Room 202B. At this point the line enters a pressure regulator, where the propane is stepped down and distributed to various gas-operated counters at approximately 2 psi.

Table 5.1. TA-48 data acquisition counter utility services requirements

Counter Type	Location	Power	Gases	Liquids
High-resolution germanium gamma-ray detector	204 (two), 24 (three), 206B (four), 206 (two), 207 (six), 205 (six)	110 V AC 0-5 kV HVP	110-psi compressed air	None
High-efficiency NaI(Tl) gamma-ray detector	208B (nine)	110 V AC 0-3 kV HVP	110-psi compressed air	Hydraulic fluid
High-resolution solid state alpha detector	206 (seven), 207 (six)	110 V AC 0-100 V BIAS	None-vacuum at ~2 Torr	None
Frisch-grid alpha/fission counter	206 (four)	110 V AC 0-3 kV HVP	Ar/CO ₂	None
Internal 2- π gross alpha counter	204 (three)	110 V AC	High purity propane	None
Beta proportional counter	202B (six), 204 (two), 24 (three)	110 V AC 0-5 kV HVP	High purity propane	Oil mister
Trochoidal positron counter	206B (two)	220 V AC 3 ϕ 0-5 kV HVP	High purity propane	H ₂ O
X-ray proportional counter	208B	110 V AC 0-3 kV HVP	Xenon	None

Natural gas lines run to Rooms 303 and 200. These rooms were previously labs and have been converted to offices. The natural gas has not been used in these areas since they were converted to offices.

Six hoists are located in the counting room. The 1-ton hoist rails run parallel in three separate rooms: two in Room 202B, two in Room 204, and two in Room 206. The hoists are used to move equipment for maintenance.

Ventilation in the counting room is made up of 80% return air, which is recirculated for temperature control. Temperature control is provide for operational convenience and does not serve a safety function.

The counting room receives 440-V, 220-V, and 110-V electrical power supply. All counters, except for the trochoidal positron counters, operate on 110-V AC electrical power. The two trochoidal positron counters use 220-V AC. These two counters each make use of a magnet and operate with an internal power of 225 V DC.

The entire counting room is supplied with a wet pipe sprinkler system, except for Room 211, which houses computers. Room 211 is supplied with a halon fire suppression system.

5.2.5 Hot Cells

The hot cells located in the northwest wing of Building RC-1 are arranged in a "U" shape. The area inside the U is referred to as the warm corridor and is bounded by the back sides of six hot cells on each side of the U and by the back side of the dispensary cell at the base of the U. At one end of the warm corridor is a set of heavy, hydraulically operated shield doors, which serve as the entrance to the dispensary cell. The other (open) end of the warm corridor is equipped with a smaller shield door, which separates the warm corridor from the truck bay.

Twelve individual process hot cells and one dispensary hot cell make up the U-shaped hot cell area. The hot cells are constructed of extremely thick concrete with heavily shielded viewing windows. A heavily shielded steel door on the warm corridor side of the U on each of the cells is used for access to the cells for maintenance. Each of the 12 process cells is equipped with remote manipulators to allow activities within the cells. The dispensary cell is larger than the process cells and is equipped with four manipulators.

The U-shaped hot cell area is equipped with a remotely operated transport system that permits the transfer of materials from one hot cell to another. The transport system consists of a trolley that runs on

rails under the floors of the hot cells and that is accessible through a port in the floor of the cell. To use the system, the port is removed to allow materials to be placed on the trolley and the trolley is then advanced to its destination, under another hot cell.

5.3 BUILDING RC-8

The Isotope Separator Facility (RC-8) is a single-story building constructed of masonry block with corrugated metal siding. The building interior consists of one large room that is partitioned into two different areas. One large area contains two isotope separators. The smaller area located in the southeast corner of Building RC-8 contains the machine shop. A sprinkler system located near the ceiling common to both areas protects them from fire.

5.3.1 Isotope Separator Area

The isotope separator area of the Isotope Separator Facility contains two complete isotope separators and their component subsystems. These subsystems include: (1) an ion source for vaporizing and ionizing samples, (2) a high-voltage ion-accelerating column, (3) a vacuum chamber providing a flight path for the ions, (4) an electrostatic lens system for focussing the ions, (5) a magnet to mass separate the ions, (6) an ion collection chamber, (7) a collection foil, (8) vacuum pumps for evacuating the isotope separator, (9) power supplies for energizing the ion source, the ion-accelerating column, the electrostatic lens system, and the magnet, (10) a high-voltage enclosure for personnel protection around the ion source and its power supplies, (11) diagnostic equipment in the collection box for determining beam parameters, and (12) an operator's console. Some of these subsystems for each isotope separator are contained within two high-voltage cages. Each cage contains the subsystem power supplies, the ion source, and the ion-accelerating column for one isotope separator. (These cages help prevent electrical shock when the high-voltage components of the isotope separators are operating.)

5.3.2 Machine Shop Area

The machine shop area for the Isotope Separator Facility (RC-8) is located in the southeast corner of the building. This area is separated from the isotope separators by partitions.

This area contains equipment that is used for any modification of the isotope separation equipment.

The equipment contained in the machine shop includes the following: a vertical milling machine, a lathe, a drill press, a vertical band saw, an abrasive cutoff saw, a belt/disc sander, a pedestal grinder, an arc welding unit, an oxy-acetylene welding unit, and various hand tools (hammer, chisel, screwdriver, etc.).

5.4 BUILDING RC-28

The Weapons Diagnostic and Instrumentation Development Building (Building RC-28) is a single-story facility constructed of masonry block and corrugated metal siding. This building houses two main laboratories, office space, and storage areas. The two laboratories in RC-28 are the laser laboratory and the laboratory that is used to measure radioactivity in water samples.

5.4.1 Building RC-28 Laser Laboratory

The laser laboratory is located in Room 107 of Building RC-28. This laboratory contains six laser systems and two mass spectrometers. The laser systems include one 30-W visible-light Class IV Argon Ion laser, one 5-W ultraviolet-light Class IV Argon Ion laser, and four Class IV tunable lasers. These instruments are used in photoionization/mass spectroscopy experiments. The laser laboratory also houses a fume hood where radionuclide samples that are used in the photoionization/mass spectroscopy experiments are prepared.

5.4.2 Building RC-28 Water Sample Laboratory

The water sample laboratory is located in Room 109 of Building RC-28. This large chemistry laboratory contains standard distillation equipment (glass beakers and columns, etc.) for carrying out the large-sample distillation reduction operations (i.e., the procedure for reducing a 206-L water sample to a 2-L sample). This distillation equipment is located on a large laboratory bench in Room 109. The vacuum line operation for collecting and removing any dissolved ^{85}Kr from the 2-L water samples takes place inside the two stills.

5.5 BUILDING RC-45

The Advanced Radiochemical Weapons Diagnostics Facility (Building RC-45) is a single-story building constructed of masonry block and corrugated metal siding. Building RC-45 contains office space and 3 general chemistry laboratories, 11 clean-room chemistry laboratories, and 7 clean-room instrument laboratories. These 18 clean-room laboratories are constructed of particulate-free, corrosion-resistant materials. Critical work areas are bathed by vertical flowing, laminar, Class 100 filtered air (i.e., <100 particles/m³), and the air flow system for the laboratories is designed to minimize cross contamination between work areas (i.e., the clean-room chemistry laboratories, the clean-room instrument laboratories, and the rest of the building have separate, independent air flow systems). The design and construction of these laboratories minimize limitations that environmental factors impose on the accuracy, precision, and sensitivity of isotope ratio measurements used in weapons test diagnostics and offer a particulate-free environment in which to prepare samples and measure isotope ratios by mass spectroscopy.

The instrument laboratories house a wide range of instruments used for mass spectroscopy. These instruments include four single-stage, one double-stage, and one triple-stage mass spectrometer for thermal ionization mass spectrometry. The instrument laboratories also contain a 3.5-in., Nier-design, Mattauch-Herzog geometry mass spectrometer; a renovated 6-in. dual-detector gas analysis mass spectrometer converted for silicon isotopic analysis; and a 10-in., Nier design, Mattauch-Herzog geometry mass spectrometer for ion source development. The instrument laboratories are shielded from external electrical interferences, and the instruments themselves are powered by isolated motor generators.

5.6 BUILDING RC-46

Building RC-46 is a prefabricated, transportable building that contains two laboratories and several offices. It is physically connected to another transportable building, RC-47. Figure 5.2 shows the floor plan for these combined structures.

Room 101 in Building RC-46 is a laboratory that contains a Philips XRD-3100 x-ray diffractometer and six small hydrothermal furnaces, all of which are used for analysis of natural rock samples. Room 102 is a chemistry laboratory equipped with work benches, a sink, a small gas chromatograph, and two small electric ovens. Reagents are stored in cabinets below the work benches. The other rooms in Building RC-46 are used for office space.

Fig. 5.2. Floor plan for Buildings RC-46 and RC-47.

6. RISK ASSESSMENT

6.1 INTRODUCTION AND METHODOLOGY

The following sections provide the methodology used in evaluating the hazards associated with the TA-48 radiochemical operations.

6.1.1 Hazard Identification and Screening

The first step of the hazard analysis is to identify the hazards associated with the radiochemical operations at TA-48. Hazards include toxic and radioactive materials and energy sources. Hazards are identified by completing the worksheet shown in Table 6.1 for each area or portion of the operation.

The list of hazards, when supplemented with accident initiating events that would expose LANL employees or members of the public to each hazard, would be very lengthy. Therefore, the next step of the analysis is to screen from further consideration those hazards that are not of concern.

Hazards other than toxic and radioactive material inventories are screened out if they are considered to be "routinely encountered industrial hazards," that is, those hazards that are encountered and routinely accepted by the public in everyday life or encountered in general industry.

Chemicals that are not listed on either the Environmental Protection Agency's (EPA's) *List of Extremely Hazardous Substances* (Appendix A to 40 CFR 355) or the *List of Highly Hazardous Chemicals, Toxics, and Reactives* (Appendix A to 29 CFR 1910.119) are screened from further consideration unless they are present in very large quantities. Chemicals that are included on one or both of these lists but are present in quantities of 1 lb or less in a given area are also screened from further consideration. (The lowest reportable release quantity for any listed chemical is 1 lb.) Listed chemicals that are present in quantities exceeding 1 lb in a given area along with very large inventories of nonlisted chemicals are subjected to a more rigorous screening process that considers the chemical's toxicity and reactivity as well as the quantity present in a given area. The following paragraphs describe this more rigorous screening process.

Table 6.1. Hazard Identification Worksheet

Facility or area:

Hazard Type	Hazard Present? (Y or N)	Hazard Source(s)	Routinely Encountered Industrial Hazard? (Y or N)	Remarks
Electrical energy				
Electromagnetic radiation				
Explosive materials				
Fissile materials				
Flammable materials				
Kinetic energy				
Potential energy				
Radioactive materials				
Reactive materials				
Thermal energy				
Toxic materials				
Other (list below):				

First, the reactivity of the chemical is addressed. The chemical reactivity matrix included in the *Handbook of Chemical Hazard Analysis Procedures* (Federal Emergency Management Agency 1989) is used to identify possible adverse consequences associated with the mixing of various classes of chemicals (e.g., acids, alcohols, halogenated organics, etc.). This matrix allows for evaluation of combinations of no more than two classes of chemicals. The mixing of a given chemical of interest with other significant quantities of listed chemicals in the area is evaluated. For purposes of this screening evaluation, less severe consequences (heat generation, solubilization, and evolution of nontoxic gases) identified in the reactivity matrix are neglected. In cases where only one significant inventory of a listed chemical is present in an area, no reactivity evaluation is performed.

With regard to chemical toxicity, if a quantity of toxic material can be shown to be so small that a significant health risk would not occur under any postulated accident scenario, then further in-depth analysis is unnecessary. Six broad classes of chemical toxicity are first defined to make analysis simpler. The classes are defined on the basis of an intake into the human body. For each class, either the class limit or, in the case of this safety assessment, a fraction of the class limit that produces insignificant health effects is related to a concentration in air. The concentration in air is in turn related to an amount released instantly. If the quantity of material in a given area is less than the amount producing insignificant health effects, then that material inventory can be screened from further consideration.

Chemicals may be grouped by toxicity rating for safety analysis purposes. Chemicals within the same toxicity rating class would be expected to have the same health effects for equivalent intakes. (Equal process inventories of materials in the same toxicity class would not necessarily produce equal intakes owing to differences in release and transport properties.) The toxicity parameter used to determine toxicity class under accident conditions should be of a fundamental nature and should be available for many chemicals. The parameter chosen is the intake producing 50% lethality, LI_{50} , which is available for humans for some chemicals and is available for mammalian species for many more chemicals. Good consistency of the dose producing 50% lethality, LD_{50} , across mammalian species occurs when expressed in mass per body weight, mg/kg, so good consistency is expected for LI_{50} when expressed in mg intake. The toxicity classes are given in Table 6.2 (Doull et al. 1980).

Guidance for chronic exposure to materials with chemical toxicity is provided by the permissible exposure limits (PELs) of the Occupational Safety and Health Administration (OSHA 1988); threshold limit values (TLVs) recommended by the American Conference of Governmental and Industrial Hygienists

Table 6.2. Chemical toxicity classes based on LI_{50}

Toxicity Rating	Estimated Human LI_{50} ^a	Descriptive Terms
1	< 350 mg	Extremely toxic
2	350 - 3500 mg	Highly toxic
3	3.5 - 35 g	Moderately toxic
4	35 - 350 g	Slightly toxic
5	0.35 - 3.5 kg	Practically nontoxic
6	> 3.5 kg	Practically harmless

^aAdapted from Doull et al. (1980). Original ratings were based on rat oral LD_{50} s in mg/kg. Ratings may also be based on LC_{50} s in mg/m³. LI_{50} s may be calculated either from LD_{50} s or LC_{50} s.

(ACGIH 1988); and recommended exposure levels (RELs) of the National Institute for Occupational Safety and Health (NIOSH), which are published as part of NIOSH criteria documents. Exposure guidance for short-term or emergency situations is provided primarily by the NIOSH/OSHA guidance on levels immediately dangerous to life and health (IDLH).

The IDLH concentration values were developed by NIOSH to prevent escape-impairing symptoms or irreversible health effects for exposure times less than 30 min. Respiratory protection would be indicated near and above IDLH levels. On the basis of this definition, intakes resulting from exposure at and below IDLH levels for 30 min should not produce irreversible health effects. Exposure to concentrations above IDLH levels for 30 min or less, or concentrations at IDLH levels for more than 30 min, could be threatening to life and health. Thus, by definition, limiting intakes corresponding to 30-min exposures at IDLH concentration levels (IDLH -30 min) should ensure that no irreversible health effects occur. Exposure to the IDLH for periods > 30 min may result in intakes that produce irreversible health effects (i.e., permanent injury) or even lethality. The intake 0.1 IDLH -30 min is selected for screening purposes. Below this intake value, health effects are not expected to occur. Exposure at the 0.1 IDLH concentration for minutes to hours would produce intakes less than exposures at the PEL concentration for hours to days.

IDLH values are available for many chemicals of interest, but other toxicity parameters are available for a broader set of chemicals. As stated previously, the LI_{50} parameter is widely available. An intake of 0.05 LI_{50} is approximately equivalent to 30-min exposures to IDLH concentrations. Since our screening criterion is 0.1 IDLH -30 min., the equivalent is 0.005 LI_{50} .

For screening releases of radionuclides in this analysis, a 1-rem effective dose equivalent (EDE) occupational dose limit and a 100-mrem EDE public dose limit are adopted as doses producing negligible effects under accident conditions. A 100-mrem EDE would not add materially to lifetime background dose (10- to 20-rem EDE) and would be only about 2% of the allowable annual chronic occupational dose. A 1-rem accidental occupational EDE is roughly equivalent to a 10-mrem/year dose rate, which is less than 0.1 times background.

For instantaneous releases and an exposure point at a distance from the source, the material released passes in a "puff," and the intake is determined by the average concentration in the puff and the time required for the puff to pass through the exposure point:

$$I = CV = Cvt \quad (6-1)$$

where C = average concentration of material at exposure point (mg/m^3),
 V = volume of air inhaled at exposure point (m^3),
 v = breathing rate (m^3/s), and
 t = time for puff to pass exposure point (s).

The time-averaged concentration can be expressed in terms of the total amount released and X/Q :

$$Ct = f_R A (\chi/Q) \quad (6-2)$$

where f_R = fraction of material released,
 A = amount in process (mg), and
 χ/Q = atmospheric dispersion factor (s/m^3).

Substituting Eq. 6-2 into Eq. 6-1 and rearranging results in an equation that can be used to determine the maximum amount allowed in a process that, if released, will not result in an off-site intake exceeding an intake limit, I :

$$A = \frac{I}{f_R (\chi/Q)v} \quad (6-3)$$

Since χ/Q models are generally not valid for distances less than 100 m from the source, an alternate model is needed for facility personnel and other on-site employees. For instantaneous releases, the concentration close to the point of release is given by the following expression:

$$C = \frac{f_R A}{V} \quad (6-4)$$

where V is the dilution volume in m^3 . In a building or room, V is usually taken as the volume of the room or building. If the exposure point is outdoors, or if the room or building is large, then V is taken to be a cylindrical volume, V , centered at the point of release:

$$V = \pi d^2 h \quad (6-5)$$

where d = distance to the escape point (m) and
 h = vertical extent of the released material (m).

Substituting Eq. 6-4 into Eq. 6-1 and rearranging results in an equation that can be used to determine the maximum amount allowed in a process that, if released, will not result in an on-site intake exceeding the intake limit.

$$A = \frac{IV}{f_R vt} \quad (6-6)$$

For screening applications of Eqs. 6-3 and 6-6, deliberately conservative values will be assumed. The dilution volume is considered to be a room of 3 m height and length equal to the product of the escape time in seconds, t_E , and the speed at which workers would walk away from the accident, 1.8 m/s. Then $V = \pi[(1.8 \text{ m/s})(t_E)]^2(3 \text{ m}) \approx 30t_E^2$. Using a breathing rate of $3.3 \times 10^{-4} \text{ m}^3/\text{s}$ and conservatively assuming $f_R = 1$, Eq. 6-6 becomes

$$A = 9.1 \times 10^4 I t_E \quad (6-7)$$

and Eq. 6-3 becomes

$$A = \frac{3 \times 10^3 I}{\chi/Q} \quad (6-8)$$

For toxic chemicals, the approach is to take the ranges of LI_{50} from Table 6.2., multiply by 0.005 to get the screening intake value, and then use either Eq. 6-7 for on-site exposure or Eq. 6-8 for off-site exposure to determine limiting amounts. Table 6.3 presents the results for on-site exposures for an escape time of 10 s. For a ground level release and F atmospheric stability, the value of χ/Q at a distance of 220 m (average distance from facilities to Pajarito Road) is about $2.0 \times 10^{-3} \text{ s/m}^3$ for a wind speed of 1 m/s using LANL dispersion parameters from Section 3. This value is used only for screening purposes. Table 6.4 presents the results for off-site exposures. Amounts limited by instantaneous release on-site intakes are more restrictive than amounts limited by instantaneous release off-site intakes.

The first step in the screening process is to determine the toxicity rating as given in Table 6.2. Using the toxicity rating of the chemical (assume Class 3 for example), Tables 6.3 and 6.4 can be utilized for Class 3 to determine limiting amounts. If the inventory in a given area is less than 15 kg, that inventory can be screened out for on-site exposures. If the inventory is greater than 150 kg, it cannot be screened out for on-site exposures. If the inventory is between 15 and 150 kg, then Eq. 6.7 can be used along with the value of 0.005 LI_{50} specific to the chemical to see if the inventory can be screened out.

**Table 6.3. Limiting release amounts for "instantaneous"
release scenarios: on-site exposures**

Toxicity Rating	Limiting "Instantaneous" Release Amount
1	< 1.5 kg
2	1.5 kg - 15 kg
3	15 kg - 150 kg
4	150 kg - 1.5 MT
5	1.5 MT - 15 MT
6	> 15 MT

**Table 6.4. Limiting release amounts for "instantaneous"
release scenarios: off-site exposures**

Toxicity Rating	Limiting "Instantaneous" Release Amount
1	< 2.6 kg
2	2.6 kg - 26 kg
3	26 kg - 260 kg
4	260 kg - 2.6 MT
5	2.6 MT - 26 MT
6	> 26 MT

If the chemical of interest is considered to be Class 1, there is no lower limit from Table 6.2. to carry into Tables 6.3. and 6.4. Thus, all chemicals exceed a zero lower limit, and the use of Eq. 6.7 is required.

For radioactive materials, the intake corresponding to a 1-rem EDE (on-site exposures) or a 100-mrem EDE (off-site exposures) is calculated by using the specific activity and dose conversion factor for the material of interest. The limiting intake is then used in either Eq. 6-7 or 6-8 to determine the limiting release amount.

The debris from weapons testing contains mixed fission products at a level corresponding to about 10^{14} fissions per gram of debris. The average time delay between weapons testing and receipt of the debris at TA-48 is 7 days.

The total activity of fission products at any time after production is proportional to the weighted sum of the individual exponential decay curves. This collective activity, between about 10 s and 1000 h after fission, decreases as (time)^{-1.2}. The activity T days after fission is estimated to within $\pm 20\%$ by the following expression (Cember 1969):

$$A = 1.03 \times 10^{-16} T^{-1.2} \text{ Ci/fission}$$

For a total number of fissions of 10^{14} per gram of debris, the total activity after 7 days is

$$\begin{aligned} A &= \left[1.03 \times 10^{-16} (7)^{-1.2} \frac{\text{Ci}}{\text{fission}} \right] \left(10^{14} \frac{\text{fissions}}{\text{g debris}} \right) \\ &= 9.99 \times 10^{-4} \text{ Ci/g} = 1 \text{ mCi/g} \end{aligned}$$

At various times after fission, different radionuclides may dominate health, safety, and environmental concerns; ⁹⁰Sr and ¹³⁷Cs are recognized as usually the most dominant radioisotopes among fission products over long periods of time. For short time periods, where neither significant radioactive decay nor daughter buildup has occurred, dominant radionuclides, in activity units, include those listed in Table 6.5. This list is based on a typical ²³⁵U fission product spectrum, excepting gases, 7 days after the end of fission. The computer code ORIGEN-PC, provided by Oak Ridge National Laboratory, was used to obtain the relative activities of the various fission products in a total activity of 1 mCi/g.

Table 6.5. Dominant fission products and corresponding inhalation doses for weapons debris

Fission Product	Concentration (mCi/g)	Dose Conversion Factor ^a (rem/ μ Ci)	Dose Per Gram Inhaled (rem)
⁸⁹ Sr	0.032	0.041	0.001
⁹¹ Y	0.036	0.049	0.002
⁹⁵ Zr	0.037	0.023	0.001
⁹⁵ Nb	0.027	0.006	0.000
¹⁰³ Rh	0.044	0.009	0.000
¹³² Te	0.008	0.009	0.000
¹⁴⁰ La	0.037	0.005	0.000
¹⁴¹ Ce	0.036	0.009	0.000
¹⁴³ Pr	0.021	0.008	0.000
¹⁴⁴ Ce	0.034	0.370	0.013
¹⁴⁷ Nd	0.005	0.007	0.000
Average 0.001 rem/g			

^aFrom Eckerman et al. (1988).

The relative activities, along with the dose conversion factors (DCFs, or dose per unit intake) given in Table 6.5 are inputs needed to calculate doses given an intake. The doses that would occur given inhalation of 1 g of debris (to 3 significant figures) containing the given concentration of each listed fission product are given in the last column of Table 6.5.

The average value of 0.001 rem/g (to three significant figures) indicates that about 1,000 g of the weapon test debris soil would need to be inhaled to produce an effective dose equivalent of 1 rem. Consequently, the intake corresponding to a 100 mrem dose is about 100 g. No scenario exists that could produce inhalation intakes this high in a short period of time (up to hours).

Table 6.6 presents the limiting release amounts for the weapons test debris.

6.1.2 Accident Initiating Event Identification and Screening

In the next step, potential accident initiators are listed for material inventories and other hazards that were not screened out. The initiating events were chosen by using the preliminary hazard analysis technique, which is described in *Guidelines for Hazard Evaluation Procedures* (Center for Chemical Process Safety 1992). In the hazard identification step, toxic, radioactive, and reactive material hazards and energy sources are identified. From the listing created in that step, mechanisms for releasing hazardous materials or directly injuring facility personnel via energy releases are postulated and tabulated. A standard set of release modes [simple spill (large or small), explosive release, and fire-enhanced release] is considered to ensure completeness. The identified events are screened on the basis of anticipated likelihood and consequences as described in the following paragraph, assuming no mitigation.

The expected frequency and potential consequences of each initiating event are characterized according to the categories defined in Table 6.7. Initiating events having Level 4 consequences or Level D likelihood are screened from further consideration. (Initiating events having Level 4 consequences and Level D likelihood are screened on the basis of consequence level.) Likewise, initiating events having Level 3 consequences (minor impacts on facility personnel and negligible impacts outside the facility) and Level C likelihood (extremely unlikely to occur) are screened out. Likelihood assignments are made by using engineering judgment.

The remaining events are grouped by type, and bounding events for accident scenario development are selected from each group.

**Table 6.6. Limiting release amounts for
"instantaneous" releases of radioactive materials for inhalation exposures**

Material	Limiting Release Amount	
	On-site Exposures	Off-site Exposures
Weapons debris	510 MT	435 MT

Table 6.7. Hazard classification scheme

Consequence Categories	
Level	Description
1	Severe impacts on persons on-site and off-site and/or on the environment.
2	Severe impacts on persons on-site and/or minor impacts on persons off-site and on the environment.
3	Minor impacts on persons on-site and negligible impacts on persons off-site and on the environment.
4	Negligible impacts on persons on-site and off-site and on the environment.
Likelihood Categories	
Level	Description
A	Anticipated ($> 1 \times 10^{-2}$ /year).
B	Unlikely (1×10^{-4} /year - 1×10^{-2} /year).
C	Extremely unlikely (1×10^{-6} /year - 1×10^{-4} /year).
D	Not credible ($< 1 \times 10^{-6}$ /year).

In assigning consequence levels to material release events such as liquid spills, powder spills, pressurized liquid or powder releases, and fire-enhanced liquid or powder releases, conservative release fractions are applied to determine the amount of material made airborne. The release fractions used are conservative values based on correlations reported in the *Nuclear Fuel Cycle Facility Accident Analysis Handbook* (Ayer et al. 1988). The correlations reported in that document are based on extensive experiments sponsored by the U. S. Nuclear Regulatory Commission and DOE. The release fractions used in this screening evaluation are conservative upper-bound values based on the analysts' experience in applying these correlations to a wide variety of materials and release conditions. Thus, they are generally larger than the recommended values tabulated by Ayer et al. Table 6.8 presents the release fractions.

As an example of how these release fractions are applied, consider a simple 100-L spill of 13% by weight nitric acid solution. The density of this solution at 20 °C is 1.07 kg/L (Perry and Chilton 1973). Therefore, the mass of material spilled is 107 kg, and the mass of nitric acid spilled is 13% of this mass, or 13.9 kg. The amount of nitric acid made airborne is estimated by taking the product of this mass (13.9 kg) and the release fraction for a simple liquid spill (0.0001). The amount made airborne (1.4 g) is compared to the limiting release amounts for on-site and off-site exposures from Tables 6.2 and 6.3 (1.5 kg and 154 kg, respectively, for a Toxicity Class 2 material). Because the amount released is far less than these limiting amounts, the event is judged to have Level 4 consequences and is screened from further consideration.

The potential effects of events involving the inadvertent mixing of incompatible reactive chemicals are further characterized in this step. For combinations that can result in the generation of toxic gases, the particular gases that would likely be formed are identified. The maximum amounts of these gases that could form are calculated by assuming that all available material reacts. The calculated quantities of gases are then screened using the limiting release amounts in Tables 6.3 and 6.4.

In cases where a combination of materials could result in a fire or explosion, the amount of stored energy available for release from the two inventories of chemicals is first estimated. Romero and Faust (1992) have published an analysis of chemical reactivity hazards at another LANL facility. In that analysis, average values for heat of combustion (in units of KJ/g) are proposed for each class of chemical included in the chemical reactivity matrix presented in the *Handbook of Chemical Hazard Analysis Procedures* (Federal Emergency Management Agency 1989). These values are adopted for this screening analysis as well. The mass of each reactant is multiplied by the heat of combustion for its chemical class, and the results are summed to estimate the total stored energy available for release.

Table 6.8. Release fractions for screening evaluations of material release events

Type of Release	Release Fraction
Gas release	1.0
Simple liquid spill	0.0001
Simple powder spill	0.001
Pressurized liquid release	0.05
Pressurized powder release	0.01
Fire-enhanced release	1.0

For potential fire events, a low burning rate of 2 g/s and an average heat of combustion of 30 KJ/g (typical of hydrocarbons) is assumed for purposes of this analysis. By using this burning rate and heat of combustion along with the available stored energy, a fire duration can be estimated, assuming that no other significant inventories of combustible materials are available to feed the fire. Fires having durations of 15 min or less are screened from further consideration because these fires would not likely spread beyond the area where they begin. Therefore, the effects of such short fires would be very localized.

For postulated explosion events resulting from inadvertent mixing of incompatible chemicals, an equivalent mass of TNT is calculated by dividing the available stored energy by the heat of combustion of TNT, 4.19 KJ/g. Events involving a TNT equivalent mass of 10 g or less are screened from further consideration. The requirements of DOE Order 6430.1A exempt laboratory facilities handling 10 g or less of explosives from meeting quantity-distance criteria, even if the laboratory also handles plutonium.

6.2 BUILDING RC-1

The following sections discuss the hazards associated with the radiochemical operations in Building RC-1.

6.2.1 Dissolver Area

The completed hazard identification worksheet for the dissolver area is presented in Table 6.9. The next step is to identify accident initiating events for hazards that are not judged to be routinely encountered industrial hazards.

Chemical inventories were characterized using the computerized inventory tracking system. Table 6.10 contains a listing of the greater-than-1 lb inventories that are listed on either the EPA's *List of Extremely Hazardous Substances* (Appendix A to 40 CFR 355) or the *List of Highly Hazardous Chemicals, Toxics, and Reactives* (Appendix A to 29 CFR 1910.119).

The initiating events for each hazard not screened out are identified in Table 6.11. Where possible, the initiating events are screened from further analysis on the basis of insignificant consequences, insignificant frequency, or a combination of the two.

Table 6.9. Hazard Identification Worksheet (dissolver area)

Facility or area: RC-1, dissolver area

Hazard Type	Hazard Present? (Y or N)	Hazard Source(s)	Routinely Encountered Industrial Hazard? (Y or N)	Remarks
Electrical energy	Y	Outlets on walls, in hoods, and in gloveboxes	Y	Maximum voltage is 240 V AC
Electromagnetic radiation	N	N/A	N/A	
Explosive materials	N	N/A	N/A	
Fissile materials	N	N/A	N/A	
Flammable materials	Y	Natural gas supply to hoods Small quantities of flammable solvents	N Y	Potential for natural gas explosion dispersing radioactive materials
Kinetic energy	Y	Centrifuge in Room 430 Forklift in Rooms 425 and 430 Pulverizer in glovebox	Y Y Y	Centrifuge is small Radioactive materials are in DOT-approved shipping containers Radioactive material sealed in can when in use

Table 6.9. (continued)

Facility or area: RC-1, dissolver area

Hazard Type	Hazard Present? (Y or N)	Hazard Source(s)	Routinely Encountered Industrial Hazard? (Y or N)	Remarks
Potential energy	N	N/A	N/A	
Radioactive materials	Y	Bulk debris and analytical samples	N	
Reactive materials	N	N/A	N/A	See Table 6.10.
Thermal energy	Y	Hot plates and flash evaporator	Y	
Toxic materials	Y	Numerous chemicals in small containers	N	See Table 6.10.
High pressure	Y	Compressed gas cylinders	Y	DOT-approved cylinders

Table 6.10. Screening analysis for inventories of listed chemicals exceeding 1 lb (dissolver area)

Location	Chemical	Quantity	Reactivity Hazards	Toxicity Data		Toxicity Rating	Disposition
				IDLH (mg/m ³)	LI ₅₀ (mg)		
Room 430	Hydrogen fluoride	80 L (80 kg)	No incompatibilities with other significant quantities of listed chemicals in this area	25 (NIOSH 1990)	297 ^a	1	Retain for toxicity only
	Hydrochloric acid	2,500 mL of 38% solution (1.1 kg HCl)	No incompatibilities with other significant quantities of listed chemicals in this area	152 (NIOSH 1990)	1,806 ^a	2	Screen out
	Nitric acid	11.5 L of 90% fuming acid (16 kg HNO ₃)	No incompatibilities with other significant quantities of listed chemicals in this area	262 (NIOSH 1990)	3,113 ^a	2	Retain for toxicity only
	Perchloric acid	11.5 L of 70% solution (14 kg HClO ₄)	No incompatibilities with other significant quantities of listed chemicals in this area	-	28,000 (Sax and Lewis 1989)	3	Screen out
	Sulfuric acid	2,500 mL (4.6 kg H ₂ SO ₄)	No incompatibilities with other significant quantities of listed chemicals in this area	80 (NIOSH 1990)	149,800 (Sax and Lewis 1989)	4	Screen out
Room 423	Nitric acid	6,200 mL (9.4 kg HNO ₃)	No incompatibilities with other significant quantities of listed chemicals in this area	262 (NIOSH 1990)	3,113 ^a	2	Retain for toxicity only
	Sulfuric acid	4.1 kg	No incompatibilities with other significant quantities of listed chemicals in this area	80 (NIOSH 1990)	149,800 (Sax and Lewis 1989)	4	Screen out
Room 421	Perchloric acid	6 L (7.0 kg HClO ₄)	No incompatibilities with other significant quantities of listed chemicals in this area	-	28,000 (Sax and Lewis 1989)	3	Screen out
Room 419	Bromine	1 kg	No incompatibilities with other significant quantities of listed chemicals in this area	66 (NIOSH 1990)	980 ^b (Sax and Lewis 1989)	2	Screen out
	Hydrogen bromide	1.2 L (2.14 kg)	No incompatibilities with other significant quantities of listed chemicals in this area	168 (NIOSH 1990)	1,996 ^a	2	Retain for toxicity only

Table 6.10. (continued)

Location	Chemical	Quantity	Reactivity Hazards	Toxicity Data		Toxicity Rating	Disposition
				IDLH (mg/m ³)	LD ₅₀ (mg)		
Room 419 (cont.)	Hydrogen peroxide	2 L (2.8 kg)	No incompatibilities with other significant quantities of listed chemicals in this area	106 (NIOSH 1990)	140,000 (Sax and Lewis 1989)	4	Screen out

^aBased on IDLH

^bBased on LD₅₀ rather than LD₅₀

Table 6.11. Identification and screening of accident initiating events (dissolver area)

Hazard Type/Source	Location(s)	Postulated Event	Consequence Category	Likelihood Category	Disposition ^a	Remarks
Radioactive materials/weapons test debris	RC-1, Room 430	Spill of one bag during transfer from shipping container caused by personnel error	4	A	C	Each bag contains up to 250 g of debris, an amount far below the limiting release amounts for on-site and off-site exposures.
		Spill of one bag during transfer into glovebox line caused by personnel error	4	A	C	Each bag contains up to 250 g of debris, an amount far below the limiting release amounts for on-site and off-site exposures.
		Spill of pulverized debris sample caused by personnel error or an external event	4	A	C	The largest samples are in the 200 - 500 g range, which is far below the limiting release amounts for on-site and off-site exposures.
		Explosive release of pulverized debris	4	D	C	Each campaign processes several kg of debris, an amount far below the limiting release amounts for on-site and off-site exposures.
		Fire-enhanced release of pulverized debris	4	C	C	Each campaign processes several kg of debris, an amount far below the limiting release amounts for on-site and off-site exposures.
Radioactive materials/weapons debris sample solutions	RC-1, Rooms 423, 426, and 430	Personnel work too close to sample solution	4	A	C	Most operations are behind lead brick barrier. Chirpers would alert personnel. At most, a few people would be affected.

Table 6.11. (continued)

Hazard Type/Source	Location(s)	Postulated Event	Consequence Category	Likelihood Category	Disposition ^a	Remarks
Radioactive materials/weapons debris sample solutions (cont.)		Spill of sample solution caused by personnel error or an external event	4	A	C	Sample solutions have much lower activity than undissolved debris.
		Explosive release of sample solution	4	D	C	Sample solutions have much lower activity than undissolved debris.
		Fire-enhanced release of sample solution	4	B	C	Sample solutions have much lower activity than undissolved debris.
Toxic materials/hydrogen bromide	RC-1, Room 419	Spill caused by personnel error or an external event	4	A	C	Toxicity Class 2; assuming a release fraction of 0.0001, a spill of the entire inventory would not exceed the limiting release amounts for on-site and off-site exposures.
		Explosive release	4	C	C	Toxicity Class 2; assuming a release fraction of 0.05, an event involving the entire inventory would not exceed the limiting release amounts for on-site and off-site exposures.
		Fire-enhanced release	2	C	Not screened	Toxicity Class 2; an event involving the entire inventory would exceed the limiting release amount for on-site exposures.
Toxic materials/nitric acid	RC-1, Rooms 423 and 430	Spill caused by personnel error or an external event	4	A	C	Toxicity Class 2; assuming a release fraction of 0.0001, a spill of the entire inventory (25.4 kg) would not exceed the limiting release amounts for on-site and off-site exposures.

Table 6.11. (continued)

Hazard Type/Source	Location(s)	Postulated Event	Consequence Category	Likelihood Category	Disposition ^a	Remarks
Toxic materials/ nitric acid (cont.)		Explosive release	4	C	C	Toxicity Class 2; assuming a release fraction of 0.05, an event involving the entire inventory would not exceed the limiting release amounts for on-site and off-site exposures.
		Fire-enhanced release	2	C	Not screened	Toxicity Class 2; an event involving the entire inventory would exceed the limiting release amounts for on-site and off-site exposures.
Toxic materials/ hydrogen fluoride	RC-1, Room 430	Spill caused by personnel error or an external event	1	A	Not screened	Toxicity Class 1; assuming a release fraction of 1.0 because of high volatility, a spill of the entire inventory would exceed the limiting release amounts for on-site and off-site exposures.
		Explosive release	1	C	Not screened	Toxicity Class 1; assuming a release fraction of 1.0 because of high volatility, an event involving the entire inventory would exceed the limiting release amounts for on-site and off-site exposures.
		Fire-enhanced release	1	C	Not screened	Toxicity Class 1; assuming a release fraction of 1.0 because of high volatility, an event involving the entire inventory would exceed the limiting release amounts for on-site and off-site exposures.

^aC - screened out on insignificant consequences or combination of minor consequences and low likelihood; F - screened out on insignificant likelihood

The remaining events are grouped as shown in Table 6.12 to facilitate selection of bounding scenarios.

6.2.2 Laboratories

The completed hazard identification worksheet for the analytical laboratories is presented in Table 6.13. Accident initiating events will be identified for hazards that are not judged to be routinely encountered industrial hazards.

Chemical inventories for the laboratories were characterized by using the computerized inventory tracking system. Table 6.14 lists the greater-than-1 lb inventories of hazardous chemicals. Thirty-four binary combinations of reactive chemicals and ten different toxic materials are retained for further evaluation in the accident initiating event definition step. Many of these chemicals are found in several different laboratories at Building RC-1.

Table 6.15 lists the accident initiating events identified for the significant hazards identified in the initial analysis steps. For each significant toxic material hazard in Table 6.15, three types of releases are addressed: spills resulting from chemist error or external events (earthquakes, aircraft crashes, etc.), pressurized releases (as might occur in an explosion), and fire-enhanced releases. The latter two release types are not initiating events in and of themselves; rather, they are possible results of other initiating events included in the table, such as natural gas leaks or inadvertent mixing of incompatible chemicals. These release types are included in this table only because the release fractions associated with them exceed those for simple spills (see Table 6.8). Simple spills of a particular material may be screened out because of the low release fraction, whereas significant consequences may result if the same inventory is involved in a fire or explosion. Significant effort can be saved in analyzing fires and explosions in later steps if all credible release types for significant chemical inventories are addressed at this level.

In the case of fire-enhanced releases, significant inventories of a given chemical in any cluster of four laboratories (e.g., RC-1, Rooms 409, 410, 411/411A, and 412/412B) are combined to determine a maximum inventory for screening purposes. This approach is taken to account for the possibility of a spreading fire.

Table 6.12. Accident initiating events (dissolver area)

Releases of Toxic Materials

Fire-enhanced release of hydrogen bromide in Room 419

Spill of hydrogen fluoride due to personnel error or external event in Room 430

Explosive release of hydrogen fluoride in Room 430

Fire-enhanced release of hydrogen fluoride in Room 430

Fire-enhanced release of nitric acid in Rooms 423 and 430

Table 6.13. Hazard Identification Worksheet (analytical laboratories)

Facility or area: RC-1, analytical laboratories

Hazard Type	Hazard Present? (Y or N)	Hazard Source(s)	Routinely Encountered Industrial Hazard? (Y or N)	Remarks
Electrical energy	Y	Wall outlets in laboratories	Y	Maximum supply voltage to RC-1 laboratories is 240 V AC.
Electromagnetic radiation	Y	Magnetic separator in Room 310C	Y	Separator magnets have very low field strength.
Explosive materials	N	N/A	N/A	
Fissile materials	N	N/A	N/A	
Flammable materials	Y	Natural gas supply to fume hoods and workbenches	N	Potential for natural gas explosion, which results in release of radioactive material from RC-1.
		Small quantities of flammable solvents	Y	
		One standard, DOT-approved cylinder and one DOT-approved lecture bottle of methane in Room 306 and one standard, DOT-approved cylinder of methane in Room 308	N	Potential for explosion, resulting in release of radioactive material from RC-1.

Table 6.13. (continued)

Facility or area: RC-1, analytical laboratories

Hazard Type	Hazard Present? (Y or N)	Hazard Source(s)	Routinely Encountered Industrial Hazard? (Y or N)	Remarks
Kinetic energy	Y	Centrifuges in laboratories	Y	Centrifuges are very small.
Potential energy	N	N/A	N/A	
Radioactive materials	Y	Analytical samples	N	
Reactive materials	Y	Numerous reactive chemicals in small containers	-	See Table 6.14.
Thermal energy	Y	Electric ovens in laboratories	Y	
Toxic materials	Y	Numerous chemicals in small containers and DOT-approved gas cylinders	-	See Table 6.14.

Table 6.13. (continued)

Facility or area: RC-1, analytical laboratories

Hazard Type	Hazard Present? (Y or N)	Hazard Source(s)	Routinely Encountered Industrial Hazard? (Y or N)	Remarks
Other (list below):				
Asphyxiants	Y	Argon cylinders	N	
		N ₂ cylinders	N	
High pressure	Y	Compressed gas cylinders in laboratories	Y	Gases are contained inside DOT-approved cylinders.
Lasers	Y	3-W argon laser in Room 341B	N	
Vacuum	Y	Vacuum service to fume hoods in laboratories	Y	Vacuum nozzles are very small (< 1/8-in. diam) so the potential for serious injury is negligible.

Table 6.14. Screening analysis for inventories of listed chemicals exceeding 1 lb (analytical laboratories)

Location	Chemical	Quantity	Reactivity Hazards	Toxicity Data		Toxicity Rating	Disposition
				IDLH (mg/m ³)	LI ₅₀ (mg)		
RC-1, Room 304	Hydrochloric acid	1.5 L (1.8 kg)	No incompatibilities with other significant quantities of listed chemicals in this area.	152 (NIOSH 1990)	1,806*	2	Retain for toxicity only
	Hydrogen bromide	500 mL (880 g)	No incompatibilities with other significant quantities of listed chemicals in this area.	168 (NIOSH 1990)	1,996*	2	Screen out
	Nitric acid	3.9 kg	No incompatibilities with other significant quantities of listed chemicals in this area.	262 (NIOSH 1990)	3,113*	2	Retain for toxicity only
	Perchloric acid	500 mL of 70% by weight solution (580 g)	No incompatibilities with other significant quantities of listed chemicals in this area.	-	28,000 (Sax and Lewis 1989)	3	Screen out
	Sulfuric acid	2.5 L (4.6 kg)	No incompatibilities with other significant quantities of listed chemicals in this area.	80 (NIOSH 1990)	149,800 (Sax and Lewis 1989)	4	Screen out
RC-1, Room 305	Ammonia	2.3 kg	No incompatibilities with other significant quantities of listed chemicals in this area.	355 (NIOSH 1990)	24,500 (Sax and Lewis 1989)	3	Screen out
	Hydrochloric acid	2.5 L of 38% by weight solution (1.1 kg)	Possible generation of toxic gases if mixed with hydrogen peroxide.	152 (NIOSH 1990)	1,806*	2	Retain for reactivity only
	Hydrogen chloride (gas)	3.6 kg	Possible generation of toxic gases if mixed with hydrogen peroxide.	152 (NIOSH 1990)	1,806*	2	Retain for toxicity and reactivity
	Hydrogen fluoride	500 mL (490 g)	Possible generation of toxic gases if mixed with hydrogen peroxide.	25 (NIOSH 1990)	297*	1	Retain for toxicity and reactivity

Table 6.14. (continued)

Location	Chemical	Quantity	Reactivity Hazards	Toxicity Data		Toxicity Rating	Disposition
				IDLH (mg/m ³)	LI ₅₀ (mg)		
RC-1, Room 305 (cont.)	Hydrogen peroxide	470 mL (660 g)	Possible generation of toxic gases if mixed with hydrochloric acid, hydrogen chloride gas, or hydrogen fluoride.	106 (NIOSH 1990)	140,000 (Sax and Lewis 1989)	4	Retain for reactivity only
	Mercuric chloride	579 g	No incompatibilities with other significant quantities of listed chemicals in this area.	-	2,030 (based on LDLo) (Sax and Lewis 1989)	2 ^b	Screen out
	Mercuric oxide	454 g	No incompatibilities with other significant quantities of listed chemicals in this area.	-	1,260 (Sax and Lewis 1989)	2	Screen out
	Nitric acid	2.5 L (3.78 kg)	No incompatibilities with other significant quantities of listed chemicals in this area.	262 (NIOSH 1990)	3,113 ^a	2	Retain for toxicity only
	Perchloric acid	500 mL of 70% by weight solution (580 g)	No incompatibilities with other significant quantities of listed chemicals in this area.	-	28,000 (Sax and Lewis 1989)	3	Screen out
	Sodium arsenite	454 g	No incompatibilities with other significant quantities of listed chemicals in this area.	-	2,870 (Sax and Lewis 1989)	2	Screen out
	Sulfuric acid	2.5 L (4.6 kg)	No incompatibilities with other significant quantities of listed chemicals in this area.	80 (NIOSH 1990)	149,800 (Sax and Lewis 1989)	4	Screen out
RC-1, Room 305B	Hydrochloric acid	2.7 kg	No incompatibilities with other significant quantities of listed chemicals in this area.	152 (NIOSH 1990)	1,806 ^a	2	Retain for toxicity only

Table 6.14. (continued)

Location	Chemical	Quantity	Reactivity Hazards	Toxicity Data		Toxicity Rating	Disposition
				IDLH (mg/m ³)	LI ₅₀ (mg)		
RC-1, Room 305B (cont.)	Hydrogen fluoride	454 g	No incompatibilities with other significant quantities of listed chemicals in this area.	25 (NIOSH 1990)	297 ^a	1	Retain for toxicity only
	Nitric acid	2.5 L (3.8 kg)	No incompatibilities with other significant quantities of listed chemicals in this area.	262 (NIOSH 1990)	3,113 ^a	2	Retain for toxicity only
	Perchloric acid	44.4 L of 70% by weight solution (74 kg)	No incompatibilities with other significant quantities of listed chemicals in this area.	-	28,000 (Sax and Lewis 1989)	3	Retain for toxicity only
	Sulfuric acid	2.5 L (4.6 kg)	No incompatibilities with other significant quantities of listed chemicals in this area.	80 (NIOSH 1990)	149,800 (Sax and Lewis 1989)	4	Screen out
RC-1, Room 306	Hydrochloric acid	500 mL (600 g)	Possible generation of toxic gases if mixed with hydrogen sulfide.	152 (NIOSH 1990)	1,806 ^a	2	Retain for reactivity only
	Hydrogen sulfide	681 g	Possible generation of toxic gases if mixed with hydrochloric acid.	426 (NIOSH 1990)	5,060 ^a	3	Retain for reactivity only
RC-1, Room 307	Chloroform	1 L (1.49 kg)	Possible generation of toxic gases if mixed with hydrochloric acid, hydrogen bromide, hydrogen chloride gas, or hydrogen fluoride; possible fire and generation of toxic gases if mixed with nitric acid or perchloric acid.	4,960 (NIOSH 1990)	2,520 (Sax and Lewis 1989)	2	Retain for reactivity only
	Hydrochloric acid	5.5 L (6.6 kg)	Possible generation of toxic gases if mixed with chloroform.	152 (NIOSH 1990)	1,806 ^a	2	Retain for toxicity and reactivity

Table 6.14. (continued)

Location	Chemical	Quantity	Reactivity Hazards	Toxicity Data		Toxicity Rating	Disposition
				IDLH (mg/m ³)	LL ₅₀ (mg)		
RC-1, Room 307 (cont.)	Hydrogen bromide	454 g	Possible generation of toxic gases if mixed with chloroform.	168 (NIOSH 1990)	1,996 ^a	2	Retain for reactivity only
	Hydrogen chloride (gas)	27.2 kg	Possible generation of toxic gases if mixed with chloroform.	152 (NIOSH 1990)	1,806 ^a	2	Retain for toxicity and reactivity
	Hydrogen fluoride	500 mL (490 g)	Possible generation of toxic gases if mixed with chloroform.	25 (NIOSH 1990)	297 ^a	1	Retain for toxicity and reactivity
	Nitric acid	1.96 kg	Possible fire and generation of toxic gases if mixed with chloroform.	262 (NIOSH 1990)	3,113 ^a	2	Retain for toxicity and reactivity
	Perchloric acid	1.5 L of 70% by weight solution (1.75 kg)	Possible fire and generation of toxic gases if mixed with chloroform.	-	28,000 (Sax and Lewis 1989)	3	Retain for reactivity only
RC-1, Room 308	Hydrochloric acid	500 mL (600 g)	No incompatibilities with other significant quantities of listed chemicals in this area.	152 (NIOSH 1990)	1,806 ^a	2	Screen out
	Hydrogen fluoride	1 L (988 g)	No incompatibilities with other significant quantities of listed chemicals in this area.	25 (NIOSH 1990)	297 ^a	1	Retain for toxicity only
RC-1, Room 309	Hydrogen fluoride	1 L (988 g)	Possible generation of toxic gases if mixed with sodium cyanide.	25 (NIOSH 1990)	297 ^a	1	Retain for toxicity and reactivity
	Nitric acid	2.5 L (3.8 kg)	Possible generation of toxic gases if mixed with sodium cyanide.	262 (NIOSH 1990)	3,113 ^a	2	Retain for toxicity and reactivity
	Sodium cyanide	454 g	Possible generation of toxic gases if mixed with hydrogen fluoride, nitric acid, or sulfuric acid.	-	448 (Sax and Lewis 1989)	2	Retain for reactivity only

Table 6.14. (continued)

Location	Chemical	Quantity	Reactivity Hazards	Toxicity Data		Toxicity Rating	Disposition
				IDLH (mg/m ³)	LI ₅₀ (mg)		
RC-1, Room 309 (cont.)	Sulfuric acid	2.5 L (4.6 kg)	Possible generation of toxic gases if mixed with sodium cyanide.	80 (NIOSH 1990)	149,800 (Sax and Lewis 1989)	4	Retain for reactivity only
RC-1, Room 309B	Cellulose tetranitrate (parlodion)	454 g	Possible explosion if mixed with nitric acid or sulfuric acid.	-	-	c	Retain for reactivity only
	Nitric acid	2.5 L (3.8 kg)	Possible explosion if mixed with cellulose tetranitrate.	262 (NIOSH 1990)	3,113*	2	Retain for toxicity and reactivity
	Sulfuric acid	4.1 kg	Possible explosion if mixed with cellulose tetranitrate.	80 (NIOSH 1990)	149,800 (Sax and Lewis 1989)	4	Retain for reactivity only
RC-1, Room 310	Hydrochloric acid	3 L (3.6 kg)	No other significant quantities of listed chemicals are located in this area.	152 (NIOSH 1990)	1,806*	2	Retain for toxicity only
RC-1, Room 311	Chlorine	454 g	No incompatibilities with other significant quantities of listed chemicals in this area.	88.5 (NIOSH 1990)	1,051*	2	Screen out
	Hydrochloric acid	1 L (1.2 kg)	Possible generation of toxic gases if mixed with hydrogen peroxide.	152 (NIOSH 1990)	1,806*	2	Retain for reactivity only
	Hydrogen fluoride	500 mL (490 g)	Possible generation of toxic gases if mixed with hydrogen peroxide.	25 (NIOSH 1990)	297*	1	Retain for toxicity and reactivity
	Hydrogen peroxide	4 L (5.6 kg)	Possible generation of toxic gases if mixed with hydrochloric acid or hydrogen fluoride.	106 (NIOSH 1990)	140,000 (Sax and Lewis 1989)	4	Retain for reactivity only

Table 6.14. (continued)

Location	Chemical	Quantity	Reactivity Hazards	Toxicity Data		Toxicity Rating	Disposition
				IDLH (mg/m ³)	LI ₅₀ (mg)		
RC-1, Room 311 (cont.)	Nitric acid	3.5 L (5.3 kg)	No incompatibilities with other significant quantities of listed chemicals in this area.	262 (NIOSH 1990)	3,113 ^a	2	Retain for toxicity only
	Sulfuric acid	3.5 L (6.4 kg)	No incompatibilities with other significant quantities of listed chemicals in this area.	80 (NIOSH 1990)	149,800 (Sax and Lewis 1989)	4	Screen out
RC-1, Room 312	Hydrochloric acid	3.5 L (4.2 kg)	Possible generation of toxic gases if mixed with hydrogen peroxide.	152 (NIOSH 1990)	1,806 ^a	2	Retain for toxicity and reactivity
	Hydrogen fluoride	1 L (988 g)	Possible generation of toxic gases if mixed with hydrogen peroxide.	25 (NIOSH 1990)	297 ^a	1	Retain for toxicity and reactivity
	Hydrogen peroxide	500 mL (700 g)	Possible generation of toxic gases if mixed with hydrochloric acid or hydrogen fluoride.	106 (NIOSH 1990)	140,000 (Sax and Lewis 1989)	4	Retain for reactivity only
	Nitric acid	500 mL (760 g)	No incompatibilities with other significant quantities of listed chemicals in this area.	262 (NIOSH 1990)	3,113 ^a	2	Screen out
	Perchloric acid	500 mL of 70% by weight solution (580 g)	No incompatibilities with other significant quantities of listed chemicals in this area.	-	28,000 (Sax and Lewis 1989)	3	Screen out
	Sulfuric acid	8.2 kg	No incompatibilities with other significant quantities of listed chemicals in this area.	80 (NIOSH 1990)	149,800 (Sax and Lewis 1989)	4	Screen out
RC-1, Room 314	Hydrochloric acid	3 L of 38% by weight solution (1.4 kg)	Possible generation of toxic gases if mixed with hydrogen peroxide.	152 (NIOSH 1990)	1,806 ^a	2	Retain for reactivity only

Table 6.14. (continued)

Location	Chemical	Quantity	Reactivity Hazards	Toxicity Data		Toxicity Rating	Disposition
				IDLH (mg/m ³)	LI ₅₀ (mg)		
RC-1, Room 314 (cont.)	Hydrogen fluoride	500 mL (490 g)	Possible generation of toxic gases if mixed with hydrogen peroxide.	25 (NIOSH 1990)	297 ^a	1	Retain for toxicity and reactivity
	Hydrogen peroxide	500 mL (700 g)	Possible generation of toxic gases if mixed with hydrochloric acid or hydrogen fluoride.	106 (NIOSH 1990)	140,000 (Sax and Lewis 1989)	4	Retain for reactivity only
	Nitric acid	500 mL (760 g)	No incompatibilities with other significant quantities of listed chemicals in this area.	262 (NIOSH 1990)	3,113 ^a	2	Screen out
	Perchloric acid	500 mL of 70% by weight solution (580 g)	No incompatibilities with other significant quantities of listed chemicals in this area.	-	28,000 (Sax and Lewis 1989)	3	Screen out
	Sulfuric acid	2.5 L (4.6 kg)	No incompatibilities with other significant quantities of listed chemicals in this area.	80 (NIOSH 1990)	149,800 (Sax and Lewis 1989)	4	Screen out
RC-1, Room 326	Cadmium oxide	454 g	No incompatibilities with other significant quantities of listed chemicals in this area.	9 (NIOSH 1990)	5,040 (Sax and Lewis 1989)	3	Screen out
	Mercury	4.5 kg	No incompatibilities with other significant quantities of listed chemicals in this area.	28 (NIOSH 1990)	333 ^a	1	Retain for toxicity only
	Nickel	454 g	No incompatibilities with other significant quantities of listed chemicals in this area.	-	350 (based on LDLo) (Sax and Lewis 1989)	2 ^b	Screen out

Table 6.14. (continued)

Location	Chemical	Quantity	Reactivity Hazards	Toxicity Data		Toxicity Rating	Disposition
				IDLH (mg/m ³)	LI ₅₀ (mg)		
RC-1, Room 326 (cont.)	Sulfuric acid	490 mL (900 g)	No incompatibilities with other significant quantities of listed chemicals in this area.	80 (NIOSH 1990)	149,800 (Sax and Lewis 1989)	4	Screen out
RC-1, Room 339D	Chloroform	1 L (1.49 kg)	Possible fire and generation of toxic gases if mixed with nitric acid, perchloric acid, or sulfuric acid; possible generation of toxic gases if mixed with hydrogen fluoride.	4,960 (NIOSH 1990)	2,520 (Sax and Lewis 1989)	2	Retain for reactivity only
	Hydrogen fluoride	2 L (1.98 kg)	Possible generation of toxic gases if mixed with chloroform.	25 (NIOSH 1990)	297*	1	Retain for toxicity and reactivity
	Nitric acid	1 L of 71% by weight solution (1 kg)	Possible fire and generation of toxic gases if mixed with chloroform.	262 (NIOSH 1990)	3,113*	2	Retain for reactivity only
	Perchloric acid	1.5 L of 70% by weight solution (1.75 kg)	Possible fire and generation of toxic gases if mixed with chloroform.	-	28,000 (Sax and Lewis 1989)	3	Retain for reactivity only
	Sulfuric acid	2.5 L (4.6 kg)	Possible fire and generation of toxic gases if mixed with chloroform.	80 (NIOSH 1990)	149,800 (Sax and Lewis 1989)	4	Retain for reactivity only
RC-1, Room 341B	Chloroform	2 L (2.98 kg)	No other significant quantities of listed chemicals are located in this area.	4,960 (NIOSH 1990)	2,520 (Sax and Lewis 1989)	2	Retain for toxicity only
RC-1, Room 402	Chloroform	5 L (7.45 kg)	Possible fire and generation of toxic gases if mixed with nitric acid or sulfuric acid; possible generation of toxic gases if mixed with hydrochloric acid.	4,960 (NIOSH 1990)	2,520 (Sax and Lewis 1989)	2	Retain for toxicity and reactivity

Table 6.14. (continued)

Location	Chemical	Quantity	Reactivity Hazards	Toxicity Data		Toxicity Rating	Disposition
				IDLH (mg/m ³)	LI ₅₀ (mg)		
RC-1, Room 402 (cont.)	Hydrochloric acid	4 L (4.8 kg)	Possible generation of toxic gases if mixed with chloroform or sodium cyanide.	152 (NIOSH 1990)	1,806*	2	Retain for toxicity and reactivity
	Nitric acid	6 L (9 kg)	Possible fire and generation of toxic gases if mixed with chloroform; possible generation of toxic gases if mixed with sodium cyanide.	262 (NIOSH 1990)	3,113*	2	Retain for toxicity and reactivity
	Sodium cyanide	500 g	Possible generation of toxic gases if mixed with hydrochloric acid, nitric acid, or sulfuric acid.	-	448 (Sax and Lewis 1989)	2	Retain for reactivity only
	Sulfuric acid	2 L (3.7 kg)	Possible fire and generation of toxic gases if mixed with chloroform; possible generation of toxic gases if mixed with sodium cyanide.	80 (NIOSH 1990)	149,800 (Sax and Lewis 1989)	4	Retain for reactivity only
RC-1, Room 406	Hydrochloric acid	500 mL (600 g)	No incompatibilities with other significant quantities of listed chemicals in this area.	152 (NIOSH 1990)	1,806*	2	Screen out
	Nitric acid	1 L (1.51 kg)	No incompatibilities with other significant quantities of listed chemicals in this area.	262 (NIOSH 1990)	3,113*	2	Retain for toxicity only
	Sulfuric acid	500 mL (920 g)	No incompatibilities with other significant quantities of listed chemicals in this area.	80 (NIOSH 1990)	149,800 (Sax and Lewis 1989)	4	Screen out

Table 6.14. (continued)

Location	Chemical	Quantity	Reactivity Hazards	Toxicity Data		Toxicity Rating	Disposition
				IDLH (mg/m ³)	LI ₅₀ (mg)		
RC-1, Room 407	Chloroform	2 L (3 kg)	Possible fire and generation of toxic gases if mixed with nitric acid, perchloric acid, or sulfuric acid; possible generation of toxic gases if mixed with hydrochloric acid or hydrogen fluoride.	4,960 (NIOSH 1990)	2,520 (Sax and Lewis 1989)	2	Retain for toxicity and reactivity
	Hydrochloric acid	2 L (2.4 kg)	Possible generation of toxic gases if mixed with chloroform.	152 (NIOSH 1990)	1,806*	2	Retain for toxicity and reactivity
	Hydrogen fluoride	1.5 L (1.48 kg)	Possible generation of toxic gases if mixed with chloroform.	25 (NIOSH 1990)	297*	1	Retain for toxicity and reactivity
	Nitric acid	1.5 L (2.3 kg)	Possible fire and generation of toxic gases if mixed with chloroform.	262 (NIOSH 1990)	3,113*	2	Retain for toxicity and reactivity
	Perchloric acid	900 g	Possible fire and generation of toxic gases if mixed with chloroform.	-	28,000 (Sax and Lewis 1989)	3	Retain for reactivity only
	Sodium arsenate	500 g	No incompatibilities with other significant quantities of listed chemicals in this area.	-	875 (based on LDLo) (Sax and Lewis 1989)	2 ^b	Screen out
	Sodium arsenite	454 g	No incompatibilities with other significant quantities of listed chemicals in this area.	-	2,870 (Sax and Lewis 1989)	2	Screen out
	Sulfuric acid	500 mL (920 g)	Possible fire and generation of toxic gases if mixed with chloroform.	80 (NIOSH 1990)	149,800 (Sax and Lewis 1989)	4	Retain for reactivity only

Table 6.14. (continued)

Location	Chemical	Quantity	Reactivity Hazards	Toxicity Data		Toxicity Rating	Disposition
				IDLH (mg/m ³)	LI ₅₀ (mg)		
RC-1, Room 408	Chlorine	1.4 kg	Possible explosion if mixed with hydroquinone; possible generation of toxic gases if mixed with chloroform.	88.5 (NIOSH 1990)	1,051*	2	Retain for reactivity only
	Chloroform	1 L (1.49 kg)	Possible explosion if mixed with hydrogen sulfide; possible fire and generation of toxic gases if mixed with nitric acid, perchloric acid, or sulfuric acid; possible generation of toxic gases if mixed with chlorine, hydrochloric acid or hydrogen fluoride.	4,960 (NIOSH 1990)	2,520 (Sax and Lewis 1989)	2	Retain for reactivity only
	Hydrochloric acid	500 mL (600 g)	Possible generation of toxic gases if mixed with chloroform or hydrogen sulfide.	152 (NIOSH 1990)	1,806*	2	Retain for reactivity only
	Hydrogen fluoride	1 L (988 g)	Possible generation of toxic gases if mixed with chloroform or hydrogen sulfide.	25 (NIOSH 1990)	297*	1	Retain for toxicity and reactivity
	Hydrogen sulfide	454 g	Possible explosion if mixed with chloroform; possible generation of toxic gases if mixed with nitric acid, perchloric acid, sulfuric acid, hydrochloric acid, or hydrogen fluoride.	426 (NIOSH 1990)	5,060*	3	Retain for reactivity only
	Hydroquinone	500 g	Possible explosion if mixed with chlorine; possible fire if mixed with nitric acid, perchloric acid, or sulfuric acid.	-	14,000 (Sax and Lewis 1989)	3	Retain for reactivity only

Table 6.14. (continued)

Location	Chemical	Quantity	Reactivity Hazards	Toxicity Data		Toxicity Rating	Disposition
				IDLH (mg/m ³)	LI ₅₀ (mg)		
RC-1, Room 408 (cont.)	Mercuric oxide	570 g	No incompatibilities with other significant quantities of listed chemicals in this area.	-	1,260 (Sax and Lewis 1989)	2	Screen out
	Nitric acid	1.5 L (2.27 kg)	Possible fire if mixed with hydroquinone; possible fire and generation of toxic gases if mixed with chloroform; possible generation of toxic gases if mixed with hydrogen sulfide.	262 (NIOSH 1990)	3,113*	2	Retain for toxicity and reactivity
	Perchloric acid	1 L of 72% by weight solution (1.2 kg)	Possible fire if mixed with hydroquinone; possible fire and generation of toxic gases if mixed with chloroform; possible generation of toxic gases if mixed with hydrogen sulfide.	-	28,000 (Sax and Lewis 1989)	3	Retain for reactivity only
	Sulfuric acid	3.1 L of 8 N solution (1.2 kg)	Possible fire if mixed with hydroquinone; possible fire and generation of toxic gases if mixed with chloroform; possible generation of toxic gases if mixed with hydrogen sulfide.	80 (NIOSH 1990)	149,800 (Sax and Lewis 1989)	4	Retain for reactivity only
RC-1, Room 409	Ammonia	7 kg	No incompatibilities with other significant quantities of listed chemicals in this area.	355 (NIOSH 1990)	24,500 (Sax and Lewis 1989)	3	Screen out
	Chlorine	454 g	Possible generation of toxic gases if mixed with chloroform.	88.5 (NIOSH 1990)	1,051*	2	Retain for reactivity only

Table 6.14. (continued)

Location	Chemical	Quantity	Reactivity Hazards	Toxicity Data		Toxicity Rating	Disposition
				IDLH (mg/m ³)	LI ₅₀ (mg)		
RC-1, Room 409 (cont.)	Chloroform	4.3 L (6.4 kg)	Possible fire and generation of toxic gases if mixed with sulfuric acid; possible generation of toxic gases if mixed with chlorine, hydrochloric acid, or sulfur dioxide.	4,960 (NIOSH 1990)	2,520 (Sax and Lewis 1989)	2	Retain for toxicity and reactivity
	Hydrochloric acid	2.6 L (3.1 kg)	Possible generation of toxic gases if mixed with chloroform or sulfur dioxide.	152 (NIOSH 1990)	1,806*	2	Retain for toxicity and reactivity
	Sulfur dioxide	908 g	Possible generation of toxic gases if mixed with chloroform or hydrochloric acid.	266 (NIOSH 1990)	3,160*	2	Retain for reactivity only
	Sulfuric acid	4.1 kg	Possible fire and generation of toxic gases if mixed with chloroform.	80 (NIOSH 1990)	149,800 (Sax and Lewis 1989)	4	Retain for reactivity only
RC-1, Room 410	Hydrochloric acid	760 g	Possible generation of toxic gases if mixed with sulfur dioxide.	152 (NIOSH 1990)	1,806*	2	Retain for reactivity only
	Hydrogen fluoride	908 g	Possible generation of toxic gases if mixed with sulfur dioxide.	25 (NIOSH 1990)	297*	1	Retain for toxicity and reactivity
	Nitric acid	1 L (1.51 kg)	No incompatibilities with other significant quantities of listed chemicals in this area.	262 (NIOSH 1990)	3,113*	2	Retain for toxicity only
	Selenious acid	500 g	Possible generation of toxic gases if mixed with sulfur dioxide.	-	1,750 (Based on LDLo) (Sax and Lewis 1989)	2 ^b	Retain for reactivity only

Table 6.14. (continued)

Location	Chemical	Quantity	Reactivity Hazards	Toxicity Data		Toxicity Rating	Disposition
				IDLH (mg/m ³)	LI ₅₀ (mg)		
RC-1, Room 410 (cont.)	Sulfur dioxide	454 g	Possible generation of toxic gases if mixed with hydrochloric acid, hydrogen fluoride, or selenious acid.	266 (NIOSH 1990)	3,160*	2	Retain for reactivity only
	Sulfuric acid	4.37 kg	No incompatibilities with other significant quantities of listed chemicals in this area.	80 (NIOSH 1990)	149,800 (Sax and Lewis 1989)	4	Screen out
RC-1, Room 411	Hydrogen fluoride	500 mL (490 g)	Possible generation of toxic gases if mixed with sodium cyanide or sulfur dioxide.	25 (NIOSH 1990)	297*	1	Retain for toxicity and reactivity
	Nitric acid	1 L (1.51 kg)	Possible generation of toxic gases if mixed with sodium cyanide.	262 (NIOSH 1990)	3,113*	2	Retain for toxicity and reactivity
	Perchloric acid	500 mL of 70% by weight solution (580 g)	Possible generation of toxic gases if mixed with sodium cyanide.	-	28,000 (Sax and Lewis 1989)	3	Retain for reactivity only
	Sodium cyanide	500 g	Possible generation of toxic gases if mixed with hydrogen fluoride, nitric acid, perchloric acid, or sulfur dioxide.	-	448 (Sax and Lewis 1989)	2	Retain for reactivity only
	Sulfur dioxide	4.8 kg	Possible generation of toxic gases if mixed with sodium cyanide or hydrogen fluoride.	266 (NIOSH 1990)	3,160*	2	Retain for toxicity and reactivity
RC-1, Room 411A	Hydrogen sulfide	454 g	No incompatibilities with other significant quantities of other listed chemicals in this area.	426 (NIOSH 1990)	5,060*	3	Screen out
	Sulfur dioxide	2.7 kg	No incompatibilities with other significant quantities of other listed chemicals in this area.	266 (NIOSH 1990)	3,160*	2	Retain for toxicity only

Table 6.14. (continued)

Location	Chemical	Quantity	Reactivity Hazards	Toxicity Data		Toxicity Rating	Disposition
				IDLH (mg/m ³)	LI ₅₀ (mg)		
RC-1, Room 412	Chloroform	5 L (7.45 kg)	Possible fire and generation of toxic gases if mixed with nitric acid or sulfuric acid; possible generation of toxic gases if mixed with hydrogen fluoride.	4,960 (NIOSH 1990)	2,520 (Sax and Lewis 1989)	2	Retain for toxicity and reactivity
	Hydrogen fluoride	500 mL (490 g)	Possible generation of toxic gases if mixed with chloroform.	25 (NIOSH 1990)	297*	1	Retain for toxicity and reactivity
	Nitric acid	1.5 L (2.27 kg)	Possible fire and generation of toxic gases if mixed with chloroform.	262 (NIOSH 1990)	3,113*	2	Retain for toxicity and reactivity
	Sulfuric acid	2.5 L (4.6 kg)	Possible fire and generation of toxic gases if mixed with chloroform.	80 (NIOSH 1990)	149,800 (Sax and Lewis 1989)	4	Retain for reactivity only
RC-1, Room 412B	Hydrochloric acid	500 mL (600 g)	No other significant quantities of listed chemicals are located in this area.	152 (NIOSH 1990)	1,806*	2	Screen out
RC-1, Room 413	Chloroform	1 L (1.49 kg)	Possible fire and generation of toxic gases if mixed with nitric acid or perchloric acid; possible generation of toxic gases if mixed with hydrochloric acid, hydrogen fluoride, or sulfur dioxide.	4,960 (NIOSH 1990)	2,520 (Sax and Lewis 1989)	2	Retain for reactivity only
	Hydrochloric acid	2.5 L of 38% by weight solution (1.1 kg)	Possible generation of toxic gases if mixed with chloroform, hydrogen sulfide, sodium cyanide, or sulfur dioxide.	152 (NIOSH 1990)	1,806*	2	Retain for reactivity only

Table 6.14. (continued)

Location	Chemical	Quantity	Reactivity Hazards	Toxicity Data		Toxicity Rating	Disposition
				IDLH (mg/m ³)	LI ₅₀ (mg)		
RC-1, Room 413 (cont.)	Hydrogen fluoride	500 mL (490 g)	Possible generation of toxic gases if mixed with chloroform, hydrogen sulfide, sodium cyanide, or sulfur dioxide.	25 (NIOSH 1990)	297*	1	Retain for toxicity and reactivity
	Hydrogen sulfide	27.2 kg	Possible fire and generation of toxic gases if mixed with nitric acid or perchloric acid; possible generation of toxic gases if mixed with hydrochloric acid or hydrogen fluoride.	426 (NIOSH 1990)	5,060*	3	Retain for toxicity and reactivity
	Nitric acid	3 L (4.5 kg)	Possible fire and generation of toxic gases if mixed with chloroform or hydrogen sulfide; possible generation of toxic gases if mixed with sodium cyanide.	262 (NIOSH 1990)	3,113*	2	Retain for toxicity and reactivity
	Perchloric acid	500 mL of 72% by weight solution (600 g)	Possible fire and generation of toxic gases if mixed with chloroform or hydrogen sulfide; possible generation of toxic gases if mixed with sodium cyanide.	-	28,000 (Sax and Lewis 1989)	3	Retain for reactivity only
	Sodium cyanide	500 g	Possible generation of toxic gases if mixed with hydrochloric acid, hydrogen fluoride, nitric acid, perchloric acid, or sulfur dioxide.	-	448 (Sax and Lewis 1989)	2	Retain for reactivity only
	Sulfur dioxide	45.4 kg	Possible generation of toxic gases if mixed with chloroform, hydrochloric acid, hydrogen fluoride, or sodium cyanide.	266 (NIOSH 1990)	3,160*	2	Retain for toxicity and reactivity

Table 6.14. (continued)

Location	Chemical	Quantity	Reactivity Hazards	Toxicity Data		Toxicity Rating	Disposition
				IDLH (mg/m ³)	LI ₅₀ (mg)		
RC-1, Room 413C	Hydrochloric acid	1 L of 38% by weight solution (450 g)	No incompatibilities with other significant quantities of listed chemicals in this area.	152 (NIOSH 1990)	1,806*	2	Screen out
	Hydrogen fluoride	1 L (988 g)	No incompatibilities with other significant quantities of listed chemicals in this area.	25 (NIOSH 1990)	297*	1	Retain for toxicity only
	Mercury	2.27 kg	No incompatibilities with other significant quantities of listed chemicals in this area.	28 (NIOSH 1990)	333*	1	Retain for toxicity only
	Nitric acid	3 L (4.5 kg)	No incompatibilities with other significant quantities of listed chemicals in this area.	262 (NIOSH 1990)	3,113*	2	Retain for toxicity only
	Perchloric acid	500 mL of 70% by weight solution (580 g)	No incompatibilities with other significant quantities of listed chemicals in this area.	-	28,000 (Sax and Lewis 1989)	3	Screen out
	Sulfuric acid	2.5 L (4.6 kg)	No incompatibilities with other significant quantities of listed chemicals in this area.	80 (NIOSH 1990)	149,800 (Sax and Lewis 1989)	4	Screen out
RC-1, Room 414	Chlorine	454 g	No incompatibilities with other significant quantities of listed chemicals in this area.	88.5 (NIOSH 1990)	1,051*	2	Screen out
	Hydrochloric acid	3 L (3.6 kg)	Possible generation of toxic gases if mixed with sulfur dioxide.	152 (NIOSH 1990)	1,806*	2	Retain for toxicity and reactivity
	Hydrogen fluoride	500 mL (490 g)	Possible generation of toxic gases if mixed with sulfur dioxide.	25 (NIOSH 1990)	297*	1	Retain for toxicity and reactivity

Table 6.14. (continued)

Location	Chemical	Quantity	Reactivity Hazards	Toxicity Data		Toxicity Rating	Disposition
				IDLH (mg/m ³)	LI ₅₀ (mg)		
RC-1, Room 414 (cont.)	Mercuric chloride	454 g	No incompatibilities with other significant quantities of listed chemicals in this area.	-	2,030 (based on LDLo) (Sax and Lewis 1989)	2 ^b	Screen out
	Nitric acid	3 L (4.5 kg)	No incompatibilities with other significant quantities of listed chemicals in this area.	262 (NIOSH 1990)	3,113 ^a	2	Retain for toxicity only
	Perchloric acid	500 mL of 70% by weight solution (580 g)	No incompatibilities with other significant quantities of listed chemicals in this area.	-	28,000 (Sax and Lewis 1989)	3	Screen out
	Sulfur dioxide	1.4 kg	Possible generation of toxic gases if mixed with hydrochloric acid or hydrogen fluoride.	266 (NIOSH 1990)	3,160 ^a	2	Retain for reactivity only
	Sulfuric acid	4.1 kg	No incompatibilities with other significant quantities of listed chemicals in this area.	80 (NIOSH 1990)	149,800 (Sax and Lewis 1989)	4	Screen out
RC-1, Room 414B	Hydrazine	500 g	Possible fire and generation of toxic gases if mixed with nitric acid, perchloric acid, or sulfuric acid.	106 (NIOSH 1990)	4,200 (Sax and Lewis 1989)	3	Retain for reactivity only
	Hydrochloric acid	2.5 L (3 kg)	No incompatibilities with other significant quantities of listed chemicals in this area.	152 (NIOSH 1990)	1,806 ^a	2	Retain for toxicity only
	Hydrogen fluoride	1.2 L (1.2 kg)	No incompatibilities with other significant quantities of listed chemicals in this area.	25 (NIOSH 1990)	297 ^a	1	Retain for toxicity only

Table 6.14. (continued)

Location	Chemical	Quantity	Reactivity Hazards	Toxicity Data		Toxicity Rating	Disposition
				IDLH (mg/m ³)	LD ₅₀ (mg)		
RC-1, Room 414B (cont.)	Nitric acid	3.45 L (5.2 kg)	Possible fire and generation of toxic gases if mixed with hydrazine.	262 (NIOSH 1990)	3,113 ^a	2	Retain for toxicity and reactivity
	Perchloric acid	500 mL of 70% by weight solution (580 g)	Possible fire and generation of toxic gases if mixed with hydrazine.	-	28,000 (Sax and Lewis 1989)	3	Retain for reactivity only
	Sulfuric acid	4.1 kg	Possible fire and generation of toxic gases if mixed with hydrazine.	80 (NIOSH 1990)	149,800 (Sax and Lewis 1989)	4	Retain for reactivity only
RC-1, Room 415	Sulfur dioxide	1.8 kg	No other significant quantities of listed chemicals are located in this area.	266 (NIOSH 1990)	3,160 ^a	2	Retain for toxicity only
RC-1, Room 416	Chloroform	1 L (1.49 kg)	No incompatibilities with other significant quantities of listed chemicals in this area.	4,960 (NIOSH 1990)	2,520 (Sax and Lewis 1989)	2	Screen out
	Hydrochloric acid	500 mL (600 g)	No incompatibilities with other significant quantities of listed chemicals in this area.	152 (NIOSH 1990)	1,806 ^a	2	Screen out
	Mercury	68 kg	No incompatibilities with other significant quantities of listed chemicals in this area.	28 (NIOSH 1990)	333 ^a	1	Retain for toxicity only

^aBased on IDLH^bBased on LDLo rather than LD₅₀^cNo toxicity data are available for this material

Table 6.15. Identification and screening of accident initiating events (analytical laboratories)

Hazard Type/Source	Location(s)	Postulated Event	Consequence Category	Likelihood Category	Disposition*	Remarks
Asphyxiants/argon cylinder	RC-1, Rooms 302, 311, 314, 315, 409, 414, and 416.	Asphyxiation of personnel	3	C	C	At most, a few people would be affected.
Asphyxiants/N ₂ cylinder	RC-1, Rooms 306, 307, 312A, 314, 315, 402, 406, 408, and 410.	Asphyxiation of personnel	3	C	C	At most, a few people would be affected.
Flammable materials/natural gas supply to fume hoods and workbenches	All RC-1 analytical laboratories except for Rooms 339A-D and 341B.	Natural gas leak into room	2	A	Not screened	Potential for explosion.
Flammable materials/methane cylinders	RC-1, Room 306	Methane leak into room	2	A	Not screened	Potential for explosion.
Lasers/3-W argon laser	RC-1, Room 341B	Severe burns to personnel	3	C	C	At most, one or two people would be affected.
Radioactive materials/analytical samples	All RC-1 analytical laboratories except for RC-1, Rooms 302B, 306, 310C, 311A, and 415.	Spill of sample solution caused by chemist error or external event	4	A	C	The largest amount of weapons debris in any laboratory sample is 75 g. This quantity is below the limiting release amounts for on-site and off-site exposures.
		Spill of dry sample material caused by chemist error or external event	4	A	C	The largest amount of weapons debris in any laboratory sample is 75 g. This quantity is below the limiting release amounts for on-site and off-site exposures.
		Fire-enhanced release of sample material	4	C	C	The largest amount of weapons debris in any laboratory sample is 75 g. This quantity is below the limiting release amounts for on-site and off-site exposures.

Table 6.15. (continued)

Hazard Type/Source	Location(s)	Postulated Event	Consequence Category	Likelihood Category	Disposition*	Remarks
Radioactive materials/ analytical samples (cont.)		Pressurized release of sample solution (as in explosion)	4	C	C	The largest amount of weapons debris in any laboratory sample is 75 g. This quantity is below the limiting release amounts for on-site and off-site exposures.
		Pressurized release of dry sample material (as in explosion)	4	C	C	The largest amount of weapons debris in any laboratory sample is 75 g. This quantity is below the limiting release amounts for on-site and off-site exposures.
Reactive materials/ cellulose tetranitrate and nitric acid	RC-1, Room 309B	Possible explosion resulting from chemist error	2	B	Not screened	Cellulose tetranitrate has a heat of combustion of 20.9 KJ/g; 454 g has 9,490 KJ of stored energy, which equates to 2.3 kg TNT - - significant explosion potential if yield is high.
Reactive materials/ cellulose tetranitrate and sulfuric acid	RC-1, Room 309B	Possible explosion resulting from chemist error	2	B	Not screened	Cellulose tetranitrate has a heat of combustion of 20.9 KJ/g; 454 g has 9,490 KJ of stored energy, which equates to 2.3 kg TNT - - significant explosion potential if yield is high.
Reactive materials/ chloroform and chlorine	RC-1, Rooms 408 and 409	Possible generation of carbon tetrachloride and hydrogen chloride vapors caused by chemist error	4	B	C	Carbon tetrachloride has an LD ₅₀ of 2,800 mg/kg (ori-rat; Sax and Lewis 1989), which translates into an LI ₅₀ of 196 g (Toxicity Class 4); hydrogen chloride has an IDLH of 152 mg/m ³ (NIOSH 1990), which translates into an LI ₅₀ of 1.8 g (Toxicity Class 2); at most, 1.9 kg of carbon tetrachloride and 454 g of hydrogen chloride could be formed (Room 408); these amounts do not exceed the limiting release amounts for on-site and off-site exposures.
Reactive materials/ chloroform and hydrochloric acid or hydrogen chloride gas	RC-1, Rooms 307, 402, 407, 408, 409, and 413	Possible generation of chlorine gas resulting from chemist error	2	B	Not screened	Chlorine has an IDLH of 88.5 mg/m ³ (NIOSH 1990), which translates into an LI ₅₀ of 1,051 mg (Toxicity Class 2); at most, 4.5 kg of chlorine could be formed (Room 402); this amount exceeds the limiting release amounts for on-site and off-site exposures.

Table 6.15. (continued)

Hazard Type/Source	Location(s)	Postulated Event	Consequence Category	Likelihood Category	Disposition*	Remarks
Reactive materials/ chloroform and hydrogen bromide	RC-1, Room 307	Possible generation of chlorine and bromine gas resulting from chemist error	4	B	C	Chlorine has an IDLH of 88.5 mg/m ³ (NIOSH 1990), which translates into an LI ₅₀ of 1,051 mg (Toxicity Class 2); bromine has an IDLH of 66 mg/m ³ (NIOSH 1990), which translates into an LI ₅₀ of 784 mg (Toxicity Class 2); at most, 202 g of chlorine and 456 g of bromine could be formed; these amounts do not exceed the limiting release amounts for on-site and off-site exposures.
Reactive materials/ chloroform and hydrogen fluoride	RC-1, Rooms 307, 339D, 407, 408, 412, and 413	Possible generation of chlorine and fluorine gas resulting from chemist error	4	B	C	Chlorine has an IDLH of 88.5 mg/m ³ (NIOSH 1990), which translates into an LI ₅₀ of 1,051 mg (Toxicity Class 2); fluorine has an IDLH of 39.5 mg/m ³ (NIOSH 1990), which translates into an LI ₅₀ of 469 mg (Toxicity Class 2); at most, 872 g of chlorine and 467 g of fluorine could be formed (Room 412); these amounts do not exceed the limiting release amounts for on-site and off-site exposures.
Reactive materials/ chloroform and hydrogen sulfide	RC-1, Room 408	Possible explosion caused by chemist error	2	B	Not screened	Chloroform has a heat of combustion of about 5.9 KJ/g; 1.49 kg has 8,791 KJ of stored energy, which equates to 2.1 kg TNT -- significant explosion potential if yield is high.
Reactive materials/ chloroform and nitric acid	RC-1, Rooms 307, 339D, 402, 407, 408, 412, and 413	Possible fire and generation of chlorine gas resulting from chemist error	2	B	Not screened	Chloroform has a heat of combustion of 5.9 KJ/g; the largest inventory (7.45 kg in Room 402) has about 44,000 KJ of stored energy, which could support a 10-15-min fire. Chlorine has an IDLH of 88.5 mg/m ³ (NIOSH 1990), which translates into an LI ₅₀ of 1,051 mg (Toxicity Class 2); at most, 2.2 kg of chlorine could be formed (Room 402); this amount exceeds the limiting release amount for on-site exposures.
Reactive materials/ chloroform and perchloric acid	RC-1, Rooms 307, 339D, 407, 408, and 413	Possible fire and generation of chlorine gas resulting from chemist error	4	B	C	Chloroform has a heat of combustion of 5.9 KJ/g; the largest inventory that could credibly combine with perchloric acid (1.49 kg in Rooms 307 and 339D) has about 8,800 KJ of stored energy, which could support only a < 5-min fire. Chlorine has an IDLH of 88.5 mg/m ³ (NIOSH 1990), which translates into an LI ₅₀ of 1,051 mg (Toxicity Class 2); at most, 893 g of chlorine could be formed (Rooms 307 and 339D); this amount does not exceed the limiting release amounts for on-site and off-site exposures.

Table 6.15. (continued)

Hazard Type/Source	Location(s)	Postulated Event	Consequence Category	Likelihood Category	Disposition*	Remarks
Reactive materials/ chloroform and sulfur dioxide	RC-1, Room 413	Possible generation of carbon disulfide, chlorine, and hydrogen chloride gases caused by chemist error	4	B	C	Carbon disulfide has an LD ₅₀ of 2,125 mg/kg (orl-gpg; Sax and Lewis 1989), which translates into an LI ₅₀ of 149 g (Toxicity Class 4); chlorine has an IDLH of 88.5 mg/m ³ (NIOSH 1990), which translates into an LI ₅₀ of 1,051 mg (Toxicity Class 2); hydrogen chloride has an IDLH of 152 mg/m ³ , which translates into an LI ₅₀ of 1.8 g (Toxicity Class 2); at most, 958 g of carbon disulfide, 893 g of chlorine, and 454 g of hydrogen chloride could be formed; these amounts do not exceed the limiting release amounts for on-site and off-site exposures.
Reactive materials/ chloroform and sulfuric acid	RC-1, Rooms 339D, 402, 407, 408, 409, and 412	Possible fire and generation of chlorine and sulfur dioxide gases caused by chemist error	2	B	Not screened	Chloroform has a heat of combustion of 5.9 KJ/g; the largest inventory that could credibly combine with sulfuric acid (7.45 kg in Rooms 402 and 412) has about 44,000 KJ of stored energy, which could support a 10-15-min fire. Chlorine has an IDLH of 88.5 mg/m ³ (NIOSH 1990), which translates into an LI ₅₀ of 1,051 mg (Toxicity Class 2); at most, 1.66 kg of chlorine could be formed (Room 412); this amount exceeds the limiting release amount for on-site exposures.
Reactive materials/ hydrazine and nitric acid	RC-1, Room 414B	Possible fire and generation of nitric oxide gas caused by chemist error	4	B	C	Hydrazine has a heat of combustion of about 20 KJ/g; 500 g has 10,000 KJ of stored energy, which could support only a < 5-min fire. Nitric oxide has an IDLH of 125 mg/m ³ (NIOSH 1990), which translates into an LI ₅₀ of 1,485 mg (Toxicity Class 2); at most, 1.4 kg of nitric oxide could be formed; this amount does not exceed the limiting release amounts for on-site and off-site exposures.
Reactive materials/ hydrazine and perchloric acid	RC-1, Room 414B	Possible fire and generation of chlorine and nitrogen dioxide gases caused by chemist error	4	B	C	Hydrazine has a heat of combustion of about 20 KJ/g; 500 g has 10,000 KJ of stored energy, which could support only a < 5-min fire. Chlorine has an IDLH of 88.5 mg/m ³ (NIOSH 1990), which translates into an LI ₅₀ of 1,051 mg (Toxicity Class 2); at most, 206 g of chlorine could be formed; this amount does not exceed the limiting release amounts for on-site and off-site exposures. Nitrogen dioxide has an IDLH of 95.5 mg/m ³ (NIOSH 1990), which translates into an LI ₅₀ of 1,135 mg (Toxicity Class 2); at most, 534 g of nitrogen dioxide could be formed; this amount does not exceed the limiting release amounts for on-site and off-site exposures.

Table 6.15. (continued)

Hazard Type/Source	Location(s)	Postulated Event	Consequence Category	Likelihood Category	Disposition*	Remarks
Reactive materials/ hydrazine and sulfuric acid	RC-1, Room 414B	Possible fire and generation of sulfur dioxide and nitric oxide gases caused by chemist error	4	B	C	Hydrazine has a heat of combustion of about 20 KJ/g; 500 g has 10,000 KJ of stored energy, which could support only a < 5-min. fire. Sulfur dioxide has an IDLH of 266 mg/m ³ (NIOSH 1990), which translates into an LI ₅₀ of 3,160 mg (Toxicity Class 2); at most, 1 kg of sulfur dioxide could be formed; this amount does not exceed the limiting release amounts for on-site and off-site exposures. Nitric oxide has an IDLH of 125 mg/m ³ (NIOSH 1990), which translates into an LI ₅₀ of 1,485 mg (Toxicity Class 2); at most, 813 g of nitric oxide could be formed; this amount does not exceed the limiting release amounts for on-site and off-site exposures.
Reactive materials/ hydrogen peroxide and hydrochloric acid or hydrogen chloride gas	RC-1, Rooms 305, 311, 312, and 314	Possible generation of chlorine gas caused by chemist error	4	B	C	Chlorine has an IDLH of 88.5 mg/m ³ (NIOSH 1990), which translates into an LI ₅₀ of 1,051 mg (Toxicity Class 2); at most, 1.2 kg of chlorine could be formed (Room 311); this amount does not exceed the limiting release amounts for on-site and off-site exposures.
Reactive materials/ hydrogen peroxide and hydrogen fluoride	RC-1, Rooms 305, 311, 312, and 314	Possible generation of fluorine vapor caused by chemist error	4	B	C	Fluorine has an IDLH of 39.5 mg/m ³ (NIOSH 1990), which translates into an LI ₅₀ of 469 mg (Toxicity Class 2); at most, 467 g of fluorine could be formed (Room 311); this amount does not exceed the limiting release amounts for on-site and off-site exposures.
Reactive materials/ hydrogen sulfide and hydrochloric acid or hydrogen chloride gas	RC-1, Rooms 306, 408, and 413	Possible generation of chlorine gas caused by chemist error	4	B	C	Chlorine has an IDLH of 88.5 mg/m ³ (NIOSH 1990), which translates into an LI ₅₀ of 1,051 mg (Toxicity Class 2); at most 1.1 kg of chlorine could be formed (Room 413); this amount does not exceed the limiting release amounts for on-site and off-site exposures.
Reactive materials/ hydrogen sulfide and hydrogen fluoride	RC-1, Rooms 408 and 413	Possible generation of fluorine gas caused by chemist error	4	B	C	Fluorine has an IDLH of 39.5 mg/m ³ (NIOSH 1990), which translates into an LI ₅₀ of 469 mg (Toxicity Class 2); at most, 509 g of fluorine could be formed (Room 408); this amount does not exceed the limiting release amounts for on-site and off-site exposures.

Table 6.15. (continued)

Hazard Type/Source	Location(s)	Postulated Event	Consequence Category	Likelihood Category	Disposition*	Remarks
Reactive materials/ hydrogen sulfide and nitric acid	RC-1, Rooms 408 and 413	Possible generation of sulfuric acid vapors and nitric oxide gas caused by chemist error	4	B	C	Sulfuric acid has an LD ₅₀ of 2,140 mg/kg (ori-rat; Sax and Lewis 1989), which translates into an LI ₅₀ of 150 g (Toxicity Class 4); nitric oxide has an IDLH of 125 mg/m ³ (NIOSH 1990), which translates into an LI ₅₀ of 1.5 g (Toxicity Class 2); at most, 2.3 kg of sulfuric acid and 714 g of nitric oxide could be formed (Room 413); these amounts do not exceed the limiting release amounts for on-site and off-site exposures.
Reactive materials/ hydrogen sulfide and perchloric acid	RC-1, Rooms 408 and 413	Possible generation of chlorine gas caused by chemist error	4	B	C	Chlorine has an IDLH of 88.5 mg/m ³ (NIOSH 1990), which translates into an LI ₅₀ of 1,051 mg (Toxicity Class 2); at most, 213 g of chlorine could be formed; this amount does not exceed the limiting release amounts for on-site and off-site exposures.
Reactive materials/ hydrogen sulfide and sulfuric acid	RC-1, Room 408	Possible generation of sulfur dioxide gas caused by chemist error	4	B	C	Sulfur dioxide has an IDLH of 266 mg/m ³ (NIOSH 1990), which translates into an LI ₅₀ of 3.2 g (Toxicity Class 2); at most, 781 g of sulfur dioxide could be formed; this amount does not exceed the limiting release amounts for on-site and off-site exposures.
Reactive materials/ hydroquinone and chlorine	RC-1, Room 408	Possible explosion caused by chemist error	2	B	Not screened	Hydroquinone has a heat of combustion of about 32.2 KJ/g; 500 g has 16,100 KJ of stored energy, which equates to 3.8 kg TNT -- significant explosion potential if yield is high.
Reactive materials/ hydroquinone and nitric acid	RC-1, Room 408	Possible fire caused by chemist error	4	B	C	Hydroquinone has a heat of combustion of about 32.2 KJ/g; 500 g has 16,100 KJ of stored energy, which could support only a < 5-min. fire.
Reactive materials/ hydroquinone and perchloric acid	RC-1, Room 408	Possible fire caused by chemist error	4	B	C	Hydroquinone has a heat of combustion of about 32.2 KJ/g; 500 g has 16,100 KJ of stored energy, which could support only a < 5-min. fire.
Reactive materials/ hydroquinone and sulfuric acid	RC-1, Room 408	Possible fire caused by chemist error	4	B	C	Hydroquinone has a heat of combustion of about 32.2 KJ/g; 500 g has 16,100 KJ of stored energy, which could support only a < 5-min. fire.

Table 6.15. (continued)

Hazard Type/Source	Location(s)	Postulated Event	Consequence Category	Likelihood Category	Disposition*	Remarks
Reactive materials/ sodium cyanide and hydrochloric acid	RC-1, Rooms 402 and 413	Possible generation of hydrogen cyanide gas caused by chemist error	2	B	Not screened	Hydrogen cyanide has an LD ₅₀ of 3.7 mg/kg (ori-mus; Sax and Lewis 1989), which translates into an LI ₅₀ of 259 mg (Toxicity Class 1); for Rooms 402 and 413, both of which are 4.88 m by 7.32 m, the limiting release amounts for on-site and off-site exposures are 11.8 g and 5.7 kg; at most, 275 g of hydrogen cyanide could be formed (either room); this amount then exceeds the limiting release amount for on-site exposures.
Reactive materials/ sodium cyanide and hydrogen fluoride	RC-1, Rooms 309, 411, and 413	Possible generation of hydrogen cyanide gas caused by chemist error	2	B	Not screened	Hydrogen cyanide has an LD ₅₀ of 3.7 mg/kg (ori-mus; Sax and Lewis 1989), which translates into an LI ₅₀ of 259 mg (Toxicity Class 1); for Rooms 309, 411, and 413, all of which are 4.88 m by 7.32 m, the limiting release amounts for on-site and off-site exposures are 11.8 g and 5.7 kg; at most, 275 g of hydrogen cyanide could be formed (Room 411 or 413); this amount then exceeds the limiting release amount for on-site exposures.
Reactive materials/ sodium cyanide and nitric acid	RC-1, Rooms 309, 402, 411, and 413	Possible generation of hydrogen cyanide gas caused by chemist error	2	B	Not screened	Hydrogen cyanide has an LD ₅₀ of 3.7 mg/kg (ori-mus; Sax and Lewis 1989), which translates into an LI ₅₀ of 259 mg (Toxicity Class 1); for Rooms 309, 402, 411, and 413, all of which are 4.88 m by 7.32 m, the limiting release amounts for on-site and off-site exposures are 11.8 g and 5.7 kg; at most, 275 g of hydrogen cyanide could be formed (Room 402, 411, or 413); this amount then exceeds the limiting release amount for on-site exposures.
Reactive materials/ sodium cyanide and perchloric acid	RC-1, Rooms 411 and 413	Possible generation of hydrogen cyanide gas caused by chemist error	2	B	Not screened	Hydrogen cyanide has an LD ₅₀ of 3.7 mg/kg (ori-mus; Sax and Lewis 1989), which translates into an LI ₅₀ of 259 mg (Toxicity Class 1); for Rooms 411 and 413, both of which are 4.88 m by 7.32 m, the limiting release amounts for on-site and off-site exposures are 11.8 g and 5.7 kg; at most, 162 g of hydrogen cyanide could be formed (Room 413); this amount then exceeds the limiting release amount for on-site exposures.

Table 6.15. (continued)

Hazard Type/Source	Location(s)	Postulated Event	Consequence Category	Likelihood Category	Disposition*	Remarks
Reactive materials/ sodium cyanide and sulfur dioxide	RC-1, Rooms 411 and 413	Possible generation of carbon dioxide and nitric oxide gases caused by chemist error	4	B	C	Carbon dioxide has an IDLH of 91,500 mg/m ³ (NIOSH 1990), which translates into an LI ₅₀ of 1.09 kg (Toxicity Class 5); nitric oxide has an IDLH of 125 mg/m ³ (NIOSH 1990), which translates into an LI ₅₀ of 1.5 g (Toxicity Class 2); at most, 449 g of carbon dioxide and 306 g of nitric oxide could be formed (either room); these amounts do not exceed the limiting release amounts for on-site and off-site exposures.
Reactive materials/ sodium cyanide and sulfuric acid	RC-1, Rooms 309 and 402	Possible generation of hydrogen cyanide gas caused by chemist error	2	B	Not screened	Hydrogen cyanide has an LD ₅₀ of 3.7 mg/kg (ori-mus; Sax and Lewis 1989), which translates into an LI ₅₀ of 259 mg (Toxicity Class 1); for Rooms 309 and 402, both of which are 4.88 m by 7.32 m, the limiting release amounts for on-site and off-site exposures are 11.8 g and 5.7 kg; at most, 275 g of hydrogen cyanide could be formed (Room 402); this amount then exceeds the limiting release amount for on-site exposures.
Reactive materials/ sulfur dioxide and hydrochloric acid or hydrogen chloride gas	RC-1, Rooms 410, 413, and 414	Possible generation of chlorine gas caused by chemist error	2	B	Not screened	Chlorine has an IDLH of 88.5 mg/m ³ (NIOSH 1990), which translates into an LI ₅₀ of 1,051 mg (Toxicity Class 2); at most, 3.1 kg of chlorine could be formed; this amount exceeds the limiting release amounts for on-site and off-site exposures.
Reactive materials/ sulfur dioxide and hydrogen fluoride	RC-1, Rooms 410, 411, 413, and 414	Possible generation of fluorine gas caused by chemist error	4	B	C	Fluorine has an IDLH of 39.5 mg/m ³ (NIOSH 1990), which translates into an LI ₅₀ of 469 mg (Toxicity Class 2); at most, 270 g of fluorine could be formed (Room 410); this amount does not exceed the limiting release amounts for on-site and off-site exposures.
Reactive materials/ sulfur dioxide and selenious acid	RC-1, Room 410	Possible generation of selenium and sulfuric acid vapors caused by chemist error	4	B	C	Selenium has an LD ₅₀ of 6,700 mg/kg (ori-rat; Sax and Lewis 1989), which translates into an LI ₅₀ of 469 g (Toxicity Class 5); sulfuric acid has an LD ₅₀ of 2,140 mg/kg (ori-rat; Sax and Lewis 1989), which translates into an LI ₅₀ of 150 g (Toxicity Class 4); at most, 284 g of selenium and 696 g of sulfuric acid could be formed; these amounts do not exceed the limiting release amounts for on-site and off-site exposures.

Table 6.15. (continued)

Hazard Type/Source	Location(s)	Postulated Event	Consequence Category	Likelihood Category	Disposition*	Remarks
Toxic materials/ chloroform	RC-1, Rooms 341B, 402, 407, 409, and 412	Spill caused by chemist error or external event	4	A	C	Toxicity Class 2; assuming a release fraction of 0.0001, a spill of the largest inventory (7.45 kg in either Room 402 or 412) would not exceed the limiting release amounts for on-site and off-site exposures.
		Pressurized release (as in explosion)	4	C	C	Toxicity Class 2; assuming a release fraction of 0.05, an event involving the largest inventory (7.45 kg in either Room 402 or 412) would not exceed the limiting release amounts for on-site and off-site exposures.
		Fire-enhanced release	2	C	Not screened	Toxicity Class 2; release of the largest combined inventory found in any four adjacent laboratories (13.9 kg from Rooms 409 and 412) would exceed the limiting release amounts for on-site and off-site exposures.
Toxic materials/ hydrochloric acid	RC-1, Rooms 304, 305B, 307, 310, 312, 313, 402, 407, 409, 414, and 414B	Spill caused by chemist error or external event	4	A	C	Toxicity Class 2; assuming a release fraction of 0.0001, a spill of the largest inventory (6.6 kg in Room 307) would not exceed the limiting release amounts for on-site and off-site exposures.
		Pressurized release (as in explosion)	4	C	C	Toxicity Class 2; assuming a release fraction of 0.05, an event involving the largest inventory (6.6 kg in Room 307) would not exceed the limiting release amounts for on-site and off-site exposures.
		Fire-enhanced release	2	C	Not screened	Toxicity Class 2; release of the largest combined inventory found in any four adjacent laboratories (10.2 kg from Rooms 307 and 310) would exceed the limiting release amounts for on-site and off-site exposures.
Toxic materials/ hydrogen bromide	RC-1, Room 419	Spill caused by chemist error or external event	4	A	C	Toxicity Class 2; assuming a release fraction of 0.0001, a spill of the entire inventory (4 kg) would not exceed the limiting release amounts for on-site and off-site exposures.
		Pressurized release (as in explosion)	4	C	C	Toxicity Class 2; assuming a release fraction of 0.05, an event involving the entire inventory (4 kg) would not exceed the limiting release amounts for on-site and off-site exposures.

Table 6.15. (continued)

Hazard Type/Source	Location(s)	Postulated Event	Consequence Category	Likelihood Category	Disposition*	Remarks
Toxic materials/ hydrogen bromide (cont.)		Fire-enhanced release	2	C	Not screened	Toxicity Class 2; release of the entire inventory (4 kg) would exceed the limiting release amounts for on-site and off-site exposures.
Toxic materials/ hydrogen chloride gas	RC-1, Rooms 305 and 307	Gas release caused by chemist error or external event	2	A	Not screened	Toxicity Class 2; release of either inventory would exceed the limiting release amounts for on-site and off-site exposures.
Toxic materials/ hydrogen fluoride	RC-1, Rooms 305, 305B, 307, 308, 309, 311, 312, 313, 314, 339D, 407, 408, 410, 411, 412, 413, 413C, 414, and 414B	Spill caused by chemist error or external event	2	A	Not screened	Toxicity Class 1; for a typical laboratory space (4.88 m by 7.32 m), the limiting release amounts for on-site and off-site exposures are 120 g and 6.6 kg, respectively; assuming a release fraction of 1.0 for this volatile material, a spill of the largest inventory (1.98 kg in Room 307) would exceed the limiting release amount for on-site exposures only.
		Pressurized release (as in explosion)	2	C	Not screened	Toxicity Class 1; for a typical laboratory space (4.88 m by 7.32 m), the limiting release amounts for on-site and off-site exposures are 120 g and 6.6 kg, respectively; assuming a release fraction of 1.0 for this volatile material, an event involving the largest inventory (1.98 kg in Room 307) would exceed the limiting release amount for on-site exposures only.
		Fire-enhanced release	2	C	Not screened	Toxicity Class 1; for a typical laboratory space (4.88 m by 7.32 m), the limiting release amount for off-site exposures is 6.6 kg; release of the largest combined inventory found in any four adjacent laboratories (4.1 kg in Rooms 411, 412, 413/413-C, and 414/414B) would exceed the limiting release amounts for on-site and off-site exposures.
Toxic materials/ hydrogen sulfide	RC-1, Room 413	Gas release caused by chemist error or external event	2	A	Not screened	Toxicity Class 3; release of the entire inventory (27.2 kg) would exceed the limiting release amounts for on-site and off-site exposures.

Table 6.15. (continued)

Hazard Type/Source	Location(s)	Postulated Event	Consequence Category	Likelihood Category	Disposition*	Remarks
Toxic materials/ mercury	RC-1, Rooms 326, 413C, and 416	Spill caused by chemist error or external event	4	A	C	Toxicity Class 1; for a typical laboratory space (4.88 m by 7.32 m), the limiting release amounts for on-site and off-site exposures are 133 g and 7.3 kg, respectively; assuming a release fraction of 0.0001, a spill of the largest inventory (68 kg in Room 416) would not exceed the limiting release amounts for on-site and off-site exposures.
		Pressurized release (as in explosion)	2	C	Not screened	Toxicity Class 1; for a typical laboratory space (4.88 m by 7.32 m), the limiting release amounts for on-site and off-site exposures are 133 g and 7.3 kg, respectively; assuming a release fraction of 0.05, an event involving the largest inventory (68 kg in Room 307) would exceed the limiting release amounts for on-site and off-site exposures.
		Fire-enhanced release	2	C	Not screened	Toxicity Class 1; for a typical laboratory space (4.88 m by 7.32 m), the limiting release amount for off-site exposures is 7.3 kg; release of the largest combined inventory found in any four adjacent laboratories (70.3 kg in Rooms 413-C and 416) would exceed the limiting release amounts for on-site and off-site exposures.
Toxic materials/nitric acid	RC-1, Rooms 304, 305, 305B, 307, 309, 309B, 311, 402, 406, 407, 408, 410, 411, 412, 413, 413C, 414, and 414B	Spill caused by chemist error or external event	4	A	C	Toxicity Class 2; assuming a release fraction of 0.0001, a spill of the largest inventory (9 kg in Room 402) would not exceed the limiting release amounts for on-site and off-site exposures.
		Pressurized release (as in explosion)	4	C	C	Toxicity Class 2; assuming a release fraction of 0.05, an event involving the largest inventory (9 kg in Room 402) would not exceed the limiting release amounts for on-site and off-site exposures.
		Fire-enhanced release	4	C	C	Toxicity Class 2; release of the largest combined inventory found in any four adjacent laboratories (22.5 kg from Rooms 411, 412, 413/413-O, and 414/414B) would exceed the limiting release amounts for on-site and off-site exposures.

Table 6.15. (continued)

Hazard Type/Source	Location(s)	Postulated Event	Consequence Category	Likelihood Category	Disposition*	Remarks
Toxic materials/ perchloric acid	RC-1, Room 305B	Spill caused by chemist error or external event	2	A	Not screened	Toxicity Class 3; assuming a release fraction of 1.0 for this volatile material, a spill of the entire inventory (74 kg) would exceed the limiting release amounts for on-site and off-site exposures.
		Pressurized release (as in explosion)	2	C	Not screened	Toxicity Class 3; assuming a release fraction of 1.0 for this volatile material, an event involving the entire inventory (74 kg) would exceed the limiting release amount for on-site and off-site exposures.
		Fire-enhanced release	2	C	Not screened	Toxicity Class 3; release of the entire inventory (74 kg) would exceed the limiting release amounts for on-site and off-site exposures.
Toxic materials/sulfur dioxide	RC-1, Rooms 411, 411A, 413, and 415	Gas release caused by chemist error or external event	2	A	Not screened	Toxicity Class 2; release of any of the inventories would exceed the limiting release amount for on-site exposures.

*C - screened out on insignificant consequences or combination of minor consequences and low likelihood; F - screened out on insignificant likelihood

Where possible, initiating events in Table 6.15 are screened from further analysis on the basis of insignificant consequences, insignificant likelihood, or the combination of the two. The remaining events are grouped as shown in Table 6.16 to facilitate selection of bounding events for accident scenario development.

6.2.3 Alpha Area

The completed hazard identification worksheet for the alpha area is presented in Table 6.17. As discussed in Section 4.2.1.5, the alpha room is being renovated, so some entries have been made by analogy to the other areas of RC-1. The chemical inventory list maintained by HS-5 is not representative of the alpha area when operating; therefore, the remaining hazard screening steps are completed explicitly for the alpha area radionuclides only. Table 6.18 shows the radionuclides, the inhalation dose conversion factors, and the limiting on-site and off-site inventories. A comparison of the inventories from Table 6.18 and the limiting amounts allows a few materials to be screened as indicated.

Table 6.19 shows the remaining radionuclides, their physical form, and the off-site and on-site release fraction required to exceed 100 mrem off-site and 1 rem on-site. The release fractions are determined by dividing the limiting inventory in Table 6.18 by the inventory in Table 6.20. To exceed the specified dose limits, a higher release fraction is required. The release fraction for screening from Table 6.8 is then used to screen out some radionuclides for the release mechanisms considered.

Table 6.20 lists the radionuclides not screened out on the basis of inventory or physical form. Owing to the very low release fraction for ^{241}Am , a spill, i.e., drop, during transfer between the safe and the glovebox has been added. Where possible, the initiating events are screened from further analysis on the basis of insignificant consequences, insignificant frequency, or the combination of the two. The remaining events are grouped as shown in Table 6.21 to facilitate selection of bounding events for accident scenario development.

This screening has been based on current inventories. The impact of future inventories and operations is discussed in the accident analysis.

Table 6.16. Accident initiating events (analytical laboratories)

Releases of Flammable Gases

Natural gas leak in any laboratory except for Room 339A-D or 341B

Methane leak in Room 306

Inadvertent Mixing of Incompatible Materials

Mixing of cellulose tetranitrate and nitric acid in Room 309B (possible explosion)

Mixing of cellulose tetranitrate and sulfuric acid in Room 309B (possible explosion)

Mixing of chloroform and hydrochloric acid in one of several laboratories (possible generation of chlorine gas)

Mixing of chloroform and hydrogen sulfide in Room 408 (possible explosion)

Mixing of chloroform and nitric acid in one of several laboratories (possible fire and generation of chlorine gas)

Mixing of chloroform and sulfuric acid in one of several laboratories (possible fire and generation of chlorine and sulfur dioxide gases)

Mixing of hydroquinone and chlorine in Room 408 (possible explosion)

Mixing of sodium cyanide and hydrochloric acid in Room 402 or 413 (possible generation of hydrogen cyanide gas)

Mixing of sodium cyanide and hydrogen fluoride in Room 309, 411, or 413 (possible generation of hydrogen cyanide gas)

Mixing of sodium cyanide and nitric acid in one of several laboratories (possible generation of hydrogen cyanide gas)

Mixing of sodium cyanide and perchloric acid in Room 411 or 413 (possible generation of hydrogen cyanide gas)

Mixing of sodium cyanide and sulfuric acid in Room 309 or 402 (possible generation of hydrogen cyanide gas)

Mixing of sulfur dioxide and hydrochloric acid or hydrogen chloride gas in Room 410, 413, or 414 (possible generation of chlorine gas)

Releases of Toxic Materials

Release of hydrogen chloride gas in Room 305 or 307 caused by chemist error or an external event

Release of hydrogen sulfide gas in Room 413 caused by chemist error or an external event

Release of sulfur dioxide gas in one of several laboratories caused by chemist error or an external event

Table 6.16. (continued)

Releases of Toxic Materials (cont.)

Spill of hydrogen fluoride in one of several laboratories caused by chemist error or an external event

Spill of perchloric acid in Room 305B caused by chemist error or an external event

Fire-enhanced release of mercury from Rooms 413-C and 416

Fire-enhanced release of chloroform from Rooms 409 and 412

Fire-enhanced release of hydrochloric acid from Rooms 307 and 310

Fire-enhanced release of hydrogen bromide from Room 419

Fire-enhanced release of hydrogen fluoride from Rooms 411, 412, 413/413C and 414/414B

Fire-enhanced release of perchloric acid from Room 305B

Table 6.17. Hazard Identification Worksheet (alpha area)

Facility or area: RC-1, alpha area

Hazard Type	Hazard Present? (Y or N)	Hazard Source(s)	Routinely Encountered Industrial Hazard? (Y or N)	Remarks
Electrical energy	Y	Outlets on walls and in gloveboxes	Y	Maximum voltage is 240 V AC
Electromagnetic radiation	N	N/A	N/A	
Explosive materials	N	N/A	N/A	
Fissile materials	Y	Analytical samples	N	Small amounts of ^{235}U and ^{239}Pu
Flammable materials	Y	Natural gas supply to hoods Small quantities of flammable solvents	N Y	Potential for explosion dispersing radioactive materials
Kinetic energy	Y	Centrifuge Pulverizer Saw	Y Y Y	Potential for small centrifuge installation Radioactive material sealed in can when in use Natural ore only

Table 6.17. (continued)

Facility or area: RC-1, alpha area

Hazard Type	Hazard Present? (Y or N)	Hazard Source(s)	Routinely Encountered Industrial Hazard? (Y or N)	Remarks
Potential energy	N	N/A	N/A	
Radioactive materials	Y	Analytical samples	N	See Table 6.18.
Reactive materials	N	N/A	N/A	Assumed similar to dissolver area
Thermal energy	Y	Hot plates Furnace	Y Y	
Toxic materials	Y	Numerous chemicals in small containers	N	Assumed similar to dissolver area
High pressure	Y	Compressed gas cylinders	Y	DOT-approved containers

Table 6.18. Screening analysis for inventories of radionuclides (alpha area)

Radionuclide	Inhalation Dose (rem/g)	Limiting Off-site Inventory (g)	Comparison to Current Inventory	Limiting On-site Inventory (g)	Comparison to Current Inventory
Depleted U	6.2×10^1	2.4×10^3	-	1.5×10^4	-
50% ϵ ^{235}U	3.7×10^3	4.1×10^1	-	2.5×10^2	Screened out
93% ϵ ^{235}U	8.5×10^3	1.8×10^1	-	1.1×10^2	-
99.7% ϵ ^{235}U	9.4×10^3	1.6×10^1	-	9.7×10^1	Screened out
^{239}Pu	2.6×10^7	5.8×10^{-3}	-	3.5×10^{-2}	-
^{242}Pu	1.6×10^6	9.4×10^{-2}	-	5.7×10^{-1}	-
^{241}Am	1.4×10^9	1.1×10^{-4}	-	6.5×10^{-4}	-
^{243}Am	8.8×10^7	1.7×10^{-3}	-	1.0×10^{-2}	-
^{249}Cf	1.6×10^9	9.4×10^{-5}	Screened out	5.7×10^{-4}	Screened out
^{232}Th	1.8×10^2	8.3×10^2	-	5.1×10^3	Screened out

Table 6.19. Screening analysis for physical form of radionuclides (alpha area)

Radionuclide	Physical form	Required Off-site Release Fraction	Required On-site Release Fraction	Spill	Explosion	Fire
Depleted U	Ingots	1.0×10^{-1}	4.6×10^{-1}	Screened out	Screened out	-
50% ϵ ^{235}U	Powder	8.7×10^{-1}	NA ^a	Screened out	Screened out	-
93% ϵ ^{235}U	Foil	1.2×10^{-1}	7.5×10^{-1}	Screened out	Screened out	-
99.7% ϵ ^{235}U	Powder	2.2×10^{-1}	NA ^a	Screened out	Screened out	-
^{239}Pu	Powder	5.8×10^{-3}	3.5×10^{-2}	Screened out	Screened out (on-site)	-
^{239}Pu	Solution	2.9×10^{-3}	1.8×10^{-2}	Screened out	-	-
^{239}Pu	Chunks	1.2×10^{-3}	7.0×10^{-3}	Screened out	-	-
^{242}Pu	Solution	4.7×10^{-2}	2.9×10^{-1}	Screened out	Screened out (on-site)	-
^{241}Am	Chunk	2.2×10^{-4}	1.3×10^{-3}	Screened out (on-site)	-	-
^{243}Am	Powder	4.3×10^{-3}	2.5×10^{-2}	Screened out	Screened out (on-site)	-
^{232}Th	Foil	8.3×10^{-1}	NA ^a	Screened out	Screened out	-

^aNA means that this material was screened out in an earlier step.

Table 6.20. Identification and screening of accident initiating events (alpha area)

Hazard Type/Source	Location(s)	Postulated Event	Consequence Category	Likelihood Category	Disposition ^a	Remarks
Depleted U ingots	Metal can	Fire	2 or 3	C	Not screened	
	Glovebox	Fire	2 or 3	C	Not screened	
50% $e^{235}\text{U}$ powder	Metal box	Fire	2 or 3	C	Not screened	
	Glovebox	Fire	2 or 3	C	Not screened	
93% $e^{235}\text{U}$ foil	Safe	Fire	4	D	C	Fire duration required for release is very large
	Glovebox	Fire	2 or 3	C	Not screened	
99.7% $e^{235}\text{U}$ powder	Safe	Fire	4	D	C	Fire duration required for release is very large
	Glovebox	Fire	2 or 3	C	Not screened	
^{239}Pu powder	Safe	Fire	4	D	C	Fire duration required for release is very large
		Explosion	3	D	C	Safe may be broken open by explosion, but damage would not be major
	Glovebox	Fire	1 or 2	C	Not screened	
		Explosion	1 or 2	C	Not screened	
^{239}Pu solution	Metal box	Fire	1 or 2	C	Not screened	
		Explosion	1 or 2	C	Not screened	
	Glovebox	Fire	1 or 2	C	Not screened	
		Explosion	1 or 2	C	Not screened	

Table 6.20. (continued)

Hazard Type/Source	Location(s)	Postulated Event	Consequence Category	Likelihood Category	Disposition ^a	Remarks
²³⁹ Pu chunks	Safe	Fire	4	D	C	Fire duration required for release is very large
		Explosion	3	D	C	Safe may be broken open by explosion, but damage would not be major
	Glovebox	Fire	1 or 2	C	Not screened	
		Explosion	1 or 2	C	Not screened	
²⁴² Pu solution	Metal box	Fire	1 or 2	C	Not screened	
		Explosion	1 or 2	C	Not screened	
	Glovebox	Fire	1 or 2	C	Not screened	
		Explosion	1 or 2	C	Not screened	
²⁴¹ Am chunk	Safe	Fire	4	D	C	Fire duration required for release is very large
		Explosion	3	D	C	Safe may be broken open by explosion, but damage would not be major
	Glovebox	Fire	1 or 2	C	Not screened	
		Explosion	1 or 2	C	Not screened	
	Transfer between safe and glovebox	Spill	4	B	C	Material is inside glass vial, lead pig, and heavy-walled can
²⁴³ Am powder	Safe	Fire	4	D	C	Fire duration required for release is very large

Table 6.20. (continued)

Hazard Type/Source	Location(s)	Postulated Event	Consequence Category	Likelihood Category	Disposition ^a	Remarks
²⁴³ Am powder (cont.)		Explosion	3	D	C	Safe may be broken open by explosion, but damage would not be major
	Glovebox	Fire	1 or 2	C	Not screened	
		Explosion	1 or 2	C	Not screened	
²³² Th foil	Glass bottle	Fire	2 or 3	C	Not screened	
	Glovebox	Fire	2 or 3	C	Not screened	

^aC - screened out on the basis of insignificant consequences or the combination of minor consequences and low likelihood; F - screened out on the basis of insignificant likelihood.

Table 6.21. Accident initiating events (alpha area)

<u>Fire</u>
Fire affecting depleted U ingots in metal can
Fire affecting depleted U ingots in glovebox
Fire affecting 50% e U powder in metal box
Fire affecting 50% e U powder in glovebox
Fire affecting 93% e U foil in glovebox
Fire affecting 99.7% e U powder in glovebox
Fire affecting ^{239}Pu powder in glovebox
Fire affecting ^{239}Pu solution in metal box
Fire affecting ^{239}Pu solution in glovebox
Fire affecting ^{239}Pu chunks in glovebox
Fire affecting ^{242}Pu solution in metal box
Fire affecting ^{242}Pu solution in glovebox
Fire affecting ^{241}Am chunk in glovebox
Fire affecting ^{243}Am powder in glovebox
Fire affecting ^{232}Th foil in glass bottle
Fire affecting ^{232}Th foil in glovebox
<u>Explosion</u>
Explosion affecting ^{239}Pu powder in glovebox
Explosion affecting ^{239}Pu solution in metal box
Explosion affecting ^{239}Pu solution in glovebox
Explosion affecting ^{239}Pu chunks in glovebox
Explosion affecting ^{242}Pu solution in metal box
Explosion affecting ^{242}Pu solution in glovebox
Explosion affecting ^{241}Am chunk in glovebox
Explosion affecting ^{243}Am powder in glovebox

6.2.4 Counting Room

The completed hazard identification worksheet for the counting room is presented in Table 6.22. The only hazard that is identified as not being routinely encountered and accepted by the public is that resulting from the radioactive materials. Radioactive materials are present in the counting room in the form of low-level-activity analytical samples. Generally, most samples received have an activity in the picocurie range or less. On occasion, low-level liquid samples may be received in small plastic bottles. Administrative controls prohibit samples above 5 mr/h in the counting room. Any accidents occurring with these bottled quantities are bounded by accidents potentially involving larger amounts of radioactive materials contained in the analytical laboratories.

A propane tank farm is located outside of the building across a driveway that runs next to the building. The tank farm consists of a tanker trailer along with five 200-gal dewars. An accident involving the explosion of one or more of these tanks could impact other radiochemical operations in Building RC-1 and result in an incident that is not routinely encountered or accepted by the public. The location of the propane tanks away from the building is not expected to result in accident scenarios with any greater consequence than those previously postulated for the alpha area; thus, no further development of accident scenarios will be performed.

6.2.5 Hot Cells

The completed hazard identification worksheet for the hot cells is presented in Table 6.23. The only hazard that is identified as not being routinely encountered and accepted by the public is that resulting from the radioactive materials.

A wide variety of radionuclides is present in the hot cell area, as was discussed in Section 4.2.5. A preliminary examination of the potential for personal injury as a result of this hazard reveals that, even if no other factors are considered, the level of external radiation and the maximum level of material available for inhalation indicate the need for further analysis to effectively assess the magnitude of the hazard. The potential for release of several radionuclides at once limits the use of the screening methodology.

Table 6.22. Hazard Identification Worksheet (counting room)

Facility or area: RC-1, counting room

Hazard Type	Hazard Present? (Y or N)	Hazard Source(s)	Routinely Encountered Industrial Hazard? (Y or N)	Remarks
Electrical energy	Y	Electrical supply to counting room equipment	Y	Electrical energy is used in common voltages to power electrical equipment in the counting room.
Electromagnetic radiation	Y	Two trochoidal counters	Y	
Explosive materials	N	N/A	N/A	
Fissile materials	N	N/A	N/A	
Flammable materials	Y	Natural gas Propane	Y Y	Present in two offices only. Tank farm is located outside RC-1, adjacent to the driveway (see discussion in text, Section 6.2.4).
Kinetic energy	Y	Heavy objects being moved by hoist	Y	
Potential energy	Y	Heavy objects on overhead hoist	Y	

Table 6.22. (continued)

Facility or area: RC-1, counting room

Hazard Type	Hazard Present? (Y or N)	Hazard Source(s)	Routinely Encountered Industrial Hazard? (Y or N)	Remarks
Radioactive materials	Y	Analytical samples	N	Very small amounts of radioactive materials are present in the samples (see discussion in text, Section 6.2.4).
Reactive materials	N	N/A	N/A	
Thermal energy	Y	Liquid nitrogen	Y	Liquid nitrogen is transferred to other containers and used in counters in the counting room.
Toxic materials	N	N/A	N/A	
Asphyxiants	Y	Argon cylinder Liquid nitrogen	Y Y	

Table 6.23. Hazard Identification Worksheet (hot cells)

Facility or area: RC-1, hot cells

Hazard Type	Hazard Present? (Y or N)	Hazard Source(s)	Routinely Encountered Industrial Hazard? (Y or N)	Remarks
Electrical energy	Y	Electrical supply to hot cell equipment	Y	Electrical energy is used in common voltages to power electrical equipment in and around the hot cells.
Electromagnetic radiation	N	N/A	N/A	
Explosive materials	N	N/A	N/A	
Fissile materials	N	N/A	N/A	
Flammable materials	Y	Process chemicals in hot cells	Y	Flammable material that is present is common within private industry and is handled in very small quantities.
Kinetic energy	Y	Heavy objects being moved by crane; cell shield doors	Y	
Potential energy	Y	Heavy objects on overhead hoist	Y	

Table 6.23. (continued)

Facility or area: RC-1, hot cells

Hazard Type	Hazard Present? (Y or N)	Hazard Source(s)	Routinely Encountered Industrial Hazard? (Y or N)	Remarks
Radioactive materials	Y	Irradiated targets	N	
Thermal energy	Y	Exothermic reaction or heating with hot plate in hot cells	Y	
Toxic materials	Y	Process chemicals in hot cells	Y	Toxic materials are present in very small quantities.
Other (list below):	N			

The radioactive materials that are present in the hot cell area have the potential to be harmful both as a result of the high levels of external radiation and as a result of the potential for internal exposure resulting from inhalation of the material. The materials have the potential to expose individuals or groups of individuals to radiation both on-site and off-site. Accident initiating events that might result in the release of radioactive materials from the hot cells are identified in Table 6.24. The analysis of the radiation hazard will be pursued by examining the potential for external and internal exposure to radiation to both the on-site and off-site populations. Section 7.3 presents a discussion of the potential for exposure of both the on-site and off-site populations to radioactive materials.

6.3 BUILDING RC-8

The completed hazard identification worksheet for the isotope separator facility (Building RC-8) is presented in Table 6.25. Building RC-8 contains many hazards that could potentially lead to a fatality or serious injury. However, through safety inspections and other reviews, efforts have been made to identify these hazards and provide safeguards that will help reduce the likelihood or mitigate the consequences of abnormal events involving these hazards.

The isotope separator facility does contain some small quantities of flammable materials. These materials include oils for pumps used in the isotope separator, methane used for discharge support in one of the ion source configurations, and ethanol used for cleaning the vacuum chamber of the isotope separator. The potential fire hazards resulting from the flammable materials are not uncommon and are mitigated by a sprinkler system.

The isotope samples that are separated in building RC-8 represent the only radioactive material hazards. The mass of one of these samples is typically 10 mg or less, and the potential radiation exposure is very low. Personnel working in RC-8 are required to wear a thermoluminescent badge that measures radiation exposure over time.

Some toxic materials, such as ammonia and carbon monoxide, are used in isotope separator operations in the Isotope Separator Facility. No chemical inventories in excess of 1 lb were identified in Building RC-8.

Table 6.24. Accident initiating events (hot cells)

<u>Internal exposure to radiation</u>
Gross structural failure of hot cell
Gross failure of target or product transport package
Dispersion of material in hot cell with hot cell doors open
Dispersion of material in hot cell without hot cell integrity (resulting from hot cell maintenance)
Spill of product outside hot cell
<u>External exposure to radiation</u>
Gross structural failure of hot cell
Gross failure of target or product transport package
Radiation streaming due to change in hot cell configuration
Movement of transport system with highly irradiated material to unshielded position
Exposure to collimated beam during Cell 11 operations
Opening of hot cell shielding door with person in warm corridor

Table 6.25. Hazard Identification Worksheet (RC-8)

Facility or area: Isotope Separator Facility (RC-8)

Hazard Type	Hazard Present? (Y or N)	Hazard Source(s)	Routinely Encountered Industrial Hazard? (Y or N)	Remarks
Electrical energy	Y	Power supplies for the ion source high-voltage equipment and the power supply for the isotope separator magnet	Y	
Electromagnetic radiation	Y	The high-voltage equipment and the isotope separator magnet	Y	The magnetic fields inside RC-8 have been mapped.
Explosive materials	N	N/A	N/A	
Fissile materials	N	N/A	N/A	
Flammable materials	Y	Small amounts of flammable materials used in routine isotope separator operations	Y	A sprinkler system mitigates fire hazards in RC-8.
Kinetic energy	Y	Machine shop equipment	Y	The machine shop equipment hazards are mitigated by procedures, training, and appropriate safety equipment.
Potential energy	N	N/A	N/A	

Table 6.25. (continued)

Facility or area: Isotope Separator Facility (RC-8)

Hazard Type	Hazard Present? (Y or N)	Hazard Source(s)	Routinely Encountered Industrial Hazard? (Y or N)	Remarks
Radioactive materials	Y	Some isotope samples	Y	Samples weigh 10 mg or less, and personnel wear TLD badges.
Reactive materials	N	N/A	N/A	
Thermal energy	Y	Vaporizing solid isotope samples at temperatures of 3000 K	Y	The areas of the isotope separator where these temperatures are generated are all enclosed.
Toxic materials	Y	Small quantities of toxic materials (NH ₃ , CO, etc.) used in routine isotope separator operations	Y	No quantities exceed 1 lb.

6.4 BUILDING RC-28

The completed hazard identification worksheet for the Weapons Diagnostic and Instrumentation Development Building (Building RC-28) is presented in Table 6.26. RC-28 contains hazards that can lead to serious injuries or fatalities. Through safety inspections and other reviews, CST personnel identify hazards and provide safeguards that help reduce the likelihood or mitigate the consequences of hazards present in RC-28.

Both the laser laboratory and the water sample laboratory contain small amounts of radioactive materials that are used as samples in the experiments performed in each laboratory. The typical mass of a sample is 5 ng or less in the laser laboratory, and the level of radioactivity in the water samples is not more than 50 nCi/mL. Protective clothing such as lab coats and safety glasses are required when personnel are handling the radioactive materials to prevent contamination. In addition, personnel are required to wear thermoluminescent badges that measure radiation exposure over time.

The laser laboratory uses some solvents in chemical preparation and pump oils for some of the equipment. The water sample laboratory uses concentrated hydrochloric acid in routine experimental procedures. No chemical inventories in excess of 1 lb were identified in Building RC-28.

6.5 BUILDING RC-45

The completed hazard identification worksheet for Building RC-45 is presented in Table 6.27. Accident initiating events will be identified for hazards that are not judged to be routinely encountered industrial hazards.

Chemical inventories for the facility were characterized by using the computerized inventory tracking system maintained by HS-5. Table 6.28 lists the greater-than-1-lb inventories of chemicals that are listed on either the EPA's *List of Extremely Hazardous Substances* (Appendix A to 40 CFR 355) or the *List of Highly Hazardous Chemicals, Toxics, and Reactives* (Appendix A to 29 CFR 1910.119). Seven binary combinations of reactive chemicals and three toxic materials are retained for further evaluation in the accident initiating event definition step.

Table 6.26. Hazard Identification Worksheet (RC-28)

Facility or area: Weapons Diagnostic and Instrumentation Development Building (RC-28)

Hazard Type	Hazard Present? (Y or N)	Hazard Source(s)	Routinely Encountered Industrial Hazard? (Y or N)	Remarks
Electrical energy	Y	High-voltage power supplies for the laser system components	Y	The power supplies are enclosed in locked cabinets.
Electromagnetic radiation	Y	High-powered laser beams	N	The laser beams hazards are mitigated by an array of hardware and procedural safeguards.
Explosive materials	N	N/A	N/A	
Fissile materials	N	N/A	N/A	
Flammable materials	Y	Acetylene cylinder in the laser laboratory	Y	The laser and water sample laboratories both contain sprinkler systems.
Kinetic energy	N	N/A	N/A	
Potential energy	N	N/A	N/A	
Radioactive materials	Y	Samples used in the water sample laboratory and the laser laboratory	N	Workers wear TLD badges and other protective clothing when handling these samples.
Reactive materials	N	N/A	N/A	

Table 6.26. (continued)

Facility or area: Weapons Diagnostic and Instrumentation Development Building (RC-28)

Hazard Type	Hazard Present? (Y or N)	Hazard Source(s)	Routinely Encountered Industrial Hazard? (Y or N)	Remarks
Thermal energy	Y	Boiling water used in the water sample laboratory	Y	The boiling water is contained in a glass pot inside an enclosed still to prevent skin burns if the glass pot ruptures.
Toxic materials	Y	Concentrated HCl used in the water sample laboratory; solvents and other chemicals used in the laser laboratory	Y	No quantities exceed 1 lb.

Table 6.27. Hazard Identification Worksheet (RC-45)

Facility or area: Advanced Radiochemical Weapons Diagnostic Facility (RC-45)

Hazard Type	Hazard Present? (Y or N)	Hazard Source(s)	Routinely Encountered Industrial Hazard? (Y or N)	Remarks
Electrical energy	Y	High-voltage power supplies for mass spectrometers	Y	The power supplies are enclosed in locked cabinets and equipped with safety interlocks.
Electromagnetic radiation	Y	Magnetic fields generated by the mass spectrometers	Y	
Explosive materials	N	N/A	N/A	
Fissile materials	N	N/A	N/A	
Flammable materials	Y	Solvents and pump lubricants	Y	RC-45 has a sprinkler system, and the flammable materials are stored in chemical cabinets when not in use.
Kinetic energy	N	N/A	N/A	
Potential energy	N	N/A	N/A	
Radioactive materials	Y	Radioactive samples	N	Samples contain extremely low levels of radioactivity, and personnel wear TLD badges.
Reactive materials	Y	Some reactive materials used in routine experimental procedures	N	See Table 6.28.

Table 6.27. (continued)

Facility or area: Advanced Radiochemical Weapons Diagnostic Facility (RC-45)

Hazard Type	Hazard Present? (Y or N)	Hazard Source(s)	Routinely Encountered Industrial Hazard? (Y or N)	Remarks
Thermal energy	N	N/A	N/A	
Toxic materials	Y	Some toxic materials used in routine experimental procedures	N	See Table 6.28.
Other (list below)	N			

Table 6.28. Screening analysis for inventories of listed chemicals exceeding 1 lb (RC-45)

Location	Chemical	Quantity	Reactivity Hazards	Toxicity Data		Toxicity Rating	Disposition
				IDLH (mg/m ³)	LI ₅₀ (mg)		
RC-45	Chloroform	5.9 kg	Possible generation of toxic gases if mixed with hydrochloric acid, hydrogen bromide, hydrogen chloride gas, or hydrogen fluoride; possible fire and generation of toxic gases if mixed with nitric acid or perchloric acid.	4,960 (NIOSH 1990)	2,520 (Sax and Lewis 1989)	2	Retain for reactivity only
	Hydrochloric acid	100 kg	Possible generation of toxic gases if mixed with chloroform.	152 (NIOSH 1990)	1,806*	2	Retain for toxicity and reactivity
	Hydrogen bromide	3.7 kg	Possible generation of toxic gases if mixed with chloroform.	168 (NIOSH 1990)	1,996*	2	Retain for reactivity only
	Hydrogen fluoride	16.5 kg	Possible generation of toxic gases if mixed with chloroform.	25 (NIOSH 1990)	297*	1	Retain for toxicity and reactivity
	Nitric acid	122.3 kg	Possible fire and generation of toxic gases if mixed with chloroform.	262 (NIOSH 1990)	3,113*	2	Retain for toxicity and reactivity
	Perchloric acid	16.3 kg	Possible fire and generation of toxic gases if mixed with chloroform.	-	28,000 (Sax and Lewis 1989)	3	Retain for reactivity only
	Hydrogen peroxide	2.1 kg	Possible generation of toxic gases if mixed with hydrochloric acid, hydrogen chloride gas, or hydrogen fluoride	106 (NIOSH 1990)	140,000 (Sax and Lewis 1989)	4	Retain for reactivity only
	Sulfuric acid	20.5 kg	Possible fire and generation of toxic gases if mixed with chloroform	80 (NIOSH 1990)	149,800 (Sax and Lewis 1989)	4	Retain for reactivity only

*Based on IDLH

Table 6.29 lists the accident initiating events identified in the initial analysis steps. For each significant toxic material hazard in Table 6.29, three types of releases are addressed: spills resulting from chemist error or external events (earthquakes, aircraft crashes, etc.), pressurized releases (as might occur in an explosion), and fire-enhanced releases. The latter two release types are not initiating events in and of themselves; rather, they are possible results of other initiating events included in the table, such as hydrogen gas leaks or inadvertent mixing of incompatible chemicals. These release types are included in this table only because the release fractions associated with them exceed those for simple spills (see Table 6.8). Simple spills of a particular material may be screened out because of the low release fraction, whereas significant consequences may result if the same inventory is involved in a fire or explosion. Significant effort can be saved in analyzing fires and explosions in later steps if all credible release types for significant chemical inventories are addressed at this level.

Where possible, initiating events in Table 6.29 are screened from further analysis on the basis of insignificant consequences, insignificant likelihood, or the combination of minor consequences and low likelihood. The remaining events are grouped as shown in Table 6.30 to facilitate selection of bounding events for accident scenario development.

6.6 BUILDING RC-46

The completed hazard identification worksheet for Building RC-46 is presented in Table 6.31. Accident initiating events will be identified for hazards that are not judged to be routinely encountered industrial hazards.

Chemical inventories for the facility were characterized by using the computerized inventory tracking system maintained by HS-5. Table 6.32 lists the greater-than-1-lb inventories of chemicals that are listed on either the EPA's *List of Extremely Hazardous Substances* (Appendix A to 40 CFR 355) or the *List of Highly Hazardous Chemicals, Toxics, and Reactives* (Appendix A to 29 CFR 1910.119). Two binary combinations of reactive chemicals and one toxic material (chloroform) are retained for further evaluation in the accident initiating event definition step.

Table 6.29. Identification and screening of accident initiating events (RC-45)

Hazard Type/Source	Location(s)	Postulated Event	Consequence Category	Likelihood Category	Disposition*	Remarks
Reactive materials/ chloroform and hydrochloric acid or hydrogen chloride gas	RC-45, Rooms 104 and 1080	Possible generation of chlorine gas resulting from chemist error	2	B	Not screened	Chlorine has an IDLH of 88.5 mg/m ³ (NIOSH 1990), which translates into an LI ₅₀ of 1,051 mg (Toxicity Class 2); at most, 1.76 kg of chlorine could be formed (Room 1080); this amount exceeds the limiting release amount for on-site exposures.
Reactive materials/ chloroform and hydrogen fluoride	RC-45, Rooms 1080 and 1100	Possible generation of chlorine and fluorine gas resulting from chemist error	4	B	C	Chlorine has an IDLH of 88.5 mg/m ³ (NIOSH 1990), which translates into an LI ₅₀ of 1,051 mg (Toxicity Class 2); fluorine has an IDLH of 39.5 mg/m ³ (NIOSH 1990), which translates into an LI ₅₀ of 469 mg (Toxicity Class 2); at most, 879 g of chlorine and 471 g of fluorine could be formed (Room 1080); these amounts do not exceed the limiting release amounts for on-site and off-site exposures.
Reactive materials/ chloroform and nitric acid	RC-45, Rooms 104, 1080, and 1100	Possible fire and generation of chlorine gas resulting from chemist error	4	B	C	Chloroform has a heat of combustion of 5.9 KJ/g; the largest inventory that could react with nitric acid (2.96 kg in Room 402) has about 17,500 KJ of stored energy, which could support a < 10 min fire. Chlorine has an IDLH of 88.5 mg/m ³ (NIOSH 1990), which translates into an LI ₅₀ of 1,051 mg (Toxicity Class 2); at most, 844 kg of chlorine could be formed (Room 1080); this amount does not exceed the limiting release amounts for on-site and off-site exposures.
Reactive materials/ chloroform and perchloric acid	RC-45, Rooms 1080 and 1100	Possible fire and generation of chlorine gas resulting from chemist error	4	B	C	Chloroform has a heat of combustion of 5.9 KJ/g; the largest inventory that could credibly combine with perchloric acid (1.49 kg in Room 1100) has about 8,800 KJ of stored energy, which could support only a < 5-min fire. Chlorine has an IDLH of 88.5 mg/m ³ (NIOSH 1990), which translates into an LI ₅₀ of 1,051 mg (Toxicity Class 2); at most, 878 g of chlorine could be formed (Room 1100); this amount does not exceed the limiting release amounts for on-site and off-site exposures.

Table 6.29. (continued)

Hazard Type/Source	Location(s)	Postulated Event	Consequence Category	Likelihood Category	Disposition ^a	Remarks
Reactive materials/ chloroform and sulfuric acid	RC-45, Rooms 104 and 1100	Possible fire and generation of chlorine and sulfur dioxide gases caused by chemist error	4	B	C	Chloroform has a heat of combustion of 5.9 KJ/g; the largest inventory that could credibly combine with sulfuric acid (1.48 kg in Room 1100) has about 8,700 KJ of stored energy, which could support a < 10 min fire. Chlorine has an IDLH of 88.5 mg/m ³ (NIOSH 1990), which translates into an LI ₅₀ of 1,051 mg (Toxicity Class 2); at most, 439 g of chlorine could be formed (Room 1100); this amount does not exceed the limiting release amounts for on-site and off-site exposures.
Reactive materials/ hydrogen peroxide and hydrochloric acid or hydrogen chloride gas	RC-45, Rooms 1040 and 1150	Possible generation of chlorine gas caused by chemist error	4	B	C	Chlorine has an IDLH of 88.5 mg/m ³ (NIOSH 1990), which translates into an LI ₅₀ of 1,051 mg (Toxicity Class 2); at most, 1.44 kg of chlorine could be formed (Rooms 1040 and 1150); this amount does not exceed the limiting release amounts for on-site and off-site exposures.
Reactive materials/ hydrogen peroxide and hydrogen fluoride	RC-45, Rooms 1040, 1100, and 1150	Possible generation of fluorine vapor caused by chemist error	4	B	C	Fluorine has an IDLH of 39.5 mg/m ³ (NIOSH 1990), which translates into an LI ₅₀ of 469 mg (Toxicity Class 2); at most, 780 g of fluorine could be formed (Room 1040); this amount does not exceed the limiting release amounts for on-site and off-site exposures.
Toxic materials/ hydrochloric acid	RC-45, Rooms 104, 1010, 1020, 1040, 1060, 1080, 1150, and 1170	Spill caused by chemist error or external event	4	B	C	Toxicity Class 2; assuming a release fraction of 0.0001, a spill of the largest inventory (38.57 kg in Room 104) would not exceed the limiting release amounts for on-site and off-site exposures.
		Pressurized release (as in explosion)	2	C	Not screened	Toxicity Class 2; assuming a release fraction of 0.05, an event involving the largest inventory (38.57 kg in Room 104) would exceed the limiting release amount for on-site exposures.
		Fire-enhanced release	2	C	Not screened	Toxicity Class 2; release of the entire building inventory (100 kg) would exceed the limiting release amounts for on-site and off-site exposures.
Toxic materials/ hydrogen fluoride	RC-45, Rooms 1040, 1070, 1080, 1090, 1100, and 1150	Spill caused by chemist error or external event	2	B	Not screened	Toxicity Class 1; assuming a release fraction of 1.0 for this volatile material, a spill of the largest inventory (12.83 kg in Room 1040) would exceed the limiting release amounts for on-site and off-site exposures.

Table 6.29. (continued)

Hazard Type/Source	Location(s)	Postulated Event	Consequence Category	Likelihood Category	Disposition*	Remarks
Toxic materials/ hydrogen fluoride (cont.)		Pressurized release (as in explosion)	2	C	Not screened	Toxicity Class 1; assuming a release fraction of 1.0 for this volatile material, an event involving the largest inventory (12.83 kg in Room 1040) would exceed the limiting release amounts for on-site and off-site exposures.
		Fire-enhanced release	2	C	Not screened	Toxicity Class 1; release of the entire building inventory (16.5 kg) would exceed the limiting release amounts for on-site and off-site exposures.
Toxic materials/nitric acid	RC-45, Rooms 104, 1010, 1020, 1040, 1060, 1070, 1080, 1090, 1100, 1150, and 1170	Spill caused by chemist error or external event	4	B	C	Toxicity Class 2; assuming a release fraction of 0.0001, a spill of the largest inventory (37.5 kg in Room 104) would not exceed the limiting release amounts for on-site and off-site exposures.
		Pressurized release (as in explosion)	2	C	Not screened	Toxicity Class 2; assuming a release fraction of 0.05, an event involving the largest inventory (37.5 kg in Room 104) would exceed the limiting release amount for on-site exposures.
		Fire-enhanced release	2	C	Not screened	Toxicity Class 2; release of the entire building inventory (122 kg) would exceed the limiting release amounts for on-site and off-site exposures.

*C - screened out on insignificant consequences or combination of minor consequences and low likelihood; F - screened out on insignificant likelihood

Table 6.30. Accident initiating events (RC-45)

Inadvertent Mixing of Incompatible Materials

Mixing of chloroform and hydrochloric acid in one of several rooms (possible generation of chlorine gas)

Releases of Toxic Materials

Fire enhanced release of hydrochloric acid in one of several rooms

Pressurized release of hydrochloric acid in one of several rooms

Spill of hydrogen fluoride in one of several rooms caused by chemist error or an external event

Pressurized release of hydrogen fluoride in one of several rooms

Fire-enhanced release of hydrogen fluoride in one of several rooms

Fire-enhanced release of nitric acid in one of several rooms

Pressurized release of nitric acid in one of several rooms

Table 6.31. Hazard Identification Worksheet (RC-46)

Facility or area: RC-46

Hazard Type	Hazard Present? (Y or N)	Hazard Source(s)	Routinely Encountered Industrial Hazard? (Y or N)	Remarks
Electrical energy	Y	Power supplied to hydrothermal furnaces, gas chromatograph, and x-ray diffractometer	Y	Maximum supply voltage to RC-46 is 220 V AC
		Internal power supply for x-ray diffractometer	N	Voltages developed are in the range of 40 kV
Electromagnetic radiation	N	N/A	N/A	
Explosive materials	N	N/A	N/A	
Fissile materials	N	N/A	N/A	
Flammable materials	Y	One standard DOT-approved cylinder of methane for gas chromatograph	N	Potential for explosion
		One standard, DOT-approved cylinder of hydrogen for gas chromatograph	N	Potential for explosion

Table 6.31. (continued)

Facility or area: RC-46

Hazard Type	Hazard Present? (Y or N)	Hazard Source(s)	Routinely Encountered Industrial Hazard? (Y or N)	Remarks
Kinetic energy	N	N/A	N/A	
Potential energy	Y	Lifting of 100-lb pressure vessels into hydrothermal furnaces with small hoist	Y	
Radioactive materials	N	N/A	N/A	
Reactive materials	Y	Chloroform and acids in small containers	N	See Table 6.32.
Thermal energy	Y	Hydrothermal furnaces	Y	
Toxic materials	Y	Numerous chemicals in small containers	N	See Table 6.32.
Other (list below):				
Asphyxiants	Y	One standard DOT- approved cylinder of N ₂	N	

Table 6.31. (continued)

Facility or area: RC-46

Hazard Type	Hazard Present? (Y or N)	Hazard Source(s)	Routinely Encountered Industrial Hazard? (Y or N)	Remarks
High pressure	Y	Compressed gas cylinders	Y	Gases are contained inside DOT-approved cylinders.
		Hydrothermal furnace pressure vessels containing samples	Y	Samples are natural rocks; each pressure vessel is equipped with a rupture disc.
Ionizing radiation	Y	X-rays produced by x-ray diffractometer	Y	X-ray beam is not exposed; door on sample chamber is interlocked with beam shutter.

Table 6.32. Screening analysis for inventories of listed chemicals exceeding 1 lb (RC-46)

Location	Chemical	Quantity	Reactivity Hazards	Toxicity Data		Toxicity Rating	Disposition
				IDLH (mg/m ³)	LI ₅₀ (mg)		
RC-46, Room 101	Chloroform	16 L (23.8 kg)	Possible fire and generation of toxic gases if mixed with sulfuric acid; possible generation of toxic gases if mixed with hydrochloric acid.	4,960 (NIOSH 1990)	2,520 (Sax and Lewis 1989)	2	Retain for toxicity and reactivity
	Hydrochloric acid	1 L (1.2 kg)	Possible generation of toxic gases if mixed with chloroform.	152 (NIOSH 1990)	1,806 ^a	2	Retain for reactivity only
	Nickel	454 g	No incompatibilities with other significant quantities of listed chemicals in this area.	-	350 (based on LDLo) (Sax and Lewis 1989)	2 ^b	Screen out
	Sulfuric acid	4.7 L (8.6 kg)	Possible fire and generation of toxic gases if mixed with chloroform.	80 (NIOSH 1990)	149,800 (Sax and Lewis 1989)	4	Retain for reactivity only

^aBased on IDLH

^bBased on LDLo rather than LD₅₀.

Table 6.33 lists the accident initiating events identified in the initial analysis steps. For each significant toxic material hazard in Table 6.33, three types of releases are addressed: spills resulting from chemist error or external events (earthquakes, aircraft crashes, etc.), pressurized releases (as might occur in an explosion), and fire-enhanced releases. The latter two release types are not initiating events in and of themselves; rather, they are possible results of other initiating events included in the table, such as hydrogen gas leaks or inadvertent mixing of incompatible chemicals. These release types are included in this table only because the release fractions associated with them exceed those for simple spills (see Table 6.8). Simple spills of a particular material may be screened out because of the low release fraction, whereas significant consequences may result if the same inventory is involved in a fire or explosion. Significant effort can be saved in analyzing fires and explosions in later steps if all credible release types for significant chemical inventories are addressed at this level.

Where possible, initiating events in Table 6.33 are screened from further analysis on the basis of insignificant consequences, insignificant likelihood, or the combination of minor consequences and low likelihood. The remaining events are grouped as shown in Table 6.34 to facilitate selection of bounding events for accident scenario development.

6.7 REFERENCES

ACGIH, *Threshold Limit Values and Biological Exposure Indices for 1990-1991*, Cincinnati, OH (1988).

Ayer, J. E. et al., *Nuclear Fuel Cycle Facility Accident Analysis Handbook*, NUREG-1320, U.S. Nuclear Regulatory Commission, Washington, DC (May 1988).

Cember, Herman, *Introduction to Health Physics*, Pergamon Press, New York, NY (1969).

Center for Chemical Process Safety, *Guidelines for Hazard Evaluation Procedures*, 2nd ed., American Institute of Chemical Engineers, New York, NY (1992).

Doull, J. et al., *Casarett and Doull's Toxicology*, 2nd ed., Macmillan, New York, NY (1980).

Table 6.33. Identification and screening of accident initiating events (RC-46)

Hazard Type/Source	Location(s)	Postulated Event	Consequence Category	Likelihood Category	Disposition ^a	Remarks
Asphyxiants/N ₂ cylinder	RC-46, Room 102	Asphyxiation of personnel	3	C	C	At most, a few people would be affected.
Electrical energy/internal power supply to x-ray diffractometer	RC-46, Room 101	Electrocution of personnel	3	C	C	At most, one person could be affected.
Flammable materials/methane cylinder	RC-46, Room 102	Methane leak into room	3	B	Not screened	Potential for explosion.
Flammable materials/hydrogen cylinder	RC-46, Room 102	Hydrogen leak into room	3	B	Not screened	Potential for explosion.
Reactive materials/chloroform and hydrochloric acid	RC-46, Room 101	Possible generation of chlorine gas resulting from operator error	2	B	Not screened	Chlorine has an IDLH of 88.5 mg/m ³ (NIOSH 1990), which translates into an LI ₅₀ of 1,051 mg (Toxicity Class 2); at most, 2.4 kg of chlorine could be formed; this amount exceeds the limiting release amount for on-site exposures.
Reactive materials/chloroform and sulfuric acid	RC-46, Room 101	Possible fire and generation of chlorine and sulfur dioxide gases resulting from operator error	2	B	Not screened	Chloroform has a heat of combustion of about 5.9 KJ/g; 23.8 kg has 140,420 KJ of stored energy, which could support a fire of greater than 30 min. Chlorine has an IDLH of 88.5 mg/m ³ (NIOSH 1990), which translates into an LI ₅₀ of 1,051 mg (Toxicity Class 2); at most, 3.1 kg of chlorine could be formed; this amount exceeds the limiting release amounts for on-site and off-site exposures. Sulfur dioxide has an IDLH of 266 mg/m ³ (NIOSH 1990), which translates into an LI ₅₀ of 3,160 mg (Toxicity Class 2); at most, 5.6 kg of sulfur dioxide could be formed; this amount exceeds the limiting release amounts for on-site and off-site exposures.

Table 6.33. (continued)

Hazard Type/Source	Location(s)	Postulated Event	Consequence Category	Likelihood Category	Disposition*	Remarks
Toxic materials/chloroform	RC-46, Room 101	Spill caused by chemist error or external event	4	B	C	Toxicity Class 2; assuming a release fraction of 0.0001, a spill of the entire inventory would not exceed the limiting release amounts for on-site and off-site exposures.
		Pressurized release (as in explosion)	4	C	C	Toxicity Class 2; assuming a release fraction of 0.05, an event involving the entire inventory would not exceed the limiting release amounts for on-site and off-site exposures.
		Fire-enhanced release	2	C	Not screened	Toxicity Class 2; release of the entire inventory would exceed the limiting release amounts for on-site and off-site exposures.

*C - screened out on insignificant consequences or combination of minor consequences and low likelihood; F - screened out on insignificant likelihood

Table 6.34. Accident initiating events (RC-46)

Releases of Flammable Gas

Hydrogen leak in Room 102

Methane leak in Room 102

Inadvertent Mixing of Incompatible Materials

Mixing of chloroform and hydrochloric acid in Room 101 (possible generation of chlorine gas)

Mixing of chloroform and sulfuric acid in Room 101 (possible fire and generation of chlorine and sulfur dioxide gases)

Releases of Toxic Materials

Fire-enhanced release of chloroform in Room 101

Eckerman, K. F., et al, *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion*, EPA-520/1-88-020, U.S. Environmental Protection Agency, Washington, DC (September 1988).

Federal Emergency Management Agency, *Handbook of Chemical Hazard Analysis Procedures*, Washington, DC (1989).

NIOSH, *Pocket Guide to Chemical Hazards*, Publication No. 90-117, U.S. Department of Health and Human Services, Washington, DC (June 1990).

OSHA, "Air Contaminants," proposed rule, in *Federal Register*, Vol. 53, No. 109, U.S. Government Printing Office, Washington, DC (1988).

Perry, R. H., and C. H. Chilton, *Chemical Engineers' Handbook*, 5th ed., McGraw-Hill Book Company, New York, NY (1973).

Romero, R. J., and C. L. Faust, *The Chemistry and Metallurgy Research (CMR) Building Interim Safety Analysis Report*, CMR-FAC-92-080, Los Alamos National Laboratory, Los Alamos, NM (1992).

7. ACCIDENT ANALYSIS

This chapter documents the analysis of bounding accident scenarios for the radiochemical operations at TA-48. Bounding accident scenarios are developed from the lists of accident initiating events developed in Section 6 and presented in Tables 6.12, 6.16, 6.21, 6.24, 6.30 and 6.34. These events are considered to have significant consequences, relatively high likelihood, or both.

For the radiochemical operations at TA-48, several bounding accident scenarios are evaluated: the intent is to identify the bounding cases for toxic material exposure as well as the bounding cases for exposure to radioactive materials. Scenarios have also been identified that could result in an explosion in one of the buildings resulting from either a leak of flammable gas or inadvertent mixing of incompatible chemicals. Such explosions may cause substantial building damage and could result in several severe injuries or fatalities among building occupants. External events, such as earthquakes, high winds, and aircraft crashes, could cause a similar level of damage. Any of these events may involve the release of radioactive and toxic materials from the affected facility. However, the impacts on persons in nearby buildings and on persons off-site would be no more severe than those impacts associated with the selected bounding accident scenarios.

7.1 TOXIC MATERIAL RELEASES

Table 7.1 summarizes the information provided in Tables 6.12, 6.16, 6.30, and 6.34 concerning events that can lead to the generation and/or release of toxic materials at the TA-48 facilities considered in this safety assessment. The inventories shown in the table are the inventories that were present at the time of the facility walkdown. They are expected to be typical of the quantities present during normal operations. The most toxic materials included in the table are HF, mercury, and hydrogen cyanide, in decreasing order of toxicity. The largest release quantities are the 122.3 kg of HNO_3 in RC-45; the 100 kg of HCl in RC-45; the 80 kg of HF in RC-1, Room 430; the 74 kg of HClO_4 in RC-1, Room 305B; and the 70.3 kg of mercury from RC-1, Rooms 413-C and 416. Thus, when toxicity and quantity released are considered, the HF and mercury releases are of primary interest. Because the HF is far more volatile than the mercury (at 20 °C, the vapor pressures of HF and mercury are about 760 mm Hg and 0.002 mm Hg, respectively [Perry and Chilton 1973]), the HF would be released more rapidly if spilled. Even in a fire, the HF should be released more rapidly because of its much lower boiling point (67°F versus 674°F for

Table 7.1. Postulated events involving the generation and/or release of toxic materials

Material	IDLH (mg/m ³)	Quantity Generated/ Released (g)	Form	Location	Cause(s) of Release
Chlorine	88.5	4,500	Gas	RC-1, Room 402	Inadvertent mixing of chloroform and hydrochloric acid
		3,100	Gas	RC-1, Room 414	Inadvertent mixing of sulfur dioxide and hydrochloric acid
		2,200	Gas	RC-1, Room 402	Inadvertent mixing of chloroform and nitric acid
		1,660	Gas	RC-1, Room 412	Inadvertent mixing of chloroform and sulfuric acid
		1,760	Gas	RC-45 Room 1080	Inadvertent mixing of chloroform and hydrochloric acid
		2,400	Gas	RC-46, Room 101	Inadvertent mixing of chloroform and hydrochloric acid
		3,100	Gas	RC-46, Room 101	Inadvertent mixing of chloroform and sulfuric acid
Chloroform	4,960	13,900	Volatile liquid	RC-1, Rooms 409 and 412	Fire
		5,900	Volatile liquid	RC-45	Fire
		23,800	Volatile liquid	RC-46	Fire

Table 7.1. (continued)

Material	IDLH (mg/m ³)	Quantity Generated/ Released (g)	Form	Location	Cause(s) of Release
Hydrogen cyanide	56	275	Gas	RC-1, Room 402 or 413	Inadvertent mixing of sodium cyanide and hydrochloric acid
		275	Gas	RC-1, Room 411 or 413	Inadvertent mixing of sodium cyanide and hydrogen fluoride
		275	Gas	RC-1, Room 402, 411, or 413	Inadvertent mixing of sodium cyanide and nitric acid
		275	Gas	RC-1, Room 402	Inadvertent mixing of sodium cyanide and sulfuric acid
		162	Gas	RC-1, Room 413	Inadvertent mixing of sodium cyanide and perchloric acid
Hydrogen bromide	168	4,000	Gas	RC-1, Room 419	Fire
Hydrogen chloride	152	27,200	Gas	RC-1, Room 307	Chemist error, explosion, or external event
Hydrochloric acid	152	10,200	Volatile liquid	RC-1, Room 307 and 310	Fire
		100,000	Liquid	RC-45	Explosion or fire
Hydrogen fluoride	25	80,000	Volatile liquid	RC-1, Room 430	Chemist error, explosion, external event, or fire
		12,830	Gas	RC-45, Room 1040	Chemist error, explosion, or external event, or fire

Table 7.1. (continued)

Material	IDLH (mg/m ³)	Quantity Generated/ Released (g)	Form	Location	Cause(s) of Release
Hydrogen sulfide	426	27,200	Gas	RC-1, Room 413	Chemist error, explosion, or external event
Mercury	28	70,300	Liquid	RC-1, Rooms 413-C and 416	Fire
Nitric acid	262	16,000	Volatile liquid	RC-1, Room 430	Fire
		122,300	Liquid	RC-45	Explosion or fire
Perchloric acid	a	74,000	Volatile liquid	RC-1, Room 305B	Chemist error, explosion, or external event
		16,300	Volatile liquid	RC-45	Chemist error, explosion, or external event
Sulfur dioxide	266	45,400	Gas	RC-1, Room 413	Chemist error, explosion, or external event

^aNo IDLH concentration has been established for perchloric acid; however, on the basis of LL_{50} , perchloric acid is less toxic than any other chemical included in this table by a factor of 5.

mercury [Perry and Chilton 1973]), resulting in higher concentrations in air downwind of the release. Therefore, the release of 80 kg of HF is chosen as the bounding accident scenario for toxic material exposures.

The HF containers are stored in a cabinet underneath a fume hood. The only credible mechanisms for spilling all of the stored material are a natural gas explosion in the area, an external event (earthquake, extreme winds, aircraft crash, etc.), or a large fire. Each of these events is expected to occur about once every 1,000 - 10,000 years, on average.

The release characteristics depend upon the initiating event. An event that causes an HF spill without damaging the building would result in a release out the exhaust stack, but fires, explosions, and external events would likely create openings in the building walls that would release the HF at ground level. The increased release height associated with the stack release provides for greater dilution of the HF plume before it reaches receptors on the ground. In addition, the volatile material would be released somewhat more slowly in a simple spill than in an energetic event such as a fire or explosion. For purposes of this analysis, the HF is assumed to be released from the building at ground level over a period of 1 min. This release duration is chosen because hydrogen fluoride is highly volatile and would rapidly flash to vapor on a warm day in events in which the walls are breached. The release rate is then calculated as follows:

$$Q = \frac{(80 \text{ kg})(1 \times 10^6 \text{ mg/kg})}{60 \text{ s}} = 1.33 \times 10^6 \text{ mg/s}$$

The maximum (plume centerline) concentration of a released gas in air at a downwind distance x from the release point is estimated by the following equation (Turner 1970):

$$\chi(x,0,0,s) = \frac{Q}{\pi \sigma_y(x,s) \sigma_z(x,s) u}$$

where $\chi(x,0,0,s)$ = contaminant concentration at ground level at downwind distance x resulting from a continuous release at ground level under conditions characterized by atmospheric stability category s (mg/m^3),

Q = contaminant release rate (mg/s),

$\sigma_y(x,s)$ = horizontal dispersion coefficient for downwind distance x and stability category s (m),

$\sigma_z(x,s)$ = vertical dispersion coefficient for downwind distance x and stability category s (m), and

u = wind speed (m/s).

The dispersion coefficients are functions of atmospheric stability class and downwind distance. Bowen (1990) reports values for LANL site-specific dispersion coefficients. These coefficients were estimated from measurements of the variation in wind direction and the vertical variation in wind speed. The values presented by Bowen (1990) are based on an assumed wind speed of 3 m/s. If these coefficients are to be used for estimating downwind contaminant concentrations for other wind speeds, they must first be corrected using the method reported by Draxler (1976).

According to Draxler (1976), σ_y is proportional to a function f_1 , defined as follows:

$$f_1 = \frac{1}{1 + 0.9(T/T_i)^{1/2}} ,$$

where T = plume travel time to receptor (equal to the downwind distance divided by the wind speed)
(s) and

T_i = an empirically derived constant (s).

For a given downwind distance, the σ_y value reported by Bowen (1990) is adjusted to a different wind speed by computing a value of f_1 for $u = 3$ m/s, computing a value of f_1 for the desired wind speed, and multiplying the reported σ_y value by the ratio $[f_1(\text{desired wind speed})/f_1(3 \text{ m/s})]$. The σ_y values presented by Bowen (1990) are based on a T_i value of 1,000; therefore, this value is used in correcting the coefficients as well.

Draxler's model assumes that the vertical dispersion coefficient, σ_z , is proportional to a function f_2 , which is defined by the same basic equation given for f_1 . However, the constant T_i is often set to a different value for estimating σ_z . The LANL site-specific σ_z values were estimated using a T_i value of 500. The reported values are adjusted to a different wind speed by using the same approach described previously for adjusting σ_y values. Specifically, values of f_2 are calculated for the desired wind speed and for $u = 3$ m/s. The reported σ_z value is then multiplied by the ratio of these functions.

DOE requires that SAR accident evaluations for ground-level releases of hazardous materials be performed using a combination of wind speed and stability class that represents the reasonable worst case (99.5% meteorology). For a ground-level release, maximum concentrations are realized downwind for stable atmospheric conditions and a low wind speed. Extremely low wind speeds (< 2 m/s) do not typically occur under stable conditions (see Table 3.3). Insufficient data are available for determining 99.5% meteorological conditions directly. However, Bowen (1990) reports that very low wind speeds

(< 2.5 m/s) prevail about 45% of the time and that stable conditions prevail from 27-34% of the time. Thus, the combination of stable conditions (E or F stability) and a wind speed of about 2 m/s can be expected to prevail no more than $(0.45)(0.34)(100) = 15\%$ of the time. Lacking better information, the combination of F stability and 2 m/s wind speed is used for this evaluation. This choice is consistent with the intent of the 99.5% meteorology requirement.

Pajarito Road is located about 140 m south of the dissolver area of Building RC-1. Although access to Pajarito Road can be controlled by LANL personnel, it is unlikely that they could close the road before passersby are exposed to the escaping HF plume. Assuming a low wind speed of 2 m/s and stable atmospheric conditions (Pasquill Stability Category F), the following values of σ_y and σ_z apply at this downwind distance:

$$\sigma_y(140 \text{ m, F}) = 23.7 \text{ m}$$

$$\sigma_z(140 \text{ m, F}) = 3.3 \text{ m}$$

The peak (plume centerline) hydrogen fluoride concentration at Pajarito Road is then estimated to be 2,710 mg/m³. This concentration is greater than 100 times the IDLH concentration (25 mg/m³). Therefore, escape-impairing symptoms may be experienced by exposed individuals. Furthermore, Thienes and Haley (1972) report that concentrations as low as 100 mg/m³ can only be tolerated for 1 min, the exposure duration of interest for this accident scenario. Therefore, this scenario should be analyzed further in a SAR.

7.2 EXPOSURE TO RADIOACTIVE MATERIAL (ALPHA AREA)

Table 7.2 summarizes key release parameters associated with the accident-initiating events identified for the alpha area in Section 6.2.3. The total available mass of each radioactive material, the radiation dose per unit mass inhaled for each material, and the release fraction associated with each combination of material and initiating event are useful in identifying a bounding event. From this information, an explosion affecting the ²⁴¹Am chunk while it is in a glovebox is found to be the bounding case for radionuclide release.

An explosion in the glovebox is not likely. An explosion in a fume hood is possible because the hoods are supplied with natural gas. The effect of an explosion in a fume hood on a chunk of metal in a glovebox may be small but cannot be dismissed.

Table 7.2. Key accidental release parameters for alpha area initiating events

Material	Total Mass (g)	Inhalation Dose (rem/g)	Initiating Event	Expected Release Fraction ^a
Depleted U ingots	33,000	6.2×10^1	Fire affecting metal can	$1.6 \times 10^{-4}{}^b$
			Fire in glovebox	$1.6 \times 10^{-4}{}^b$
50% $\underline{e}$ U powder	47	3.7×10^3	Fire affecting metal box	1.3×10^{-2}
			Fire in glovebox	1.3×10^{-2}
93% $\underline{e}$ U foil	147	8.5×10^3	Fire in glovebox	$1.6 \times 10^{-4}{}^b$
99.7% $\underline{e}$ U powder	74	9.4×10^3	Fire in glovebox	1.3×10^{-2}
^{239}Pu powder	1	2.6×10^7	Fire in glovebox	1.3×10^{-2}
			Explosion affecting glovebox	$1.0 \times 10^{-2}{}^c$
^{239}Pu solution	2	2.6×10^7	Fire affecting metal box	1.1×10^{-1}
			Fire in glovebox	1.1×10^{-1}
			Explosion affecting metal box	$5.0 \times 10^{-2}{}^d$
			Explosion affecting glovebox	$5.0 \times 10^{-2}{}^d$
^{239}Pu chunks	5	2.6×10^7	Fire in glovebox	$1.6 \times 10^{-4}{}^b$
			Explosion affecting glovebox	$1.0 \times 10^{-2}{}^c$
^{242}Pu solution	2	1.6×10^6	Fire affecting metal box	1.1×10^{-1}
			Fire in glovebox	1.1×10^{-1}
			Explosion affecting metal box	$5.0 \times 10^{-2}{}^d$

Table 7.2. (continued)

Material	Total Mass (g)	Inhalation Dose (rem/g)	Initiating Event	Expected Release Fraction ^a
			Explosion affecting glovebox	5.0×10^{-2} ^d
²⁴¹ Am chunk	0.5	1.4×10^9	Fire in glovebox	1.6×10^{-4} ^b
			Explosion affecting glovebox	1.0×10^{-2} ^c
²⁴³ Am powder	0.4	8.8×10^7	Fire in glovebox	1.3×10^{-2}
			Explosion affecting glovebox	1.0×10^{-2} ^c
²³² Th foil	1000	1.8×10^2	Fire affecting glass bottle	1.6×10^{-4} ^b
			Fire in glovebox	1.6×10^{-4} ^b

^aSource: Ayer et al. (1988)

^bThis value is derived from a release rate of 8.9×10^{-8} /s for burning pyrophoric metal and an assumed fire duration of 30 min.

^cThis value relates to pressurized release of powder.

^dThis value relates to pressurized release of liquid.

On the basis of the preceding discussion, the following scenario is postulated as the bounding event for the alpha area.

1. Natural gas leaks into a fume hood.
2. Ventilation flow through the fume hoods is lost, and the leaking natural gas forms a flammable mixture with the air in the alpha area.
3. The flammable gas mixture is ignited by a spark or open flame (e.g., from a bunsen burner in another fume hood).
4. The resulting deflagration damages the glovebox that contains the ^{241}Am chunk, and the metal chunk is crushed and dispersed by the pressure pulse. The walls of the alpha area are also breached, providing a pathway for the airborne material to escape the building without filtration.

Few data are available for estimating a release fraction for the impact of a vapor cloud explosion on a metal chunk. However, the release in this case should be bounded by the release from an equivalent mass of powder subjected to the same forces. Powder is lighter and more finely divided. Both of these factors tend to enhance its dispersibility. Thus, a bounding release fraction for a pressurized release of powder is applied in this case. The value of 0.01, which was used in Section 6 for screening purposes, is used here as well. This value is judged to be conservative for a pressurized release on the basis of the analysts' experience in applying the release fraction correlations given by Ayer et al. (1988).

Using the values of σ_y and σ_z from Section 7.1, the χ/Q at Pajarito Road is $2.0 \times 10^{-3} \text{ s/m}^3$. The dose to an off-site receptor from the ^{241}Am release is calculated as follows:

$$(0.5 \text{ g})(0.01)(1.4 \times 10^9 \text{ rem/g})(2.0 \times 10^{-3} \text{ s/m}^3)(3.3 \times 10^{-4} \text{ m}^3/\text{s}) = 4.62 \text{ rem.}$$

This dose exceeds permissible guidelines but would not cause any significant health effects. Further analysis of radioactive release scenarios for this area should be included in a SAR. It should be noted that the frequency of this bounding event may be low, on the order of $10^{-2}/\text{year}$ to $10^{-5}/\text{year}$, perhaps smaller.

7.3 EXPOSURE TO RADIOACTIVE MATERIAL (HOT CELLS)

The radioactive materials that are present in the hot cells present a hazard of both internal and external exposures. The highly irradiated target assemblies that are unpackaged in the dispensary cell may have radiation levels in excess of 100,000 rem/h. This radiation level is measured with a monitor in the dispensary cell and is assumed to be measured at a distance of 1 m from the source. The radioactive target material is converted into forms that might be ingested or inhaled as it is processed in the other hot cells. The potential consequences of an accidental exposure to radioactive material are discussed in the following sections.

7.3.1 Internal Exposure to Radioactive Material

Chemical processing of irradiated targets to separate the individual radionuclides for medical use requires conversion of the target into useful forms. The individual radionuclides are typically processed and shipped in the form of liquids. Because the radioactive materials that are present in the hot cells are in a dispersible form and because their release could result in an exposure, the potential impact of a release is examined in more detail.

The maximum inventory of each radionuclide that might be present at any one time is identified in Table 4.6, in which the dispersibility of the inventory is also indicated. The information is taken directly from the hazard classification exercise for the hot cells and was developed by hot cell operations personnel.

In the table, highly dispersible materials are gases, vapors, and volatile solids. Moderately dispersible materials are mists, aerosols, spilled liquids or powders, and liquids or powders under flammable or explosive conditions. Low dispersibility materials are bulky metals or sealed sources in flammable or explosive conditions.

The potential for adverse health effects off-site resulting from an accidental release of radionuclides from the hot cells is evaluated by determining the limiting inventory that, if released, would result in a 100-mrem EDE. Next, the fraction of the limiting inventory that might actually be available for release from the hot cells is determined.

Initial inspection of the amount of material available for release from the hot cells indicates that a conservative analysis can be performed to demonstrate that the release of the radionuclide inventories from the hot cells would result in minimal adverse health effects. The atmospheric dispersion factor and

breathing rate used for the analysis are the same as those used in analyzing a release from the alpha area (described in Section 7.2).

These conditions are used to calculate the limiting inventory of each radionuclide present that would result in a dose of 100-mrem EDE to an off-site receptor. The release fractions from the hazard classification exercise are used (1.0, 0.01, and 0.001 for high moderate, and low dispersibility, respectively).

Table 7.3 presents the results of the analysis. The results indicate that none of the radionuclides are present in sufficient quantity to exceed the 100-mrem EDE dose limit. The potential for more than one radionuclide to be released during one accident does exist. The effects of exposures to multiple radionuclides are additive, so all of the fractional inventories are summed to determine if release of all of the radionuclides in a single accident (they are not all present at the same time) would exceed the 100-mrem limit. The sum of fractions is 1.0, indicating that for this set of assumptions, the release would not result in exceeding the specified dose limit.

The potential also exists for radioactive materials to be inhaled on-site as the result of an accidental release. Such an event would be most likely to occur after processing of a particular radionuclide is complete, when the product may be handled outside the hot cells. Such an accident could involve as much as 1 Ci of material.

To determine the potential consequence of such an event, a simple box model is used to estimate the dispersion of the material that is spilled. To make the analysis conservative, a small, nonexpanding cylindrical volume is assumed to contain the dispersed material. The cylinder is assumed to have a 1-m radius and a height of only 2 m. The volume of the cylinder is 6.3 m^3 . The fractional release for a simple liquid spill is assumed to be 0.0001.

An exposure period of 1 min is assumed. In the event of an actual spill, emergency procedures would require immediate evacuation of the area, which would result in a shorter exposure time. For a typical escape speed of 1.5 m/s (NFPA 1988), personnel would be able to exit the area within a few seconds; thus, the 1-min exposure period is conservative. The highest dose conversion factor of all the radionuclides handled in the hot cells is that of ^{60}Co , so the assumption is that 1 Ci of ^{60}Co is released in a simple liquid spill. The resulting dose, given the aforementioned conservative assumptions, is 60 mrem EDE.

Table 7.3. Radionuclide limiting inventories

Radionuclide	Committed Dose Equivalent per Unit Intake (Sv/Bq) with Lung Clearance Class	Dose Conversion Factor (rem/ μ Ci)	Radioisotope Inventory (Ci)	Dispersibility of Material	Limiting Inventory (Ci) (100 mrem dose)	Fraction of Limiting Inventory
Be-7	8.67×10^{-11} Y	3.21×10^{-4}	0	High	5.5×10^2	0
			1	Moderate	5.5×10^4	1.8×10^{-5}
			30	Low	5.5×10^5	5.4×10^{-5}
Na-22	2.07×10^{-9} D	7.66×10^{-3}	0	High	2.4×10^1	0
			.3	Moderate	2.4×10^3	1.3×10^{-4}
			100	Low	2.4×10^4	4.2×10^{-5}
V-48	2.76×10^{-9} W	1.02×10^{-2}	0	High	1.8×10^1	0
			2.5	Moderate	1.8×10^3	1.4×10^{-3}
			1.4	Low	1.8×10^4	8.0×10^{-5}
Cr-51	9.03×10^{-11} Y	3.34×10^{-4}	0	High	5.5×10^2	0
			1.8	Moderate	5.5×10^4	3.2×10^{-5}
			0	Low	5.5×10^5	0
Mn-52	1.54×10^{-9} W	5.70×10^{-3}	0	High	3.2×10^1	0
			1.8	Moderate	3.2×10^3	5.8×10^{-4}
			0	Low	3.2×10^4	0
Mn-54	1.81×10^{-9} W	6.70×10^{-3}	0	High	2.7×10^1	0
			2.4	Moderate	2.7×10^3	8.8×10^{-4}
			60	Low	2.7×10^4	2.2×10^{-3}
Co-57	2.45×10^{-9} Y	9.06×10^{-3}	0	High	2.0×10^1	0
			.5	Moderate	2.0×10^3	2.6×10^{-4}
			47	Low	2.0×10^4	2.2×10^{-3}
Co-58	2.94×10^{-9} Y	1.09×10^{-2}	0	High	1.7×10^1	0
			2	Moderate	1.7×10^3	1.2×10^{-3}
			1.5	Low	1.7×10^4	9.0×10^{-5}
Co-60	5.91×10^{-8} Y	2.19×10^{-1}	0	High	8.0	0
			1	Moderate	8.0×10^1	1.3×10^{-2}
			58	Low	8.0×10^2	7.2×10^{-2}

Table 7.3. (continued)

Radionuclide	Committed Dose Equivalent per Unit Intake (Sv/Bq) with Lung Clearance Class	Dose Conversion Factor (rem/ μ Ci)	Radioisotope Inventory (Ci)	Dispersibility of Material	Limiting Inventory (Ci) (100 mrem dose)	Fraction of Limiting Inventory
Cu-64	7.48×10^{-11} Y	2.77×10^{-4}	0	High	6.5×10^2	0
			1.5	Moderate	6.5×10^4	2.4×10^{-5}
			0	Low	6.5×10^5	0
Zn-65	5.51×10^{-9} Y	2.04×10^{-2}	0	High	9.0×10^1	0
			1	Moderate	9.0×10^3	1.1×10^{-3}
			5.3	Low	9.0×10^4	0
Cu-67	3.32×10^{-10} Y	1.23×10^{-3}	0	High	1.5×10^2	0
			3.2	Moderate	1.5×10^4	2.2×10^{-4}
			3.4	Low	1.5×10^5	2.4×10^{-5}
Ga-67	1.51×10^{-10} W	5.59×10^{-2}	0	High	3.2	0
			1.7	Moderate	3.2×10^2	5.4×10^{-3}
			3.4	Low	3.2×10^3	1.1×10^{-3}
Ge-68	1.41×10^{-8} W	5.18×10^{-2}	0.5	High	3.5	1.4×10^{-1}
			0	Moderate	3.5×10^2	0
			1	Low	3.5×10^3	2.8×10^{-4}
Ge-69	2.27×10^{-10} W	8.40×10^{-4}	0.5	High	2.2×10^2	2.4×10^{-3}
			0	Moderate	2.2×10^4	0
			1	Low	2.2×10^5	4.6×10^{-6}
Se-72	1.1×10^{-9} (As-72)	4.07×10^{-3}	1.5	High	4.4×10^1	3.4×10^{-2}
			0	Moderate	4.4×10^3	0
			3	Low	4.4×10^4	6.8×10^{-5}
As-73	9.34×10^{-10} W	3.46×10^{-3}	4	High	5.0×10^1	8.0×10^{-2}
			15	Moderate	5.0×10^3	3.0×10^{-3}
			21	Low	5.0×10^4	4.2×10^{-4}
As-74	2.15×10^{-9} W	7.96×10^{-3}	3	High	2.3×10^1	1.3×10^{-1}
			9	Moderate	2.3×10^3	3.0×10^{-3}
			15	Low	2.3×10^4	6.6×10^{-4}

Table 7.3. (continued)

Radionuclide	Committed Dose Equivalent per Unit Intake (Sv/Bq) with Lung Clearance Class	Dose Conversion Factor (rem/ μ Ci)	Radioisotope Inventory (Ci)	Dispersibility of Material	Limiting Inventory (Ci) (100 mrem dose)	Fraction of Limiting Inventory
Se-75	2.29×10^{-9} W	8.47×10^{-3}	4	High	2.2×10^1	1.9×10^{-1}
			39	Moderate	2.2×10^3	1.8×10^{-2}
			43	Low	2.2×10^4	2.0×10^{-3}
Br-82	4.13×10^{-10} W	1.53×10^{-2}	1	High	1.2×10^1	8.4×10^{-2}
			0	Moderate	1.2×10^3	0
			1.6	Low	1.2×10^4	1.3×10^{-4}
Sr-82	1.66×10^{-8} W	6.14×10^{-2}	0	High	3.0	0
			12	Moderate	3.0×10^2	4.0×10^{-2}
			12	Low	3.0×10^3	4.0×10^{-3}
Rb-83	1.33×10^{-9} D	4.92×10^{-3}	0	High	3.7×10^1	0
			26	Moderate	3.7×10^3	7.2×10^{-3}
			27	Low	3.7×10^4	7.4×10^{-4}
Rb-84	1.76×10^{-9} D	6.51×10^{-3}	0	High	2.8×10^1	0
			15	Moderate	2.8×10^3	5.4×10^{-3}
			27	Low	2.8×10^4	9.8×10^{-4}
Sr-85	1.36×10^{-9} D	5.03×10^{-3}	0	High	3.6×10^1	0
			21	Moderate	3.6×10^3	5.8×10^{-3}
			20	Low	3.6×10^4	9.8×10^{-4}
Rb-86	1.79×10^{-9} D	6.62×10^{-3}	0	High	2.7×10^1	0
			13	Moderate	2.7×10^3	4.8×10^{-3}
			26	Low	2.7×10^4	9.6×10^{-4}
Y-88	7.59×10^{-9} Y	2.81×10^{-2}	0	High	6.5	0
			9	Moderate	6.5×10^3	1.4×10^{-3}
			10	Low	6.5×10^3	1.5×10^{-4}
Nb-91m	7.90×10^{-9} (Nb-93m)	TBD	0	High	TBD	0
			25	Moderate	TBD	TBD
			25	Low	TBD	TBD

Table 7.3. (continued)

Radionuclide	Committed Dose Equivalent per Unit Intake (Sv/Bq) with Lung Clearance Class	Dose Conversion Factor (rem/ μ Ci)	Radioisotope Inventory (Ci)	Dispersibility of Material	Limiting Inventory (Ci) (100 mrem dose)	Fraction of Limiting Inventory
Zr-95	6.39×10^9 D	2.36×10^{-2}	0	High	7.5	0
			10	Moderate	7.5×10^2	1.3×10^{-3}
			10	Low	7.5×10^3	1.3×10^{-4}
Nb-95	1.57×10^9 Y	5.81×10^{-3}	0	High	3.1×10^1	0
			80	Moderate	3.1×10^3	2.6×10^{-2}
			80	Low	3.1×10^4	2.6×10^{-3}
Tc-95m	1.05×10^9 W	3.89×10^{-3}	0	High	4.7×10^1	0
			4	Moderate	4.7×10^3	8.6×10^{-4}
			4	Low	4.7×10^4	8.6×10^{-5}
Rh-101	1.07×10^8 Y	3.96×10^{-2}	0	High	4.6	0
			1	Moderate	4.6×10^2	2.2×10^{-3}
			10	Low	4.6×10^3	2.2×10^{-3}
Rh-102	3.24×10^8 Y	1.20×10^{-1}	0	High	1.5	0
			1	Moderate	1.5×10^2	6.6×10^{-3}
			2	Low	1.5×10^3	1.3×10^{-3}
Rh-102m	1.29×10^8 Y	4.77×10^{-2}	0	High	3.8	0
			1.6	Moderate	3.8×10^2	4.2×10^{-3}
			13	Low	3.8×10^3	3.4×10^{-3}
Ag-105	1.26×10^9 D	4.66×10^{-3}	0	High	3.9×10^1	0
			1	Moderate	3.9×10^3	2.6×10^{-2}
			3.2	Low	3.9×10^4	8.2×10^{-5}
Cd-109	3.09×10^8 D	1.14×10^{-1}	0	High	1.6	0
			4	Moderate	1.6×10^2	2.6×10^{-2}
			10	Low	1.6×10^3	6.2×10^{-3}
In-113m	1.11×10^{-11}	4.1×10^{-5}	0	High	4.4×10^3	0
			1	Moderate	4.4×10^5	2.2×10^{-6}
			3.2	Low	4.4×10^6	7.4×10^{-7}

Table 7.3. (continued)

Radionuclide	Committed Dose Equivalent per Unit Intake (Sv/Bq) with Lung Clearance Class	Dose Conversion Factor (rem/ μ Ci)	Radioisotope Inventory (Ci)	Dispersibility of Material	Limiting Inventory (Ci) (100 mrem dose)	Fraction of Limiting Inventory
Sn-113	2.88×10^{-9} W	1.07×10^{-2}	0	High	1.7×10^1	0
			1	Moderate	1.7×10^3	5.8×10^{-4}
			3.2	Low	1.7×10^4	1.9×10^{-4}
In-114m	2.40×10^{-8} D	8.88×10^{-2}	0	High	2.1	0
			6	Moderate	2.1×10^2	3.0×10^{-2}
			20	Low	2.1×10^3	9.8×10^{-3}
Sb-125	3.30×10^{-9} W	1.22×10^{-2}	0	High	1.5×10^1	0
			0	Moderate	1.5×10^3	0
			5	Low	1.5×10^4	3.4×10^{-4}
Cs-134	1.25×10^{-8} D	4.63×10^{-2}	0	High	3.9	0
			1	Moderate	3.9×10^2	2.6×10^{-3}
			1	Low	3.9×10^3	2.6×10^{-4}
Pm-145	8.23×10^{-9} Y	3.05×10^{-2}	0	High	6.0×10^{-1}	0
			1	Moderate	6.0×10^2	1.7×10^{-3}
			0	Low	6.0×10^3	0

7.3.2 External Exposure to Radioactive Material

The very high radiation levels of the irradiated targets are the reason that processing must take place in the heavily shielded hot cells. Radiation from a freshly irradiated target in the dispensary cell may be in excess of 100,000 rem/h at an estimated distance of 1 m. Radiation levels of this magnitude can cause serious health effects: the onset of lethality is generally accepted to be around the 200 rem level, and a dose of 400 rem is expected to be lethal to half of the exposed population. The dose that a person might receive as the result of an accidental exposure to an irradiated target is a function of the length of time of exposure and the distance from the source. Exposures are higher for longer periods of time and at smaller distances.

The greatest concern associated with external exposure to high levels of radiation arises as the result of the dispensary cell operations, where the freshly irradiated targets are unpackaged from their shipping container. After unpackaging, the radiation levels decrease as the target irradiation container is removed and left in the dispensary cell safe to "cool." Then the target is processed, and the individual radionuclides are separated. Much of the radiation in the dispensary cell is attributed to the container that the target is irradiated in, which is not removed from the dispensary cell until it is repackaged and removed for disposal.

Procedures are in place to control entry into the hot cell warm corridor, where radiation levels could be the highest. Current procedures require that warm corridor operations be performed in the presence of an RCT and include visual inspections of warning signs and lights to determine if hot cell doors are open or may be opened. While standing outside the entrance to the warm corridor, personnel also visually inspect the hot cell doors to determine if any are open. When workers are ready to enter the hot cell warm corridor, a sign is posted at the controls of the dispensary cell doors and a warning light is activated at the entrance to the corridor to indicate that the dispensary cell doors should not be opened. A new safety interlock system is being installed to further reduce the likelihood that the dispensary cell would be opened with workers in the warm corridor. Anti-c clothing and dosimeters are required for entry into the warm corridor. A hand-held radiation survey meter is used to check radiation levels as workers enter the corridor. The procedure is reversed for proper exit from the warm corridor.

The potential also exists for accidental exposures to radiation if the material transfer trolley system is inadvertently transferred to an unshielded position while carrying a radioactive source. Another highly unlikely event that could result in an external exposure to high levels of radiation is the failure of a

shipping container while it is being handled outside the shielded hot cells. However, the containers are designed and constructed to survive such events and should not pose a danger as the result of mishandling.

The consequence of an accidental external exposure to radiation would be dependent upon the time of exposure and the distance from the radiation source. Complete accident scenarios are not developed in this analysis, but the length of time of exposure and distance from the radiation source could vary greatly. Table 7.4 presents a matrix of doses for varying exposure times and distances. From the table, it is evident that potentially fatal exposures are possible. The safety of workers or others who might be exposed to unshielded radiation sources in the hot cell area is achieved primarily through the use of formal operating procedures.

7.4 REFERENCES

Ayer, J. E. et al., *Nuclear Fuel Cycle Facility Accident Analysis Handbook*, NUREG-1320, U.S. Nuclear Regulatory Commission, Washington, DC (May 1988).

Bowen, B. M., *Los Alamos Climatology*, LA-11735-MS, Los Alamos National Laboratory, Los Alamos, NM (1990).

Draxler, R. R., "Determination of Atmospheric Diffusion Parameters," *Atmospheric Environment*, Vol. 10, 99-105 (1976).

NFPA, *Life Safety Code*, NFPA 101, National Fire Protection Association, Quincy, MA (1988).

Perry, R. H., and C. H. Chilton, *Chemical Engineers' Handbook*, 5th ed., McGraw-Hill Book Company, New York, NY (1973).

Thienes, C., and T. J. Haley, *Clinical Toxicology*, 5th ed., Lea and Feibiger, Philadelphia, PA (1972).

Turner, D. B., *Workbook of Atmospheric Dispersion Estimates*, NTIS No. PB191482, U. S. Department of Health, Education, and Welfare, Washington, DC (1970).

**Table 7.4. Dose (rem) resulting from external exposure to 100,000 rem/h (28 rem/s)
source (100,000 rem/h @ 1 m)**

Distance (m)

Time	1	2	5	10	20	50	100
10 s	278	69	11	2.8	.7	.1	2.7×10^{-2}
30 s	833	208	33	8.3	2.1	.3	8.3×10^{-2}
1 min	1.6×10^3	417	66	17	4.2	.7	1.7×10^{-1}
5 min	8.3×10^3	2.1×10^3	333	83	21	3.3	8.3×10^{-1}
10 min	1.7×10^4	4.2×10^3	667	167	42	6.7	1.7
30 min	5.0×10^4	1.3×10^4	2.0×10^3	333	125	20	5
1 h	1.0×10^5	2.5×10^4	4.0×10^3	667	250	40	10

Note: 200 rem - onset of lethality
400 rem - LD₅₀