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ASSESSMENT OF ALTERNATIVES TO ROUTINE OPERATION OF THE FLUIDIZED BED INCINERATOR

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Prepared by
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1.0 PURPOSE OF THE STUDY

The proposed action at the Rocky Flats Plant (RFP) considered in this study is the routine operation of the Fluidized Bed Incinerator (FBI) for treatment of mixed wastes, i.e., wastes comprising both low-level radioactive (containing up to 100 nanocuries of transuranic alpha activity per gram) and chemically hazardous components. Following successful operation of the FBI during the Trial Burn, a Resource Conservation and Recovery Act (RCRA) Part B permit may be issued to allow the incineration of both solid and liquid mixed wastes generated at the RFP. The purpose of the incinerator operation is to substantially reduce the volume of mixed wastes needing land disposal. Based on its hazardous chemical content, the ash would then be disposed of at either a licensed low-level radioactive waste site or a mixed waste site.

To conduct an environmental assessment of routine operation of the FBI that is consistent with the requirements of the National Environmental Policy Act, alternatives to the proposed action must be considered. The purpose of this study is to evaluate the waste management options available at the RFP, including the no-action alternative or continued onsite storage of mixed waste. Each alternative is discussed in terms of its effect on RFP programs and operations, the cost for implementation, and the associated health effects. Also discussed are the potential releases and health effects calculated for abnormal events (i.e., natural phenomenon and operational) associated with each alternative.

The methods used to calculate the health effects associated with the radiological and nonradiological hazardous chemical releases are detailed in Appendix B and D of the "Draft Environmental Assessment for the Fluidized Bed Incinerator Trial Burn at the Rocky Flats Plant," (LATA, 1987). Details of the selection of the abnormal events and analysis methods are found in Appendix C of that Environmental Assessment.

2.0 WASTE DESCRIPTION

The FBI will be used to incinerate liquid and solid mixed wastes generated at the RFP. The liquid wastes are composed of various organic solvents, degreasing fluids, lubricating and cutting oils, and various laboratory chemical reagents. The solid waste consists primarily of paper, latex, and small amounts of various other combustible and noncombustible process wastes (Weston, 1987). The volume of liquid waste currently stored onsite is 20,000 gal and is accumulating at a rate of about 1,000 gal/mo. Solid waste already accumulated onsite amounts to about 1,500 cu ft and accumulates at a rate of about 100 cu ft/mo. Table 2-1 shows the composition of the solid and liquid wastes that was the basis for analysis of each alternative in this study.

Update per Barbara Greer

TABLE 2-1

SOLID AND LIQUID WASTE COMPOSITION FOR ANALYSIS OF ALTERNATIVES TO THE FLUIDIZED BED INCINERATOR

Solid Wastes	Weight Percent of Solid Wastes	Liquid Wastes	Weight Percent of Liquid Waste
Solvents	1.9	Petroleum Oil/Water Mixture	80.0
Freon 113	0.4	Carbon Tetrachloride	5.0
Teflon	0.2	Xylene	3.0
Polyvinyl Chloride	2.2	Pyridine	3.0
Paper	58.4	Toluene	3.0
Polyethylene	18.0	Methanol	3.0
Inert Solids (floor sweepings)	18.9	Other (traces of chemicals and solvents)	3.0
Plutonium[a]	0.00014	Plutonium[a]	0.00014
Uranium[b]	0.2	Uranium	<0.01

a. Based on 100 nanocuries of transuranic alpha activity per gram of waste.
b. Maximum amount; typically much less.

To evaluate the impacts of waste generation and the effects of possible waste management alternatives, it was assumed that implementation would begin in 1990. Projected waste quantities are approximately 4,000 ft^3 of solid waste and 45,000 gal of liquid waste.

3.0 DESCRIPTION OF ALTERNATIVES TO ROUTINE OPERATION OF THE FLUIDIZED BED INCINERATOR

The alternatives to routine FBI operation considered in this study are

1. No Action: Continued onsite storage of waste. At the RFP, the FBI would not be used, but waste generation would continue at the same rate.

2. Discontinue Waste Generation: Waste generation would cease, requiring closure of the RFP.

3. Offsite Waste Treatment and/or Disposal: Waste would be transported offsite for treatment and ultimate disposal.

4. Use of Alternate Technologies: Technologies other than the FBI would be used at the RFP for treatment and/or disposal of mixed wastes.

Emphasize that health effect evaluation come first.

Each of the alternatives is assessed for its effect on programmatic operations and costs at the RFP. ~~Also,~~ The health effects resulting from implementation of each alternative were assessed for the public and for RFP personnel. The evaluation of the health effects of the alternatives includes both expected effects from routine operations and potential effects from abnormal events, which are discussed in Section 4.0. The exposure from nonradiological hazardous chemical releases was calculated for a maximally exposed individual. Maximum individual and population doses for the population within 80 km (50 mi.) of the RFP were calculated for those alternatives that involve routine releases of radionuclides. The maximally exposed individual is a hypothetical individual who resides at the RFP boundary at the point of maximum ground-level concentration where the maximum exposure would be received. The exposure of this individual to hazardous chemicals is calculated using the method described in Appendix D: "Nonradiological Health Effects" of the "Draft Environmental Assessment for the Fluidized Bed Incinerator Trial Burn at the Rocky Flats Plant" (LATA, 1987). Dose calculations for radiological releases were performed using the Environmental Protection Agency (EPA) methodology, which is detailed in Appendix B: "Methods Used to Calculate Environmental Effects" (LATA, 1987).

Federal, state, regional, and local land use plans and policies were reviewed to determine how they might affect the alternatives. Current land use plans and policies would not prohibit the consideration of any of the proposed alternatives.

3.1 Alternative 1 – No Action

Under the no-action alternative, present RFP operations would continue unchanged. The mixed wastes currently stored onsite and any waste generated in the future would be stored at the RFP. This alternative could be called the store-and-delay alternative because the waste would still need to be treated and disposed of at some future time in an environmentally acceptable manner, either by operation of the FBI when it is permitted, or by use of an alternative process such as those evaluated in this study.

3.1.1 Programmatic and Operational Effects

At this time there are no treatment or disposal facilities permitted by either a state environmental agency or the EPA available to handle the mixed wastes generated at the RFP. Therefore, storage on the RFP site would need to continue until final disposition of the mixed waste was determined.

Over 20,000 gal of liquid mixed wastes and 1,500 ft^3 of solid mixed wastes are currently stored at the RFP awaiting treatment and ultimate disposal. Liquid mixed wastes are accumulating at the rate of approximately 1,000 gal/mo, and existing storage tanks are expected to be filled by early 1988. After that time, the waste will be collected in 55-gal drums, which will be stored in cargo containers. Two sizes of cargo containers will be used, one that will hold forty 55-gal drums and one that will hold eighteen drums. These storage units, comparable to large trailer beds, have a steel frame, corrugated metal housing, and either a heavy wooden or steel plate floor. An area will be established for the collection and storage of both the liquid and solid mixed wastes.

Solid mixed wastes, also collected in 55-gal drums, will be brought to a specified storage area and placed in racks. At the present time, all plutonium-contaminated wastes are stored in Building 776, while the uranium-contaminated solid wastes are stored in the open. At some future time, it may also be necessary to store plutonium-contaminated solid wastes outside.

Storage of hazardous waste is regulated by the Colorado Department of Health (CDH) and the EPA. Hazardous waste that is stored for more than 90 days must be stored in a facility that has a RCRA Part B permit. Therefore, under the no-action alternative a RCRA permit would be needed prior to storing hazardous waste in a new storage facility for more than 90 days.

The continued storage of wastes onsite would require additional personnel for handling, transporting, and monitoring the waste, and for custodial housekeeping, maintenance, and record keeping.

3.1.2 Cost

At the current rate of waste generation, all the solid and liquid wastes generated annually would fill over 400 55-gal drums. Allowing 9 ft^2 of storage area per drum (2-ft diameter), the storage space required would be 3,700 ft^2, or less than one-tenth of an acre. Existing space would most probably be adequate for several years.

If the work force ~~was~~ ~~est~~imated for packaging, measuring each drum in a drum counter, ~~paperwork~~ records keeping (logs, etc.), transporting from the building dock to the storage area, unloading drums and placing them in storage, ongoing monitoring of the storage area, and necessary housekeeping and maintenance; the labor costs would approach \$100/ft^3 of waste, or \$250,000 to \$300,000/yr.

3.1.3 Requirements for Management of Chemically Hazardous Waste

When placed in storage, chemically hazardous waste must be stored in accordance with the CDH rules and regulations (CDH, 1985). In addition, containers used to store and transport hazardous waste must comply with the specifications of the Department of Transportation hazardous materials regulations (49 CFR 171-173) (DOT, 1983a, b, and c). These regulations, together with prudent management to protect the environment from contamination, require a number of precautions before and during the storage and handling of the hazardous waste. These precautions may require the construction of additional facilities, the employment of personnel, and a number of other actions. Some examples of the necessary precautions include:

- employee training,
- inspection procedures,

- secondary containment for the storage areas to contain any spilled liquids,
- provision and maintenance of equipment to clean up spills,
- sufficient security for storage areas, and
- keeping records and meeting reporting requirements.

3.1.4 Health Effects

Selection of the no-action alternative would result in health effects from two sources. First, this alternative would result in minor effects caused by prolonged storage of increasing amounts of mixed wastes. Second, the no-action alternative would necessitate the implementation, at a later date, of some method of treatment and/or disposal that would cause effects associated with that method.

3.1.4.1 Releases Associated with Storage

There are no expected releases during storage; the only releases would be caused by abnormal events that result in the loss of tank or drum integrity. The probability of a spill within a properly designed and operated storage facility is small, if the mixed waste has been packaged and stored according to CDH and EPA regulations. However, the risk of an accident occurring increases with the volume of waste stored and the length of storage. Emissions could result from fires, explosions, leaks, or spills during handling.

Releases would be gaseous, liquid, and solid materials. Gaseous emissions would result from volatilization of spilled or leaked hazardous chemicals and redrumming of deteriorated drums. Solid releases would include solid waste released from drums, the deteriorated or leaky drums themselves, sorbent materials used to clean up spills, and other materials (such as soil) contaminated as a result of spills or leaks. Water used to extinguish fires and storm water from diked areas could contain traces of low-level radioactive materials and hazardous chemicals from leaked or spilled waste. Liquid waste could be released from failed drums.

The emissions from the no-action alternative would not be significant unless a major spill or leak occurred. However, treatment and/or disposal of these stored wastes must ultimately occur; emissions from a treatment and/or disposal operation would only be postponed and would depend on the method selected.

3.1.4.2 Health Effects of Releases

The no-action alternative was examined for potential impacts on the environment. No health effects are expected from storage unless a major spill or leak occurs. It is assumed that the mixed waste is stored in accordance with all applicable regulations. Gaseous emissions would enter the atmosphere when minor leaks or spills and redrumming occur. These emissions would have an insignificant impact on air quality. However, in the case of a major spill, dispersal of the hazardous constituents of the mixed waste could adversely affect air quality.

Depending on the anticipated length of storage, a regular program of facility maintenance with transfer of contaminated material from drums of questionable integrity to new drums would be required. Transfer would take place in an enclosed area with precautions such as curbs or dikes and a spill control program to prevent an accident from affecting areas outside the building where the material is stored.

The potential for exposure of RFP workers to radionuclides and hazardous chemicals from the no-action alternative would depend on the frequency and severity of spills, the frequency of redrumming, and the personal protective equipment and mitigative measures employed. Occupational health and safety procedures are followed at the RFP to ensure that occupational exposures are kept within acceptable limits.

Public health effects from the no-action alternative would be insignificant, except perhaps in the case of a major spill. A major spill could expose the public to increased doses of the radionuclides and hazardous chemicals released; the effects of such exposures are addressed in Section 4.0.

3.1.5 Summary of Impacts of the No-Action Alternative

The health effects from operation of the no-action alternative would be negligible. Ultimately, however, treatment and disposal of the mixed wastes must occur and the associated effects would depend on the treatment and/or disposal methods used. Thus the no-action alternative would not avoid health effects but merely delay those effects while increasing the risk of accidental release from storage and the effects associated with such a release.

3.2 Alternative 2 - Discontinue Waste Generation

Under the second alternative, discontinue waste generation, operations at the RFP would cease, preventing the plant from meeting its primary mission. The primary mission at the RFP is fabrication and assembly of nuclear weapons components from plutonium, beryllium, uranium, and stainless steel. The RFP is also responsible for plutonium recovery.

Operations involving uranium and plutonium generate solid and liquid wastes. For example, solids, such as Kimwipes®, polyethylene, and polyvinyl chloride, accumulate minute amounts of the radionuclides present during cleaning, polishing, and degreasing activities. If hazardous solvents are used for cleaning, the waste material becomes a mixed waste containing both radionuclides and hazardous chemicals. Since cleaning is a necessary maintenance procedure at the RFP, the plant cannot operate without generating mixed waste.

Efforts are being made to improve handling techniques so that the amount of waste generated will be reduced. Despite the progress made in this area, it is impossible to eliminate completely the generation of all waste during routine operations at the RFP. Even if the elimination of new waste were possible, the accumulated waste stored onsite would require disposal.

In July 1986, the State of Colorado and the Department of Energy (DOE) signed a consent agreement leading to an aggressive compliance schedule. The delay in licensing the FBI for processing mixed waste, however, is retarding this effort and extending the time necessary to bring the RFP into compliance with all EPA regulations for waste management.

The alternative to discontinue waste generation is not reasonable under any conditions short of suspending operations at the RFP. Even permanent closure would add to the amount of mixed waste requiring treatment and/or disposal. Nor would the alternative solve the problem of currently stored mixed waste. The health effects of this alternative are the same as for Alternative 1 - No Action for waste already generated.

3.3 Alternative 3 - Offsite Waste Treatment and/or Disposal

The feasibility of transporting mixed waste offsite for treatment and/or disposal depends on the risks involved in shipment and the criteria for transportation, treatment, and disposal of waste. If the mixed waste were distributed among 55-gal drums for transport offsite, the backlogged solid waste would require approximately 600 drums. In addition, about 35 drums/mo would be required for the liquid and solid waste as it continues to be generated.

Transportation by truck is assumed to be the most likely method of transport because of the location of the RFP. The average load of a semitrailer truck is 80 drums. Thus the waste backlog of 600 drums would require approximately eight truck shipments. An additional six shipments/yr would be required for transporting waste offsite as it accumulates. To evaluate the hazard associated with transporting this relatively small volume of waste, data on hazardous material releases during transport were reviewed (OTA, 1986). Transport on highways is considered to have the greatest probability for accidents of all means of transportation (air, water, rail).

There were 1,171 incidents where hazardous materials were released during highway transport accidents in Colorado between 1976-1984, or approximately 146 incidents/yr. However, in the entire United States from 1971 to 1984, there were a total of only 2,552 transportation accidents (all modes) involving low-specific-activity radioactive materials; material releases occurred from only 67 packages. The total number of hazardous material shipments by truck within the Pacific Southwest states of Colorado, New Mexico, Arizona, Utah, Nevada, and California amounted to approximately 80,000 shipments in 1977. The small number of waste shipments expected from the RFP (the initial eight shipments plus an additional six shipments/yr) would be negligible compared to the large number of shipments in the region. Therefore, this small number of shipments is not expected to add appreciably to the risk of a release from hazardous materials transported by truck in Colorado.

There are, however, policy and regulatory barriers to shipping waste offsite without prior treatment. Department of Energy practice does not allow shipment of radioactive material in liquid form; consequently, liquid waste would have to be solidified before transport. A recent EPA rule requires that hazardous waste (solid or liquid) containing more than 1,000 mg/kg of specific halogenated-organic compounds (such as the solvents in the RFP mixed waste) must be incinerated, and such wastes may not be disposed of by land burial (EPA, 1987). Solidification of the RFP mixed waste, as required by DOE, would preclude its incineration and land disposal. Consequently, no treatment or disposal site could accept this waste. In fact there is no currently EPA-permitted site for disposal of mixed waste.

The alternative of transporting waste offsite would pose a negligible risk to health in the RFP area because of the small number of shipments involved. The waste form and the policy and regulatory requirements for its treatment and/or disposal preclude offsite shipment. Can u think of another word that connotes less of an official documented policy?

3.4 Alternative 4 - Alternate Technologies

Several alternative technologies were considered, and the factors used in comparing the technologies (as shown in Table 3-1) are listed below:

- ability to process both liquid and solid waste,
- flexibility in feed rates,
- primary and secondary residues generated,
- volume of offgas to be treated,
- reaction products anticipated,
- ease of confinement of the system, and
- adaptability to existing services and area.

The two technologies discussed in detail are an infrared volume reduction system and a molten salt destruction process. These were chosen based on their adaptability to the existing system, their ability to process both liquid and solid feed streams, and demonstrated capability to process chlorinated organic feeds with acceptable effluents. The other alternatives considered are discussed briefly; however, these technologies are not considered to be viable processes at this time.

3.4.1 Infrared Volume Reduction System

The infrared volume reduction system evaluated for RFP mixed waste is the Smeiser-Hobbs Infra Red Company (SHIRCO) incinerator. This incinerator features a

TABLE 3-1

COMPARISON OF ALTERNATIVES FOR MIXED WASTE PROCESSING

Technology[a]	Type	Heat Source	Feed Limitations	Offgas Treatment	Other Wastes Generated	Compatibility with Nuclear Systems	Adaptability to Existing Facility and Application	Estimated Cost ($ Millions)
Infrared (SHIRCO)	Preshred solids or liquid/solid mix	Electric, Infrared	Pregrinding, mixing CaO addition	Afterburner, filter	$CaCl_2$ and CaF_2 in ash, HEPAs, low volume offgas	Unit in service at SRP[b]	Good; use existing feed system and offgas treatment	1.7
Molten Salt (Rockwell)	Solids, liquids, or mix; cofeed or separate	Electric air, Preheat	Process limited to low ash, low water, waste	Filters (all reactions in primary vessel)	NaCl and NaF in ash, HEPAs, high volume offgas	No record but easily adaptable	Very good; similar to FBI	1.0
Rotary Kiln (Industronics, PEDCO)	Solids, liquids, or mix; cofeed or separate	Fuel oil	Practically no limitations	Afterburner and/or scrubber, filters	Ash, slag, firebrick, Scrubber liquid, HEPAs, high volume offgas	Potential offgas leakage around drum used at LLNL[c]	Fair; equipment is bulky, could overheat existing process area	2.5
Waste Agglomeration	Liquids/solids premixed	Electric resistance	Fine pregrinding of solids required	Afterburner, filters	Unreacted binder, pellet fines, HEPAs, low volume offgas	Tested by PNWL[d] with simulated wastes	Good; similar to SHIRCO	1.4
Molten Metal/ Molten Glass (Westinghouse)	Preshred solids or liquid/solids	Electric resistance	Limited to low ash material	Afterburner, scrubber, filters	Ash, firebrick, vitrified slag, scrubber liquid, HEPAs, high volume offgas	No record; development required	Fair; existing prototype oversized; rated 5 tons/day	7.5
Controlled Air Incineration	Primarily solids, liquids injected separately	Natural gas	Solids are prepackaged, ram-fed into firebox	Afterburner, filters, scrubber	Ash, slag, large clinkers, scrubber liquid, HEPAs, high volume offgas	Unit in service at LANL[e] currently undergoing renovation	Fair; good space utilization; capacity limited	2.0
Plasma Arc	Liquids only	Electric plasma torch	Liquids only	No record; relatively new technology	NaOH scrubber, gas/water separator, filters	H_2, Co, N_2 scrubber liquid, carbon	Poor; not able to treat solids	5.0

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a Membrane separation and chemical digestion were considered However, membrane separation is not an acceptable alternative to the FBI because it has no volume reduction or chemical destruction capability. Chemical destruction technology is not being developed: it was not well received by potential users because of the hazards associated with handling hazardous chemicals.

b SRP = Savannah River Plant.

c LLNL = Lawrence Livermore National Laboratory

d PNWL = Pacific Northwest Laboratory.

e LANL = Los Alamos National Laboratory.

slowly moving conveyor belt that uses electric infrared heating elements to burn solid wastes and sludges (liquid wastes mixed with solids). A SHIRCO furnace with the same capacity as the existing FBI would consist of a series of flanged rectangular boxes, 3-4 ft wide, that are bolted together to form an enclosed insulated housing approximately 20 ft long. Enclosed in the housing, a woven belt of alloy metal conveys the waste material under a roof-mounted heating element where it is progressively dried, heated, and ignited.

The SHIRCO unit is insulated by a light ceramic fiber blanket instead of the heavy firebrick required by conventional incinerators. The unit is easy to construct because of the light weight insulation and modular design. The insulation has a long service life because the conveyor belt prevents contact between the waste material and the refractory surface. The unit operates within a moderate range of temperatures (i.e., 1,350-1,400°F). It does not use fossil fuels for the primary heat source and produces little offgas.

The SHIRCO unit could be installed in the space currently occupied by the FBI and could also use the existing storage, pretreatment, and offgas treatment systems. In order to process liquid wastes, however, it would be necessary to construct other pretreatment equipment to produce a thick sludge consisting of measured amounts of liquid wastes, finely ground solids, and a caustic additive to neutralize acid.

Since installing its first sewage sludge incinerator in 1975, SHIRCO has been successful in the field of incineration, carbon regeneration, and chemical processing. SHIRCO has installed a unit at the DOE Savannah River Plant that is now incinerating low-level wastes.

3.4.1.1 Programmatic and Operational Effects

Complete installation of the SHIRCO furnace involves engineering and design of the unit; removal of the FBI; and fabrication, installation, testing, and startup of the SHIRCO unit. Installation would take between 30 and 36 months followed by a trial burn and permitting. Waste would continue to accumulate during the 3-yr installation period, and the costs and risks associated with waste storage would increase.

3.4.1.2 Cost

The total cost of a SHIRCO unit installed and ready for a trial burn (i.e., in the same condition as the existing FBI) is approximately $1.7 million. This figure does not include the cost of storing waste over 3 yr, nor does it include the cost of operating the SHIRCO 3 shifts/day for a year to process the backlog of accumulated waste.

3.4.1.3 Health Effects

Nonradiological Effects

Nonradiological emissions from routine operation of the SHIRCO incinerator depend on the type of waste material incinerated. Based on typical RFP waste composition (Table 2-1), release rates for possible emissions were estimated, and associated health effects were calculated (Table 3-2). The major releases would be products of incomplete combustion in gaseous form that would be released from the stack during operation of the incinerator. These emissions are expected to be very similar to those produced during other forms of incineration, including the FBI. However, no actual emissions data were available from SHIRCO.

In addition to the gaseous emissions, some particulates might be released to the atmosphere. It is assumed that some polychlorinated dibenzodioxins (PCDDs) would be absorbed onto these particles because PCDD emissions have been associated with various incineration processes (Rappe et al., 1986; Tong and Karasek, 1986). The SHIRCO incinerator includes an afterburner, or secondary combustion chamber. The estimated PCDD emissions (Table 3-3) were calculated based on data from other incinerators with this configuration, because it results in lower PCDD emissions than in the absence of the secondary combustion chamber (Cavallaro et al., 1987).

The total lifetime exposure to emissions from the SHIRCO infrared incinerator are not expected to present a health risk to the public. The air concentration of hazardous chemicals that may result from operation of the SHIRCO incinerator are expected to be extremely low (Table 3-2). Comparison with threshold limit values (TLVs) show air concentrations to be one hundred thousand to more than one million times less than these guidelines (TLVs are promulgated for protection of worker health and are presented only for comparison). The carcinogenic risk for gaseous emissions from the

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TABLE 3-2

ESTIMATED NONRADIOLOGICAL EMISSIONS FROM THE SHIRCO INFRARED INCINERATOR AND HEALTH RISKS FOR THE MAXIMALLY EXPOSED INDIVIDUAL[a]

Hazardous Chemical	Release Rate (mg/hr)	Air Concentration (mg/m^3)	Air Concentration (ppm)	Total In Body[b] (mg/kg/d)	TLV Guide[c] (ppm)	Cancer Risk[d]
Carbon Tetrachloride	1.8×10^{2}	2.6×10^{-8}	4.1×10^{-9}	2.4×10^{-9}	2.0	3.1×10^{-10}
Phosgene	4.1×10^{2}	6.0×10^{-8}	1.4×10^{-8}	5.6×10^{-9}	0.1	0
Hydrogen Chloride	4.8×10^{4}	6.9×10^{-6}	4.9×10^{-6}	6.5×10^{-7}	5.0	0
Vinyl Chloride	1.8×10^{2}	2.6×10^{-8}	1.0×10^{-8}	2.5×10^{-9}	5.0	6.1×10^{-11}
Freon 113	8.2×10^{1}	1.2×10^{-8}	1.5×10^{-9}	1.1×10^{-9}	1,000.0	0
Hydrogen Fluoride	5.2×10^{2}	7.5×10^{-8}	1.1×10^{-7}	7.0×10^{-9}	3.0	0
Total						3.7×10^{-10}

a. The hypothetical individual who is assumed to reside at the RFP boundary at the point of maximum ground level concentration, where the maximum exposure would be received.

b. Total lifetime exposure to a 70-kg adult male via inhalation was calculated based on 2,000 hr/yr of operation for 70 yr.

c. Threshold Limit Values (TLVs) are promulgated for protection of worker health by the American Conference of Governmental Industrial Hygienists (NIOSH, 1987). While these are not applicable to environmental exposures, they are presented here for comparison.

d. The cancer risk is expressed as the probability of developing cancer at the calculated exposure (dose) level.

TABLE 3-3

ESTIMATED POLYCHLORINATED DIBENZODIOXIN EMISSIONS FROM THE SHIRCO INFRARED INCINERATOR AND HEALTH RISKS FOR THE MAXIMALLY EXPOSED INDIVIDUAL[a]

Polychlorinated Dibenzodioxin (PCDD) Congeners[b]	Release Rate (mg/hr)	Air Concentration (mg/m^3)	Total in Body[c] (mg/kg/d)	Cancer Risk
Tetra-CDD	1.3×10^{-3}	1.8×10^{-13}	3.7×10^{-11}	5.8×10^{-7}
Penta-CDD	8.7×10^{-3}	1.2×10^{-12}	2.5×10^{-10}	1.9×10^{-7}
Hexa-CDD	5.6×10^{-3}	7.7×10^{-13}	1.6×10^{-10}	1.0×10^{-8}
Hepta-CDD	5.1×10^{-3}	7.0×10^{-13}	1.5×10^{-10}	2.3×10^{-10}
Octa-CDD	3.4×10^{-3}	4.7×10^{-13}	9.7×10^{-11}	1.5×10^{-8}
2,3,7,8-Tetra-CDD	1.0×10^{-4}	1.4×10^{-14}	2.8×10^{-12}	4.4×10^{-7}
2,3,7,8-Penta-CDD	1.2×10^{-3}	1.7×10^{-13}	3.4×10^{-11}	2.7×10^{-6}
2,3,7,8-Hexa-CDD	1.9×10^{-3}	$2/7 \times 10^{-13}$	5.4×10^{-11}	3.4×10^{-7}
2,3,7,8-Hepta-CDD	6.9×10^{-3}	9.5×10^{-13}	2.0×10^{-11}	3.1×10^{-8}
TOTAL				4.3×10^{-6}

a. This hypothetical individual resides at the RFP boundary at the point of maximum ground level concentration where the maximum exposure is received.

b. The composition of PCDD congeners was estimated based on Cavallaro et al., 1987 and Suter-Hofmann and Schlatter, 1986. The 2,3,7,8-congeners were calculated separately because they are believed to be the most toxic (Bellin et al., 1987).

c. The total lifetime dose was calculated based on the conservative assumption that all meat, milk, and vegetables consumed by the maximally exposed individual were grown on a plot adjacent to the RFP boundary. The exposure, via ingestion of these foodstuffs and inhalation of particulates, was calculated for a 70-kg adult male following 2,000 hrs/yr of operation for 70 yr.

d. The cancer risk is expressed as the probability of developing cancer at the calculated exposure (dose) level.

SHIRCO incinerator is approximately four in ten billion. The carcinogenic risk associated with PCDDs is much higher but is still less than five in one million. The estimated emissions of PCDDs are expected to be in the microgram range, but these compounds are considered to be very potent carcinogens (Hiremath et al., 1986). The risk calculated for PCDDs is based on the conservative assumption that all vegetables, meat, and milk consumed by the maximally exposed individual are grown on a plot adjacent to the RFP boundary. ~~Therefore,~~ the risk to the members of the public would be lower than that shown in Table 3-3. This is the same assumption used for other alternatives and while leading to an overestimate of risk for all alternatives does allow for comparison among alternatives.

Radiological Effects

Radiological releases from the routine operation of the SHIRCO unit would consist of very small quantities of plutonium (primarily Pu-239) and uranium (primarily U-238). Radiological doses to offsite locations were calculated for the maximally exposed individual located at the site boundary and for the wind sector that most often is downwind from the RFP.

The doses result primarily from inhalation of Pu-239 and U-238. The effective dose equivalent to the maximally exposed individual is calculated as 6.2×10^{-6} rem/yr. This dose is much lower than the DOE guideline 5480.1 of 0.01 rem/yr (DOE, 1981). The whole body dose equivalent to the maximally exposed individual is 5.4×10^{-6} rem/yr as compared to the EPA standard of 0.025 rem/yr (EPA, 1986). Background radiation results in an annual dose of 0.26 rem to an individual (Rockwell, 1987). The doses to the maximally exposed individual are slightly more than one millionth of those received from background radiation. Doses to individual organs would be several orders of magnitude less than the applicable EPA standard of 0.075 rem/yr (EPA, 1986).

A population dose of 0.21 man-rem/yr was calculated for the sector containing the Denver metropolitan area. This very low dose would produce no detectable health effects in the exposed population and would be indistinguishable from the effects of the natural background radiation (2.0×10^5 man-rem/yr). No adverse health effects are expected from operational radiological releases from the SHIRCO unit.

3.4.2 Molten Salt Destruction Process

This combustion process uses molten salt, usually sodium carbonate, as a heat transfer and reaction medium to convert (oxidize) waste to carbon dioxide and water. In the process, the waste material is dispersed into a stream of air and the mixture is injected beneath the surface of the molten sodium carbonate. The bed is designed to operate safely and efficiently in the range of 800-1000°C. Combustion byproducts containing elements such as phosphorus, sulfur, arsenic, and chloride react with the sodium carbonate and are retained in the melt as inorganic salts rather than being released to the atmosphere as volatile gases. The combustion products gradually accumulate in the molten salt, changing its characteristics. The concentration is controlled by drawing off a portion of the melt and replacing the volume removed with fresh sodium carbonate. The solidified melt, or slag, becomes the solid waste product.

With minor modifications to the existing feed preparation systems of the FBI, either solid or liquid wastes can be fed into the molten salt combustor. Although the original design was keyed to the destruction of liquid wastes containing hazardous chemicals, the molten salt unit can also handle shredded solids.

The offgas from the molten salt unit could be treated through the same offgas train presently used in the FBI system, i.e., the sintered metal filters, heat exchanger, two stages of process high-efficiency particulate air (HEPA) filtration, and final filtration through the four-stage HEPA filter system.

Pilot scale demonstrations have been conducted on chemical warfare agents, pesticides, chemical wastes, and combustible wastes from nuclear plants (Yosim et al., 1979). Tests of offgas have demonstrated destruction removal efficiencies (DREs) of greater than 99.9999% for polychlorinated biphenyls (PCBs), greater than 99.999% for trichloroethane and chloroform, and greater than 99.99999% for chemical warfare agents. The concentrations of hydrochloric acid in the offgas during destruction of wastes containing organic chlorides was consistently less than 5 ppm.

Experiments that emphasized the treatment of chlorinated hydrocarbons in a pilot scale (250 lb/hr) molten salt system were conducted with the support of the EPA (Johanson et al., 1982). Hexachlorobenzene, as a substitute for PCBs, and chlordane, as an example of liquid organic chlorinated waste, were used as feed to demonstrate the effective destruction of both. Test results demonstrated DREs more than adequate to meet RCRA criteria.

3.4.2.1 Programmatic and Operational Effects

The molten salt unit could be installed in the same building as the FBI and could take advantage of several of the support systems with minor modifications. The design, installation, and startup would take a minimum of 3 yr, however; and a trial burn would be required to obtain a permit to process mixed wastes. Meanwhile, there would be an accumulation of an additional three years of generated waste, with the associated costs and risks inherent with onsite storage.

3.4.2.2 Cost

The cost of engineering design, construction, and startup of the molten salt system would be approximately $1 million. The operating costs of a system are based on handling both the current generation of wastes (1 shift/day) and the backlog of stored wastes (an additional 2 shifts/day). The cost would be approximately $1 million/yr/shift. Within 1 yr, the backlog should be eliminated and the operation of the molten salt unit reduced to 1 shift/day.

3.4.2.3 Health Effects

Nonradiological Effects

Similar to the nonradiological emissions from the SHIRCO incinerator, emissions from routine operation of the molten salt unit would depend on the type of waste material incinerated. Based on typical RFP waste composition, release rates for possible emissions were estimated, and associated health effects were calculated (Table 3-4).

Although the molten salt unit does not include an afterburner, the long residence time (the time the waste material is present in the combustion chamber), the high operating temperature of the unit, and the molten salt in which the waste is oxidized are expected to reduce the PCDD emissions to levels at least as low as those of the SHIRCO infrared incinerator. Therefore, the PCDD levels presented in Table 3-3 are expected to represent the upper boundary of PCDD emissions from the molten salt unit as well.

The total lifetime exposures to emissions from the molten salt unit are not expected to present a health risk to the public. The air concentrations are well below the TLVs, and the carcinogenic risk is less than two in one billion for the volatile gaseous emissions. The carcinogenic risk from PCDDs is estimated to be similar to that for the SHIRCO unit (Table 3-3).

Radiological Effects

The doses result primarily from inhalation of Pu-239 and U-238. The effective dose equivalent to the maximally exposed individual is calculated as 6.2×10^{-6} rem/yr. This dose is much lower than the DOE guideline 5480.1 of 0.01 rem/yr (DOE, 1981). The

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TABLE 3-4

ESTIMATED NONRADIOLOGICAL EMISSIONS FROM THE MOLTEN SALT DESTRUCTION UNIT AND HEALTH RISKS FOR THE MAXIMALLY EXPOSED INDIVIDUAL[a]

Hazardous Chemical	Release Rate (mg/hr)	Air Concentration (mg/m^3)	Air Concentration (ppm)	Total In Body[b] (mg/kg/d)	TLV Guide[c] (ppm)	Cancer Risk[d]
Carbon Tetrachloride	5.9×10^{2}	8.5×10^{-8}	1.4×10^{-8}	8.0×10^{-9}	2.0	1.0×10^{-9}
Phosgene	3.6×10^{2}	5.2×10^{-8}	1.3×10^{-8}	4.9×10^{-9}	0.1	0
Hydrogen Chloride	1.9×10^{3}	2.7×10^{-7}	1.9×10^{-7}	2.6×10^{-8}	5.0	0
Hydrogen Fluoride	1.8×10^{2}	2.6×10^{-8}	3.9×10^{-8}	2.4×10^{-9}	3.0	0
Trichloroethane	6.4×10^{2}	9.2×10^{-8}	1.7×10^{-8}	8.7×10^{-9}	350.0	5.0×10^{-10}
Freon 113	2.7×10^{2}	3.9×10^{-8}	5.1×10^{-9}	3.7×10^{-9}	1,000.0	0
Total						1.5×10^{-9}

a. The hypothetical individual who is assumed to reside at the RFP boundary at the point of maximum ground level concentration, where the maximum exposure would be received.

b. Total lifetime exposure to a 70-kg adult male via inhalation was calculated based on 2,000 hr/yr of operation for 70 yr.

c. Threshold Limit Values (TLVs) are promulgated for protection of worker health by the American Conference of Governmental Industrial Hygienists (NIOSH, 1987). While these are not applicable to environmental exposures, they are presented here for comparison.

d. The cancer risk is expressed as the probability of developing cancer at the calculated exposure (dose) level.

whole body dose equivalent to the maximally exposed individual is 5.4 x 10^{-6} rem/yr as compared to the EPA standard of 0.025 rem/yr (EPA, 1986). Background radiation results in an annual dose of 0.26 rem to an individual (Rockwell, 1987). The doses to the maximally exposed individual are slightly more than one millionth of those received from background radiation. Doses to individual organs would be several orders of magnitude less than the applicable EPA standard of 0.075 rem/yr (EPA, 1986).

A population dose of 0.21 man-rem/yr was calculated for the section containing the Denver metropolitan area. This very low dose would produce no health effects in the exposed population and would be indistinguishable from the effects of the natural background radiation (2.0 x 10^5 man-rem/yr). No adverse health effects are expected from the radiological releases from the molten salt destruction process.

3.4.3 Status of Other Technologies

This section contains a brief discussion of several waste treatment technologies that were investigated as possible alternatives to the FBI, but were not developed quantitatively. In each case, the technology either does not meet the needs of the RFP or has not been adequately proven for treatment of waste from the nuclear industry.

3.4.3.1 Rotary Kiln

Traditional rotary kilns contain a primary oxidation chamber and a secondary oxidation (afterburner) chamber to complete oxidation of the wastes. As the wastes pass through the cylindrical, refractory-lined kiln, the reaction in the 1000°-1200°C range converts all the waste to ash and offgas. Complete oxidation results in an offgas composed primarily of carbon dioxide, water, and hydrogen chloride, which is then treated by a traditional offgas scrubber and filtration system.

Both solid and liquid feed streams can be processed in this equipment, but there are several disadvantages in using this equipment for processing mixed wastes, such as:

- the firebrick lining contributes a sizable secondary waste stream,
- confinement would be difficult because of the basic design,
- offgas treatment would require caustic scrubbing, and
- optimum operation requires a significant bed depth.

3.4.3.2 Waste Agglomeration

Waste agglomeration reduces the volume of premixed liquid and solid wastes and then immobilizes them in ceramic agglomerates. Mixing is accomplished in a pin-type pellet mill that continuously produces small, spheroidal agglomerates from feed material consisting of finely ground solid wastes, liquid wastes in spray form, and a catalytic additive or binder in powder form. These small agglomerates are then dehydrated in a continuous electric dryer before being sintered in a controlled-atmosphere furnace.

Offgas from the process is treated in a high-temperature afterburner before being cooled and filtered. Hazardous waste materials and products of chemical neutralization are encased in the ceramic micro-pellets for final disposal. Further volume reduction is available through optional vitrification in a melting furnace or by hot pressing into forms.

This basic technology has had wide industrial acceptance and has been successfully tested with simulated waste material. However, details of confinement necessary for handling plutonium-contaminated residues have yet to be developed.

3.4.3.3 Molten Metal/Molten Glass

The Westinghouse Electric Pyrolyzer is typical of several processes in which solid wastes (with premixed liquids as an option) are fed into an electrically heated reaction chamber that is constructed around a pool of molten metal in the bottom. The operating temperature of electric pyrolyzer is approximately 1,600°C. Other systems use a pool of molten glass and operate at approximately 1,300°C.

Solid wastes are fed into the reaction chamber where large particles fall into the molten pool. Inorganic materials melt or vaporize and organic materials dissociate into molecular constituents. Aluminates, silicates, and other siliceous components form a vitreous slag that is eventually skimmed or tapped from the surface of the molten mass. Heavier material is drained from a lower tap, and the offgas emitted from the reaction chamber is recycled until it meets all applicable standards for air quality before filtration and release to the atmosphere.

These systems are effective when properly applied. However, the systems are large (the Westinghouse prototype handles 5 tons of waste/day, whereas the RFP produces approximately 500 lb/day), expensive, energy intensive, and unproven in the nuclear industry. Extensive development would be necessary for use of a molten metal system at the RFP.

3.4.3.4 Controlled Air Incineration

The controlled air incineration (CAI) system consists of a conventional stationery hearth unit with two chambers and controlled air. The system has been frequently used in the disposal of municipal, pathological, and industrial solid wastes.

A CAI unit, modified for service in the nuclear industry, has been incinerating transuranic wastes at Los Alamos National Laboratory (LANL) for nearly 10 yr. In the LANL system, solid wastes are prepackaged into cardboard boxes and ram-fed into the incinerator's fire box. Liquid wastes are fed separately through a vortex burner in the unit's primary chamber.

The normal operating temperatures are 870°C in the primary chamber and 1,100°C in the afterburner chamber. The LANL unit uses natural gas as the main heat source. The offgas passes through a quench tower, high-energy venturi scrubber, packed-column absorber tower, condenser, mist eliminator, gas reheater, HEPA filter bank, and carbon absorber before release to the atmosphere.

A CAI unit could be installed in the existing RFP facility. The unit does, however, generate contaminated scrubber fluid and contaminated firebrick. In addition, prepackaging of solid wastes makes the process labor intensive. The LANL unit is currently undergoing extensive renovation.

3.4.3.5 Plasma Arc

In the plasma arc system, low-pressure air is passed through an electric arc, which converts the electrical energy into thermal energy and ionizes the air molecules. The resulting gas is in an electrically neutral plasma with temperatures up to 28,000°C. Atomized wastes are introduced into the reactor. As the activated components of the plasma decay, their energy is transferred to the waste materials and the wastes are ultimately destroyed. The end products are principally hydrogen, carbon monoxide, carbon dioxide, and hydrogen chloride (when chloride-bearing wastes are involved).

Treatable wastes include liquid organics, finely divided fluidized sludges, PCBs, chlorinated organics, and other complex organics. During the development stage, performance testing with liquid wastes produced organic chemical destruction efficiencies in excess of 99.9999%, indicating that the system has potential for development. However, further development and testing of the plasma arc system are required before the method is fully operational.

3.4.3.6 Membrane Separation

In this method, liquid wastes are pumped through semipermeable membranes that selectively reject contaminants based on particle size or valence. The current technologies include use of reverse-osmosis, hyper-filtration, ultra-filtration, and electro-dialysis. Other applications demonstrated on a developmental basis include removal of PCBs, chlorinated organics, and insecticides/herbicides from groundwater. Liquid wastes with suspended solids and/or oils and solid wastes are not suitable for this process.

This technology does have potential for reducing concentrations satisfactorily for internal recycling in controlled areas and is being evaluated for use on laundry water at the RFP. However, membrane separation would not be satisfactory for treatment of the solid and liquid low-level mixed wastes generated at the RFP.

4.0 ANALYSIS OF SELECTED HYPOTHETICAL ABNORMAL EVENTS

This section presents the analysis of abnormal releases of radionuclides and nonradiological hazardous chemicals that were postulated for various waste management alternatives. Release scenarios for natural phenomena and operations accidents were developed and analyzed to determine their consequences and health risks to the general public. The process used for selecting abnormal events to be analyzed includes the development of a screening methodology, the determination of the probability of release, and the identification of events with the highest consequences and highest probability of release. To evaluate the consequences of abnormal events on the public, a set of accident scenarios was developed to ensure that the maximum effects of bounding credible accidents would be analyzed.

Two categories of abnormal events were considered: natural phenomena, and operations accidents. The initial list of abnormal events was further evaluated to select the events requiring detailed analysis. To screen these events and identify those posing the greatest hazard, probabilistic risk assessment guidance developed by the NRC for nuclear power reactors (NRC, 1983) was used.

The four screening criteria used to eliminate events with minor effects are listed below.

- The event has less potential for damage than events for which the facility was designed.
- The event has a lower probability of release than other events of similar consequence.
- The event cannot occur near enough to the facility to cause a release of radionuclides.
- The consequence of an event are less than those of another event assessed.

Event frequencies for abnormal occurrences considered in this study were taken from other published studies whenever possible. For scenarios that had not been quantified, a study was conducted to estimate the probability of release of the initiating event. Where appropriate data were available, accident probabilities were based on past operating experience at the RFP site. Design and safety features that have been incorporated in the facilities to contain radionuclides and reduce operator error were considered.

For abnormal releases, the general public is considered to be the population within 80 km (50 mi) downwind from the release location. The conservative assumption is made that the wind blows at 1 m/s toward the area of greatest urban development, thereby exposing the largest population group. The wind direction that is used to conservatively determine the maximum individual dose (1 m/s toward the north) differs from the one yielding the maximum population dose. Therefore, the maximum individual dose and maximum population dose cannot both occur at the same time. The exposure from nonradiological hazardous chemical releases were calculated for a maximally exposed individual. Maximum individual and population doses for the population were calculated for those alternatives that involve routine releases of radionuclides. The exposure of the maximum individual to hazardous chemical releases is calculated using the method described in Appendix D: "Nonradiological Health Effects" of the "Draft Environmental Assessment for the Fluidized Bed Incinerator Trial Burn at the Rocky Flats Plant" (LATA, 1987). Dose calculations for radiological releases were performed using EPA methodology, which is detailed in Appendix B: "Methods Used to Calculate Environmental Effects" (LATA, 1987).

For each scenario, a brief narrative describing the event is presented and the factors judged to determine the amount of waste released are listed.

4.1 Alternative 1 - No Action

Because there are no operations associated with this alternative, the accidents considered are those resulting from human error and natural phenomena events.

4.1.1 Fork Lift Accident

As liquid wastes continue to accumulate and the 10,000-gal storage tanks in Building 774 become full, additional liquid wastes will be stored outside in 55-gal drums. The drums will be placed in storage containers using a fork lift. The accident is assumed to occur as a fork lift loads a 55-gal drum (contains 50 gal of waste) into a container. The release of waste postulated for the scenario is based on the following assumptions:

- The drum is punctured or dropped by the fork lift, rupturing upon impact; the entire contents are spilled.

- Volatilization of the spilled material occurs in the 30 minutes following the spill while cleanup is in progress.

- The probability that a drum containing high plutonium concentrations is breached from the fork lift accident is 0.0006 events/yr (Southward, 1987).

- The release height of the volatized material is ground level.

- The release fraction of uranium and plutonium from a pool is 4×10^{-6}.

- The concentration in the air above the spill of nonradiological hazardous chemicals is calculated for a pool with a 20-m^2 surface area at 30°C.

- The fork lift operator leaves the area immediately; no workers are affected.

4.1.1.1 Nonradiological Releases and Health Effects

The fork lift accident causes releases of volatile organic compounds contained in the drum. The constituents and estimated quantities released and the associated health risks for the maximally exposed individual are presented in Table 4-1. The air concentrations of hazardous chemicals reaching the maximally exposed individual at the RFP boundary are estimated to not present a significant health risk. In all cases, the air concentrations are estimated to be less than 50% of the TLV guideline presented for comparison; consequently no acute toxic effects would be expected. The only chemical released that is considered to be a probable human carcinogen is carbon tetrachloride. The carcinogenic risk to the maximally exposed individual from the release of carbon tetrachloride was calculated to be less than two in ten million.

The worker involved in the accident is assumed to have received proper safety training and to evacuate the area immediately. Therefore, no worker exposure is predicted.

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TABLE 4-1

NONRADIOLOGICAL RELEASES FROM A FORK LIFT ACCIDENT (ALTERNATIVE 1) AND HEALTH RISKS FOR THE MAXIMALLY EXPOSED INDIVIDUAL[a]

Hazardous Chemical	Release Rate (mg/hr)	Air Concentration (mg/m^3)	Air Concentration (ppm)	Total In Body[b] (mg/kg/d)	TLV Guide[c] (ppm)	Cancer Risk[d]
Carbon Tetrachloride	1.0×10^{8}	5.7×10^{0}	9.1×10^{-1}	1.2×10^{-6}	2.0	1.6×10^{-7}
Xylene	4.2×10^{6}	2.4×10^{-1}	5.5×10^{-2}	1.7×10^{-7}	100.0	0
Pyridine	1.2×10^{7}	6.8×10^{-1}	2.2×10^{-1}	4.5×10^{-7}	5.0	0
Toluene	1.3×10^{7}	7.4×10^{-1}	1.9×10^{-1}	4.0×10^{-7}	100.0	0
Methanol	6.2×10^{7}	3.5×10^{0}	2.7×10^{0}	3.6×10^{-7}	200.0	0
Total						1.6×10^{-7}

a. The hypothetical individual who is assumed to reside at the RFP boundary at the point of maximum ground level concentration, where the maximum exposure would be received.

b. Total lifetime exposure to a 70-kg adult male via inhalation was calculated based on a 70-yr lifespan.

c. Threshold Limit Values (TLVs) are promulgated for protection of worker health by the American Conference of Governmental Industrial Hygienists (NIOSH, 1987). While these are not applicable to environmental exposures, they are presented here for comparison.

d. The cancer risk is expressed as the probability of developing cancer at the calculated exposure (dose) level.

4.1.1.2 Radiological Releases and Health Effects

The releases and effects from accidents in the no-action alternative are summarized in Table 4-2. The fork lift accident results in a release of 9.8×10^{-11} g of plutonium and 4.5×10^{-5} g of uranium. The dose to the maximally exposed individual from the spill is 3.5×10^{-10} rem, which is a very small fraction of the average dose received from background radiation (0.15 rem), and is negligible. The calculated population dose (3.1×10^{-7} man-rem) from this accident is negligible compared to background radiation (1.4×10^{5} man-rem), and would produce no health effects. The maximum individual and population dose commitments result primarily from inhalation of U-238 and Pu-239. No workers would be exposed to radionuclides from the drum spill. In summary, no health effects would be caused by this accident.

4.1.2 Earthquake

A design-basis earthquake (DBE) with a lateral ground-rock acceleration maximum of 0.14 g is assumed to pose the greatest maximum risk potential associated with the no-action alternative. Building 774, the location of the storage tanks, is predicted to maintain its structural integrity throughout such an event (LATA, 1986). However, differential movement is assumed to result in partial or total breakage of the pipe leading from one of the 10,000-gal storage tanks in Building 774. The release postulated from this scenario is based on the following assumptions:

- The pipe breaks upstream of the valve nearest the tank, causing the entire 10,000-gal contents to drain in 75 minutes. Because only 1-2% of the anchored process piping will break (LATA, 1986), it is unlikely that piping to both storage tanks will be severed.

- The spill is contained by the silled floor area (9.3 m^3).

- Radionuclides are dispersed by two mechanisms. (1) Some waste is accidentally moved outside on worker clothing; the ground level release fraction is 0.01. (2) Radionuclides pass through the damaged two-stage HEPA filters (DF = 0.01) and are released at a height of 18.3 m.

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TABLE 4-2

SUMMARY OF ABNORMAL EVENTS FOR THE NO-ACTION ALTERNATIVE

Abnormal Event	Material at Risk (g)	Release Fraction	Initial Source Term (g)	Filter DF	Release to Atmosphere (g)	Release Height (m)
Earthquake	4.81×10^{-3} Pu	1.0×10^{-2}[a]	4.8×10^{-5}	NA[b]	4.8×10^{-5}	0
		4.0×10^{-6}[c]	1.9×10^{-8}	1.0×10^{-2}	1.9×10^{-10}	18.3
	2.33×10^{3} U	1.0×10^{-2}[a]	2.3×10^{1}	NA	2.3×10^{1}	0
		4.0×10^{-6}[c]	9.3×10^{-3}	1.0×10^{-2}	9.3×10^{-5}	18.3
Fork Lift Accident	2.40×10^{-5} Pu	4.0×10^{-6}	9.6×10^{-11}	NA	9.8×10^{-11}	0
	1.17×10^{1} U	4.0×10^{-6}	4.7×10^{-5}	NA	4.5×10^{-5}	0

a. This release fraction results from accidental removal by workers or clean-up crew on their clothing.

b. Not applicable.

c. This release fraction results from a liquid pool containing radionuclides.

- The air concentration of released hazardous chemicals is calculated assuming

  - the surface area of the spill is 197 m^2,
  - the temperature of the room and the spilled material is 30°C,
  - the addition of absorbent material does not reduce volatilization of the compounds, which volatilize for 90 minutes as cleanup progresses.

- The probability of a DBE is 0.0012 events/yr (TERA, 1982), and

- A worker is assumed to be in the room at the time of the accident, and requires two minutes to evacuate.

4.1.2.1 Nonradiological Releases and Health Effects

The earthquake accident was assumed to release the contents of a 10,000-gal waste storage tank in a confined room with venting to the outside air. The air concentrations resulting from the release of the hazardous chemical waste stored in the tank, and the associated health risks for the maximally exposed individual are presented in Table 4-3.

Although the release rates are high, dissipation and dispersal by air currents will significantly dilute the concentrations in the air by the time the release reaches the RFP site boundary. For all the chemicals involved, except carbon tetrachloride, the air concentrations are less than 10% of the TLV, presented for comparison. The concentration of carbon tetrachloride at the site boundary is estimated to be twice the TLV. However, at a concentration of only four parts per million, no acute toxic effects are expected (Clayton and Clayton, 1982), and the carcinogenic risk is less than seven in one million to the maximally exposed individual.

Because the room is a confined space, the air concentrations of hazardous chemicals released in the spill are expected to rise rapidly, posing a toxic threat before the worker evacuates. A respirator would not protect the worker from inhaling toxic fumes. The estimated air concentration in the room at two minutes is used to calculate the expected health effects and risks (Table 4-4).

TABLE 4-3

NONRADIOLOGICAL RELEASES FROM AN EARTHQUAKE EVENT (ALTERNATIVE 1) AND HEALTH RISKS FOR THE MAXIMALLY EXPOSED INDIVIDUAL[a]

Hazardous Chemical	Release Rate (mg/hr)	Air Concentration (mg/m^3)	Air Concentration (ppm)	Total In Body[b] (mg/kg/d)	TLV Guide[c] (ppm)	Cancer Risk[d]
Carbon Tetrachloride	6.3×10^8	2.7×10^1	4.4×10^0	4.9×10^{-5}	2.0	6.4×10^{-6}
Xylene	2.6×10^7	1.1×10^0	2.6×10^{-1}	2.0×10^{-6}	100.0	0
Pyridine	7.2×10^7	3.1×10^0	1.0×10^0	5.6×10^{-6}	5.0	0
Toluene	8.2×10^7	3.6×10^0	9.2×10^{-1}	6.4×10^{-6}	100.0	0
Methanol	3.2×10^8	1.4×10^1	1.1×10^1	2.5×10^{-5}	200.0	0
Total						6.4×10^{-6}

a. The hypothetical individual who is assumed to reside at the RFP boundary at the point of maximum ground level concentration, where the maximum exposure would be received.

b. Total lifetime exposure to a 70-kg adult male via inhalation was calculated based on a 70-yr lifespan.

c. Threshold Limit Values (TLVs) are promulgated for protection of worker health by the American Conference of Governmental Industrial Hygienists (NIOSH, 1987). While these are not applicable to environmental exposures, they are presented here for comparison.

d. The cancer risk is expressed as the probability of developing cancer at the calculated exposure (dose) level.

TABLE 4-4

NONRADIOLOGICAL WORKER EXPOSURE FROM AN EARTHQUAKE EVENT (ALTERNATIVE 1)

Hazardous Chemical	Air Concentration (mg/m^3)	Air Concentration (ppm)	Total In Body[a] (mg/kg/d)	TLV Guide[b] (ppm)	% Guide	Cancer Risk
Carbon Tetrachloride	2.2×10^4	3.5×10^3	1.0×10^{-3}	2.0	9.0×10^4	1.4×10^{-4}
Xylene	8.9×10^2	2.0×10^2	4.3×10^{-5}	100.0	2.0×10^2	0
Pyridine	2.6×10^3	8.6×10^2	1.3×10^{-4}	5.0	1.7×10^4	0
Toluene	2.9×10^3	7.5×10^2	1.4×10^{-4}	100.0	7.5×10^2	0
Methanol	1.3×10^4	1.0×10^4	6.3×10^{-4}	200.0	5.0×10^3	0
Total						1.4×10^{-4}

a. Total exposure to a 70-kg adult male via inhalation was calculated based on a 70-year lifespan.

b. Threshold Limit Values (TLVs) are promulgated for protection of worker health by the American Conference of Governmental Industrial Hygienists (NIOSH, 1987).

c. The cancer risk is expresed as the probability of developing cancer at the calculated exposure (dose) level.

The TLVs of all the hazardous chemicals are exceeded by two-to-four orders of magnitude in the room containing the tank. The air concentration of carbon tetrachloride alone is estimated to be 3,500 parts per million compared to the TLV ceiling limit of 2 ppm. All the compounds released may cause depression of the central nervous system and its associated effects of nausea, vomiting, diarrhea, confusion, dizziness, and incoordination (Proctor and Hughes, 1978; Clayton and Clayton, 1982). Irritation of the eyes, nose, and throat have been reported for exposures similar to that predicted for xylene. Moreover, acutely toxic doses of carbon tetrachloride have been associated with kidney injury, including acute renal failure. Because of the short exposure time of two minutes, the major acute effects are expected to be nausea, headache, and irritation of mucous membranes. The carcinogenic risk level for carbon tetrachloride is predicted to be about one in ten thousand.

4.1.2.2 Radiological Releases and Health Effects

The releases and effects from accidents in the no-action alternative are summarized in Table 4-2. The earthquake and ensuing tank leak result in the release of 4.8×10^{-5} g of plutonium and 23.3 g of uranium to the environment. The population dose from the tank spill would be 1.7×10^{-1} man-rem, which would result in much less than one excess cancer death, as compared to the 32 cancer deaths predicted to occur from natural background radiation.

To assess the radiological dose to the worker, it is assumed that the worker is exposed, unprotected, for 15 seconds, followed by a 105-second exposure during which a half-face respirator (90% efficient at particulate removal) is donned. The calculated whole-body effective dose equivalent (2.4×10^{-7} rem) results primarily from inhalation of plutonium. This very low dose commitment would not affect the health of the exposed worker who commonly receives one million times this dose in background radiation.

4.2 Alternative 2 - Discontinue Waste Generation

The releases from abnormal events considered for this alternative are bounded by the events analyzed for the no-action alternative. Currently, no Pu-containing drums are stored outside and are, therefore, not considered at risk. The worst-case scenario from an abnormal event is identical to the tank/piping breach during an earthquake that was analyzed for the no-action alternative.

4.3 Alternative 3 - Offsite Waste Treatment and/or Disposal

Abnormal events were not evaluated for offsite waste treatment and/or disposal because this alternative is not considered feasible and because the consequences would depend on the type of treatment, local population, and meteorology.

4.4 Alternative 4 - Alternate Technologies

4.4.1 Effects of Abnormal Events on the Infrared Volume Reduction System

4.4.1.1 Operations Accident

The accident with the greatest consequence that could occur during operation of the SHIRCO unit is a fire in the feed system. In this scenario, it is assumed that a fire occurs when finely shredded solid wastes containing some metal pieces are mixed with liquid wastes containing organic solvents. The resulting emissions include partially combusted material and are calculated based on the following assumptions:

- All combustion products pass through four stages of HEPA filters (DF = 2.0×10^{-12}) before exhausting to the atmosphere from an 18.3-m stack.
- Approximately 19 kg of waste are burned; the waste feed consists of 0.00014% Pu and 0.136% depleted U.
- The fire burns for five minutes while material feed ceases immediately; the release continues for eight minutes.
- Thirty-six percent of the radionuclides is converted to suspended fine particulates in the glovebox; 5% of the organic materials is converted to phosgene.
- The probability of occurrence is 0.01/yr based on historical data.

Nonradiological Releases and Health Effects

The fire in the feed system causes briefly elevated emissions of carbon tetrachloride, trichloroethylene, phosgene, and freon 113. The estimated air concentrations and health risks at the location of the maximally exposed individual are presented in Table 4-5. None of the air concentrations approaches the TLV presented for comparison, and the carcinogenic risk level is approximately one in one billion. Consequently, no significant health or environmental effects are predicted to result from this accident.

Radiological Releases and Health Effects

Radiological releases would occur from the fire in the feed system of the SHIRCO (Table 4-6). The releases from the fire are very small amounts of plutonium (2.2×10^{-13} g) and uranium (2.1×10^{-10} g), which result in a maximum individual dose of 4.8×10^{-13} rem or, alternatively, a population dose 4.3×10^{-10} man-rem. These doses result primarily from plutonium inhalation and are so exceedingly small that they are effectively zero.

Workers should not be in the contaminated area during the accident and should not be affected by the release from the fire in the feed system. No health effects should result from this accident.

4.4.1.2 Earthquake

The natural phenomena event most likely to occur and cause damage to the SHIRCO unit is a DBE with a peak lateral bedrock acceleration of 0.14 g (LATA, 1985). Damage to Building 776, the location of the waste treatment unit, would include failure of containment and disruption of the ventilation system.

The most vulnerable part of the incinerator is judged to be the glovebox surrounding the end of the ash conveyor. For this scenario, the glovebox is assumed to separate from the conveyor, the ash drum tips over, and ash is dumped into the operating area. The following assumptions are made to evaluate the source terms:

- At the time of the accident, the ash drum is full, containing 364 kg of ash.

TABLE 4-5

NONRADIOLOGICAL RELEASES FROM AN OPERATIONS ACCIDENT IN THE SHIRCO UNIT (ALTERNATIVE 4) AND HEALTH RISKS TO THE MAXIMALLY EXPOSED INDIVIDUAL[a]

Hazardous Chemical	Release Rate (mg/hr)	Air Concentration (mg/m^3)	Air Concentration (ppm)	Total In Body[b] (mg/kg/d)	TLV Guide[c] (ppm)	Cancer Risk[d]
Carbon Tetrachloride	1.3×10^{6}	5.6×10^{-2}	9.0×10^{-3}	1.1×10^{-8}	2.0	1.4×10^{-9}
Trichloroethylene	1.4×10^{6}	6.1×10^{-2}	1.1×10^{-2}	1.1×10^{-8}	50.0	5.2×10^{-11}
Freon 113	6.1×10^{5}	2.6×10^{-2}	3.4×10^{-3}	5.0×10^{-9}	1,000.0	0
Phosgene	6.5×10^{4}	2.8×10^{-3}	6.8×10^{-4}	5.3×10^{-10}	0.1	0
Total						1.4×10^{-9}

a. The hypothetical individual who is assumed to reside at the RFP boundary at the point of maximum ground level concentration, where the maximum exposure would be received.

b. Total lifetime exposure to a 70-kg adult male via inhalation was calculated based on a 70-yr lifespan.

c. Threshold Limit Values (TLVs) are promulgated for protection of worker health by the American Conference of Governmental Industrial Hygienists (NIOSH, 1987). While these are not applicable to environmental exposures, they are presented here for comparison.

d. The cancer risk is expressed as the probability of developing cancer at the calculated exposure (dose) level.

TABLE 4-6

COMPARISON OF RELEASES FROM OPERATIONS ACCIDENTS FOR THE ALTERNATE TECHNOLOGIES[a]

Technology	Material at Risk (g)	Material Released (g): Room Ventilation System[c]	Material Released (g): Glovebox Ventilation System	Filter DF	Release to Environment[b]
SHIRCO	3.8×10^{-2} Pu	7.6×10^{-3} Pu		2×10^{-6}	1.5×10^{-8} Pu
			3.0×10^{-2} Pu	8×10^{-12}	2.4×10^{-13} Pu
	5.5×10^{1} U	1.1×10^{1} U		2×10^{-6}	2.2×10^{-5} U
			4.4×10^{1} U	8×10^{-12}	3.5×10^{-10} U
Molten Salt	2.7×10^{-2} Pu		2.7×10^{-2} Pu	8×10^{-12}	2.2×10^{-13} Pu
	2.6×10^{1} U		2.6×10^{1} U	8×10^{-12}	2.1×10^{-10} U

a. Feed system fire.

b. Release height is 18.3 m.

c. Glovebox breach allows release of some material to room.

- Twenty-five percent (91 kg) of the material spills, and 1% of this material (.91 kg) is resuspended (Elder et al., 1986). Air exchange from the incinerator room to the environment through exterior wall cracks is 50% during 24 hr. The breach is assumed sealed after 24 h.

- Small amounts of PCDDs are assumed to be formed during incineration and to adhere to the ash particles. The PCDD formation rate is assumed to be 3.4×10^{-5} g/hr. All of the PCDDs are assumed to adhere to ash particles, of which 80% are recovered by cyclone separation. The full drum then would contain 2.2×10^{-4} g dioxin.

Nonradiological Releases and Health Effects

The ash drum spill that is predicted to result from an earthquake is not expected to cause significant health effects (Table 4-7). The release of PCDDs to the atmosphere is estimated to be very small (less than 0.3 micrograms) and therefore, the carcinogenic risk level at the location of the maximally exposed individual would be less than 8 in 100 trillion, i.e., nonexistent.

Radiological Releases and Health Effects

Doses resulting from the ash spill are larger than those from the fire in the SHIRCO feed system but are much smaller than those received from background radiation (Table 4-8). The ash spill results in the release of 0.0034 g of plutonium and 3.2 g of uranium to the environment. Maximum individual and population doses that result from inhalation of Pu-239 are 7.6×10^{-3} rem and 6.7×10^{0} man-rem, respectively. These doses are small relative to those received from background radiation, which, for population doses, are almost one million times greater.

Workers should not be in the contaminated area during the accident and should not be affected by the release from the ash spill.

TABLE 4-7

POLYCHLORINATED DIBENZODIOXIN RELEASES FROM AN EARTHQUAKE EVENT (ALTERNATIVE 4) AND HEALTH RISKS TO THE MAXIMALLY EXPOSED INDIVIDUAL[a]

Polychlorinated Dibenzodioxin (PCDD) Congeners	Release Rate (mg/hr)	Air Concentration (mg/M^3)	Total In Body[b] (mg/kg/d)	Cancer Risk
Tetra-CDD	4.5×10^{-7}	1.9×10^{-14}	6.6×10^{-16}	1.0×10^{-11}
Penta-CDD	3.1×10^{-6}	1.3×10^{-13}	4.5×10^{-15}	3.5×10^{-12}
Hexa-CDD	2.0×10^{-6}	8.2×10^{-14}	2.9×10^{-15}	1.8×10^{-13}
Hepta-CDD	2.0×10^{-6}	$8.2 \times 1\text{-}^{-14}$	2.9×10^{-15}	4.6×10^{-15}
Octa-CDD	1.2×10^{-6}	4.9×10^{-14}	1.8×10^{-15}	2.7×10^{-13}
2,3,7,8-Tetra-CDD	3.5×10^{-8}	1.4×10^{-15}	5.1×10^{-17}	8.0×10^{-12}
2,3,7,8-Penta-CDD	4.2×10^{-7}	1.7×10^{-14}	6.1×10^{-16}	4.8×10^{-11}
2,3,7,8-Hexa-CDD	6.7×10^{-7}	2.8×10^{-14}	9.8×10^{-16}	6.1×10^{-12}
2,3,7,8-Hepta-CDD	2.4×10^{-6}	9.9×10^{-14}	3.5×10^{-15}	5.5×10^{-13}
Total				7.7×10^{-11}

a. The hypothetical individual who is assumed to reside at the RFP boundary at the point of maximum ground level concentration, where the maximum exposure would be received.

b. The total lifetime dose was calculated based on the conservative assumption that all meat, milk, and vegetables consumed by the maximally exposed individual were grown on a plot adjacent to the RFP boundary. The exposure, via ingestion of these foodstuffs and inhalation of particulates, was calculated for a 70-kg adult male based on a 70-year lifespan.

c. The cancer risk is expressed as the probability of developing cancer at the calculated exposure (dose) level.

4.4.2 Effects of Abnormal Events on the Molten Salt Incinerator System

4.4.2.1 Operations Accident

For the molten salt incinerator, the operations accident scenario involves a fire in the sorting glovebox of the feed system. The solid waste feed stock used in the molten

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<u>TABLE 4-8</u>

COMPARISON OF RELEASES FROM AN EARTHQUAKE EVENT
FOR THE ALTERNATE TECHNOLOGIES[a]

Technology	Material at Risk (g)	Material Released During Spill (g)	Material Resuspended (g)	Release to Environment (g)
SHIRCO	2.7×10^{0} Pu	6.8×10^{-1} Pu	6.8×10^{-3} Pu	3.4×10^{-3} Pu
	2.6×10^{3} U	6.5×10^{2} U	6.5×10^{0} U	3.2×10^{0} U
Molten Salt	1.7×10^{0} Pu	4.3×10^{-1} Pu	4.3×10^{-3} Pu	2.2×10^{-3} Pu
	2.4×10^{3} U	6.0×10^{2} U	6.0×10^{0} U	3.0×10^{0} U

a. Ash drum spill with ground level release.

salt destruction process contains a large percentage of readily combustible materials. For this accident, it is assumed that a drum of waste has been dumped into the sorting glovebox and that a spark from the shredder blade ignites paper in the feed chute. The fire spreads to the glovebox where all the material burns. The following assumptions were used in determining the releases from the event:

- Approximately 27 kg of solid waste are combusted.
- The fire burns for five minutes; the material feed ceases but air flow continues, resulting in the continued release of hazardous chemicals for eight minutes.
- Two gloves on the operating side of the glovebox burn, breaching the glovebox containment. Twenty percent of the material in the glovebox escapes to the room and is exhausted through a 2-stage HEPA filter (DF = 2.0×10^{-6}); 80% passes through the glovebox exhaust system and four-stage HEPA filters (DF = 8.0×10^{-12}). Air exhausts from the building through a 18.3-m stack.
- Thirty-six percent of the radionuclides is converted to suspended fine particulates in the glovebox; 5% of the organic materials are converted to phosgene.
- The probability of occurrence is 0.01/yr, based on historical data.
- The waste feed consists of 0.00014% Pu and 0.2% U (depleted).

Nonradiological Releases and Health Effects

The fire in the molten salt unit feed system would not have significant health effects. The nonradiological releases would be very similar to the releases estimated from the fire in the SHIRCO feed system (Table 4-9). The carcinogenic risk would be two in one billion.

TABLE 4-9

NONRADIOLOGICAL RELEASES FROM AN OPERATIONS ACCIDENT IN THE MOLTEN SALT UNIT (ALTERNATIVE 4) AND HEALTH RISKS TO THE MAXIMALLY EXPOSED INDIVIDUAL[a]

Hazardous Chemical	Release Rate (mg/hr)	Air Concentration (mg/m³)	Air Concentration (ppm)	Total In Body[b] (mg/kg/d)	TLV Guide[c] (ppm)	Cancer Risk[d]
Carbon Tetrachloride	1.8×10^{6}	7.8×10^{-2}	1.2×10^{-2}	1.5×10^{-8}	2.0	1.9×10^{-9}
Trichloroethylene	2.0×10^{6}	8.7×10^{-2}	1.6×10^{-2}	1.6×10^{-8}	50.0	7.5×10^{-11}
Freon 113	9.0×10^{5}	3.9×10^{-2}	5.1×10^{-3}	7.3×10^{-9}	1,000.0	0
Phosgene	9.0×10^{4}	3.9×10^{-3}	9.4×10^{-4}	7.3×10^{-10}	0.1	0
Total						2.0×10^{-9}

a. The hypothetical individual who is assumed to reside at the RFP boundary at the point of maximum ground level concentration, where the maximum exposure would be received.

b. Total lifetime exposure to a 70-kg adult male via inhalation was calculated based on a 70-yr lifespan.

c. Threshold Limit Values (TLVs) are promulgated for protection of worker health by the American Conference of Governmental Industrial Hygienists (NIOSH, 1987). While these are not applicable to environmental exposures, they are presented here for comparison.

d. The cancer risk is expressed as the probability of developing cancer at the calculated exposure (dose) level.

Radiological Releases and Health Effects

A very small release of radionuclides is expected from the feed-system fire. Approximately 1.5 x 10^{-8} g of plutonium and 2.2 x 10^{-5} g of uranium would be released as a result of a fire in the sorting glovebox. These small releases would result in a maximum individual dose of 3.3 x 10^{-8} rem as compared to the background radiation dose of 0.15 rem. The maximum population exposure from this accident is 2.9 x 10^{-5} rem, which would be indistinguishable from background radiation.

No workers should be in the conveyor area and therefore should not be affected.

4.4.2.2 Earthquake

The natural phenomenon event for the molten salt unit is very similar to that described for the SHIRCO incinerator: a DBE causes an ash collection drum at the end of the ash conveyor to spill. The only difference between the two scenarios is that the radionuclide content of the drum is less for the molten salt unit than for the SHIRCO. This difference results in slightly lower source terms and doses for the molten salt incinerator than for the SHIRCO.

Nonradiological Releases and Health Effects

The risk from the release of PCDDs during the earthquake and subsequent ash spill are predicted to be identical to those for the SHIRCO accident (Table 4-5) because the formation of PCDDs in the two processes is presumed to be similar.

Radiological Releases and Health Effects

In the event that the drum at the end of the conveyor is knocked over during an earthquake, approximately 2.2 x 10^{-3} g Pu and 3.0 g U would be released to the atmosphere. Although these releases are much greater than those from the fire, they still cause relatively small doses as compared to those from background radiation. The dose to the maximum individual would be 0.0049 rem as compared to 0.15 rem from background radiation. The population dose is 4.3 man-rem, which would result in no health effects in the exposed population.

No workers should be in the conveyor area and, therefore, should not be affected.

4.5 Comparison of Health Effects for Abnormal Events

4.5.1 Health Effects from Nonradiological Releases

None of the alternatives was predicted to cause a significant health effect in the population surrounding Rocky Flats as a result of abnormal events (Table 4-10). Only in one case, Alternative 1 - No Action, were serious health effects predicted as a result of nonradiological releases during an accident. In this case, a worker present at the site of the accident (a tank spill) was expected to experience acute adverse effects from inhaling toxic fumes and to incur a carcinogenic risk of one in ten thousand. The exposure to the maximally exposed individual residing at the RFP boundary was not expected to result in acute adverse health effects, and the carcinogenic risk was estimated to be six in one million. Dispersal of the toxic fumes by wind currents would reduce even more the exposure beyond the RFP boundary.

4.5.2 Health Effects from Radiological Releases

The doses received as a result of abnormal events are small for all the alternatives (Table 4-11). In fact, releases from operations accidents in the alternatives are so small that they are essentially nonexistent and no health effects would occur as a result of the events. The greatest maximum individual and population doses would result from an earthquake-induced spill of the ash drum, which collects the ash from the SHIRCO incinerator. Even this, the most serious event, would result in a maximum individual dose that is less than the dose received from background radiation. No health effects would be observed in the exposed population. The worker dose of 2.4×10^{-7} rem, resulting from the tank spill, is an extremely small dose that would not harm the worker. None of the other scenarios involve worker doses. In summary, abnormal events would cause no health effects.

TABLE-10

COMPARISON OF HEALTH RISKS FROM NONRADIOLOGICAL RELEASES RESULTING FROM ABNORMAL EVENTS

Alternative	Abnormal Event	TLV Exceeded	Cancer Risk[a]
1. No Action	Fork lift accident	No	1.6×10^{-7}
	Earthquake	Yes	6.4×10^{-6}
			worker 1.4×10^{-4}[b]
2. Discontinue Waste Generation	Fork lift accident	No	1.6×10^{-7}
	Earthquake	Yes	6.4×10^{-6}
			worker 1.4×10^{-4}[b]
3. Offsite Treatment and/or Disposal	Alternative determined infeasible		
4.1 SHIRCO Infrared	Feed system fire	No	1.4×10^{-9}
	Earthquake	N/A[c]	7.7×10^{-11}
4.2 Molten Salt Destruction	Feed system fire	No	2.0×10^{-9}
	Earthquake	N/A	7.7×10^{-11}

a. Cancer risk level calculated for the maximally exposed individual.

b. Worker risk was calculated for this abnormal event only because a worker could reasonably be expected to be present in the operations area.

c. No TLVs are promulgated for the contaminant of interest.

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TABLE 4-11

COMPARISON OF HEALTH EFFECTS FROM RADIOLOGICAL RELEASES RESULTING FROM ABNORMAL EVENTS

Alternative	Abnormal Event	Source Term (g)	Maximum Individual Dose[a] (rem)	Population Dose[b] (man-rem)	Health Effects[c]	Worker Dose (rem)
No Action	Fork lift accident	4.5×10^{-5} U/9.8×10^{-11} Pu	3.5×10^{-10} U,Pu	3.1×10^{-7} U,Pu	7.1×10^{-11}	None
	Earthquake	23.3×10^{0} U/4.8×10^{-5} Pu	2.8×10^{-4} U,Pu	1.7×10^{-1} U,Pu	3.9×10^{-5}	2.4×10^{-7}
Discontinue Waste Generation	Earthquake	23.3×10^{0} U/4.8×10^{-5} Pu	2.8×10^{-4} U,Pu	1.7×10^{-1} U,Pu	3.9×10^{-5}	2.4×10^{-7}
Other Technologies						
SHIRCO:	Feed system fire	2.1×10^{-10} U/2.2×10^{-13} Pu	4.8×10^{-13} Pu	4.3×10^{-10} Pu	9.9×10^{-14}	None
	Earthquake	3.2×10^{0} U/3.4×10^{-3} Pu	7.6×10^{-3} Pu	6.7×10^{0} Pu	1.5×10^{-3}	None
Molten Salt:	Feed system fire	2.2×10^{-5} U/1.5×10^{-8} Pu	3.3×10^{-8} Pu	2.9×10^{-5} Pu	6.7×10^{-9}	None
	Earthquake	3.0×10^{0} U/2.2×10^{-3} Pu	4.9×10^{-3} Pu	4.3×10^{0} Pu	9.9×10^{-4}	None
Background Radiation Dose and Effects			1.5×10^{-1}	1.4×10^{5}	3.2×10^{1}	

a. The dose to a hypothetical individual located at the perimeter of RFP to maximize the exposure from a release.

b. The dose is calculated for the sector containing the greatest population (946,000) and includes Denver and other metropolitan areas.

c. Health effects are excess cancer deaths expected to occur in the exposed population as a result of a radiation dose. Approximately 32 deaths result from background radiation in a population of 946,000. Fractional health effects are meaningless other than as a method for statistically comparing population doses.

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