Private Fuel Storage, LLC

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U.S. Nuclear Regulatory Commission
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August 11, 2000

LICENSE APPLICATION AMENDMENT No. 16
DOCKET NO. 72-22/TAC NO. L22462
PRIVATE FUEL STORAGE FACILITY
PRIVATE FUEL STORAGE L.L.C.

This letter submits Amendment No. 16 to the Private Fuel Storage Facility (PFSF) License Application (LA). This amendment updates the PFSF Safety Analysis Report (SAR) to incorporate clarifications discussed in several phone calls between the NRC, CNWRA and PFS dated August 4, 7, 8, and 9, 2000. The discussions involved: a) the potential for tipping of the storage cask transporter when it is carrying a cask and is postulated to be impacted by the worst case design basis tornado-driven missile; b) potential propane vapor cloud resulting from a ruptured pipe near the Canister Transfer Building; c) size of the propane tanks for the Administration and Operations and Maintenance Building; d) update of the Aircraft Crash Impact Hazard for the PFSF; and e) other text clarifications in the SAR.

If you have any questions regarding this submittal, please contact me at 608-787-1236 or Mr. J. L. Donnell, Project Director, at 303-741-7009.

Sincerely,

John L Donnell fw

John D. Parkyn, Chairman
Private Fuel Storage L.L.C.

JDP

Enclosure

NMSS01 Public

PREFACE

PRIVATE FUEL STORAGE FACILITY

LICENSE APPLICATION

AMENDMENT 16

Enclosed are the following revisions to the Private Fuel Storage Facility License Application documents:

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by common carrier along Skull Valley Road, but the safe packaging of those shipments is strictly regulated by the Department of Transportation so as to prevent a release even in the event of an accident. Hazardous wastes shipped from Dugway Proving Ground do not include chemical agent but rather only chemically neutralized agent, which is far less hazardous and would not threaten the PFSF even if spilled on Skull Valley Road.

Unexploded ordnance would not pose a significant hazard to the PFSF in that 1) it is extremely unlikely that such ordnance would explode spontaneously or accidentally and 2) even if it did, the PFSF is far enough away that the material in the round would not pose a significant hazard. Unexploded ordnance is not likely to be found off Dugway Proving Ground close enough to pose a risk to the PFSF, in that the firing ranges at Dugway are all at least 15 miles away and Army records of where munitions were fired at Dugway give no indication that munitions were fired elsewhere.

The Dugway Proving Ground receives and ships conventional Army weapons approximately 95 times a year. Some of these shipments could travel the Skull Valley Road, which present the only credible potential for an explosion near the PFSF. An accident associated with the transportation of explosives along the Skull Valley Road would be a minimum of 1.9 miles from the Canister Transfer Building and 2 miles from the nearest cask storage pad. Based on the methodology of Regulatory Guide 1.91, the Skull Valley Road is located much further from the PFSF than the distances required to exceed 1 psi overpressure for detonation of explosives transported by highway, as discussed in Section 8.2.4.

The Tooele Army Depot facilities, where toxic gas munitions are stored and incinerated, are located west and south, respectively, of Tooele City. The North Tooele Army Depot is 17 miles east-northeast of the PFSF and the South Tooele Army Depot is 21 miles

east-southeast of the PFSF. The Stansbury Mountains, with an elevation of approximately 8,000 feet, lie between the PFSF and the Tooele Army Depots. The activities and materials at the Tooele Army Depots will therefore present no credible hazard to the PFSF, because of their relative distance and the intervening Stansbury Mountains.

2.2.2 Hazards from Air Crashes

Aircraft flights in the vicinity of the PFSF take place to and from Michael Army Airfield on Dugway Proving Ground, on and around the Utah Test and Training Range (UTTR), and on federal airways J-56 and V-257. While there are no civilian airports within 25 miles of the PFSF, general aviation aircraft, while not reported, may also transit the region. The average annual probability of an aircraft crashing into the PFSF has been calculated to be less than 1 E-6 per year and qualitative factors indicate that the true probability of an aircraft impacting the PFSF is less than 1 E-7 per year. (PFS August 2000) This is an extremely low probability, well below the 1 E-6 regulatory standard the NRC has promulgated for above ground facilities at geologic repositories (which are similar to ISFSIs) (61 Fed. Reg. 64,257, 64,261-62, 64,265-66 (1996)) and below the 1E-7 guideline of NUREG-0800 established for nuclear power plants. Therefore, aircraft crashes do not present a credible hazard to the PFSF and the facility does not need to be designed to withstand the impact of an aircraft crash.

2.2.2.1 Michael Army Airfield and Airway IR-420

Michael Army Airfield is located on the Dugway Proving Ground, 17 miles south-southwest of the PFSF. This military airfield has a 13,125 foot runway, and can accommodate all operative aircraft in the Department of Defense inventory, although the majority of the aircraft flying to and from Michael AAF are large cargo aircraft such

as the C-5, C-17, and C-141. The airspace over the Dugway Proving Ground is restricted. Military airway IR-420 passes over the PFSF site area. The methods of NUREG-0800 Section 3.5.1.6 were used to estimate the probability of an aircraft impacting the PFSF from this airway, using the equation:

$$P = C \times N \times A / w, \quad \text{where}$$

P = probability per year of an aircraft crashing into the PFSF
C = in-flight crash rate per mile
N = number of flights per year along the airway
A = effective area of the PFSF in square miles
w = width of airway in miles

NUREG-0800 states the in-flight crash rate as 4 E-10 per mile, which is appropriate to apply to the types of aircraft flying to and from Michael AAF. (PFS August 2000) Information provided by the Dugway Proving Ground states that there are approximately 414 flights annually at this airfield. The effective area of the PFSF is 0.2116 mi^2, calculated using Department of Energy (DOE) formulas. (DOE 1996) The width of the airway is 10 nautical miles (nm), or 10nm x 1.15 mile/nm = 11.5 miles. The probability of an aircraft impacting the PFSF is therefore 3.0 E-9 per year. Because of the distance from the PFSF to Michael Army Airfield, takeoff and landing operations at Michael pose a negligible hazard to the PFSF.

Consideration was given to the plans for landing the X-33 aircraft at Michael Army Airfield. The X-33 is an unmanned half-scale demonstrator launch vehicle planned to test critical components for the next generation space transport system. The X-33 will not pose a hazard to the PFSF because, first, tests for the X-33 at Michael Army Airfield

are scheduled to be completed by mid-2000, before the PFSF would be operational, and second, the X-33's flight plan does not take it over Skull Valley, let alone the PFSF.

2.2.2.2 Utah Test and Training Range

The UTTR is an Air Force training and testing range over which the airspace is restricted to military operations. It is divided into a North Area, located on the western shore of the Great Salt Lake, north of Interstate 80, and a South Area, located to the west of the Cedar Mountains, south of Interstate 80 and northwest of Dugway Proving Ground. (PFS August 2000) The airspace over the UTTR extends somewhat beyond the range's land boundaries and is divided into military operating areas (MOAs) and restricted areas. The MOAs on the UTTR are located on the edges of the range, adjacent to the restricted areas. The PFSF site is located over 18 statute miles east of the eastern land boundary of the UTTR South Area and 8.5 statute miles northeast of the northeastern boundary of Dugway Proving Ground. The site lies within the Sevier B MOA, two statute miles to the east of the edge of restricted airspace. (PFS August 2000)

Military aircraft flying in or around the UTTR South Area comprise three groups: 1) F-16 fighter aircraft flying from Hill Air Force Base (AFB), near Ogden, Utah, down Skull Valley en route to the range (Section 2.2.2.2.1); 2) aircraft conducting training in the restricted airspace on the range (Section 2.2.2.2.2); and 3) aircraft departing the range via the Moser Recovery to return to Hill AFB (Section 2.2.2.2.3). Aircraft flying in or around the UTTR North Area pose no credible hazard to the PFSF because of the distance from the facility.

2.2.2.2.1 F-16s Transiting Skull Valley

F-16 fighter aircraft fly north to south down Skull Valley, within Sevier B MOA, en route from Hill AFB to the UTTR South Area. The F-16s use the eastern side of Skull Valley as their predominant route of travel and typically pass approximately five miles to the east of the PFSF site. The U.S. Air Force has indicated that the F-16s typically fly between 3,000 and 4,000 ft. above ground level (AGL), with a minimum altitude of 1,000 ft AGL. In 1998, 3,871 such flights passed through Skull Valley.

Because the predominant route of travel for the F-16s is down the eastern side of Skull Valley, away from the PFSF; because the likely nature of an F-16 crash in Skull Valley would be such that a crashing aircraft would not pose a hazard to the PFSF unless it was pointed directly at the site at the time of the event leading to the crash; and because Air Force pilots are instructed to avoid ground facilities in the event of a mishap in which the pilot retained control of the direction of the aircraft, it is not credible that a crashing F-16 would impact the PFSF. Nevertheless, an impact probability was calculated, using the methodology of NUREG-0800, in which it was conservatively assumed that the F-16 flights are uniformly distributed within the Sevier B MOA airspace in the vicinity of the PFSF. (PFS August 2000)

To calculate the F-16 impact probability using the NUREG-0800 method, the Sevier B MOA airspace in the vicinity of the PFSF was treated as an airway with a width of 10 miles. Given the flight characteristics of the F-16, the PFSF has an effective area of 0.1337 mi^2, assuming a facility at full capacity with 4,000 spent fuel storage casks on site. The number of flights through the valley was taken to be 3,871 per year. The crash rate for the F-16 was calculated from Air Force data to be 2.736 E-8 per mile. It was also determined, from an extensive review of Air Force F-16 accident investigation reports, that over 90 percent of the F-16 crashes that would result from accident-

initiating events that could occur in Skull Valley would leave the pilot in control of the aircraft after the event. Furthermore, because of the training Air Force pilots receive in responding to such in-flight events, the flight characteristics of the F-16, the absence of other built up areas in Skull Valley, and the small effort required for the pilot to avoid the PFSF site in the event of a crash caused by an accident-initiating event leaving him in control of the aircraft, the pilot would be able to direct the aircraft away from the PFSF at least 95 percent of the time in which such an event caused a crash in Skull Valley. Accordingly, 85.5 percent (90% x 95%) of the crashing F-16s would be able to avoid the PFSF and hence the calculated crash impact hazard to the PFSF would be reduced by this fraction. Thus, the annual crash impact probability for the F-16s in Skull Valley (assuming a fully loaded facility) was calculated to be 2.05 E-7. (PFS August 2000)

PFS also calculated the probability that ordnance jettisoned from a crashing F-16 in Skull Valley would impact the PFSF. (PFS August 2000) Some of the F-16 flights through Skull Valley carry ordnance (live or inert) and in the event of an incident leading to a crash in which the pilot would have time to respond before ejecting from the aircraft (e.g., an engine failure), one of the pilot's first actions would be to jettison any ordnance carried by the aircraft. PFS used an approach similar to that of NUREG-0800 to calculate the probability that such ordnance would impact the PFSF. The fraction of the 3,871 F-16s transiting Skull Valley per year that would be carrying ordnance was determined from Air Force data to be 11.8 percent. Thus the number of aircraft carrying ordnance through Skull Valley per year, N, would be 457. The crash rate for the F-16s, C, was taken to be 2.736 E-8 per mile, as above. Nonetheless, the pilot was assumed to jettison ordnance in only 90 percent of all crashes, the fraction of the crashes, e, assumed to be attributable to engine failure or some other event leaving him in control of the aircraft (in crashes attributable to other causes it was assumed that the pilot would eject quickly and would not jettison ordnance). Skull Valley was treated as an airway with a width, w, of 10 miles. As with the calculation for F-16s transiting Skull

Valley, PFS conservatively assumed that the F-16s are uniformly distributed across the 10 miles, despite the fact that their predominant route of flight is down the eastern side of the valley and that, according to the Air Force, aircraft carrying live ordnance avoid flying over populated areas to the maximum extent possible. The area of the PFSF, from the perspective of a piece of ordnance jettisoned from an aircraft flying from north to south over the site, A, was taken to be the product of the width and the depth of the cask storage area (assuming a full facility with 4,000 casks) plus the product of the width and depth of the canister transfer building, in that the pieces of ordnance are small relative to an aircraft and impact the ground at a steep angle. Thus, the area of the PFSF was calculated to be 0.08763 mi^2. The probability that the ordnance would impact the PFSF is given by P = N x C x e x A/w, or:

P = 457 x 2.736 E-8 x 0.90 x 0.08763 / 10 = 9.85 E-8

In addition to the potential hazard posed by direct impacts of crashing aircraft and jettisoned ordnance, PFS also calculated the hazard to the PFSF posed by jettisoned live ordnance that might land near the facility and explode on impact, as well as the hazard posed by a potential explosion of live ordnance carried aboard a crashing aircraft that might impact the ground near the PFSF. (PFS August 2000) At the outset, aircraft transiting Skull Valley near the PFSF do not carry armed live ordnance. Furthermore, the U.S. Air Force has indicated that the likelihood that unarmed live ordnance would explode when impacting the ground after being jettisoned is "remote" and the Air Force has no records of such incidents in the last 10 years. Thus, it is highly unlikely that jettisoned live ordnance or live ordnance carried aboard a crashing aircraft that did not directly impact the PFSF would damage the facility. Nevertheless, to calculate a numerical hazard to the facility, PFS assumed that such ordnance would have a 1 percent chance of exploding and assessed that damage to the PFSF would result if an explosion occurred close enough that the blast overpressure would damage

a storage cask or the Canister Transfer Building, without hitting either one. The explosive overpressure limit for a storage cask was taken to be 10 psi. The limit for the Canister Transfer Building was taken to be 1.5 psi. PFS assumed that the ordnance in question was a 2,000 lb. bomb, the largest single piece of ordnance carried by the F-16s that transit Skull Valley. The Air Force indicated that 193 F-16s transited Skull Valley in 1998 with live ordnance. PFS calculated the probability that an F-16 carrying live ordnance would crash and jettison the ordnance so as to impact near the PFSF, or crash near the PFSF without jettisoning the ordnance, following the same method it used to calculate the probability that an F-16 would crash and impact the facility. The results of PFS's final calculation showed that the annual probability that a storage cask or the Canister Transfer Building would be damaged by an explosion of live ordnance jettisoned from a crashing aircraft or carried aboard a crashing aircraft that impacted the ground near the PFSF was equal to 2.43 E-10. This is exceedingly low and is insignificant relative to the other aircraft crash and jettisoned ordnance impact hazards calculated for the PFSF.

2.2.2.2.2 Aircraft Training on the UTTR

According to the Air Force, 8,284 sorties were flown over the UTTR South Area in 1998. (PFS August 2000) Those aircraft conducted a variety of activities, including air-to-air combat training, air-to-ground attack training, air-refueling training, and transportation to and from Michael Army Airfield (which is located beneath UTTR airspace). Hazards posed by aircraft flying to and from Michael Army Airfield are addressed in Section 2.2.2.1 above. Of the remaining aircraft, only fighter aircraft conducting air-to-air training represent a potential hazard to the PFSF, in that aircraft conducting air-to-ground attack training do so over targets that are located more than 20 miles from the PFSF site and aircraft conducting air refueling training do so on the far western side of

the UTTR, over 50 miles from the site. The Air Force indicated 6,360 fighter sorties were flown on the UTTR South Area in 1998 and one-third, or approximately 2,120, involved fighter aircraft conducting air-to-air training.

The crash impact probability for fighter aircraft conducting air-to-air training on the UTTR was calculated as follows:

$$P = C_a \times A_c \times A/A_p \times R, \text{ where}$$

P = annual crash impact probability

C_a = total air-to-air training crash rate per square mile on the UTTR

A_c = the area of the UTTR from which aircraft could credibly impact the PFSF in the event of a crash

A = effective area of the PFSF in square miles

A_p = the footprint area, in which a disabled aircraft could possibly hit the ground in the event of a crash

R = the probability that the pilot of a crashing aircraft would be able to take action to avoid hitting the PFSF

The total air-to-air training crash rate per square mile on the UTTR, C_a, was calculated from the total number of hours flown in air-to-air training on the UTTR South Area (2,468), the crash rate per hour for fighter aircraft (the F-16) in combat training (3.96 E-5), the distribution of air operations over the sectors of the UTTR nearest the PFSF, and the ground areas of those sectors. (PFS August 2000) As with the F-16s transiting Skull Valley, 95 percent of the crashes on the UTTR attributable to engine failure or some other cause leaving the pilot in control of the aircraft were determined not to pose a hazard to the PFSF, in that the pilot would retain control of the aircraft and would be able to avoid the site. Based on Air Force data, 45 percent of all F-16 crashes

occurring during combat training are attributable to engine failure; thus the factor R in the equation above was set equal to 0.573 (1-(45% x 95%)). The area from which an aircraft could credibly impact the PFSF in the event of a crash, A_c, was taken to be the portion of the UTTR within 10 miles of the PFSF and outside a three-mile buffer zone assumed to exist on the edge of the UTTR restricted areas. A crashing aircraft more than 10 miles from the PFSF would have to be under control of the pilot in order to glide and reach the site, and the pilot would guide any such aircraft away from the site, which is outside the land boundaries and the restricted airspace of the UTTR. The buffer zone represents the fact that aircraft do not fly within three miles of the edges of the restricted areas while conducting training on the UTTR. The site effective area, A, was determined as in Section 2.2.2.2.1 above for a facility at a full capacity of 4,000 storage casks. The footprint area, A_p, was calculated by assuming that a crashing aircraft could glide in any direction up to a distance equal to the product of its starting altitude above ground and its glide ratio. Accordingly, the aircraft conducting air-to-air training over the UTTR were divided into altitude bands and an impact probability calculated for each band. Aircraft too low to glide to the PFSF in the event of a mishap were calculated not to contribute to the crash impact hazard, in that they would have no chance of reaching the site. The maximum annual air crash impact probability for aircraft conducting air-to-air training on the UTTR South Area was calculated from the sum of impact probabilities of the altitude bands to be 7.35 E-8.

2.2.2.2.3 Aircraft Using the Moser Recovery

Most of the F-16s returning to Hill AFB from the UTTR South Area exit the northern edge of the range (away from the PFSF) in coordination with air traffic control. However, some aircraft returning to Hill from the UTTR South Area may use the Moser recovery route, which runs from the southwest to the northeast, approximately two

miles from the PFSF site. (PFS August 2000) The Moser route is only used during marginal weather conditions or at night under specific wind conditions which require the use of Runway 32 at Hill AFB. Based on information from local air traffic controllers, conservatively estimated, the Moser recovery is used by less than five percent of the aircraft returning to Hill. According to the Air Force, 5,726 F-16 sorties were flown on the UTTR South Area, almost all of which flew from Hill AFB (not all aircraft transit Skull Valley en route to the South Area); thus fewer than 286 aircraft per year (5% x 5,726) would use the Moser recovery on their return flights.

The average annual crash impact probability for aircraft flying the Moser recovery was calculated using the NUREG-0800 method. The Moser recovery is defined as an airway with a width, w, of 10 nautical miles (11.5 statute miles) (equal to the width of military airway IR-420). The number of aircraft, N, is conservatively taken to be 286; the crash probability, C, is equal to 2.736 E-8 per mile; the effective area of the site is 0.1337 mi^2; and it is calculated that 85.5 percent of all crashes would be attributable to events leaving the pilot in control of the aircraft, in which the pilot could direct the aircraft away from the PFSF (see Section 2.2.2.2.1). Thus, the annual crash impact probability is conservatively estimated to be 1.32 E-8.

2.2.2.3 Aircraft Flying Federal Airways

Federal airway J-56 runs east-northeast to west-southwest at a distance (from the airway centerline) of 11.5 miles north of the PFSF. (PFS August 2000) Local air traffic controllers have indicated that fewer than 12 aircraft per day use the airway. The crash impact probability for aircraft on the airway was calculated for the PFSF using the method of NUREG-0800. Using the standard width for federal airways, J-56 is 8 nautical miles (9.2 statute miles) wide and the closest edge of J-56 is 6.9 miles from the

PFSF. For facilities outside an airway, the effective width of the airway, w, is equal to the actual width plus twice the distance from the facility to the closest edge. Thus, J-56 has an effective width of 23 miles. The number of aircraft, N, is conservatively taken to be 12 per day, the crash rate, C, from NUREG-0800 is 4 E-10 per mile, and the effective area of the PFSF for commercial airliners (the most common aircraft on the airway) is 0.2615 mi^2, assuming a full facility with 4,000 casks. Accordingly, the maximum annual crash impact probability is 1.9 E-8. (PFS August 2000)

Federal airway V-257 runs north and south at a distance (from the airway centerline) of 19.5 miles east of the PFSF. (PFS August 2000) Local air traffic controllers have indicated that fewer than 12 aircraft per day use the airway. The crash impact probability for aircraft on the airway was calculated for the PFSF using the method of NUREG-0800. V-257 is 12 nautical miles (13.2 statute miles) wide and its closest edge is 12.6 miles from the PFSF. Thus, V-257 has an effective width of 39 miles. The number of aircraft, N, is conservatively taken to be 12 per day, the crash rate, C, is 4 E-10 per mile, and the effective area of the PFSF is 0.2615 mi^2. Accordingly, the annual crash impact probability is 1.2 E-8. (PFS August 2000)

2.2.2.4 General Aviation

There are no civilian airports within 25 miles of the PFSF, the PFSF is located in a sparsely populated area, and the PFSF is located inside a military operating area (MOA) in which flight by civilian aircraft is restricted while the MOA is being used by the Air Force (and which is avoided by general aviation pilots because of the difficulty of getting clearance through it). Thus, the general aviation traffic over Skull Valley is negligible; in fact F-16 pilots who have flown from Hill AFB through Skull Valley indicate never having seen general aviation traffic there. Therefore, it is highly unlikely that a general aviation aircraft would crash into the PFSF. (PFS August 2000) Nevertheless,

a conservative upper bound on the crash impact probability for general aviation aircraft was calculated using National Transportation Safety Board (NTSB) crash data and the population of general aviation aircraft in the state of Utah. (PFS August 2000) The crash impact probability is equal to C_a x A, where C_a is the crash rate per square mile and A is the effective area of the PFSF. In 1995, the 182,600 general aviation aircraft in the United States suffered 412 fatal accidents. There are 1,218 general aviation aircraft in the state of Utah, which covers an area of 84,094 mi^2. FAA crash data indicate, however, that only 15 percent of all general aviation crashes occur during the cruise mode of flight, which, because there are no airports nearby, is the mode in which general aviation aircraft would be flying near the PFSF. Furthermore, business jets experience 7.85 percent of all general aviation fatal crashes and they can be excluded from this calculation, in that they fly mostly on federal airways. The effective area of the PFSF with respect to general aviation aircraft crashes is 0.1173 mi^2 (assuming a fully loaded facility with 4,000 casks). Accordingly, the average annual crash impact probability for general aviation aircraft is 5.25 E-7. (PFS August 2000)

The crash impact hazard to the PFSF, however, would be reduced below the calculated impact probability, in that the spent fuel storage casks would be able to withstand the crash impact of most general aviation aircraft. Fifty-five percent of all general aviation aircraft are single-engine piston types weighing less than 3,500 lbs. (PFS August 2000) Such aircraft typically fly at speeds under 100 knots (114 mph). Therefore, the impact of such aircraft at the PFSF would be bounded by the design basis tornado missile impact for the PFSF, an automobile weighing 1800 kg (3,968 lbs.) moving at a speed of 126 mph. (p. 8.2-17) Thus, the impact of such light general aviation aircraft would not cause a radioactive release from a storage cask. Therefore, the calculated general aviation crash impact hazard to the PFSF can be reduced by 55 percent to 2.36 E-7.

2.2.2.5 Cumulative Air Crash Impact Probability

The cumulative maximum air crash impact probability is given in the table below.

Aircraft Crash Impact Probabilities	
Aircraft	**Maximum Annual Probability**
Skull Valley F-16s	2.05 E-7
Aircraft Using the Moser Recovery	1.32 E-8
UTTR Aircraft	7.35 E-8
Aircraft on Airway J-56	1.9 E-8
Aircraft on Airway V-257	1.2 E-8
General Aviation Aircraft	2.36 E-7
Aircraft on Airway IR-420	3.0 E-9
Cumulative Crash Probability	5.62 E-7
Jettisoned Military Ordnance	9.85 E-8
Cumulative Hazard	6.60 E-7

The table shows that the cumulative air crash impact probability is less than 1 E-6 for the PFSF. Qualitative factors discussed below show further that the true impact probability for both facilities is less than 1 E-7. Thus, air crash impact does not pose a credible hazard to the PFSF and the PFSF does not need to be designed to withstand the effects of air crash impacts.

2.2.2.6 Projected Growth in Air Traffic

The Federal Aviation Administration projects that the number of commercial aviation flights in the United States will increase by approximately 66 percent between 1998 and 2025, that the number of general aviation flights will increase by approximately 14 percent over the same period, and that the number of military flights will not increase during this period. (FAA 1999) Because most of the air traffic near the PFSF site is military, the growth in commercial and general aviation projected by the FAA will have no material effect on the air crash impact probability calculated for the facility.

2.2.2.7 Conservatism in the PFSF Air Crash Impact Probabilities

While the calculated cumulative hazard for the PFSF is 6.60 E-7, qualitative factors indicate that the true probability of an aircraft or jettisoned ordnance impacting the site is significantly lower, less than 1 E-7 per year. With respect to the F-16s transiting down Skull Valley en route to the UTTR South Area (and jettisoned military ordnance), these factors include the fact that, according to the U.S. Air force, the predominant route of choice for the F-16s is the east side of the Valley, approximately five miles from the site. Thus, the uniform distribution assumed in calculations in Section 2.2.2.2.1 is highly conservative, especially considering the fact that the only aircraft that pose a real hazard to the site are those that are pointed directly toward it at the time of the incident leading to a crash. In addition, the Skull Valley F-16 calculations assume that F-16s will crash at the 10-year average rate rather than the more recent and lower 5-year average rate.

The calculations of the crash impact hazard posed by other aircraft are conservative as well. The calculations assume that the density of flight operations involving air-to-air training near the edge of the UTTR (near the PFSF) is the same as it is near the center

of the range, when in fact it is much lower. They also assume that an aircraft could glide up to 10 miles to impact the PFSF in a crash in which the pilot could not retain control over the aircraft, when in fact such aircraft would most likely fall to the ground without flying a significant distance. The calculation of the general aviation aircraft crash hazard assumes that the density of aircraft over Skull Valley is equal to the average density over the State of Utah, when in fact it is much lower. Therefore, the true crash hazard from those aircraft is significantly lower than the calculated value and in fact is insignificant.

Furthermore, the cumulative hazard calculated above is also conservative in two other major respects. First, the calculated probability is for a fully loaded, 4,000 cask facility, which would be the case for only a short period in the life of the PFSF. The average area of the PFSF site, and hence the average annual probability that an aircraft or jettisoned ordnance would impact the site, is 55 percent of that of the full facility. Thus, the average annual impact probability is roughly 4 E-7. Second, no credit was taken for the resistance to the effects of an air crash impact provided by the concrete storage casks in which the spent fuel canisters will be located (other than resistance to impacts of light general aviation aircraft). The cask construction is robust enough that a significant fraction of the potential air crash impacts at the PFSF would not cause a release of radioactivity. (Davis et al. 1998) The casks could withstand the direct impact of a jet fighter or commercial airliner at a speed of over 370 knots, which is significantly greater than typical air crash impact velocities, and the casks could withstand the impact of the great majority of general aviation aircraft altogether. (PFS August 2000) This resistance of the casks to penetration further reduces significantly the calculated risk to the PFSF from aircraft crashes or jettisoned ordnance.

2.2.3 The Use of Ordnance on the UTTR

As discussed in Section 2.2.2.2, military aircraft conduct air-to-ground attack training using air-delivered ordnance on the UTTR South Area. Military aircraft also conduct weapons testing, including the testing of cruise missiles. (PFS August 2000) As shown in the following paragraphs, the use of air-delivered ordnance on the UTTR does not pose a significant hazard to the PFSF (the hazard posed by jettisoned ordnance in Skull Valley was calculated in Section 2.2.2.2.1 above). The PFSF site is located 18 miles to the east of the easternmost land boundary of the range. Based on the following paragraphs it is concluded that weapons use on the UTTR does not pose a credible hazard to the PFSF and the facility does not need to be designed to withstand a weapon impact.

Weapons use on the UTTR is strictly controlled and the UTTR has never experienced an unanticipated munitions release outside of designated launch/release areas. Aircraft flying over Skull Valley are not permitted to have their armament switches in a release capable mode, and all switches are "safe" until the aircraft are inside DOD land boundaries. Master Arm switches are not actually armed until the aircraft are on the ranges within the UTTR where the bombs are to be dropped. Furthermore, the targets on the UTTR are all over 20 miles from the PFSF site and there are no run-in headings for weapons delivery over the Skull Valley area.

Hung Ordnance

The probability of "hung ordnance" (i.e., the failure of ordnance to release from an aircraft when delivery is attempted) and an unintentional release of the ordnance in Skull Valley are exceedingly low. First, most aircraft do not even carry live ordnance but instead carry training ordnance such as Bomb Dummy Units (BDU) or inert filled or empty MK82 500 lb bombs. According to the U.S. Air Force, only approximately 15% of

the 8,711 UTTR sorties flown in Fiscal Year 1998 actually carried live ordnance. Training bombs, by contrast, pose no explosive hazard to the PFSF and the dead weight of the BDUs pose no risk to the facility as well. BDU-33's have ballistic characteristics similar to MK 82 bombs but carry only a small smoke charge for marking purposes. They weigh only 25 pounds and are often the weapon of choice for training missions. Second the probability that any ordnance will "hang" is very low. Michael AAF is the designated primary airfield for aircraft landing with live hung ordnance that has failed to release. There were only five hung ordnance aircraft diversions/recoveries into Michael AAF during 1998. Since only approximately 15% of the aircraft sorties carry live ordnance, a total of only five hung ordnance recoveries in 1998 for a total of about 2,000 sorties (approximately 15% of the 13,367 over the UTTR) produces a probability for failing to release of approximately one in 400. Moreover, a failure to release does not mean there will be an inadvertent release or an inadvertent release and explosion. As indicated above, the Air Force has never had an unintentional release of ordnance outside the launch/drop/shoot boxes on the UTTR. All of these are obviously within the UTTR and in fact are over 20 statute miles from the PFSF site.

Finally, the probability of "hung ordnance" striking the PFSF is not credible because aircraft carrying hung ordnance do not fly over Skull Valley. In the event of hung ordnance, the first priority is to maintain aircraft control and then assess the situation and take appropriate action. Pilots contact Clover Control Air Traffic Control Facility and advise them of the situation. When hung ordnance is encountered, the pilot has the option of either jettisoning the rack and munitions on the range, if able, or recovering to base. Michael AAF is the designated primary recovery base for hung ordnance, although Hill AFB is available as well. Pilots request clearance to Michael AAF for hung ordnance recovery/landing. Pilots maintain a stable flight path and remain in Visual Meteorological Conditions by avoiding clouds. Clover Control provides assistance as required and ensures Michael AAF is prepared to receive the aircraft to

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The storage area is surrounded by a perimeter road. The Administration Building, shown on Figure 4.1-3, and the Operations and Maintenance (O&M) Building, shown on Figure 4.1-4, which are not directly associated with the actual handling or storage of spent fuel, are located approximately one-half mile and one-third mile respectively southeast of the storage area. The Administration, and the O&M buildings house offices and equipment for administrative and maintenance personnel.

The facility layout is also designed to ensure that all SSCs are accessible to emergency equipment in the event of an emergency condition per 10 CFR 72.122(g).

4.1.2.1 Site Boundary

The PFSF site boundary is identified by the owner controlled area (OCA). The OCA boundary is shown on Figure 1.1-2.

4.1.2.2 Controlled Area

The controlled area, established by providing a minimum distance of 100 meters from storage and handling operations to the controlled boundary in accordance with 10 CFR 72.106, is the same as the site boundary discussed in Section 4.1.2.1 above, defined as the OCA.

4.1.2.3 Site Utility Supplies and Systems

The site requires few utility supplies and systems. None of the SSCs classified as Important to Safety require utility services to maintain their safety function. Therefore, the site utility services do not need to be considered as being Important To Safety and need no redundant components, as otherwise would be required by 10 CFR 72.122(k). Electric power is provided to the PFSF for lighting, general utilities, security system, and

cranes. Although the overhead bridge and semi-gantry cranes are Important to Safety, their safety function does not rely on electric power. A standby diesel-generator provides backup power for the security system, emergency lighting loads, storage cask temperature monitoring system, and communication systems.

4.1.2.4 Storage Facilities

There are no ancillary storage facilities such as holding ponds, chemical gas storage vessels, or other open-air tanks required to maintain Important to Safety functions at the PFSF. However, the PFSF does utilize water tanks for fire protection and propane gas supply tanks for the Canister Transfer Building, Administration, O&M, and Security and Health Physics buildings heating. The water tanks are located near the Security & Health Physics Building. The propane tank or tanks that supply propane for heating the Administration and O&M buildings will be relatively small (less than 5,000 gallons capacity), located in the vicinity of these buildings. The group of four propane storage tanks that will supply the Canister Transfer Building and Security and Health Physics Building will have a total capacity of no greater than 20,000 gallons, and each individual tank shall have a capacity no greater than 5,000 gallons. All of these propane tanks shall be located a minimum distance of 1,800 ft from the Canister Transfer Building and the cask storage area, as discussed in Sections 4.3.12 and 8.2.4.

4.1.2.5 Stacks

There are no stacks required or provided at the PFSF.

Fire Zone 2 is classified as a Storage Occupancy in accordance with NFPA-101. The area consists of the low level waste storage room. This area will contain storage containers (55-gallon drums) of ordinary combustibles that will be sealed and kept in the storage area. This area is not required to be protected by an automatic sprinkler system and therefore will only use fire extinguishers for fire suppression.

Fire Zone 3 is classified as a Business Occupancy in accordance with NFPA-101. The area consists of the office and building services areas of the building. This area is not required to be protected by an automatic sprinkler system and therefore will only use fire extinguishers for fire suppression.

The Canister Transfer Building is constructed of noncombustible materials and is considered a construction Type II structure in accordance with NFPA-220 (Reference 73) as referenced by NFPA-801 and a construction Type II – Fire Rating per the UBC. (The UBC Construction Type II-FR is also used because it is more restrictive and has higher fire-resistance requirements than the NFPA-220 construction Type II classification). The building is designed to limit the potential effects from a diesel fuel fire with curbs and sloped floors located to contain spilled diesel fuel away from SSCs.

A summary of the Canister Transfer Building fire protection design requirements is as follows:

a. Fire barriers will be designed to the worst case code, i.e. 1 hour fire rated walls and doors per the UBC.
b. A fire suppression system as required by NFPA-801 will be installed in the Cask Load/Unload Bays of the CTB to suppress a possible fire from the 300 gallon diesel fuel spill. The system will consist of a foam-water system per NFPA-16, which is specifically designed for the suppression of fuel type fires. This type of fire suppression is an extremely conservative approach since a 300 gallon leak is

highly unlikely (the fuel is contained in two 150 gallon side saddle truck tanks) and the shipping cask system are designed to withstand accidents per 10CFR71 that bound the worst case postulated fire for the building.

c. The foam-water system will be designed to discharge for a minimum of 60 minutes in accordance with NFPA 16.

d. Standpipes with hose systems as required by NFPA-801 will be installed at either end of the office area corridor and adjacent to the cask transporter bay, crane bay, and load/unload bay exit locations so that every portion of the building is reachable by a firewater stream from a 100 ft. hose.

e. The transfer cell rooms will not be provided with automatic fire suppression systems in order to prevent any possible radioactive contamination on the canisters from being dislodged by the water spray. It was determined that the transfer cells do not require automatic fire suppression because the rooms will primarily contain only components that are constructed of noncombustible fire resistive materials (e.g. the storage or shipping cask) that have been analyzed for fires that bound the worst case postulated fire for the building (Ref. storage system SARs).

f. Portable fire extinguishers as required by NFPA-801 will be installed in appropriate locations throughout the building.

g. A fire detection system as required by NFPA-801 will be installed in the all areas of the building in accordance with NFPA 72 (Reference 78).

Security and Health Physics Building

The Security and Health Physics Building fire protection provisions will be designed in accordance with the requirements of the UBC and NFPA 101 as applicable. The building is classified as Group B – for business related functions. The building as a whole will not require any automatic fire suppression systems based on the occupancy of less than 50 persons (UBC 304.1) and floor area of less than 12,000 sq. ft. (UBC

Table 5-B). The building construction is classified as a Type II N, which does not require any special fire rated components for this building (UBC Table 6-A).

The diesel-generator that will be located in the Security and Health Physics Building will be no larger than 150 kW. For 150 kW diesel-generator sets, the maximum fuel consumption is approximately 12 gal/hr. The unit is required to provide a minimum of 24 hours backup power per IEEE 692 (Reference 68) and NUREG-0908 (Reference 74) plus the required 30 minute monthly tests per NUREG/CR-0509 (Reference 75). Conservatively assuming 1 hour monthly test for up to 3 months, then the minimum required fuel tank size must be:

(24 hr x 12 gal/hr) + (3 tests x 1 hr/test x 12 gal/hr) = 324 gallons

Assume 350 gallons for the purposes of determining the Security and health Physics Building UBC building classification and fire zone requirements. The fuel will be contained in a dual wall sub-base tank, which is pre-designed to meet NFPA-37 (Reference 76), requirements on tanks and spill containment requirements.

As addressed above, the diesel generator tank will hold approximately 350 gallons, which exceeds the exempt amount of 120 gallons for closed systems in UBC Table 3-D. Therefore, the diesel generator room, which is classified as a hazardous material control area, will be provided with a fire sprinkler system in accordance with NFPA 13 and will be separated from all other adjacent interior spaces by a 1 hour fire resistive barrier in accordance with UBC Table 3-D.

Where combustible liquids are present in Group B structures, the UBC requires that the storage and use of such combustibles be in accordance with the fire code, i.e. the NFPA. As noted above, the diesel fuel will be contained in a dual wall tank that will meet all the fire prevention controls required per the NFPA-37 and therefore, will not

require any other provisions for fire protection.

Design Code Compliance

The foam-water sprinkler system will be designed in accordance with NFPA 16 (Reference 65). The sprinkler system for the diesel generator room will be designed in accordance with NFPA 13 (Reference 26). The standpipe and hose systems will be designed in accordance with NFPA 14 (Reference 82). The fire pumps and water supply tanks will be provided in accordance with NFPA 20 (Reference 28) and NFPA 22 (Reference 29) respectively. Fire hydrants and water mains will be designed in accordance with NFPA 24 (Reference 83). The portable fire extinguishers will be provided in accordance with NFPA 10 (Reference 30). The fire protection equipment at the PFSF including the Canister Transfer Building foam-water system, diesel generator room sprinkler room, yard hydrants, fire pumps, water storage tank, service mains, and all associated components will be maintained in accordance with NFPA 25 (Reference 77). The fire detection systems shall be designed in accordance with NFPA 72 (Reference 78). All fire protection systems will be designed to the latest code in affect at the time of the design.

4.3.8.2 System Description

The fire protection system in the load/unload bays of the Canister Transfer Building is a foam-water sprinkler system. The foam-water sprinkler system is a special system that is connected by piping to a source of foam concentrate and to a water supply. When the system is activated, water flows into the piping system where foam is injected into the water, resulting in a foam solution discharging through special sprinkler heads. The foam-water discharge continues until shut off manually.

The fire protection system in the diesel generator room of the Security and Health Physics Building will be a standard wet pipe sprinkler system.

Fire hydrants are located near the buildings to support fire suppression of the buildings. A PFSF fire truck is stationed at the site. Presently, a second fire truck is located at the Goshute Village 3.5 miles from the site.

The Canister Transfer Building foam-water sprinkler system, Security and Health Physics Building diesel generator room sprinkler system, and outdoor fire hydrants will be fed water from one of two fire pumps at a fire pump house located outside the restricted area near the Security and Health Physics Building. The foam supply for the foam-water sprinkler system will be located immediately outside of the Canister Transfer Building where it will be connected to the water supply lines. Water for the pumps is supplied by a primary and a backup water tank, each with a capacity of 100,000 gallons. One pump is powered by an electric motor, the other by a diesel engine in the event of a loss of electrical power.

The fire detection system consists of photo-sensitive smoke detectors located in all the facility buildings. The smoke detectors are interconnected within each building and are connected to a central alarm panel located in the Security and Health Physics Building. Annunciation of the smoke alarms occurs within both the building where the detector is located and the central alarm panel. A trip of the fire detection system in the Canister Transfer Building will automatically set off the building's foam-water sprinkler system.

Smoke from a fire in the Canister Transfer Building will be removed by the building's ventilation exhaust fans.

4.3.8.3 System Evaluation

An evaluation of potential fires affecting SSCs classified as Important to Safety is shown in Section 8.2.5. The analysis concludes that these fires will not produce an unsafe condition or preclude the ability of SSCs from performing their safety related

function. The foam-water sprinkler system further ensures that fires that could occur in the Canister Transfer Building load/unload bay will be extinguished within minutes.

PFS will perform a Fire Hazards Analysis (FHA) in accordance with NFPA-801 prior to detailed design of the facility. A review of the list of items recommended for inclusion into the FHA determined that a majority of the analyses and information required in the FHA have already been presented in the SAR, EP, and supporting calculations. Specific information includes:

- Fire protection system and performance criteria (Section 4.3.8.1).
- Design considerations for fire in the storage systems and PFSF buildings (Sections 4.2.1.5.1J, 4.2.2.5.1J, 4.7.1.5.1G, 4.7.3.5.1E, and 4.7.4.5.1D, which show that the spent fuel storage system and transportation systems are already qualified for potential fires that bound the fires at the PFSF).
- Methods for fire prevention, extinguishing, and control (Section 4.3.8.1).
- Types of potential fires (Section 8.2.5)
- That there are no essential power requirements because of the passive safety design of the components (Section 4.3.2).
- Available offsite fire protection (EP Section 1.3 and 3.2D).
- Inspection, testing and maintenance (Section 4.3.8.1).
- Life safety, protection of critical SSCs, and radioactivity releases (Sections 4.2.1.5.1J, 4.2.2.5.1J, 4.7.1.5.1G, 4.7.3.5.1E, and 4.3.8.1).

A fire loading calculation will also be prepared prior to detail design of the facilities as required for the FHA. However, it has been concluded from evaluations already performed that the combustible loading in the building is negligible and that a fire at the site will not adversely affect nuclear safety of the facility nor the health and safety of the public.

4.3.11 Air Sampling Systems

Continuous air monitors, located in the exhaust of each canister transfer cell, monitor radioactivity concentrations in the air leaving each canister transfer cell, where the potential exists for contamination on external canister surfaces to become airborne during canister transfer operations (Section 7.3.5). Since the spent fuel is totally contained within sealed canisters, there is no need for air sampling systems or airborne monitors outside, where storage casks are stored on the pads. A hand held monitor is used to analyze the air sample taken from the shipping cask prior to opening the cask.

4.3.12 Gas Utilities

Propane will be used to provide fuel to all gas heating units located in the PFSF buildings rather than natural gas due to the remote location of the site. Propane for heating the Canister Transfer Building and the Security and Health Physics Building will be stored in a centralized group of four propane fuel storage tanks, with the volume of each tank less than or equal to 5,000 gallons, and the volume of all four tanks no greater than 20,000 gallons (Section 8.2.4.1). This group of tanks shall be located a minimum distance of 1,800 ft south or southwest of the Canister Transfer Building, and shall be a minimum distance of 1,800 ft from the nearest cask storage pads. In addition, this group of propane storage tanks will be located approximately 1,000 ft west-southwest of the Operations and Maintenance Building (it will be further from the Administration Building). The 1,800 ft distance requirement provides a conservative safe standoff distance to assure that a postulated propane vapor cloud explosion will not result in significant damage to the Canister Transfer Building or to loaded storage casks, as discussed in Section 8.2.4.2. Propane for heating the Operations and Maintenance Building and the Administration Building will be stored in one or two relatively small propane tanks located in the vicinity of these buildings. This tank or each of the tanks, shall be less than 5,000 gallons capacity and shall also be located a minimum distance of 1,800 ft from the Canister Transfer Building and the nearest cask storage pads.

The propane storage tanks will be above-ground, designed in accordance with the requirements of NFPA 58. The effects of a postulated propane vapor cloud explosion from propane assumed to leak from the group of tanks that supplies the Canister Transfer Building and Security and Health Physics Building are analyzed in Section 8.2.4.2. NFPA 58 requires that propane tanks between 50 and 2,000 gallon capacity be located at least 25 ft away from any building or adjacent property, and that propane tanks between 2,001 and 30,000 gallons be located at least 50 ft away from any building or adjacent property and 5 ft away from any adjacent container. The propane heating system will be installed in accordance with NFPA requirements. Outdoor piping between the tanks and the buildings will be located below ground and coated or wrapped.

4.3.13 Diesel Fuel Supply

In general, all fueling activities at the PFSF comply with applicable regulations. Operation and use of the stored fuel will be in accordance with 29 CFR 1910 (OSHA) regulations to ensure employee health and safety requirements are met. Prior to fueling, a management plan and procedures will be developed to ensure that personnel are properly trained and fuel deliveries are carried out in accordance with the plan.

4.3.13.1 Fueling of on-site vehicles used at the PFSF

As stated in SAR Section 8.2.4.1, a diesel fuel oil storage tank will be located inside the restricted area (RA), and will supply diesel fuel oil for the cask transporter. This tank will be located near the RA fence, approximately 200 ft northeast of the northeast corner of the Canister Transfer Building and approximately 700 ft from the nearest storage casks. The outdoor tank will be above-ground, mounted on a concrete pad, with a double wall, having all necessary equipment for pumping and dispensing diesel fuel. The tank will have a capacity of approximately 1000 gallons and will store low grade sulfur No. 2-D diesel fuel. The tank includes a double wall for primary and

17. CECSAP Computer Program, Version 1.0, International Civil Engineering Consultants, Inc., October 1996.

18. SASSI Computer Program for IBM/RS-6000 Workstation, Version 1.2, International Civil Engineering Consultants, Inc., March 1997.

19. Development of Soil and foundation Parameters in Support of Dynamic Soil-Structure Interaction Analysis, Calculation No. 05996.01 G(P05)-1, Geomatrix Consultants, Inc., March 31, 1997.

20. ASCE-4, Seismic Analysis of Safety-Related Nuclear Structures and Commentary on Standard for Seismic Analysis of Safety-Related Nuclear Structures, American Society of Civil Engineers, 1986.

21. J & R Engineering Company Inc., Cask Transporter Catalog Data.

22. Private Fuel Storage Facility Storage Facility Design Criteria, Section 4.0, Geotechnical Design Criteria, Revision 2.

23. 10 CFR 73.51, Requirements for the Physical Protection of Stored Spent Fuel or High - Level Radioactive Waste, (Proposed).

24. (deleted)

25. Uniform Building Code, International Conference of Building Officials, 1994 edition.

26. NFPA 13, Standard for the Installation of Sprinkler Systems, National Fire Protection Association, 1996.

27. (deleted)

28. NFPA 20, Standard for the Installation of Centrifugal Fire Pumps, National Fire Protection Association, 1996.

29. NFPA 22, Standard for Water Tanks for Private Fire Protection, National Fire Protection Association, 1996.

30. NFPA 10, Standard for Portable Fire Extinguishers, National Fire Protection Association, 1994.

31. ASCE-7, Minimum Design Loads for Buildings and Other Structures, American Society of Civil Engineers, 1995.

32. ASME NOG-1, Rules for Construction of Overhead and Gantry Cranes (Top Running Bridge, Multiple Bridge), 1989.

33. NUREG-0554, Single-Failure-Proof Cranes for Nuclear Power Plants, U.S. Nuclear Regulatory Commission, 1979.

34 ANSI N14.6, Radioactive Materials - Special Lifting Devices for Shipping Containers, 1993.

71. Stone & Webster Engineering Corporation (SWEC), 2000a, Calculation No. 05996.02-G(B)-5, Revision 2, Document Bases for Geotechnical Parameters Provided in Geotechnical Design Criteria.

72. NFPA-801, Standard for Fire Protection for facilities Hanlding Radioactive Materials, 1998.

73. NFPA-220, Standard on Types of Building Construction, 1995.

74. NUREG-0908, Acceptance Criteria for the Evaluation of Nuclear Power Reactor Security Plans, 1982.

75. NUREG/CR-0509, Emergency Power Supplies for Physical Security Systems, November 1979.

76. NFPA-37, Standard Installation and Use of Stationary Combustion Engines and Gas Turbines, 1998.

77. NFPA-77, Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems, 1998.

78. NFPA-72, National Fire Alarm Code, 1996.

79. 10 CFR 72 Certificate of Compliance 1014, Rev. 0, HI-STORM 100 System, May, 2000.

80. 10 CFR 71 Certificate of Compliance 9261, Rev. 0, HI-STAR 100 System, March, 1999.

81. (deleted)

82. NFPA 14, Standard for the Installation of Standpipe and Hose Systems, 1996.

83. NFPA 24, Standard for the Installation of Private Fire Service Mains and Their Appurtenances, 1995.

84. PFSF Calculation No. 05996.02 G(B)-11, Dynamic Settlements of the Soils Underlying the Site, Revision 1, Stone & Webster.

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While unlikely, it is considered possible that collision or tornado-driven missile impact with the outdoor tank could result in tank rupture and spillage of diesel fuel oil. If there were an ignition source at the location of the spilled diesel fuel, it would be possible to initiate a fire, though diesel fuel is difficult to ignite due to its low volatility. Rupture of a storage tank and spillage of diesel fuel does not create the potential for an explosion. It is planned to use Grade Low Sulfur No. 2-D diesel fuel oil in both applications (onsite vehicles and backup diesel generator), which has a flash point of 126°F (52°C) per Reference 48. Diesel fuel is not a flammable liquid (defined as a liquid having a flash point below 100°F), but falls into the classification of a Class II combustible liquid which has a flash point above 100°F and below 140°F (Reference 49). The flash point is defined as the lowest temperature at which the vapor pressure of the liquid is just sufficient to produce a flammable mixture at the lower limit of flammability above the surface of the liquid. In recognition of the relatively high flash point of diesel fuel oil (at above-ambient temperatures), NFPA 30 does not require use of explosion proof electrical equipment in the vicinity of diesel fuel oil. While spilled diesel fuel could burn it could not detonate, and therefore an explosion associated with diesel fuel oil is not considered to be a credible event. The outdoor diesel fuel oil storage tank is sufficiently removed from the Canister Transfer Building and the storage casks (nearest important-to-safety structures, systems, and components) that radiant heat energy from a diesel fuel oil fire at the storage tank would not result in damage.

A double-wall subbase diesel fuel oil tank will be mounted on the backup diesel generator skid in the Security and Health Physics Building to provide fuel for operation of the backup diesel generator. This area will be protected with a fire suppression system designed to NFPA 13 (Reference 63) requirements for water sprinklers. A fire involving the indoor tank will not affect structures, systems or components outside of the Security and Health Physics Building. There are no important to safety items within this building.

Propane for heating the Canister Transfer Building and the Security and Health Physics Building will be supplied by a propane distribution system that originates from a group of four propane fuel storage tanks having a total volume of no greater than 20,000 gallons, with each individual tank having a volume no greater than 5,000 gallons. This group of tanks shall be located a minimum distance of 1,800 ft south or southwest of the Canister Transfer Building, and shall be a minimum distance of 1,800 ft from the nearest cask storage pads. This provides a conservative safe standoff distance to assure that a postulated explosion associated with a propane release from this group of tanks will not result in significant damage to the Canister Transfer Building or to loaded storage casks, as discussed in Section 8.2.4.2. In addition, this group of propane storage tanks will be located approximately 1,000 ft west-southwest of the Operations and Maintenance (O&M) Building (it will be further from the Administration Building). Propane for heating the O&M and the Administration buildings will be stored in one or two relatively small propane tanks located in the vicinity of these buildings. This tank, or each of these tanks, shall be less than 5,000 gallon capacity and shall also be located a minimum distance of 1,800 ft from the Canister Transfer Building and the nearest cask storage pads. The storage tanks will be above-ground, designed in accordance with the requirements of NFPA 58 (Reference 64).

The propane distribution system will consist of buried all-welded steel piping to minimize the possibility of propane leakage. Due to the relatively large distances from the group of propane storage tanks to the Canister Transfer Building and the Security and Health Physics Building, the design of the propane distribution system will include a compressor, located near the storage tanks, to provide the motive force necessary to transfer propane vapor from the storage tanks to these buildings. Excess flow control features will be installed at the group of storage tanks that will isolate flow of propane into the affected distribution line in the event of an abnormally high flow rate, which could be indicative of a large leak or pipe rupture. The propane heaters at the Canister

addition, a single excess flow shutoff valve shall be located on the 2 inch piping header that supplies propane to the Canister Transfer Building and Security and Health Physics Building, downstream of the connection points of the lines from the 4 propane tanks. This valve shall also be designed to automatically close upon sensing high flow conditions indicative of a line rupture or large leak. This system of automatic isolation valves will serve to automatically isolate pipeline ruptures, thus preventing significant leakage of propane in the vicinity of the Canister Transfer Building or Security and Health Physics Building.

As discussed above, overpressures were evaluated using the TNT energy equivalent methodology for each of the four propane release scenarios, assuming ignition of the dispersed propane vapor clouds. In all cases analyzed, with the exception of postulated rupture of a 20,000 gallon tank, overpressures decreased to less than 1 psi prior to reaching the Canister Transfer Building and nearest storage casks. Release of the total 20,000 gallons inventory of propane from all four tanks is not a credible scenario.

A fifth scenario was evaluated to determine the effects of a rupture in the propane supply pipe next to the Canister Transfer Building. The loss of propane would cause a low-pressure indication at the heaters that would shut off the fuel supply to the heaters and isolate the gas line at the tank. This low-pressure indication would be an indicator of a pipe leak between the tank and the heaters. The rupture is assumed to be large enough to allow the remaining propane in the pipe downstream of the propane tank shutoff valve to escape and form a vapor cloud next to the building without being dispersed.

Based on current design information, the propane line will be a 2 inch schedule 80 steel pipe approximately 2200 ft long from the shutoff valve to 1.5 inch branch lines to each of the roof mounted heaters. The total branch line length to the heaters is estimated to

be less than 100 ft. The inside diameter of a 2-inch sch. 80 pipe is 1.939 in. (0.162 ft) and a 1.5-inch sch. 80 pipe is 1.5 in. (0.125 ft) per Table 11-1 of Reference 64. The volume in the pipe would be V = Area x Length = $\pi d^2 L/4 = (3.1416)(0.162\ ft)^2\ (2200\ ft)/4 + (3.1416)(0.125\ ft)^2\ (100\ ft)/4 = 47\ ft^3$. To be conservative, it is assumed that the pressure in the line is at a maximum design pressure of 125 psi for vapor LP-gas service in accordance with Reference 64. From the ideal gas law the worst case mass of the cloud that could be released from the isolated pipe was calculated as mass = molecular weight x pressure x volume / R (Univ. Gas Constant) x temp.(°R) = (44 lbm/lbmole)(125 lbs/in^2)(47 ft^3) / (1545/144 $lbs\text{-}ft^3/in^2$-lbmole-°R)(70+460°R) = 45.5 lbm (20.6 kg). Studies of unconfined vapor cloud explosions, as reported in Section 3, Chapter 16 of the SFPE Handbook (Reference 71), indicate that a much larger amount of propane (1000 kg to 10,000 kg) is required for an ignited cloud to develop a pressure wave characteristic of an explosion. If ignition of this small release occurs before the vapor disperses, the result would be a flash fire of a few seconds duration that would not damage the structure or any equipment inside or outside the structure.

The propane supply pipe will surface next to the Canister Transfer Building on the southwest side of the building. At this location, the nearest opening into the building is more than 50 ft away. It is unlikely that any significant amount of vapor could enter the building because of the separation distance from the openings and the small amount of gas released. Because of the large volume of the Canister Transfer Building (greater than 1.2 million cubic feet), even if all 45.5 lbm were to get into the building, it could not create an explosion hazard.

8.2.4.3 Accident Dose Calculations

Since there is no potential for significant overpressures occurring at structures, systems, and components at the PFSF that are important to safety as a result of nearby

explosions, there would be no damage to the cask storage or transfer systems and no resultant dose.

8.2.5 Fire

Fire is classified as a human-induced Design Event IV as defined in ANSI/ANS-57.9.

8.2.5.1 Cause of Accident

The only combustible material at the PFSF storage pads during storage operations is insulation on the temperature monitoring instrumentation wiring, which is present in insignificant quantities at each storage cask. No combustible or explosive materials are allowed to be stored on or near the storage pads. The PFSF Restricted Area (RA) is cleared of vegetation and the entire RA surfaced with compacted gravel. The concrete pads and storage casks are located a minimum distance of 150 ft from the outer edge of the RA (i.e., the inner fence surrounding the RA); the Canister Transfer Building is located a minimum distance of 112 ft from the outer edge of the RA. The area between the outer edge of the RA and the outer edge of the perimeter road (50 ft distance, see Figure 1.2-1) is also covered with crushed rock. The only significant sources of combustibles that would be present inside the RA would be: 1) the diesel fuel in the tanks of the tractor, and tires on the tractor and trailer, of any heavy haul vehicles transporting shipping casks to/from the PFSF site; 2) the diesel fuel in the tanks of any train locomotive transporting shipping casks to/from the PFSF site; 3) the diesel fuel in the cask transporter vehicle that would move casks from the Canister Transfer Building to the storage pads; 4) the diesel generator fuel tank inside the Security and Health Physics Building; and 5) the diesel fuel storage tank, which would be located at least 50 ft inside the inner fence surrounding the RA, approximately 200 ft northeast of the Canister Transfer Building and 700 ft east of the nearest storage casks.

The group of propane storage tanks having relatively large total capacity that will supply propane to heat the Canister Transfer Building and the Security and Health Physics Building (described in Section 8.2.4.1) shall be located a minimum of 1,800 ft south or southwest of the Canister Transfer Building, and a minimum distance of 1,800 ft from

It is also assumed that the transporter components will retain structural integrity during missile impact. In the event a component, such as the lift beam, fails, the cask will simply drop approximately 4" to the ground. The HI-STORM and TranStor storage casks are determined to be structurally sound for drops up to 11 inches and 18 inches respectively, as shown in Section 8.2.6.

The event can be thought of as two separate events. The first event is the collision, during which some of the kinetic energy of the missile is transferred to the cask/transporter system (target). How much of the energy is imparted to the target depends upon the nature of the collision. Not all of the missile energy can be transferred to the target, since this would violate the law of conservation of momentum. The energy not transferred to the target remains as kinetic energy of the rebounding missile.

The most conservative collision would be a perfectly elastic collision, where no energy is lost and both momentum and kinetic energy are conserved during impact. The angular momentum and kinetic energy of the missile before and after the impact is:

Before impact: Angular momentum of the missile = $m_m V_o H$
Kinetic energy of the missile = $0.5\, m_m V_o^2$

After impact: Angular momentum of the missile = $m_m V_f H$
Kinetic energy of the missile = $0.5\, m_m V_f^2$

where:

m_m = mass of missile = 3990 lbs / 386 in/sec^2 = 10.34 lb-sec^2 / in.
V_o = initial velocity of missile = 134 fps = 1608 in./sec
H = height of transporter = 271 inches
V_f = velocity of missile after impact

After impact the angular momentum of the transporter = $I_p \omega_p$

where:

I_p = mass moment of inertia of loaded transporter about pivot point P
ω_p = angular velocity of the transporter after impact

The mass moment of inertia of the cask about pivot point P is:

$$I_{p\,cask} = m_{cask}/12(3r_{cask}^2 + h_{cask}^2) + m_{cask}\, d_{cg\,cask}^2$$

where:

m_{cask} = mass of cask = 307,600 lbs / 386 in/sec^2 = 797 lb-sec^2 / in.
r_{cask} = radius of cask = 136 in./2 = 68 in.
h_{cask} = height of cask = 223 in.
$d_{cg\,cask}$ = distance from cask center of gravity to pivot point P calculated from the cask center of gravity height raised 4" (118") and the horizontal distance from the center of gravity to pivot point P (taken as half the transporter width, 228 in. /2 = 114) or $d_{cg\,cask} = [(118)^2 + (114)^2]^{1/2} = 164$ in.

Therefore, the cask mass moment of inertia about pivot point P is:

$$I_{p\,cask} = 797/12\ [3(68)^2 + (223)^2] + (797)(164)^2 = 25.66 \times 10^6 \text{ in·lb·sec}^2$$

The mass moment of inertia of the transporter about pivot point P is (assume the transporter is a rectangular parallelepiped that represents the lower "track" portion of the transporter where most of the weight is located):

$$I_{p\,xptr} = m_{xptr}/12\ (h_{xptr}^2 + w_{xptr}^2) + m_{xptr}\, d_{cg\,xptr}^2$$

where:

m_{xptr} = mass of transporter = 160,000 lbs / 386 in/sec^2 = 415 lb-sec^2/in.
h_{xptr} = height of transporter for calculating center of gravity (assume twice the height of the center of gravity) = 66 in. x 2 = 132 in.
w_{xptr} = overall width of transporter = 228 in.
$d_{cg\,xptr}$ = distance from transporter center of gravity to pivot point P calculated from the transporter center of gravity height (66") and the horizontal distance from the center of gravity to pivot point P (taken as half the transporter width, 228 in./2 = 114") or $d_{cg\,xptr} = [(66)^2 + (114)^2]^{1/2} = 132$ in.

Therefore, the transporter mass moment of inertia about pivot point P is:

$$I_{p\,xptr} = 415/12\ (132^2 + 228^2) + (415)(132)^2 = 9.63 \times 10^6 \text{ in·lb·sec}^2$$

The total mass moment of inertia of the loaded transporter about pivot point P then is:

$$\text{Total } I_p = 25.66 \times 10^6 + 9.63 \times 10^6 = 35.29 \times 10^6 \text{ in·lb·sec}^2$$

The kinetic energy of the cask after impact = $0.5\ I_p\ \omega_p^2$

Equating the angular momentum of the missile before impact to the total angular momentum after impact,

$$m_m\ V_o\ H = m_m\ V_f\ H + I_p\ \omega_p$$

Equating the kinetic energy before impact to the total kinetic energy after impact,

$$0.5\ m_m\ V_o^2 = 0.5\ m_m V_f^2 + 0.5\ I_p\ \omega_p^2$$

Substituting the values of m_m, V_o, H and I_p, and solving for V_f and ω_p,

V_f = -1540 in/sec (missile rebound velocity)

ω_p = 0.250 rad/sec

The second part of the event consists of motion of the target after impact. Immediately after impact, the target is in it's original position and starts to rotate about the pivot point P with an angular velocity of 0.250 rad/sec. The weight of the cask/transporter creates a moment (torque) about the pivot point, which opposes the motion and decelerates the target. This moment reduces the angular velocity until it reaches zero, and then gravity

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While unlikely, it is considered possible that collision or tornado-driven missile impact with the outdoor tank could result in tank rupture and spillage of diesel fuel oil. If there were an ignition source at the location of the spilled diesel fuel, it would be possible to initiate a fire, though diesel fuel is difficult to ignite due to its low volatility. Rupture of a storage tank and spillage of diesel fuel does not create the potential for an explosion. It is planned to use Grade Low Sulfur No. 2-D diesel fuel oil in both applications (onsite vehicles and backup diesel generator), which has a flash point of 126°F (52°C) per Reference 48. Diesel fuel is not a flammable liquid (defined as a liquid having a flash point below 100°F), but falls into the classification of a Class II combustible liquid which has a flash point above 100°F and below 140°F (Reference 49). The flash point is defined as the lowest temperature at which the vapor pressure of the liquid is just sufficient to produce a flammable mixture at the lower limit of flammability above the surface of the liquid. In recognition of the relatively high flash point of diesel fuel oil (at above-ambient temperatures), NFPA 30 does not require use of explosion proof electrical equipment in the vicinity of diesel fuel oil. While spilled diesel fuel could burn it could not detonate, and therefore an explosion associated with diesel fuel oil is not considered to be a credible event. The outdoor diesel fuel oil storage tank is sufficiently removed from the Canister Transfer Building and the storage casks (nearest important-to-safety structures, systems, and components) that radiant heat energy from a diesel fuel oil fire at the storage tank would not result in damage.

A double-wall subbase diesel fuel oil tank will be mounted on the backup diesel generator skid in the Security and Health Physics Building to provide fuel for operation of the backup diesel generator. This area will be protected with a fire suppression system designed to NFPA 13 (Reference 63) requirements for water sprinklers. A fire involving the indoor tank will not affect structures, systems or components outside of the Security and Health Physics Building. There are no important to safety items within this building.

Propane for heating the Canister Transfer Building and the Security and Health Physics Building will be supplied by a propane distribution system that originates from a group of four propane fuel storage tanks having a total volume of no greater than 20,000 gallons, with each individual tank having a volume no greater than 5,000 gallons. This group of tanks shall be located a minimum distance of 1,800 ft south or southwest of the Canister Transfer Building, and shall be a minimum distance of 1,800 ft from the nearest cask storage pads. This provides a conservative safe standoff distance to assure that a postulated explosion associated with a propane release from this group of tanks will not result in significant damage to the Canister Transfer Building or to loaded storage casks, as discussed in Section 8.2.4.2. In addition, this group of propane storage tanks will be located approximately 1,000 ft west-southwest of the Operations and Maintenance (O&M) Building (it will be further from the Administration Building). Propane for heating the O&M and the Administration buildings will be stored in one or two relatively small propane tanks located in the vicinity of these buildings. This tank, or each of these tanks, shall be less than 5,000 gallon capacity and shall also be located a minimum distance of 1,800 ft from the Canister Transfer Building and the nearest cask storage pads. The storage tanks will be above-ground, designed in accordance with the requirements of NFPA 58 (Reference 64).

The propane distribution system will consist of buried all-welded steel piping to minimize the possibility of propane leakage. Due to the relatively large distances from the group of propane storage tanks to the Canister Transfer Building and the Security and Health Physics Building, the design of the propane distribution system will include a compressor, located near the storage tanks, to provide the motive force necessary to transfer propane vapor from the storage tanks to these buildings. Excess flow control features will be installed at the group of storage tanks that will isolate flow of propane into the affected distribution line in the event of an abnormally high flow rate, which could be indicative of a large leak or pipe rupture. The propane heaters at the Canister

addition, a single excess flow shutoff valve shall be located on the 2 inch piping header that supplies propane to the Canister Transfer Building and Security and Health Physics Building, downstream of the connection points of the lines from the 4 propane tanks. This valve shall also be designed to automatically close upon sensing high flow conditions indicative of a line rupture or large leak. This system of automatic isolation valves will serve to automatically isolate pipeline ruptures, thus preventing significant leakage of propane in the vicinity of the Canister Transfer Building or Security and Health Physics Building.

As discussed above, overpressures were evaluated using the TNT energy equivalent methodology for each of the four propane release scenarios, assuming ignition of the dispersed propane vapor clouds. In all cases analyzed, with the exception of postulated rupture of a 20,000 gallon tank, overpressures decreased to less than 1 psi prior to reaching the Canister Transfer Building and nearest storage casks. Release of the total 20,000 gallons inventory of propane from all four tanks is not a credible scenario.

A fifth scenario was evaluated to determine the effects of a rupture in the propane supply pipe next to the Canister Transfer Building. The loss of propane would cause a low-pressure indication at the heaters that would shut off the fuel supply to the heaters and isolate the gas line at the tank. This low-pressure indication would be an indicator of a pipe leak between the tank and the heaters. The rupture is assumed to be large enough to allow the remaining propane in the pipe downstream of the propane tank shutoff valve to escape and form a vapor cloud next to the building without being dispersed.

Based on current design information, the propane line will be a 2 inch schedule 80 steel pipe approximately 2200 ft long from the shutoff valve to 1.5 inch branch lines to each of the roof mounted heaters. The total branch line length to the heaters is estimated to

be less than 100 ft. The inside diameter of a 2-inch sch. 80 pipe is 1.939 in. (0.162 ft) and a 1.5-inch sch. 80 pipe is 1.5 in. (0.125 ft) per Table 11-1 of Reference 64. The volume in the pipe would be V = Area x Length = πd^2 L/4 = (3.1416)(0.162 ft)^2 (2200 ft)/4 + (3.1416)(0.125 ft)^2 (100 ft)/4 = 47 ft^3. To be conservative, it is assumed that the pressure in the line is at a maximum design pressure of 125 psi for vapor LP-gas service in accordance with Reference 64. From the ideal gas law the worst case mass of the cloud that could be released from the isolated pipe was calculated as mass = molecular weight x pressure x volume / R (Univ. Gas Constant) x temp.(°R) = (44 lbm/lbmole)(125 lbs/in^2)(47 ft^3) / (1545/144 lbs-ft^3/in^2-lbmole-°R)(70+460°R) = 45.5 lbm (20.6 kg). Studies of unconfined vapor cloud explosions, as reported in Section 3, Chapter 16 of the SFPE Handbook (Reference 71), indicate that a much larger amount of propane (1000 kg to 10,000 kg) is required for an ignited cloud to develop a pressure wave characteristic of an explosion. If ignition of this small release occurs before the vapor disperses, the result would be a flash fire of a few seconds duration that would not damage the structure or any equipment inside or outside the structure.

The propane supply pipe will surface next to the Canister Transfer Building on the southwest side of the building. At this location, the nearest opening into the building is more than 50 ft away. It is unlikely that any significant amount of vapor could enter the building because of the separation distance from the openings and the small amount of gas released. Because of the large volume of the Canister Transfer Building (greater than 1.2 million cubic feet), even if all 45.5 lbm were to get into the building, it could not create an explosion hazard.

8.2.4.3 Accident Dose Calculations

Since there is no potential for significant overpressures occurring at structures, systems, and components at the PFSF that are important to safety as a result of nearby

explosions, there would be no damage to the cask storage or transfer systems and no resultant dose.

8.2.5 Fire

Fire is classified as a human-induced Design Event IV as defined in ANSI/ANS-57.9.

8.2.5.1 Cause of Accident

The only combustible material at the PFSF storage pads during storage operations is insulation on the temperature monitoring instrumentation wiring, which is present in insignificant quantities at each storage cask. No combustible or explosive materials are allowed to be stored on or near the storage pads. The PFSF Restricted Area (RA) is cleared of vegetation and the entire RA surfaced with compacted gravel. The concrete pads and storage casks are located a minimum distance of 150 ft from the outer edge of the RA (i.e., the inner fence surrounding the RA); the Canister Transfer Building is located a minimum distance of 112 ft from the outer edge of the RA. The area between the outer edge of the RA and the outer edge of the perimeter road (50 ft distance, see Figure 1.2-1) is also covered with crushed rock. The only significant sources of combustibles that would be present inside the RA would be: 1) the diesel fuel in the tanks of the tractor, and tires on the tractor and trailer, of any heavy haul vehicles transporting shipping casks to/from the PFSF site; 2) the diesel fuel in the tanks of any train locomotive transporting shipping casks to/from the PFSF site; 3) the diesel fuel in the cask transporter vehicle that would move casks from the Canister Transfer Building to the storage pads; 4) the diesel generator fuel tank inside the Security and Health Physics Building; and 5) the diesel fuel storage tank, which would be located at least 50 ft inside the inner fence surrounding the RA, approximately 200 ft northeast of the Canister Transfer Building and 700 ft east of the nearest storage casks.

The group of propane storage tanks having relatively large total capacity that will supply propane to heat the Canister Transfer Building and the Security and Health Physics Building (described in Section 8.2.4.1) shall be located a minimum of 1,800 ft south or southwest of the Canister Transfer Building, and a minimum distance of 1,800 ft from

It is also assumed that the transporter components will retain structural integrity during missile impact. In the event a component, such as the lift beam, fails, the cask will simply drop approximately 4" to the ground. The HI-STORM and TranStor storage casks are determined to be structurally sound for drops up to 11 inches and 18 inches respectively, as shown in Section 8.2.6.

The event can be thought of as two separate events. The first event is the collision, during which some of the kinetic energy of the missile is transferred to the cask/transporter system (target). How much of the energy is imparted to the target depends upon the nature of the collision. Not all of the missile energy can be transferred to the target, since this would violate the law of conservation of momentum. The energy not transferred to the target remains as kinetic energy of the rebounding missile.

The most conservative collision would be a perfectly elastic collision, where no energy is lost and both momentum and kinetic energy are conserved during impact. The angular momentum and kinetic energy of the missile before and after the impact is:

Before impact: Angular momentum of the missile = $m_m V_o H$
Kinetic energy of the missile = $0.5\ m_m V_o^2$

After impact: Angular momentum of the missile = $m_m V_f H$
Kinetic energy of the missile = $0.5\ m_m V_f^2$

where:

m_m = mass of missile = 3990 lbs / 386 in/sec^2 = 10.34 lb-sec^2 / in.
V_o = initial velocity of missile = 134 fps = 1608 in./sec
H = height of transporter = 271 inches
V_f = velocity of missile after impact

After impact the angular momentum of the transporter = $I_p \omega_p$

where:

I_p = mass moment of inertia of loaded transporter about pivot point P
ω_p = angular velocity of the transporter after impact

The mass moment of inertia of the cask about pivot point P is:

$$I_{p\,cask} = m_{cask}/12(3r_{cask}^2 + h_{cask}^2) + m_{cask}\, d_{cg\,cask}^2$$

where:

m_{cask} = mass of cask = 307,600 lbs / 386 in/sec^2 = 797 lb-sec^2 / in.
r_{cask} = radius of cask = 136 in./2 = 68 in.
h_{cask} = height of cask = 223 in.
$d_{cg\,cask}$ = distance from cask center of gravity to pivot point P calculated from the cask center of gravity height raised 4" (118") and the horizontal distance from the center of gravity to pivot point P (taken as half the transporter width, 228 in. /2 = 114) or $d_{cg\,cask} = [(118)^2 + (114)^2]^{1/2} = 164$ in.

Therefore, the cask mass moment of inertia about pivot point P is:

$$I_{p\,cask} = 797/12\ [3(68)^2 + (223)^2] + (797)(164)^2 = 25.66 \times 10^6 \text{ in·lb·sec}^2$$

The mass moment of inertia of the transporter about pivot point P is (assume the transporter is a rectangular parallelepiped that represents the lower "track" portion of the transporter where most of the weight is located):

$$I_{p\,xptr} = m_{xptr}/12\ (h_{xptr}^2 + w_{xptr}^2) + m_{xptr}\, d_{cg\,xptr}^2$$

where:

m_{xptr} = mass of transporter = 160,000 lbs / 386 in/sec^2 = 415 lb-sec^2/in.
h_{xptr} = height of transporter for calculating center of gravity (assume twice the height of the center of gravity) = 66 in. x 2 = 132 in.
w_{xptr} = overall width of transporter = 228 in.
$d_{cg\,xptr}$ = distance from transporter center of gravity to pivot point P calculated from the transporter center of gravity height (66") and the horizontal distance from the center of gravity to pivot point P (taken as half the transporter width, 228 in./2 = 114") or $d_{cg\,xptr} = [(66)^2 + (114)^2]^{1/2} = 132$ in.

Therefore, the transporter mass moment of inertia about pivot point P is:

$$I_{p\,xptr} = 415/12\,(132^2 + 228^2) + (415)(132)^2 = 9.63 \times 10^6 \text{ in}\cdot\text{lb}\cdot\text{sec}^2$$

The total mass moment of inertia of the loaded transporter about pivot point P then is:

$$\text{Total } I_p = 25.66 \times 10^6 + 9.63 \times 10^6 = 35.29 \times 10^6 \text{ in}\cdot\text{lb}\cdot\text{sec}^2$$

The kinetic energy of the cask after impact = $0.5\, I_p\, \omega_p^2$

Equating the angular momentum of the missile before impact to the total angular momentum after impact,

$$m_m V_o H = m_m V_f H + I_p \omega_p$$

Equating the kinetic energy before impact to the total kinetic energy after impact,

$$0.5\, m_m V_o^2 = 0.5\, m_m V_f^2 + 0.5\, I_p\, \omega_p^2$$

Substituting the values of m_m, V_o, H and I_p, and solving for V_f and ω_p,

V_f = -1540 in/sec (missile rebound velocity)

ω_p = 0.250 rad/sec

The second part of the event consists of motion of the target after impact. Immediately after impact, the target is in it's original position and starts to rotate about the pivot point P with an angular velocity of 0.250 rad/sec. The weight of the cask/transporter creates a moment (torque) about the pivot point, which opposes the motion and decelerates the target. This moment reduces the angular velocity until it reaches zero, and then gravity

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