APPENDIX E

CRITICALITY EVENT ANALYSIS FOR PLUTONIUM COMPONENTS

The investigation of the potential for a criticality incident involving plutonium components in the modified-Richmond and steel arch construction (SAC) magazines was undertaken in two complementary, but separate, steps. The first approach, generally termed deterministic, was to model the pits and containers in their most reactive configuration and then to estimate the effective multiplication factor (k_{eff}) of the array for a number of postulated scenarios. The second approach involved a structured examination of the potential for a criticality incident. This approach examines the conditions required for criticality and the likelihood that those conditions could be met. These two approaches are discussed below. A calculations were made by one analyst and verified by a second analyst as a quality assurance measure.

E.1 Deterministic Model

In this approach, the initial step involved developing a conservative physical model of the packages and facility to be studied. This model was then converted to an analytical model and estimates of k_{eff} were generated for several scenarios.

E.1.1 Physical Model

The initial model selected represents the most reactive configuration of plutonium pits and containers that could be stored on a interim basis in the magazine. That is, each pit is assumed to have the largest mass and smallest volume that might be anticipated and to reside in the container of smallest volume. The maximum allowable number of containers is assumed to be in the magazine.

The pits are modeled as a spherical shell of plutonium with an assumed mass of 6.5 kilograms (kg). The pit is assumed to be centered in the container. For modelling purposes, the Rocky Flats AL-R8 package was selected. The smallest container of this series is the 2030, nominally a container with a 20-inch diameter and a 30-inch height. Actually, the 2030 is an 18-gauge (0.048-inch thickness) steel can with a minimum inside diameter of 18.12 inches and an inside height of 27.21 inches. This container is lined with Celotex and contains a minimal amount of other hardware (see Figure E-1). The modeling of the pit and the container is described in Section E.1.2.

The number of AL-R8 containers that are arranged vertically and without stacking could be as high as 378 in a modified-Richmond magazine and 406 in a SAC magazine. (The figures represent the physical capacity of the magazines.) When the AL-R8 containers are laid horizontally on pallets and stacked, the modified-Richmond magazine can typically hold 440 containers and the SAC magazine 392 containers. (Plan and elevation views of the storage configurations are presented in Chapter 5.0, "Description of Operations," Figures 5-2 through 5-5). The limiting physical arrangements of the containers were modeled to bound the potential for a criticality incident under normal, abnormal, and severe accident conditions. The specific scenarios are discussed in Section E.1.3.

E.1.2 Analytical Model

A portion of the criticality estimates were generated using the KENO 5a code (Ref. 1) and Hansen-Roach 16-group cross sections. This Monte Carlo code and cross-section set combination is widely used and is known to produce reliable and accurate k_{eff} values for plutonium and high-enriched uranium systems. The remainder of the estimates were generated using the MCNP4 neutron/photon transport code (Ref. 2).

The computer model for the pit-and-container combination incorporated several simplifying assumptions. Because the exact composition of the plutonium varies in the higher mass number isotopes, the shell is assumed to be made entirely of fissile ^{239}Pu. The outer container is assumed to be a right circular cylinder of steel of a uniform thickness (i.e., neglecting perturbations such as rings, bolts, and clamps). The modest amount of refractory fiber insulation in the drum over the pressure relief vent is modeled by an equivalent amount of Celotex. This is considered to be a reasonable substitution and is consistent with previous AL-R8 evaluations (Ref. 3).

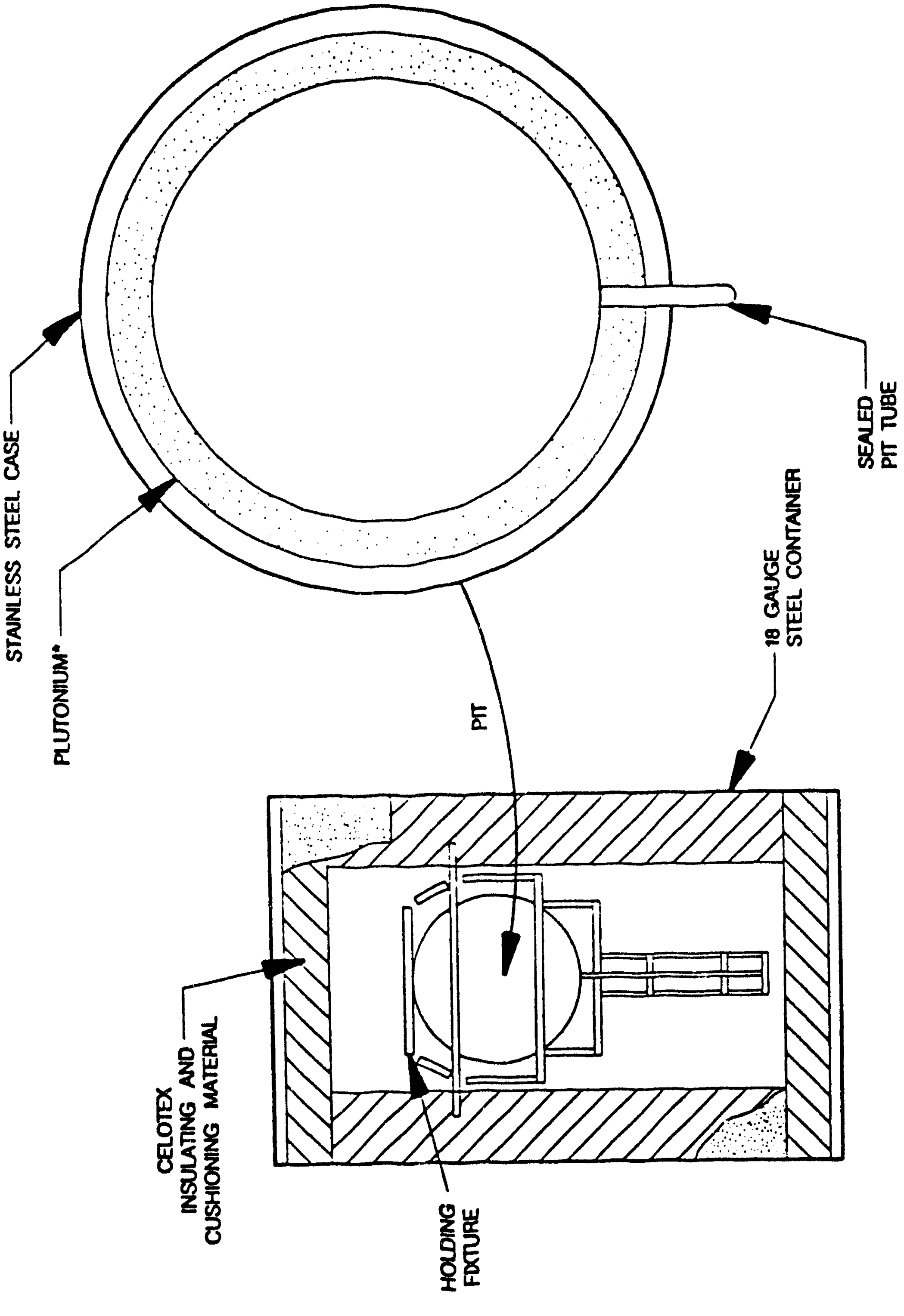

FIGURE E-1
AL-R8 CONTAINER DETAIL

* And / or Special Nuclear Material

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The KENO code most readily models arrays of rectangular pitch. However, because the arrays in many potential upset or accident conditions are likely to be more closely packed, the container pitch (diameter) is reduced to an "equivalent hexagonal pitch" (i.e., the dimension that will give the resulting rectangular array the same "surface density," or mass per unit area, as a close-packed hexagonal lattice). In practice, this reduces the outer container diameter by about 7% and increases the array reactivity accordingly. The thickness of the annular Celotex liner is retained at its original value.

The calculations were run on the KENO 5a and MCNP4 versions developed for IBM-286 class personal computers. Code validation for the specific computer used was performed on KENO 5a, consistent with the guidance of ANSI/ANS Standard 8.1, by computing k_{eff} values for benchmark experiments. Calculations were performed for nine benchmark critical experiments with plutonium and seven with high-enriched uranium. The lowest calculated value of k_{eff} for these cases, less three times its computational bias (i.e., in a Gaussian distribution, three times the standard deviation or a 99.9% lower tolerance limit), served to establish the value k_{eff} = 0.96 as corresponding to a subcritical system. (As a point of reference, earlier Rocky Flats computations used k_{eff} = 0.965 as this same limit [Ref. 3]). Subcriticality for a given configuration in this safety analysis is considered to be established when the computed k_{eff} plus two standard deviations is less than the level specified above.

MCNP4 was benchmarked against selected experimental data. In addition, several direct comparisons between KENO 5a and MCNP4 estimates were made and the results are consistent.

For these safety analyses, the KENO 5a and MCNP4 calculations are run with at least 103 generations of 300 neutrons each. As is the usual practice, the first three or more generations are discarded when evaluating the results. Among the routine checks for each case, convergence receives special attention (e.g., via the sigma-value plots and the k_{eff}-distribution histogram). Configurations for which convergence was slow or otherwise non-uniform were rerun with an increased number of neutron generations.

E.1.3 Computational Scenarios

The initial or scoping cases represent the following scenarios:

- A single container, first dry and unreflected, then water reflected, and fully flooded (i.e., all void spaces within container and shell assumed to be water-filled). These serve as baseline cases and provide a basis for comparison with previously reported results.

- Infinite tight-packed planar X-Y arrays of containers. These provide a comparison between a single container and a very large array. The fully flooded configuration is infinite in all dimensions and indicates the extent to which individual units are coupled neutronically.

- Infinite planar array of containers assumed to be dry internally (i.e., container integrity not compromised), but with water in the interstitial spaces between containers. The density of the water can be varied to investigate the effects of partial to full moderation upon the estimated k_{eff}.

As noted, current planning considers a magazine capacity of 378 (modified-Richmond) or 406 (SAC) containers sitting vertically on the floor with no stacking (maximum) or typically 392 to 440 containers lying horizontally on pallets. The calculational scenarios are thus extended to include the following array configurations.

- An infinite planar array (X - Y) of containers one high, dry, unreflected, and with internal spacing consistent with that in the palletized array.

- An infinite planar array (X - Y) of containers two high, dry, unreflected, and with internal spacing consistent with that in the palletized array.

Facility models are based on symmetry between the two sides. One side is modeled explicitly, then a reflecting plane is used to account for the effect of the other side. The facilities are modeled with concrete floor, walls, and ceiling. Thus, the configurations are:

- A generic facility (264 AL-R8 containers, 6 high in 2 rows, 22 containers long) with containers palletized and dry.
- A modified-Richmond facility (176 AL-R8 containers, 4 high in 2 rows, 22 containers long) with containers horizontal and dry.
- A SAC facility (198 AL-R8 containers, 6 high in 1 row, 3 high in another row, and 22 containers long) with containers horizontal and dry.

Arrays that would literally fill (or more than fill) the building were calculated as the following bounding scenarios:

- Array 25 deep by 16 across by 5 high of vertical (upright) AL-R8 containers.
- Array 25 deep by 9 across by 9 high of horizontal (on side) AL-R8 containers.
- Array 25 deep by 17 across by 6 high of vertical (upright) AL-R8 containers.
- Array 25 deep by 10 across by 10 high of horizontal (on side) AL-R8 containers.

Arrays in a roughly cubic and maximum reactivity configuration were also computed for:

- Array 16 deep by 16 across by 10 high of vertical (upright) AL-R8 containers.
- Array 15 deep by 15 across by 10 high of vertical (upright) AL-R8 containers.

E.1.4 Results

Results of the KENO 5a and MCNP4 calculations are shown in Table E-1. Each configuration that was modeled is subcritical (and actually more so than the calculations suggest, due to the conservative model assumptions [e.g., large mass pits, small volume containers, and tight array packing]). The results of this study are consistent with previously reported k_{eff} values for these containers with a range of contents (Ref. 4). These estimates of k_{eff} are lower because the model more closely approximates the actual conditions than the large cubic arrays previously reported.

The infinite planar arrays (from 1 high to 4 containers high) are subcritical. Such infinite arrays are very conservative models for the magazines. In the single layer, vertical configuration (see Figures 5-2 and 5-3), each side of a modified-Richmond has an array 27 x 7 x 1, and the SAC magazine an array 28 x 14.5 x 1. (The 14.5 accounts for an arrangement in which the rows alternate between 15 and 14 containers.) When the infinite planar array is calculated with water interstitial among the containers, k_{eff} decreases confirming that the containers are overmoderated. This result, and parametric studies of low density interspersed water moderation in the AL-R8 SARP (Ref. 3) indicate that the presence of water or other moderating material among the intact containers decreases, rather than increases multiplication.

In the palletized configuration, the modified-Richmond array is nominally 4 high by 2 rows by 22 containers long (per side). The SAC magazine array is nominally 6 high by 2 rows by 22 containers down the middle of the magazine with 3 high by 1 row by 22 containers along each of the 2 side walls. These, as well as the generic facility (6 high by 2 rows by 22 containers), are substantially subcritical as are the bounding case arrays, as shown in Table E-1.

Several finite arrays were examined to determine k_{eff} for a variety of unmoderated close-packed three-dimensional configurations. All were subcritical. The least number of pits examined in any of these arrays is considerably more than the maximum number of pits that could be placed into either a modified-Richmond or SAC magazine.

Table E-1. Calculated k_{eff} for 6.5-kg Spherical Shell in Arrays of AL-R8 Containers - $k_{eff}(2\sigma)$

Configuration	Unmoderated Unreflected	Unmoderated, Concrete Reflected at the Periphery	Interstitial Water, Concrete Reflected at the Periphery	Water Flooded[1]
Single Container[2]	0.320 (0.007)^K 0.312 (0.016)^M		0.396 (0.008)^K	0.824 (0.010)^K
Infinite X-Y Planar Arrays				
One High[3]	0.654 (0.004)^K	0.676 (0.009)^K 0.702 (0.014)^M	0.543 (0.009)^K	0.820 (0.010)$^{K[5]}$
Two High [3]		0.807 (0.009)^K	0.573 (0.008)^K	
Three High[3]		0.877 (0.009)^K	0.595 (0.008)^K	
Four High[3]		0.931 (0.009)^K		
Infinite X-Y Planar Arrays (Palletized Spacing)				
One High[4]	0.376 (0.018)^M			
Two High[4]	0.480 (0.016)^M	0.686 (0.012)^M	0.442 (0.016)^M	0.835 (0.012)^M
Facility Models				
Modified-Richmond[4] 2 x 176 Containers		0.495 (0.016)^M		
SAC Magazine[4] 2 x 198 Containers		0.474 (0.016)^M		
Generic Facility[4] 2 x 264 Containers		0.549 (0.14)^M		

Table E-1. Calculated k_{eff} for 6.5-kg Spherical Shell in Arrays of AL-R8 Containers - $k_{eff}(2\sigma)$

Configuration	Unmoderated Unreflected	Unmoderated, Concrete Reflected at the Periphery	Interstitial Water, Concrete Reflected at the Periphery	Water Flooded[1]
Finite Arrays (Maximum Packing)				
25 x 16 x 5 Array (Vertical)[2]		0.911 (0.009)[M]		
25 x 9 x 9 Array (Horizontal)[2]		0.915 (0.011)[M]		
25 x 17 x 6 Array (Vertical)[2]		0.932 (0.010)[M]		
25 x 10 x 10 Array (Horizontal)[2]		0.930 (0.010)[M]		
16 x 16 x 10 Array (Vertical)[2]		0.937 (0.010)[M]		
15 x 15 x 10 Array (Vertical)[2]		0.938 (0.004)[M]		

[1] Water flooded = water filling shell, container, and interstitial spaces between containers; single container is surrounded by 30 cm of water.
[2] Standard = actual diameter modified to model close-packed hexagonal array spacing.
[3] Close-fitting concrete (Z-direction), containers close-packed.
[4] Internal spacing consistent with palletized containers, but with no credit for neutron absorbing material in the pallets.
[5] The array is infinite in all dimensions.
[K] Indicates calculation done with KENO 5a.
[M] Indicates calculation done with MCNP4.

It was assumed in other configurations (for instance, those in the Building 12-26 Pit Vault and Cell 8) that an external event (e.g., an earthquake) could cause the containers that are located on shelves or in a configuration with substantial open floor space to tumble from the shelves. It was postulated that such an event could lead to a situation in which containers of "reduced" diameter were lying on their sides in an array. In this instance, palletized pit containers may be stacked up to 6 containers high in some configurations. However, as stated in Appendix C, "Structural Analysis," the palletized assemblies would prevent any significant structural change from occurring to the pit containers.

It has also been postulated that, in arrangements such as those in the magazines, external events could cause a roof collapse, thereby altering the geometry of the array. However, in the case of the magazines, even if the roof were to fall, the massive side walls would prevent the dispersal of the containers. Under these circumstances, even if the array were reduced in height, the "areal density" of fissile material would remain the same and, therefore, the array would remain subcritical. Similar arguments apply in the case of an aircraft impact causing failure of the roof structure. Furthermore, if there were sufficient energy in such an impact to cause the rupture of the walls and the dispersal of containers, the potential for criticality would be further reduced.

Thus, it is concluded that a criticality incident involving the pit/container combination is not a credible event. This is attributable to the solid form of the fissile material (i.e., metallic shells) and to the ruggedness of the containers and their palletized assemblies.

E.2 Structured Analysis

This analysis involved a structured examination of the potential for a criticality in a modified-Richmond or SAC magazine. It examines the conditions required to cause a criticality and the likelihood that such conditions can exist for the magazine. There are no operational incidents (equipment failures or procedure violations) that can result in criticality; external events are the only conceivable mechanisms for initiating criticality events. Thus, in this approach, the fault tree analysis process is applied to the assessment of the potential for criticality events arising from external events. Only a limited fault tree is required to illustrate the analysis. The fault tree used in the following discussion appears as Figure E-2.

For a criticality incident to occur, three basic conditions must be met. There must be a sufficient mass of fissile material, appropriately moderated, in an appropriate geometric array. A bare solid sphere of plutonium containing approximately 9.8 kg is critical in air with no reflecting medium. A solid sphere containing approximately 5 kg of plutonium is critical when completely water reflected. Nominal inventories in the magazines involve significantly larger amounts of fissile material, although it is always in the form of hollow spherical shells (a less

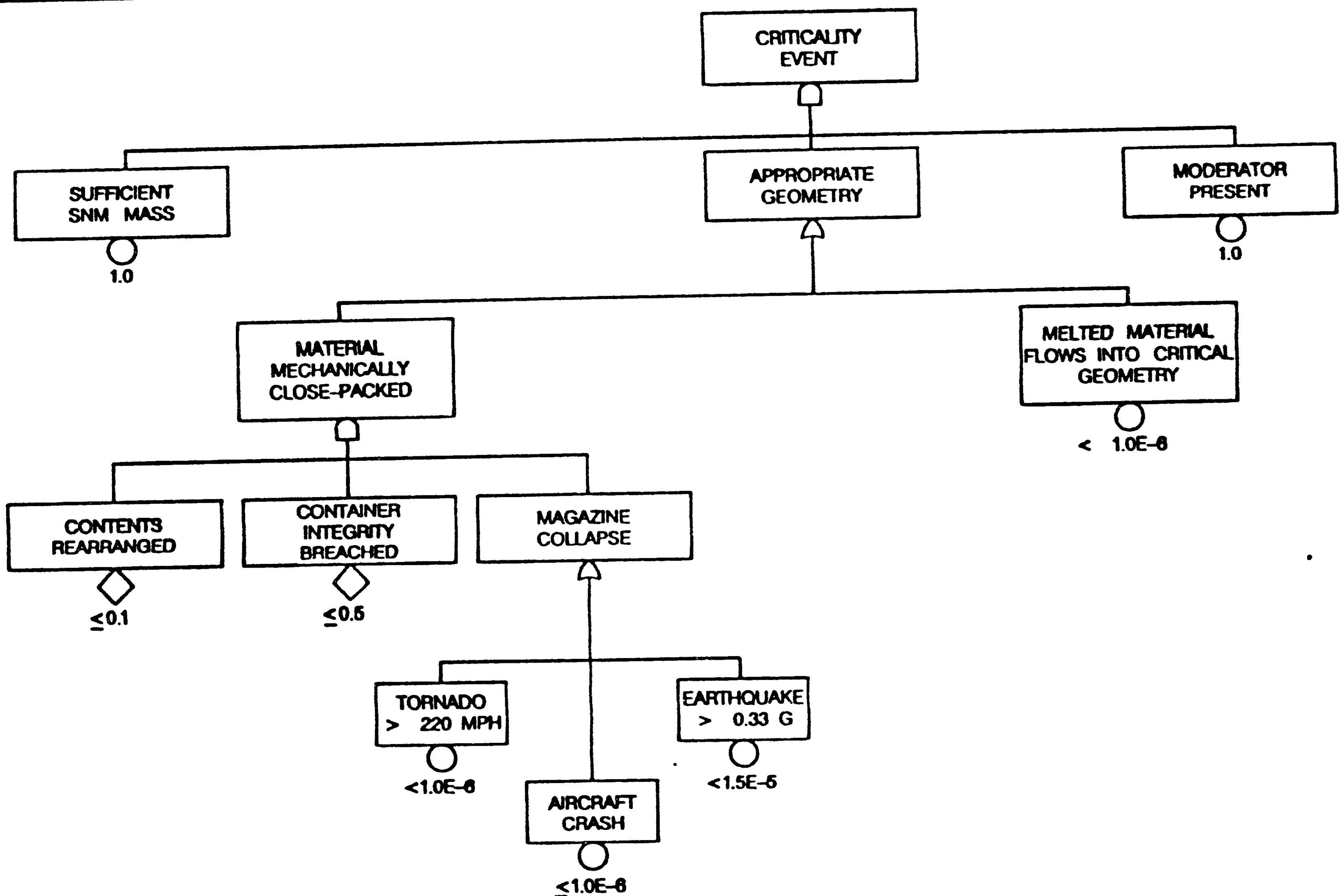

FIGURE E-2
CRITICALITY EVENT FAULT TREE (PIT CONTAINERS)

reactive geometry), not solid spheres. Nevertheless, in this analysis the likelihood that there is sufficient mass to support a criticality is taken, conservatively, as unity.

Criticality can be achieved with smaller masses of fissile material if the "assembly" is reflected and moderated as noted above. In the normal pit/container configuration within the magazine the concrete in the walls serves as a reflector for the array of containers. The steel in the container walls provides some reflection for individual containers (while also absorbing some of the neutrons that could otherwise cause interaction among containers). Water is an effective neutron moderator, but there are no sources of water present in the magazine. However, the containers all contain Celotex, a commercial roofing and insulating material, that is a neutron moderator because of the hydrogen and carbon content of the wood fibers and the organic binder material. Therefore, for this analysis, the likelihood of moderator being present is also taken, conservatively, as unity.

Thus, two of the three conditions required for criticality are assumed to be met. The remaining condition involves arranging the fissile material in an appropriate array. It has been demonstrated by analysis that a single undamaged pit/container assembly is subcritical by a substantial amount (see Section E.1 and Reference 3). Even a close-packed array of such containers is subcritical (see Section E.1). Under current transportation guidance, up to 500 containers of the AL-R8 type could be combined in a single shipment, if that were physically possible (Ref. 5). This is further evidence that a normal array of these containers is subcritical. Therefore, the question to be addressed is the following: What are the mechanisms or processes that could lead to the creation of a critical geometry?

It may be argued that an earthquake that does not cause collapse could still have sufficient energy and motion to cause the containers to be tumbled and, as a result, produce an alternative array that might be critical. However, even earthquake conditions in excess of the Maximum Credible Earthquake (MCE) (0.33g), which is an event beyond the design basis, cannot produce forces sufficient to damage a stack of palletized AL-R8 containers. Although the pallets could be toppled by this event, the specially designed pallets and the pit containers are designed to withstand dropping conditions that far exceed this environment. So, because it has been demonstrated that arrays of intact containers remain subcritical, the achievement of a critical geometry in this manner is not considered a credible event. Therefore, it is necessary to explore alternative ways in which container integrity might be compromised, and, thereby, generate a critical geometry.

If the magazine structure were to collapse on the containers, it could be possible to crush or otherwise deform the cans. Such structural damage could conceivably occur as a result of natural phenomena (earthquake, tornado) or human-induced phenomena (aircraft crash). That same initiating event could conceivably cause the contents of the breached containers to be rearranged so as to create a close-packed array of fissile material. The analysis contained in Appendix C indicates that it would require an earthquake with a peak acceleration much greater than 0.33g to cause such a structural failure of the magazine. The frequency of such an event is significantly less than 1.5E-05 per year. Therefore, even if magazine structural failure, breach of the containers, rearrangement of the contents, and the formation of a close-packed array are all assumed to occur with a probability of 1 (an extremely conservative estimate), given the occurrence of an earthquake exceeding the MCE, the likelihood of the sequence is below the threshold of concern. It also should be noted that an earthquake induced collapse would tend to cover the containers with rubble and, thus, make it even more difficult to form a potentially critical array. This is illustrated on Figure E-2.

Similarly, the Appendix C analysis also indicates that the magazine will withstand the effects of a 220 mph tornado. The frequency of such a tornado at Pantex is estimated to be about 1.0E-06 per year. The probability of a tornado-initiated accident sequence will, therefore, be well below the threshold of concern, even if all the containers are retained in the magazine and, as postulated above, the subsequent damage and rearrangement were certain as a result of the tornado.

It is estimated in Appendix F that the frequency of a crash of an aircraft heavy enough or with sufficient velocity to cause collapse of a Zone 4 magazine is approximately 6.0E-07 per year. Even if such an impact were to occur, structural collapse, container integrity breach, and content rearrangement would all still be required for a criticality to be caused. If it is assumed that the impact causes structural failure with a probability of 1, then the question remains as to the combined probability of breaching the container integrity and appropriately rearranging the contents. Even if there is a 0.5 probability that the structural collapse causes containers to be breached in a manner such as to release the contents (this is considered to be a conservative estimate), the probability of the released material being assembled into an appropriate geometry is estimated to be 0.1 or less under the chaotic conditions of a crash-induced collapse. Thus, the combination of events required for a mechanical assembly of fissile material into a critical configuration is considered incredible (P = 3.0E-08/yr = 6.0E-07 x 0.5 x 0.1). That is, the combined set of events has a probability less than 1.0E-06 per year, which is below the threshold of concern (Ref. 6). Thus, it is concluded that there are no credible means to mechanically deform and reconfigure the storage array so as to cause a criticality incident.

An alternative mechanism that could conceivably compromise the integrity of the containers and their contents, and thereby create a critical assembly, is excessive exposure to fire. There are two potential fire sources to consider: fire from an accident during handling operations and fire subsequent to an aircraft crash.

A fire hazards analysis for the magazines indicates that negligible amounts of combustible materials are used in the construction and finish. Furthermore, the contents of the magazine are such that fire would not be expected to propagate throughout the magazine, even in the event of an incipient fire and the total failure of any fire suppression actions, because there is no continuity of combustible materials that would promote fire propagation. Because all flame-producing devices are excluded from Zone 4, the presence of a threatening fire inside a magazine filled with pit containers is not considered credible (see Appendix D, "Fire Hazard Analysis"). Furthermore, the threat of external fires propagating into a pit container magazine is also considered incredible because of the thermal barrier posed by the magazine front wall and steel plate doors. In the maximum credible external fire scenario applicable to the magazines (a diesel fuel fire), the thermal barrier presented by the magazine doors is sufficient to prevent the magazine internal temperature from exceeding 234°F (see Appendix D, "Fire Hazards Analysis"). This temperature could not cause thermal damage to the pits inside the AL-R8 containers.

The other potential cause of container failure is a long-duration fuel fire subsequent to an aircraft crash. Given the nature of such impacts, it is conservatively assumed that fire occurs with a probability of 1.0 (although it is recognized that many crashes do not entail fire) and that undamaged portions of the magazine could be "flooded" with fuel. For a jet fuel fire, theoretical and experimental studies show that the fire intensity can be reasonably approximated by an 1850°F black body flame temperature. Aircraft accident data on fire duration indicate that 90% of all aircraft accident fires have a duration of less than 40 minutes (Ref. 7). Therefore, it is assumed that there is a 10% probability that the containers, although undamaged, may be exposed to fire. As noted above, the AL-R8 containers have been exposed to temperatures of 1475°F for 30 minutes with no effects other than the charring of the Celotex (Ref. 3). Although the behavior of AL-R8 containers in other fire environments has not been established, it appears reasonable to expect that the effects of fire alone will not cause the significant failures of the AL-R8 containers. Rupture of the containers due to thermal expansion of the air inside (such that the contents are disgorged) is not expected because the containers are not sealed and they have a relief vent in the lid that would relieve any pressure buildup. Nevertheless, for the added conservatism it provides, it is assumed that the plutonium in the additional undamaged containers also could be subject to release due to fire. However, this scenario, crash of an aircraft large enough or at sufficiently high velocity to collapse the magazine with a fuel-fed fire exceeding 40 minutes is determined to be incredible, i.e., one with an estimated probability 6.0E-08/yr ($P_{crash} \times P_{fire>40min}$ = 6.0E-07/yr x 0.1) under the current guidance (Ref. 6). Therefore, no estimate of consequences is presented.

Based on the arguments presented in this section, it is concluded that the probability of a combination of conditions sufficient to cause a criticality incident is, in fact, well below 1.0E-06 per year and, therefore, requires no further analysis.

References

1. KENO 5a-PC - Monte Carlo Criticality Program with Supergrouping, RSIC Computer Code Collection Package CCC-548 A/B, Oak Ridge National Laboratory, May 1991.

2. MCNP 4 - Monte Carlo Neutron and Photon Transport Code System, RSIC Computer Code Collection Package CCC-200 A/B, Oak Ridge National Laboratory, October 1991.

3. Rocky Flats Container, Model AL-R8 Safety Analysis Report for Packaging, RFE-8801, Rocky Flats Plant, April 1988 (revised October 1989).

4. "Criticality in the Cell 8 Vault," letter from C.D. Alley, Pantex Plant, to P.M. Ramey, U.S. Department of Energy, Amarillo Area Office, December 14, 1989.

5. "Criticality Control for DOE Couriered Shipments," letter from J.R. Roeder to P.R. Wagner, et al., July 8, 1982.

6. DOE/AL Order 5481.1B, "Safety Analysis and Review System," U.S. Department of Energy, Albuquerque Field Office, January 27, 1988.

7. An Assessment of the Risk of Transporting Plutonium Dioxide by Cargo Aircraft, BNWL-2030, McSweeney, T.I. and J.F. Johnson, Battelle Pacific Northwest Laboratories, Richland, Washington, June 1977.

Table 4-1. Containers Used in Modified-Richmond and SAC Magazines

Component	Type of Container	Dimensions and Structural Characteristics (General)
Pits	AL-R8	• 18-gauge carbon steel drum (20" diameter; 30", 40", 50", or 60" height) • 1" vent plug in top • Celotex insulation
	FL	• 16-gauge stainless steel outer containment drum (22.5" diameter, 50" height) • 12-gauge stainless steel inner containment drum (13.8" diameter, 38" height) • Celotex insulation • Meets Type B package requirements (10 CFR 71)
Oak Ridge Operation (ORO) Components	DT-9	• 18-gauge carbon steel drum (24" diameter, 35" height) • Celotex insulation
	DT-23	• 16-gauge stainless steel outer containment drum (33.2" diameter, 40.9" height) • 0.165" stainless steel inner containment drum (20.8" diameter, 27" height) • Celotex insulation • Meets Type B package requirements (10 CFR 71)
	Other Types of Metal Drums	• Various wall thickness ranging from 18- to 14-gauge • Carbon or stainless steel • Various sizes ranging from 30 to 110 gallons
	4000 Series Boxes	• Wooden box measuring 23.75" high, 21" deep, 35.5" long • Plywood plank sides • Steel base; 3" steel band around width of device
	7000/8000 Series Boxes	• Wooden box measuring 38" high, 34" deep, 82" long • Plywood plank sides • Steel base; 3" steel band around width of device
	H-gear	• Various
Radioisotopic Thermoelectric Generators (RTGs)	DT-6M	• 20-gauge, 10-gallon carbon steel drum (13" diameter, 24" height) • Four, 0.5" vent holes in top • Steel pipe inner container (5.25" diameter, 10.5" long) with threaded plug • Celotex insulation
Weapon Assemblies	None/Various	• Various

containers, which are double-containment stainless steel drums categorized as Type B shipping packages. The outer containment drum of an FL shipping package measures 22.5 inches in diameter and 50 inches in height. The drum is constructed of 16-gauge

Safety Code. By direct reference, the DOE Orders also require that DOE facilities comply with many other national standards, including all of the NFPA standards published in the National Fire Codes, the UL Product Directory, the Factory Mutual Approval Guide, and NFPA-70 (National Electrical Code). However, it should be noted that DOE Order 6430.1A strictly applies only to new facilities or major modifications to existing facilities, and is therefore not binding on the Zone 4 magazines. It serves in this SAR as a screening guide for comparison purposes.

Only those criteria that explicitly address safety-related issues and are applicable to these facilities are included in this comparison to criteria. Criteria that (1) deal with non-safety-related issues (e.g., thermal and moisture protection, door and window installation, etc.), (2) are repetitious, or (3) cannot be addressed explicitly are not included in this review. In general, the selection of criteria for this comparison is based on conservative engineering and regulatory judgment. The modified-Richmond and SAC magazines in Zone 4 are used for the staging of nuclear weapons, ORO components, RTGs, and nuclear explosive-like assemblies (NELAs) pending their disassembly at Pantex or movement to another site, and for the interim storage of pits pending a future decision on their ultimate disposition. All weapons, weapon components, and NELAs are sealed and are kept in handling-gear or sealed containers (see Section 4.4).

Pits are sealed components, normally with a stainless steel outer casing. The pits are packaged in AL-R8 containers, a previously approved shipping container now used for onsite transportation and interim storage and placed, for interim storage, in the modified-Richmond and SAC magazines in Zone 4. The interim storage of pits at Pantex is limited to a 20-year period (Ref. 23). Further, the analysis (see Chapter 7.0) reveals no credible accident sequences that could lead to a significant offsite exposure of the public. The environment to which the sealed, containerized plutonium components is exposed is benign. Therefore, confinement and other requirements associated with Plutonium Storage Facilities in Division 13 of the DOE General Design Criteria (Ref. 12) are not necessary. Further, Section 1305-1 specifically exempts plutonium that is packaged in accordance with DOE Order 5480.3, "Safety Requirements for the Packaging and Transportation of Hazardous Material, Hazardous staged one-high in compartmentalized magazines (due to size limitations) and one-high stacking is most common in non-compartmentalized magazines. However, some weapon assemblies in specially designed roadables may be stacked two-high in non-compartmentalized magazines. (This two-high configuration is based on physical convenience so that staging and transportation space may be maximized. These roadables are designed to allow for a two-high configuration.)

<u>Pits</u>

Pit containers are currently brought into the magazines on "pit pallets" (5 vertically-oriented pit containers per pallet). Workers manually remove the containers from a pallet and place them one-high on the floor, using a manual hand truck, if necessary. Figures 5-2 and 5-3 illustrate typical pit container configurations for the magazines. Other configurations are allowed, up to the one-high, vertical physical capacity of the magazines. There are no constraints on the minimum separation distance between pit containers. Under these conditions, workers are required to wear protective clothing (e.g., lead aprons) as directed by the Radiation Safety Department when handling the containers. It is possible that a shielded forklift equipped with a yet-to-be-designed electromagnetic or electromechanical barrel handler may be used for handling of pits arranged in the one-high, vertical configuration at some time in the future.

Individual pit containers may rest on casters rather than on the concrete floor of the magazines. Pit containers may reside on pallets, which have casters. Both of these schemes are under consideration to make inventory operations easier and safer for plant personnel. Neither scheme would, in any way, permit a higher packing density than is shown in Figures 5-2 and 5-3.

There are also plans to transport pit containers to the magazines on "precision pallets" (4 or 6 horizontally-oriented pit containers semi-permanently affixed to the pallet) secured to a specially equipped shielded forklift. As illustrated in Figures 5-4 and 5-5, these pit container/pallet assemblies could be stacked 5 horizontally-oriented containers high (one, 4-container pallet and one, 6-container pallet, either of which may be on top of the other) in

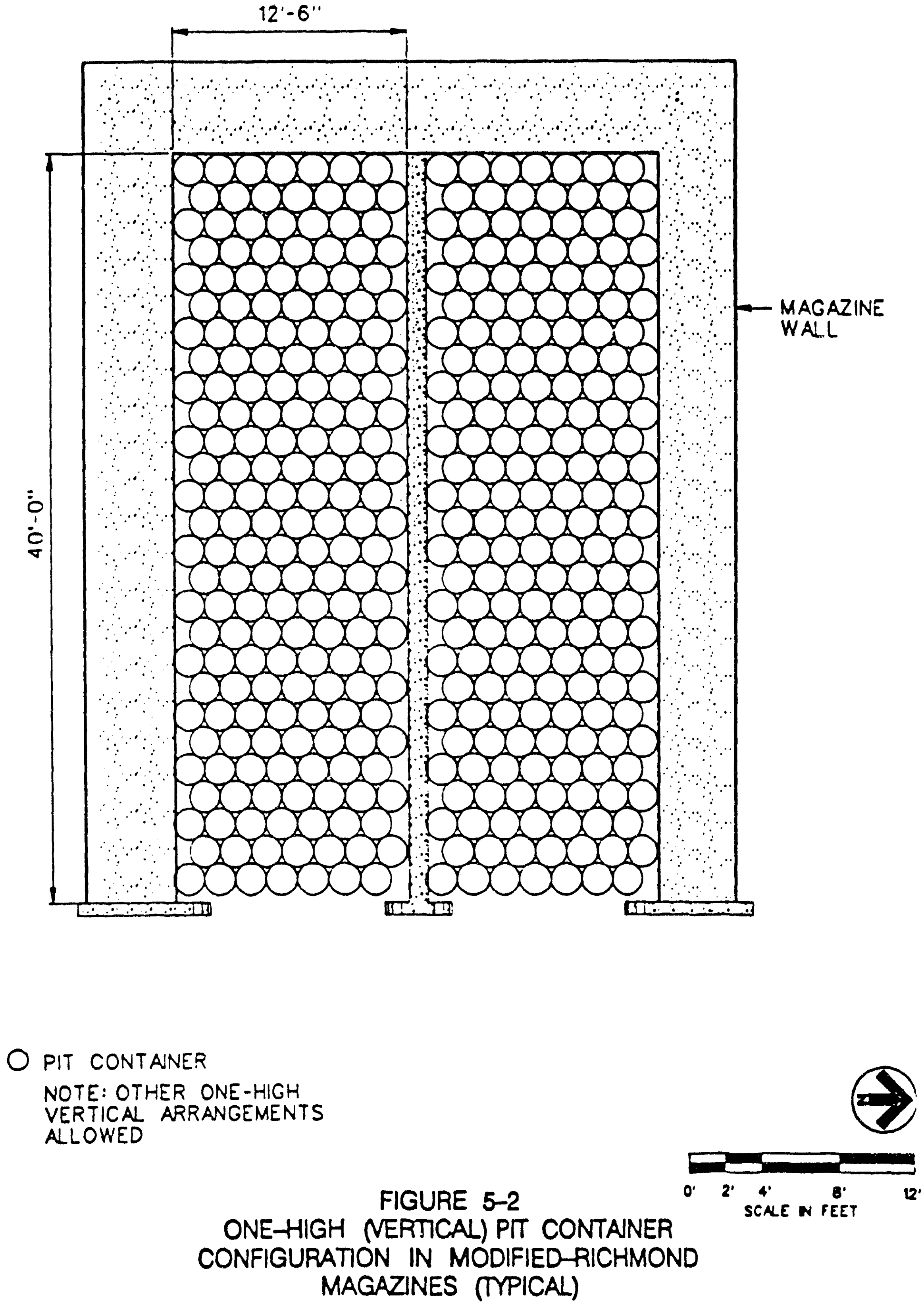

FIGURE 5-2
ONE-HIGH (VERTICAL) PIT CONTAINER CONFIGURATION IN MODIFIED-RICHMOND MAGAZINES (TYPICAL)

I:\PROJ\PANTEX\ZONE\Z4-5-2 8' 8-18-92

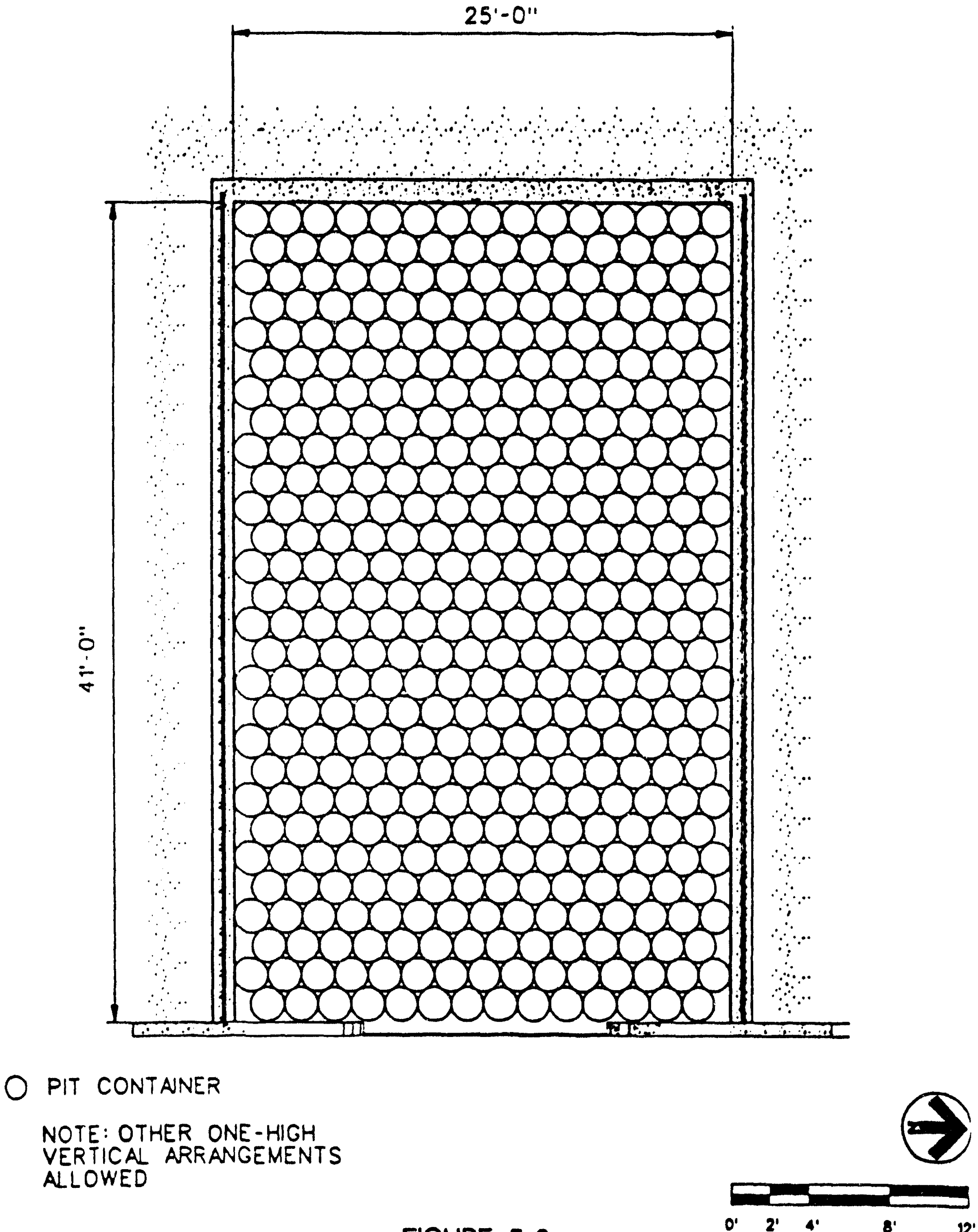

FIGURE 5-3
ONE-HIGH (VERTICAL) PIT CONTAINER
CONFIGURATION IN SAC MAGAZINES
(TYPICAL)

I:\PROJ\PANTEX\ZONE\Z4-5-3 8' 8-18-92

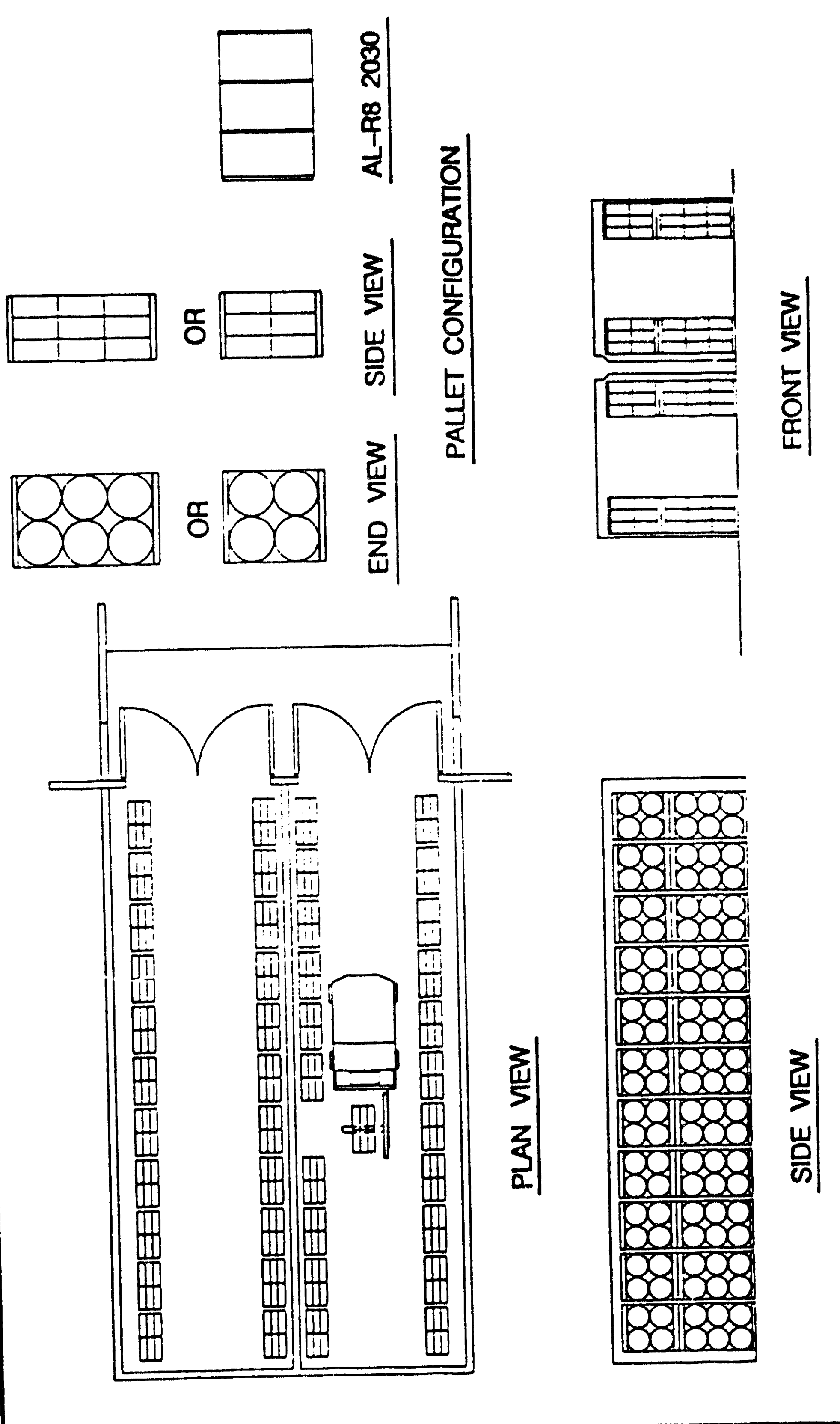

FIGURE 5-4
MODIFIED-RICHMOND MAGAZINE HORIZONTAL
PIT STACKING CONFIGURATION

I:\PROJ\PANTEX\ZONE\Z4-5-4 6' 10-6-92

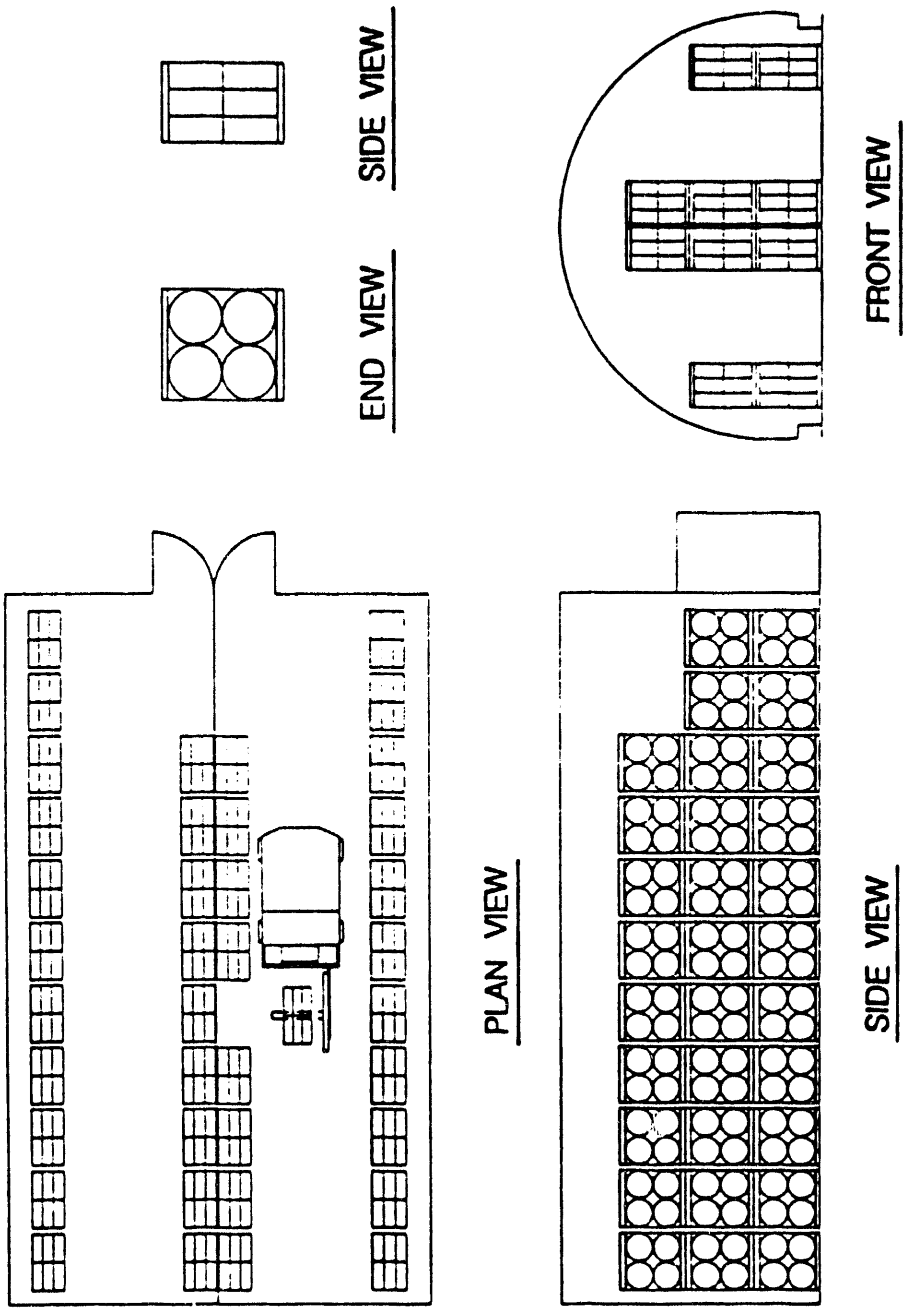

FIGURE 5-5
SAC MAGAZINE HORIZONTAL
PIT STACKING CONFIGURATION

the modified-Richmond magazines and 6 horizontally-oriented containers high (three, 4-container pallets or two, 6-container pallets) in the center of a SAC magazine. The purpose of this system is to minimize personnel residence time inside the magazines (and, therefore, minimize radiation exposures) and to maximize the interim storage space for pit containers. The horizontal orientation of the pit containers will not cause damage to the pit tubes since they are clamped in a fixed position by a frame inside the AL-R8 container. The pallets themselves neither hinder nor aid safety and, as such, have no effect in the accident analysis in Chapter 7.0.

Although currently under design, the precision pallet/shielded forklift system is scheduled to be operational in 1993. Depending on future requirements, both types of pit container configurations (vertical and horizontal) may be in use. The forklift will be equipped with a lateral motion, turret-type fork assembly that will allow pallets to be stacked and retrieved without having the forklift itself turn (see Figures 5-4 and 5-5). The pallets will be transported by a standard electric forklift to a portable guide-rail ramp in a vertical orientation. They will then be rotated 90° to a horizontal orientation, using a hand-cranked turning fixture. After rotation, they will be picked up by the shielded forklift, which runs on the ramp's guide rails, and taken into the magazine. The turning fixture provides no increased risk to the operations. The shielded forklift will be designed to minimize the possibility of operational accidents leading to a release of radioactive material. For this reason, a number of electronic and physical interlocks will be designed into the forklift. The physical interlocks will include rail guides to prevent the forklift from veering into a stack of pallets, and overrun wheel chocks at the back end of each aisle to prevent the forklift from crashing into the magazine back wall, thus crushing the load it is carrying. The electronic interlocks will include vertical and horizontal positioning sensors which prevent the boom attachment from attempting to pick up a pallet unless it is properly positioned, so the boom will not crush the pallet. Furthermore, a sensor in the boom tip will stop the boom's motion if the boom encounters resistance to its motion. Finally, an interlock will prevent the forklift from moving forward or backward when the boom is extended for retrieving or placing a load.