DOE/LLW--78T

DE90 006965

LONG-TERM STRUCTURAL AND RADIOLOGICAL PERFORMANCE ASSESSMENT FOR AN ENHANCED ABOVEGRADE EARTH-MOUNDED CONCRETE VAULT

December 1989

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ABSTRACT

This report presents an analysis of the long-term structural and radiological performance of a hypothetical abovegrade earth-mounded concrete vault used for the disposal of low-level radioactive waste. The vault structure design is based on the application of accepted standard engineering codes. The degradation of the concrete vault and the grouted waste forms over time and the resultant changes in the leaching and migration of radionuclides through the environment are modeled using a combination of the HELP, BARRIER, PATHRAE, and PRESTO-CPG computer codes. The resultant radiological doses to a farmer living adjacent to the facility and to several types of inadvertent intruders are calculated. These calculations show the performance of this total-system treatment and disposal concept to greatly exceed the Department of Energy's performance objectives for the protection of the general public and inadvertent intruders.

SUMMARY

The Department of Energy's Defense Low-Level Waste Management Program, operated by EG&G Idaho, Inc., is currently evaluating the feasibility of an abovegrade earth-mounded concrete vault system for disposal of low-level radioactive waste. This report examines the expected performance of this disposal system and its ability to comply with performance objectives as set forth in DOE Order 5820.2A. The report describes: (1) an optimum implementation of the design basis of the disposal vaults system, (2) the modeling of the deterioration of the vault system over time, and (3) the modeling of contaminant releases and migration to arrive at projections of the potential radiological impacts on members of the general public and inadvertent intruders over time.

The hypothetical disposal facility analyzed is assumed to be located in the humid northeastern United States, which has relatively abundant rainfall, shallow aquifers, lush vegetation, and freeze-thaw cycles. Therefore, radionuclide release and transport via groundwater and biotic pathways can be expected to predominate over atmospheric pathways in most situations. The disposal site receives approximately 1 m of precipitation annually. Annual infiltration is .73 m for non-cap portions of the site. Infiltrating water intercepts the aquifer at a depth of 28 m below natural grade, at which point it may flow horizontally to regional wells.

The disposal facility consists of three disposal vaults. Each vault is constructed using high-grade Type V Portland cement, and all vaults are situated abovegrade and above the probable maximum flood plain. Using a bridge crane to create a tightly stacked monolith, treated waste, grouted in carbon-steel disposal boxes, is stacked within each vault. As the vault is filled, an impervious membrane is placed on the waste stack and a concrete roof slab is poured. For final closure, the entire vault is covered with an impervious membrane and an engineered, multi-layered earthen cover system is applied.

The hypothetical disposal facility was analyzed using the BARRIER, HELP, PRESTO-CPG, and PATHRAE computer codes. BARRIER was used to analyze the long-term hydrologic and structural performance of the disposal vaults. The HELP code was used to project rates of water infiltration through the intact disposal vaults and through the earthen cover system. Contaminant migration from the disposal vaults, and the doses resulting therefrom, were modeled using the PRESTO-CPG and PATHRAE computer codes.

Performance was modeled for two values of cover system water infiltration: 0.1 cm/yr (based on the performance of full-scale tests conducted by the French for the engineered closure cover at the Centre de la Manche, the French LLW disposal site) and 2.8 cm/yr (based on HELP calculations). The facility was analyzed against the performance objectives of DOE Order 5820.2A, Radioactive Waste Management, Chapter III, Management of Low-Level Waste. Performance was simulated for a period of 10,000 years following facility closure. The following exposure scenarios were considered: adjacent farmer, intruder-explorer, intruder-construction, and intruder-agriculture.

Previously, abovegrade disposal options were generally perceived as being more susceptible to exposure of the waste through erosion, flooding, and increased degradation rates of exposed concrete barriers. This has been in part due to the fact that past abovegrade disposal concepts did not incorporate the use of an earthen cover system designed to protect the disposal vault from continuous exposure to the natural elements. The abovegrade earth-mounded concrete vault facility examined in this report corrects this omission by use of several design features, including, but not limited to, stabilized inorganic waste forms, a fully supported vault roof, and a multilayer earthen cover over the disposal vaults.

Each vault, as modeled by BARRIER acts as an effective infiltration barrier for just over 5,000 years, regardless of the cover system placed over the vault. Critical to this performance is the behavior of the waste forms placed in the vaults. The tightly stacked array of grouted waste forms is assumed to provide uniform support for the roof across its entire area. Changes in this support condition due to corrosion of the carbon-steel disposal boxes and the degradation of the grouted waste form are minor and do not significantly degrade the support provided for the roof. The contributions of the waste form, vault, and cover system to the performance of the facility are:

- The use of tightly packed, grouted, inorganic waste forms provides uniform support for the vault roof and the overlying cover system, essentially eliminating subsidence and subsidence-induced degradation of the roof and cover system.
- The vault provides just over 5,000 years delay in the time at which radionuclides start to move through the environment.
- The vault delays inadvertent intrusion for just over 5,000 years barring a catastrophic disruption of the structure.

- After the 5000+ years of delay, the more permeable cover system (2.8 cm/yr) provides a transit time of 210 years from the vault to the adjacent farmer well for the most mobile radionuclides in the waste inventory.
- After the 5000+ years of delay, the less permeable cover system (0.1 cm/yr) provides a 5,500-year transit time (vault to well) for the most mobile radionuclides.

The results calculated for the enhanced, abovegrade, earth-mounded, concrete vault show that the facility, as analyzed, exceeds all performance objectives of DOE Order 5820.2A:

- The performance objective of the Order allows a dose rate of 25-mrem/yr to members of the general public. If the 2.8-cm/yr vault cover system is used, the maximum dose to the public is 7.4E-04 mrem/yr (effective dose equivalent) and occurs 5,249 years after site closure. Stated another way, that dose is some 30,000 times better than the performance objective of the Order. If the cover system performs as did the French system (0.1 cm/yr infiltration), no dose whatsoever is received by a member of the public within the 10,000-year analysis period.
- The performance objective of the Order allows a dose rate of 100-mrem/yr to any inadvertent intruder. If the 2.8-cm/yr cover system is used, the maximum dose to any intruder is 1.3E-03 mrem/yr and occurs 5,204 years after site closure (more than 70,000 times better than the DOE performance objective). If the cover system performs as did the French system (0.1 cm/yr infiltration), a maximum intruder dose of only 5.8E-04 mrem/yr occurs 5,008 years after site closure.

The calculated performance of the abovegrade earth-mounded concrete vault is directly attributable to the use of a combination of several design features that were not included in previous analyses of abovegrade facilities. The design features most critical to the performance reported herein concern the support conditions for the vault's roof and the use of an engineered earthen cover system. Critical to the long-term uniform support provided for the roof and earthen cover system is the use of grouted, fully treated waste that is essentially inorganic. This greatly restricts the generation of gases that are prevalent in other disposal systems. The cover and the unique support conditions used in the design of the disposal facility act together to negate the surface exposure pathways, which were the major exposure pathways for previously analyzed abovegrade facilities. The slope of the cover, the use of cover vegetation, and the unique support conditions for the concrete roof work together to ensure the isolation of the waste even after many thousands of years.

CONTENTS

FIGURES

TABLES

1. INTRODUCTION

Increasingly stringent requirements for the treatment and disposal of low-level radioactive waste (LLW) have prompted interest in alternatives to disposal by shallow-land burial. The majority of these disposal alternatives employ engineered barriers, typically concrete, in an attempt to further isolate waste contaminants from the surrounding environment. Among the predominant disposal technologies under consideration by state and federal entities, three are most prevalent. These include modular concrete canisters, and belowgrade and abovegrade concrete vaults.

The Department of Energy Defense Low-Level Waste Management Program (DOE-DLLWMP) is evaluating the feasibility of a LLW treatment and disposal complex, which includes an Abovegrade Earth-Mounded Concrete Vault (AGEMCV) as the disposal system.[1] The DOE-DLLWMP's evaluation provides estimated costs for the development and operation of the complex. Through this document, it will also assess the performance of the disposal facility, AGEMCV over time and its ability to meet regulatory requirements.

Until now, abovegrade disposal options were generally perceived as being more susceptible to exposure of the waste through erosion, flooding, and increased degradation rates of concrete barriers such as vaults. This has been in part due to the fact that past abovegrade disposal concepts did not incorporate the use of an earthen cover system designed to protect the disposal system from continuous exposure to the natural elements.[2] The disposal facility examined in this report corrects this omission by use of several design features, including, but not limited to, stabilized inorganic waste forms, a fully supported vault roof, and a multilayer earthen cover over the disposal units.

This report addresses the performance of an AGEMCV and its ability to comply with performance objectives set forth in DOE Order 5820.2A.[3] It provides an optimum implementation of the design basis of the disposal vault system (see Reference 1) and models the deterioration of the system over time. Contaminant releases and migration are modeled to arrive at projections of the potential radiological impacts on members of the general public and inadvertent intruders over time. Finally, modifications in design characteristics that would lessen the postulated impacts are discussed.

Section 2 provides a description of the disposal facility, including site and waste characteristics, a summary of waste treatment and disposal operations, and a brief description of the design basis. The technical approach taken in the performance assessment is detailed in Section 3. Also in Section 3, the source term used in the analysis is derived and the important pathways for the disposal site are discussed. The exposure scenarios considered for the assessment are described and the assumptions used in the analysis are established. Results of the performance assessment are presented and discussed in Section 4. Conclusions are presented in Section 5. The input data used in the performance assessment are included in Appendix A. Finally, Appendix B contains the detailed design basis of the AGEMCV facility.

2. DISPOSAL FACILITY DESCRIPTION

2.1 Site Characteristics

Since an AGEMCV disposal facility is not currently sited, it is impossible to provide information on a specific location and on characteristics of a site. For the purpose of performing the radiological assessment of the disposal technology, however, the hypothetical facility is considered to be located[4] in the humid northeastern United States. The same hypothetical site as the one developed for the DOE's comparative report on alternative disposal technologies (see Reference 2) was used for this analysis. This site was used for three reasons: (1) the site's characteristics are typical of the northeastern part of the country, (2) the site characteristic data base was already developed, and (3) using the same site allows one to more easily make a qualitative comparison of the performance of the abovegrade vault analyzed in Reference 2 to the abovegrade vault analyzed in this report. (A quantitative comparison is not possible for several reasons, among them being differences in the source terms used and the level of analysis conducted.)

The hypothetical disposal site receives approximately 1 m of precipitation annually. Annual infiltration is 0.73 m for non-cap portions of the site. Infiltrating water intercepts the aquifer at a depth of 28 m below natural grade, at which point it may flow horizontally to regional wells. Average wind speed at the disposal site is 5 m/s under moderately stable conditions, Postural stability Class D. Complete site characterization data, as used in the performance assessment, are included in Appendix A.

2.2 Waste Characteristics

An estimated 22,370 m^3 of waste are expected to be disposed of in the AGEMCV during the 30-year operational period. The source term used in the assessment is derived from disposal records for 1988 for the Radioactive Waste Management Complex at the Idaho National Engineering Laboratory.[4] These data are reproduced in Table 2-1.

TABLE 2-1. 1988 SOLID LOW-LEVEL WASTE DISPOSAL DATA

Radionuclide	Activity (Ci)
H-3	4.7E+1
C-14	1.2E-2
Ca-45	1.0E-3
Cr-51	2.4E+3
Mn-54	5.0E+4
Fe-55	1.1E+3
Co-58	7.6E+4
Fe-59	3.4E+2
Ni-59	5.4E+0
Co-60	1.6E+4
Ni-63	3.3E+3
Zn-65	2.5E-1
Sr-90	3.0E+1
Y-90	1.8E+1
Nb-95	5.5E+0
Zr-95	5.5E+0
Tc-99	1.0E-6
Rh-106	1.8E+1
Ru-106	1.8E+1
Cd-109	1.7E-5
Ag-110m	2.4E-2
Sb-125	7.8E+0
Cs-134	1.2E+0
Cs-137	2.0E+1
Ce-144	4.3E+1
Pr-144	3.3E+1
Eu-152	1.0E-5
Hf-181	7.6E-2
Ta-182	3.4E+2
Ra-226	1.0E-1
Th-228	1.0E-5
Th-232	1.8E-4
U-232	2.2E+0
U-235	1.8E-2
Np-237	4.9E-5
Pu-238	2.1E-4
U-238	3.6E-1
Pu-239	1.8E-2
Pu-240	1.6E-3
Am-241	3.5E-3
Pu-241	2.1E-2
Pu-242	4.1E-5
Am-243	2.0E-4

2.3 Waste Treatment and Disposal

All waste is wrapped/packaged to preclude the inadvertent release of contaminants. This waste is delivered to the waste treatment facility (WTF) by truck in reusable cargo containers or bins. Dirt, rock, sand, concrete, asphalt, and other inorganic materials from decommissioning and decontamination are also transported in reusable bins. Waste items too large for these containers are received separately after prior approval.

The WTF treats the waste for disposal in the AGEMCV facility. Volume reduction of the waste is achieved through sorting, shredding, plasma-arc sizing, shearing, incinerating, and grouting. All waste processed in the WTF is fully treated, regardless of DOE or NRC waste classification, and is in the form of grouted inorganics when processing is complete. Approximately 98% of the treated waste is inorganic. Additional details on waste treatment may be found in Reference 1.

Packages of waste exceeding 500 mrem/h are grouted in WTF disposal boxes or in high-integrity containers by the generator prior to shipment to the WTF. Resin, sludge, zirconium chips, and other pyrophoric materials are grouted in the WTF carbon-steel disposal boxes and shipped directly to the disposal vault after being approved by WTF personnel.

The waste disposal facility is made up of three disposal vaults. The vaults are constructed using high-grade Type V Portland cement and are situated abovegrade and above the probable maximum flood plain. The treated waste, grouted in carbon steel disposal boxes, is stacked inside the covered vaults using a bridge crane. The absence of appendages on the boxes permits the formation of a tightly stacked monolith (Figure 2-1). Stacking of the waste begins at the side walls of the vaults and proceeds inward. A vertical gap of approximately 15 cm is left in the center, and is filled with concrete prior to vault closure.

As sections of each vault is filled, impervious membranes are placed on the waste stack and a concrete roof slab is poured. When the entire vault is filled, the end wall is poured against the waste and the roof is completed. For final closure, the entire vault is covered with an impervious membrane and an earthen cover system (Figure 2-2).

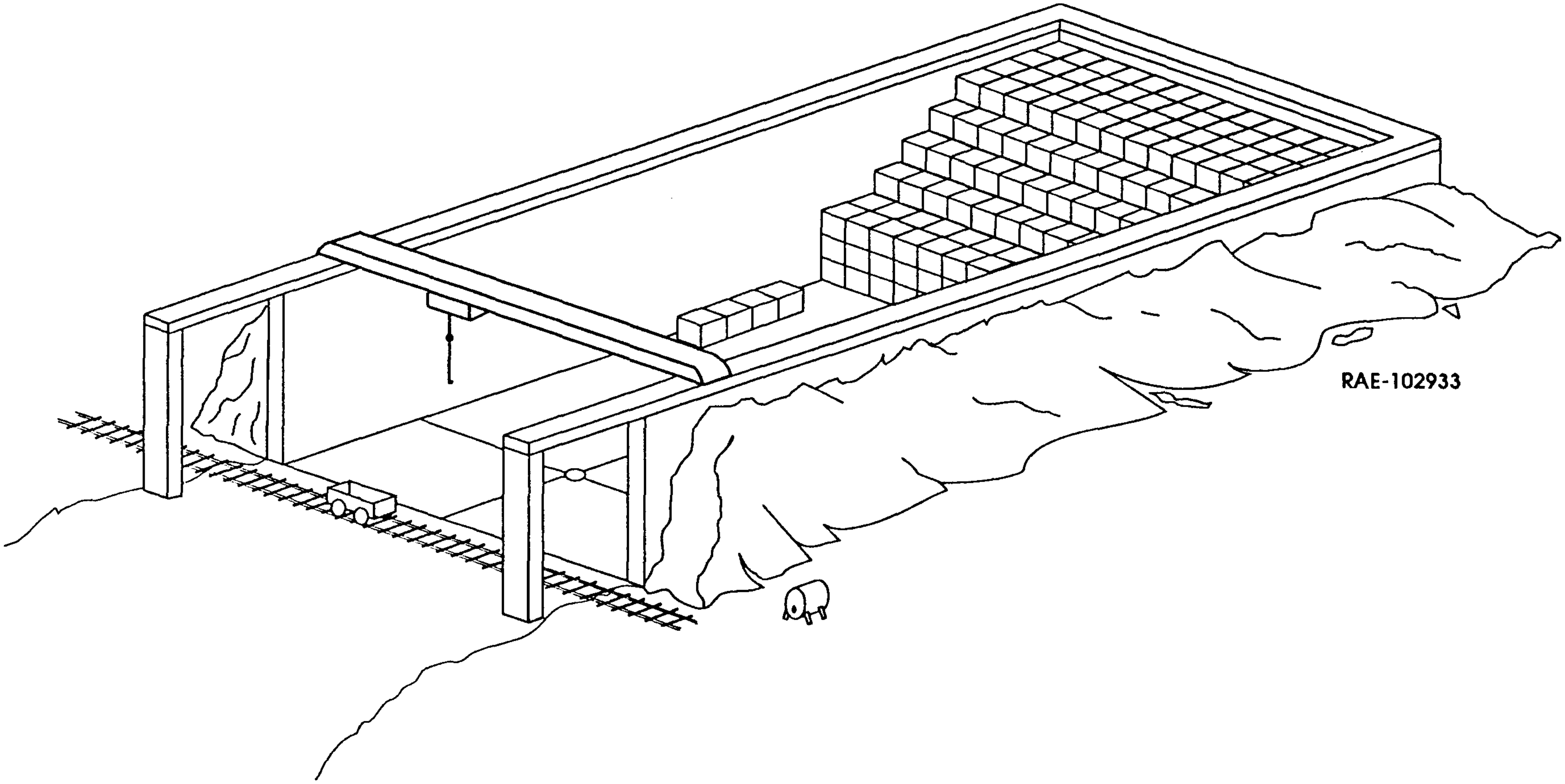

Figure 2-1. AGEMCV facility filling procedure.

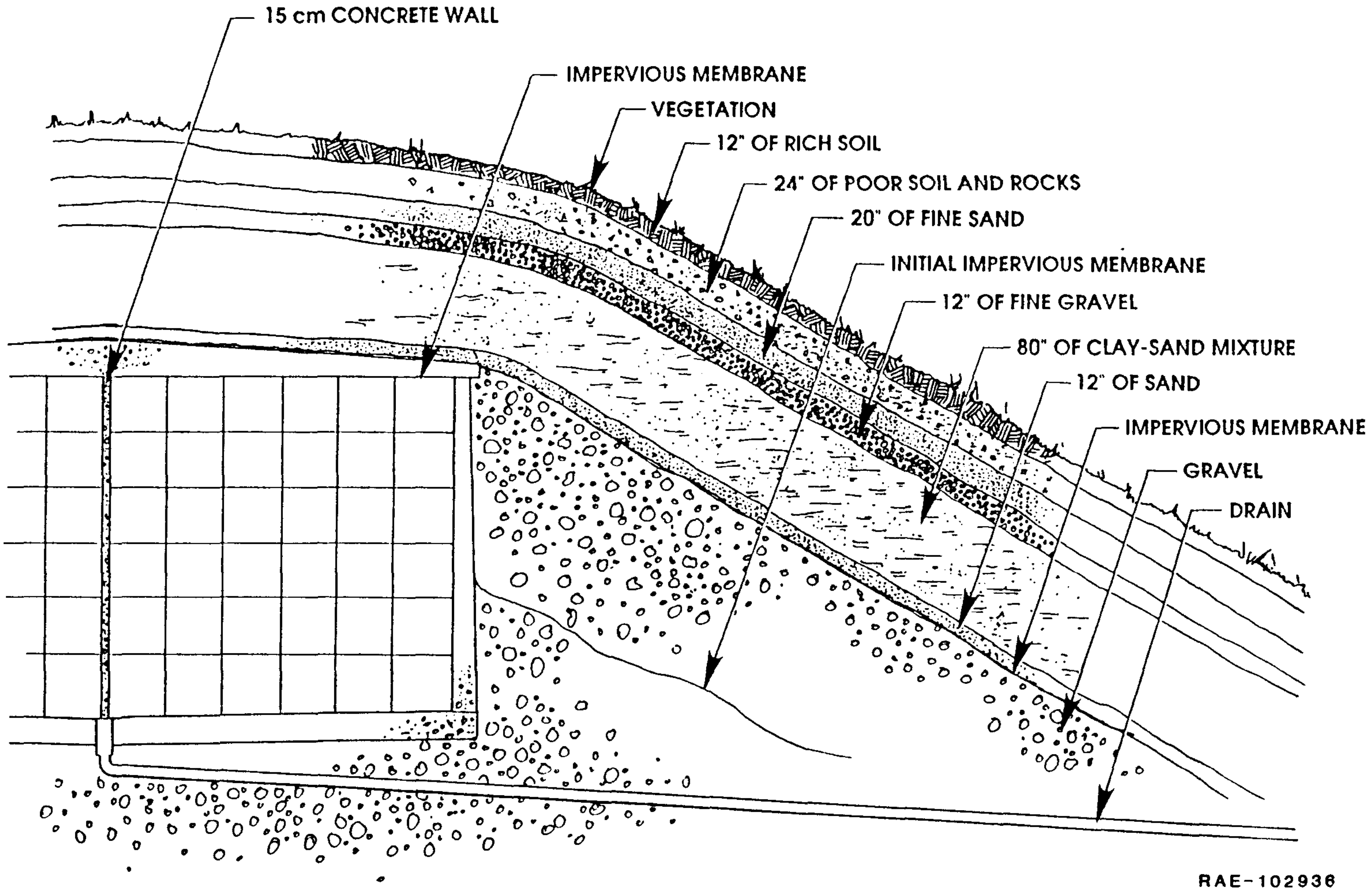

Figure 2-2. AGEMCV earthen cover system.

2.4 Design Basis

The design and construction of the AGEMCV facility must satisfy pertinent building codes and regulations. These include the uniform 1982 edition of ANSI 58.1,[5] ACI 349-85[6] and ACI 350R-83[7]. The first of these addresses minimum design loads in buildings and other structures. ACI 349-85 pertains to the design of reinforced concrete for structures related to nuclear safety, while ACI 350R-83 regulates the design of sanitary structures.

The hypothetical AGEMCV facility consists of three vaults, arranged end to end. Each vault is constructed on natural grade with a 4-m earthen cover. A diagram of one vault is shown in Figure 2-3. Each vault is approximately 72 m long, 16.5 m wide, and 9.6 m tall. Inside cell dimensions are 70 x 15.8 x 7.3 m.

The vaults are designed to bear anticipated loads and to counteract vault degradation processes. Concrete cover thicknesses over steel reinforcement are fortified to counteract chemical attack and corrosion. The steel reinforcement is epoxy-coated, and serves as a deterrent to corrosion processes.

The roof is sloped to the sides of the facility to promote drainage. Roof thickness ranges from 91 cm at the outer edges to 122 cm at centerline. Number 8 steel reinforcement is placed on 10-cm centers in the upper and lower faces of the roof. A 15-cm internal wall runs down the center of each vault, for a roof span length of 7.9 m. The roof is fully supported by the vault contents and by the vault walls.

Exterior walls are 107 cm thick and 7.3 m tall. Steel reinforcement is placed on 10-cm centers in the exterior face and 15 cm in the interior face of the vaults. Number 8 steel reinforcement is used to withstand loads due to Figure 2-2 soil backfill against the walls. Corrosion of ferrous components of the waste is not expected to impose expansive forces on the walls.

The vault floors are 107 cm thick with #8 steel reinforcement on 10-cm centers throughout. The floors are constructed on-grade and are supported by a structural backfill. Structural analysis of the floors considers concentrated loads from exterior and interior walls, uniform loads on this structural component are neglected. The complete design basis of the disposal vaults is provided in Appendix B.

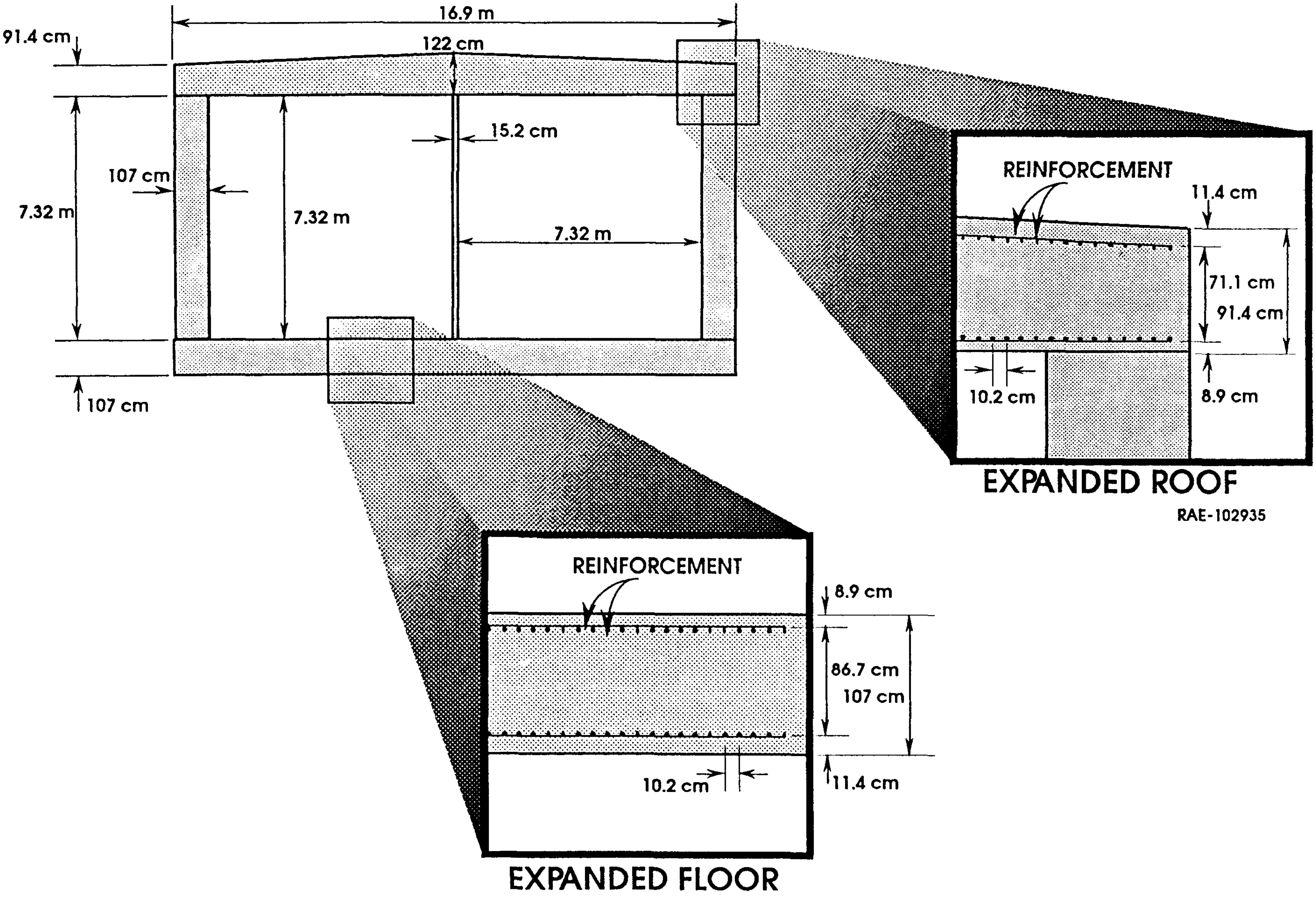

Figure 2-3. General design of the AGEMCV facility.

3. ANALYSIS OF PERFORMANCE

3.1 Source Term

The source term used in the performance assessment was derived from the data discussed in Section 2. In order to minimize modeling complexity while accounting for the expected ingress of daughter radionuclides, a number of adjustments were made. These are outlined below.

Many of the nuclides included in the original data base are short-lived. When these short half-lives are considered in conjunction with the period of operation of the facility, the inventory of nuclides in question, and the site decongestive, as represented by nuclide distribution coefficients, it is evident that a number of these contaminants will have no impact on the overall dose projections. Given this, a number of radionuclides were omitted from further consideration. The nuclides excluded were Ca-45, Cr-51, Co-58, Fe-59, Zn-65, Cd-109, Ag-110m, Ce-144, Pr-144, Hf-181, and Ta-182. While the criteria for exclusion varied by nuclide, the majority of the omitted isotopes had half-lives of less than one year.

A number of radionuclides were added to the inventory to account for the ingress of daughter nuclides. These radionuclides were identified on the basis of the parent and daughter half-lives, which determine the rate of ingress, and the level of risk posed by the daughters relative to the parent. The daughter products identified were included at the appropriate activity levels. Each daughter nuclide included was assumed to share the transport properties of its parent.

The addition of daughter nuclides to the inventory was complicated by the fact that two of the nuclides originally present in the waste, U-232 and Th-228, have decay chains that overlap. Here, then, a portion of the inventory of a radionuclide arising from each chain would exhibit decay characteristics of one parent while the remainder would decay according to the other parent. In these cases, a distinction was made between the two factions, modeling them separately throughout the simulation. Total nuclide doses for these isotopes were determined by summing the doses for each portion of the nuclide inventory.

Two radionuclides projected to be present due to ingress were gases, Rn-220 and Rn-222. These nuclides were considered to be present at levels equal to their parent nuclides, never emanating from the disposal site.

The final set of radionuclides used in the performance assessment, following these adjustments, is listed in Appendix A. The number of curies disposed of at the AGEMCV facility annually is included for each nuclide.

3.2 Pathways and Scenarios

3.2.1 Pathways

The pathways by which radionuclides will be released and transported from the disposal facility will be strongly influenced by the disposal site location. The humid northeastern United States has relatively abundant rainfall, shallow aquifers, lush vegetation, and freeze-thaw cycles. Therefore, radionuclide release and transport via groundwater and biotic pathways can be expected to predominate over atmospheric pathways in most situations.

The release of waste contaminants will be dominated by the dissolution of radionuclides in groundwater percolating through the disposal facility. The rate of release will be a function of the strength of adsorption of waste nuclides by the waste form and the solubility of the contaminants in the groundwater. Those portions of the inventory released from the waste form will migrate vertically to the aquifer with the infiltrating water.

Upon reaching the aquifer, dissolved nuclides will travel within the saturated zone until intercepted by groundwater wells or bodies of surface water. From either of these groundwater sources, contaminants may enter the foodchain through the irrigation of food crops, ingestion by livestock, and direct consumption by humans.

3.2.2 Exposure Scenarios

The AGEMCV must satisfy the performance objectives of DOE Order 5820.2A (see Reference 3). These objectives can be divided into two classes: those dealing with the protection of the general public and those addressing the safety of the inadvertent site intruder. The exposure scenarios considered for each of these aspects are outlined below.

3.2.2.1 **Protection of the General Public**. DOE Order 5820.2A sets forth regulations for protecting the general public. These requirements, as expanded upon in Reference 8, include the following:

1. The annual effective dose equivalent to any member of the public from LLW facilities within a DOE site, via all effluent and exposure pathways, shall not exceed 25 mrem.
2. Radioactive materials released to the air from DOE facilities shall not cause any member of the general public to receive, in a year, a dose equivalent greater than 25 mrem to the whole body and 75 mrem to the critical organ.
3. No more than 4 mrem, annual effective dose equivalent, shall be received by any person through ingestion of water from a drinking water supply operated by, or for, DOE.
4. Radioactive materials in liquid effluents released by DOE facilities shall not cause private or public drinking water systems downstream of the facility discharge to result in any member of the general public receiving an annual dose equivalent exceeding 4 mrem to the whole body or to any organ.

Although Paragraphs 3 and 4 above are cited in DOE Order 5820.2A, they are EPA Safe Drinking Water Act requirements. Other federal, state, and local requirements must also be met.

To ensure that no doses in excess of these limits resulted from facility operation, an exposure scenario, which produces the maximum exposure that could reasonably be expected by a member of the general public was constructed. This exposure scenario, referred to as the adjacent farmer scenario, is illustrated in Figure 3-1.

For this exposure scenario, an individual is assumed to reside at a location 100 m from the disposal vaults beginning at the time of facility closure. Food crops, which supply the resident farmer with 50 percent of his food requirements, are grown. Contaminants are released due to leaching of the waste form. Nuclide releases are transported to the off-site farm via groundwater. Surface water transport is not considered to be a likely path of contaminant migration from the site as the extensive cover system and low potential for significant erosion at the site will prevent exposure of the waste.

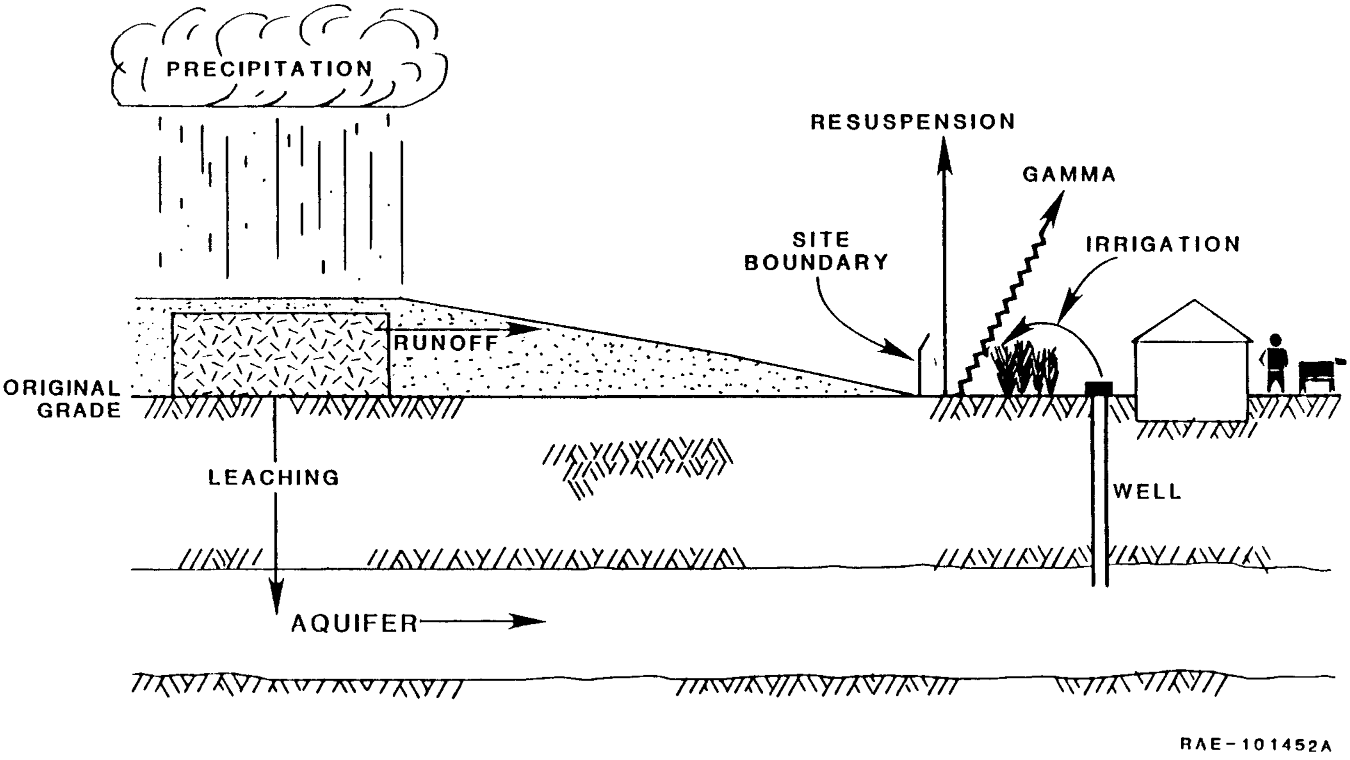

Figure 3-1. Adjacent farmer exposure scenario.

The exposures for the adjacent farmer scenario include both internal and external pathways. Internal exposures include inhalation of contaminated dust suspended from the soil surface and ingestion of contaminated water, vegetables grown in contaminated soil, and animal products derived from animals grazing on contaminated feed. External exposures are due to direct radiation from the soil surface.

3.2.2.2 **Protection of the Inadvertent Intruder**. Regulatory requirements for exposures to the inadvertent intruder, as put forth by DOE Order 5820.2A, include:

1. The annual effective dose equivalent received by individuals who may inadvertently intrude into the facility after the loss of institutional control shall not exceed 100 mrem for continuous exposure or 500 mrem for a single acute exposure.

Three exposure scenarios were formulated to provide assurance that these dose limits were met. Two of these, the intruder-explorer and intruder-construction exposure scenarios, address the acute dose limit of 500 mrem, while the intruder-agriculture scenario represents a continuous or chronic exposure. These exposure scenarios are depicted in Figures 3-2 through 3-4.

For the intruder-explorer exposure scenario it is assumed that a person arrives at the waste disposal facility following the institutional control period and spends 1,000 hours over the course of a year exploring or wandering about the site surface. No attempt is made to dig into the disposal vaults during this time, thus limiting exposures to direct radiation from (1) buried waste while the facility is intact, and (2) waste exposed through erosion or vault failure. Following vault failure, the possibility for inhalation of contaminated particulates also exists.

In modeling the intruder-construction scenario, it is assumed that an intruder will construct a house over a disposal vault following both the end of institutional control and the failure of the concrete roof. The intruder excavates a basement 100 m^2 in area to a depth of 3 m below the ground surface (over or into the waste) and drills a well through the waste. Excavated material brought to the surface is mixed with the surface soil. The construction process is assumed to require 500 hours over a three-month period. Exposure pathways during this time include direct radiation from the contaminated surface soil and inhalation of contaminated soil suspended during the construction process.

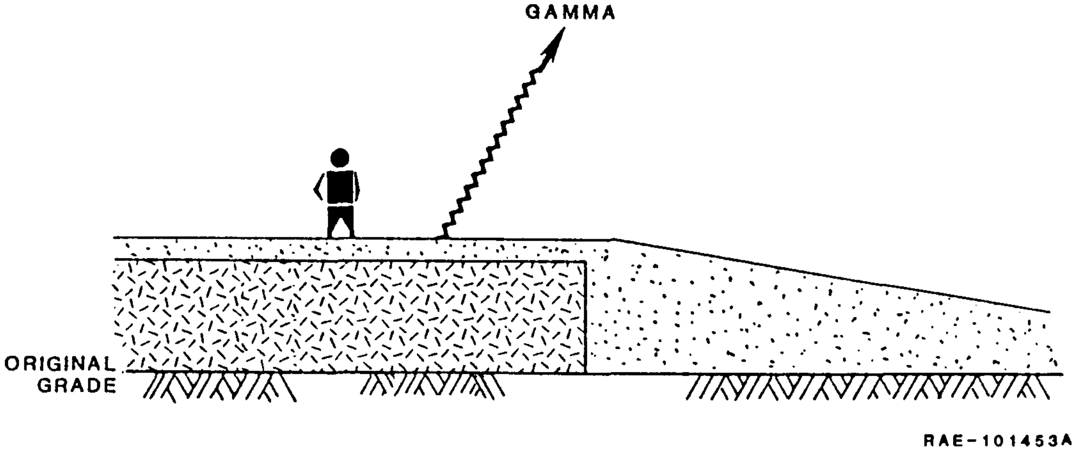

Figure 3-2. Intruder-explorer exposure scenario.

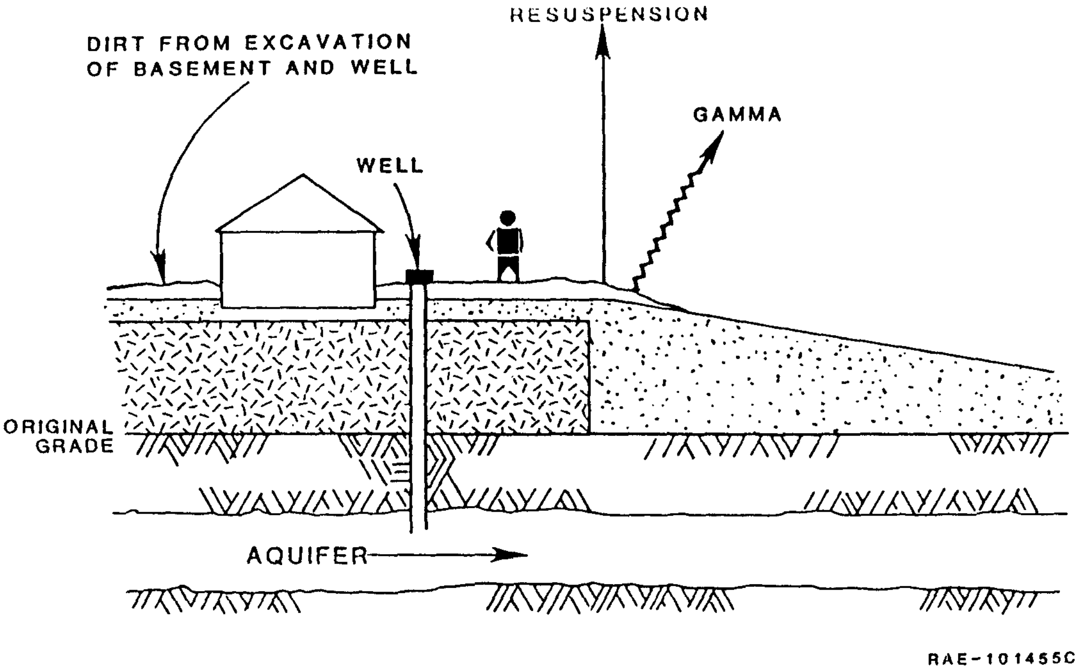

Figure 3-3. Intruder-construction exposure scenario.

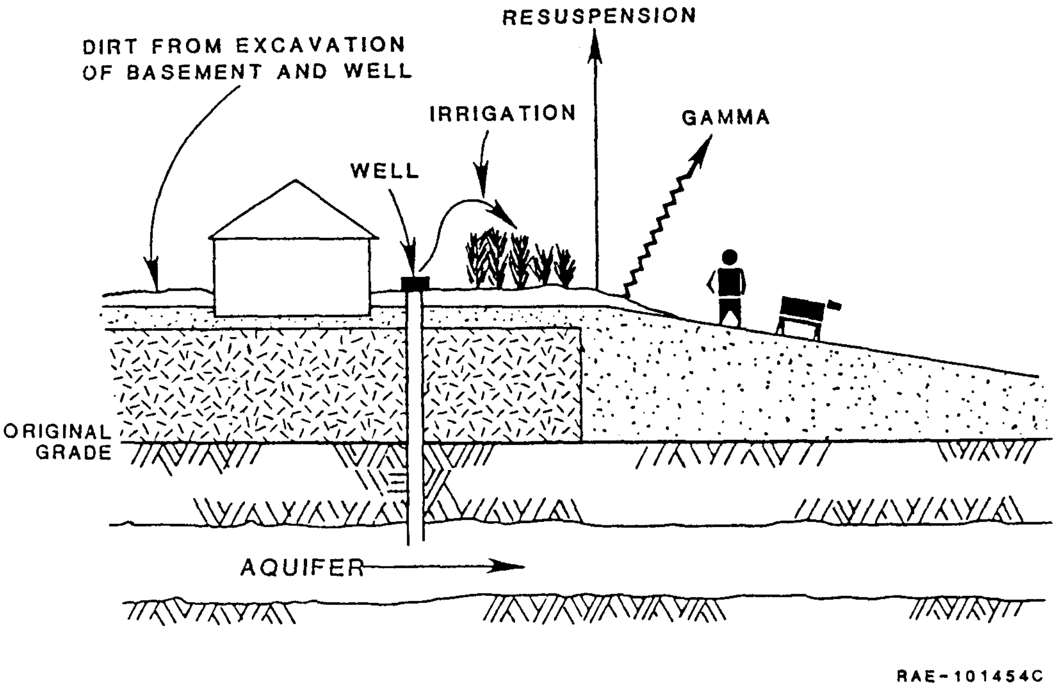

Figure 3-4. Intruder-agriculture exposure scenario.

The intruder-agriculture scenario assumes that an individual moves onto the waste disposal site and resides in the house built in the intruder-construction scenario. This scenario is assumed to occur following the institutional control period and following failure of the roof of the vaults. The individual plants food crops which supply 50 percent of his food requirements. Waste radionuclides are taken up by these crops from contaminated soil unearthed during home construction. Exposure pathways include inhalation of contaminated dust suspended from the soil surface, ingestion of contaminated water, vegetables grown in contaminated soil, and animal products derived from animals grazing on contaminated feed, and direct radiation from the soil surface.

3.3 Assumptions

A host of environmental factors will act to undermine the structural integrity of the facility over time. The impact these factors have upon facility performance must be assessed to ensure compliance with regulatory requirements. The assumptions made in modeling the long-term stability of the facility are outlined here.

It is assumed that deterioration of the AGEMCV will occur due to corrosion of the steel reinforcement and to chemical attack on the concrete itself. The onset of corrosion of the reinforcement is delayed due to the highly alkaline environment surrounding the steel. Eventually the passive layer around the steel reinforcement is broken down due to the penetration of waterborne chloride ions into the concrete. At this point, corrosion may begin and is considered to be limited only by the supply of oxygen at the steel reinforcement.

The concentration of chloride ions in groundwater determines the period of time necessary to de-passivate the steel reinforcement. Concentrations outside the vaults are derived from conditions representative of the site environment (see Appendix A). Chloride ion concentrations within the vault are based on chemical characteristics of the waste due to treatment (see Reference 1).

Additional protection of steel reinforcement from corrosion may be gained through the use of epoxy coatings. This protection, however, will last only as long as this coating is intact. Little information exists which addresses the long-term performance of these coatings in the face of chemical attack and physical stresses. Consequently, the performance of these coatings was not explicitly modeled. Rather, it was assumed that the epoxy coating afforded no significant protection against corrosion past that time when the passive layer around the steel was penetrated by chloride ions.

The concrete vaults are subject to degradation by sulfate attack, which effectively reduces the thickness of the structural components. The rate of attack depends upon the concentrations of sulfate and magnesium ions in the groundwater and the rate of diffusion of these ions through the concrete.

In modeling the performance of the disposal vaults, it is assumed that sulfate and magnesium ions are present in the waste in quantities equal to those outside the vaults. These ionic concentrations are derived from conditions representative of the disposal environment.

According to the design basis (see Reference 1), it is assumed that the roof is uniformly supported by the waste prior to corrosion of the steel waste disposal boxes. Corrosion is expected to begin immediately, as it is assumed that sufficient moisture and oxygen occur within the vaults following closure. Given the expansive nature of the corrosion process, deterioration of the disposal boxes is accompanied by the formation of internal forces, i.e. within the vaults, exerted against the roof and floor of each vault.

Upon completion of the corrosion of the carbon-steel waste disposal boxes, degradation of the solidified waste form within is assumed to begin due to sulfate attack of the grout. It is not assumed that degradation of the solidified waste form will result in changes in the overall waste volume, over and above those noted for corrosion of the waste disposal boxes.

Chemical attack of the internal supporting wall is assumed to occur due to sulfate attack once failure of the waste disposal boxes had occurred. Prior to failure of the waste disposal boxes, concentrations of sulfate and magnesium ions are considered negligible. As no steel reinforcement is used in the construction of the internal wall, no corrosion is considered.

In addition to the concrete vaults, the earthen cover system (refer to Figure 2-2) plays an important role in the performance of the disposal facility. In modeling the facility, it is assumed that the cover will allow 0.1 percent of the site precipitation, or 0.1 cm, to reach the roof of the concrete vaults as demonstrated by the French (see Reference 1). A higher rate of infiltration, 2.8 cm/yr, is also modeled. Prior to failure of the roof of the vaults, an infiltration rate of 0.01 cm/yr through the intact concrete was used. (The bases for the 2.8 cm/yr infiltration rate and the infiltration rate through the intact concrete are discussed in Section 3.4.).

Following failure of the vault roof, it is assumed that all water that penetrates the cover system will percolate through the waste. No deterioration in the performance of the cover system is assumed to occur over the period of simulation. Consequently, the amount of water percolating through the waste is unaffected, save for changes in the hydraulic properties of the roof.

3.4 Performance Assessment Methodology

In order to demonstrate compliance with DOE Order 5820.2A performance objectives, a performance assessment of the AGEMCV disposal facility was carried out. Long-term stability of the vaults and the exposures resulting from the disposed waste were analyzed for a total of 10,000 years following site closure.

The performance of the AGEMCV facility was assessed using the BARRIER,[9] HELP,[10] PRESTO-CPG,[11] and PATHRAE[12] computer codes. The portions of the assessment for which each code was used are illustrated in Figure 3-5.

BARRIER was used to analyze the long-term hydrologic and structural performance of the disposal vaults. The code models the degradation of concrete structures over time due to chemical and physical forces, and the cracking and ultimate failure that accompany this deterioration. Further, the code models the degradation of solidified waste forms and the consequent contaminant release rates.

The HELP code was used to project rates of water infiltration through the intact concrete disposal vaults and through the earthen cover system. Due to very low porosity and hydraulic conductivity, infiltration through intact concrete was calculated to be approximately 0.01 cm/yr. The minimum cover percolation rate calculated by the HELP code (2.8 cm/yr) is modeled in addition to the lower infiltration rate prescribed by the French (see Reference 1), and represents a reduced level of effectiveness in excluding water from the disposed waste. HELP was developed to facilitate rapid, economical estimation of the amounts of surface runoff, subsurface drainage, and leachate that may be expected to result from the operation of a wide

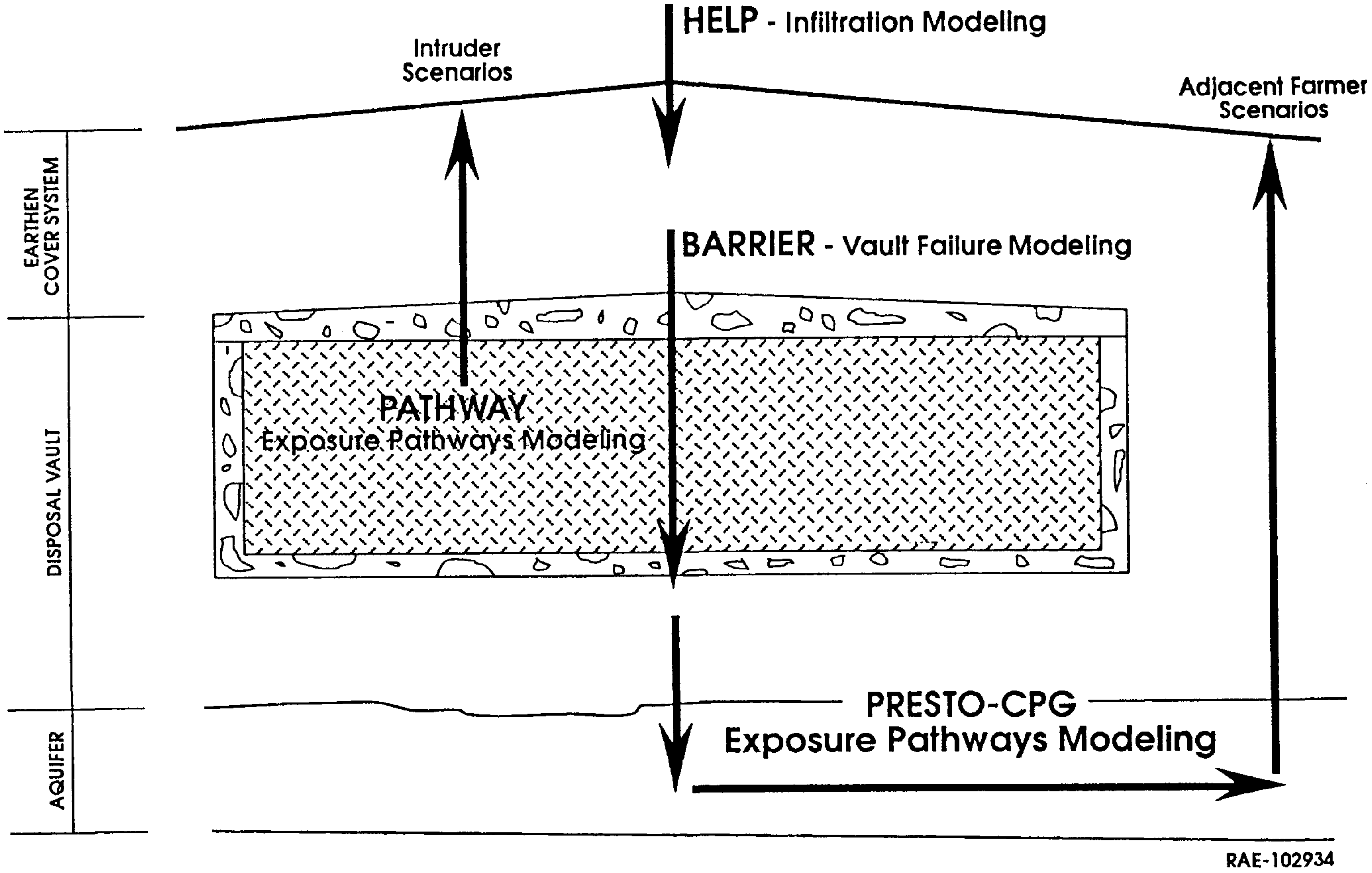

Figure 3-5. Computer codes used in the AGEMCV performance assessment.

variety of landfill designs. The program models the effects of hydrologic processes including precipitation, surface storage, runoff, infiltration, percolation, evapotranspiration, soil moisture storage, and lateral drainage using a quasi-two-dimensional approach.

Contaminant migration from the disposal vaults, and the resulting doses, were modeled using the PRESTO-CPG and PATHRAE computer codes. These codes, developed for use by the U.S. Environmental Protection Agency (EPA) in establishing LLW disposal regulatory standards, evaluate maximum annual doses to a critical population group. The codes account for radionuclide migration via groundwater, surface water, atmospheric, and biotic pathways, and calculate doses for specified times as well as for the years of maximum exposure.

4. RESULTS OF ANALYSIS

4.1 Long-Term Disposal Facility Stability

Each aspect of concrete and waste package deterioration weakens the roof, floor, and walls of the disposal vaults. Concrete cover over the reinforcing steel is considered effectively lost when cracking due to corrosion occurs. Concrete is also lost as sulfate attack proceeds and the strength of the remaining concrete is reduced through $Ca(OH)_2$ leaching.

4.1.1 Steel Corrosion

The rates of corrosion of steel reinforcement vary for the upper and lower faces of the roof and floor because exposure and design conditions differ within and outside the vaults (refer to Figure 2-3). For the upper face of the roof and the lower face of the floor, de-passivation of the steel reinforcement is complete 654 years after site closure. Upon initiation, corrosion of the steel in each of these faces proceeds rapidly, and cracking due to corrosion is seen 700 years after closure of the site. The cracks extend from the steel to the surface of the concrete and run parallel with the steel.

Corrosion of steel reinforcement begins at a later time inside the vault, reflecting the lower chloride ion concentrations. These less severe exposure conditions are offset partially by a thinner concrete cover over the steel reinforcement, minimizing the distance chloride ions must penetrate. Corrosion begins 714 years after site closure for the inner faces of the roof and floor, with cracking due to corrosion occurring within an additional 36 years. Once again, these cracks run along the steel and extend outward from the reinforcement.

4.1.2 Sulfate Attack

The loss of concrete due to sulfate attack is limited to the upper and lower faces of the roof and floor, respectively, until the steel waste disposal boxes have failed. Corrosion of the 12-gauge carbon steel disposal boxes begins at the time of site closure and is complete within 232 years. At that time, deterioration of the grouted waste form begins. Complete degradation of the grouted waste occurs within 4,000 years of site closure. After year 232 of the simulation, chemical conditions are altered to reflect assumed waste characteristics, and deterioration of the inner faces of the vault begins. Approximately 5.6E-3 cm of concrete on each face of the structure are lost annually to sulfate attack.

As the solidified waste degrades, the rate of release of waste contaminants due to leaching is enhanced. This is due to the fact that the degraded waste undergoes advective leaching, while contaminants are released from the solidified waste form through much slower diffusive processes.

4.1.3 $Ca(OH)_2$ Leaching

The loss of concrete yield strength due to leaching of $Ca(OH)_2$ results in a 10% loss within 6,500 years after site closure. This rate of loss is constant throughout the simulation because pertinent exposure conditions do not change.

4.1.4 Vault Failure

Vault failure is considered to have occurred when the roof has either lost sufficient strength to no longer withstand the forces acting on it or when 75% of the original thickness (and therefore the strength) of the roof has been reduced to rubble. In the first case, cracking due to bending occurs. The uniform support of the roof by the contents of the vault, and the lack of subsidence of those contents with time, minimize bending of the roof. Under these conditions, much of the roof's strength must be lost before cracking due to bending is possible. Under those conditions where 75% of the roof thickness (and the roof's bearing strength) is reduced to rubble, the structural properties of the roof are considered lost. This loss in strength results from the gradual decay of the concrete via sulfate attack.

The effects of deterioration upon the roof and floor of each disposal vault differ significantly from each other. Whereas the floor of each disposal vault fails due to loading within 1,200 years of site closure, the roof does not fail until just after 5,000 years.

The additional time required for roof failure reflects the relatively mild loading conditions on this portion of the structure. As the waste disposal boxes corrode, limited expansion of the vault contents occurs, which results in an upward lifting of the vault roof. The expansion projected by the BARRIER code, however, is quite small, not sufficient to cause cracking due to bending.

The time to failure of the vaults is not affected by the rate of infiltration through the earthen cover. While the concrete is intact it represents the limiting factor in terms of flow through the structure. Water in excess of the 0.01 cm/yr concrete infiltration rate drains laterally along the peaked roofs. Consequently, groundwater chemical concentrations and rates of $CaOH_2$ leaching are unaffected.

The structural integrity of the disposal vaults plays two important roles in the performance of the disposal facility. First, the intact concrete vaults provide a barrier which discourages excavation into the waste and subsequent dispersal of contaminants. Secondly, the low permeability of the concrete itself minimizes the amount of water percolating through the waste. Since the predominant mechanism of contaminant release is leaching of the waste, this, in turn, minimizes potential exposures.

While the floor fails structurally, and therefore hydraulically, rather early in the assessment period, the fact that the roof remains intact for several thousand years minimizes the importance of this failure. That is, the intact roof still represents an intruder barrier and effectively isolates the waste from increased infiltration rates. These advantages are lost, however, when the roof fails, just after 5,000 years. At this time, the amount of water percolating through the waste increases to post-failure values, either 0.1 or 2.8 cm/yr.

4.2 Protection of the General Public

The maximum annual doses (effective dose equivalent) for the adjacent farmer scenario for the two post-failure percolation rates used in the analysis are given in Table 4-1. Under conditions in which the earthen cover system permits 0.1 cm of annual percolation through the waste following roof failure, no doses are projected for this pathway. This is because the contaminant travel times to the well for even the most mobile radionuclides exceed

TABLE 4-1. RADIONUCLIDE DOSE SUMMARY FOR THE ADJACENT FARMER EXPOSURE SCENARIO

Exposure Scenario	Dose Summary Post-Failure Percolation Rate 0.1 cm/yr	 2.8 cm/yr
Adjacent Farmer		
Year of maximum dose	*	5249
Maximum effective dose equivalent (mrem/yr)	0.0E+00	7.4E-04
Dominant pathway	*	Ingestion
Dominant nuclide	*	C-14

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* The year of maximum dose occurs after the 10,000-yr investigative period. During the 10,000 yr period, the dose equivalent is zero. Accordingly, there is neither a dominant pathway nor a dominant nuclide to report.

10,000 years. In fact, while C-14 and Tc-99 are projected to arrive at the well within 11,500 years, the vast majority of contaminants do not arrive at the well until 200,000 or more years after the start of the simulation.

In contrast, doses are projected to occur within the 10,000-year simulation period for this scenario when a post-failure percolation rate of 2.8 cm/yr is assumed. In this case, contaminant travel times for C-14 and Tc-99 are less than 5,250 years (vault failure plus a travel time of about 210 years), while the remaining radionuclides arrive at the well in 13,000 or more years. All projected doses, however, fall well within the proposed EPA groundwater standard of 4 mrem/yr.

The doses for the 2.8-cm/yr infiltration rate exposure scenario as a function of time are illustrated in Figure 4-1. As discussed above, contaminants do not reach the offsite well until about 5,250 years after site closure. A peak dose is seen shortly after arrival, at which point exposures decline for the duration of the simulation due to decay of C-14 and Tc-99. Note: Because the 0.1-cm/yr scenario does not result in contaminants reaching the offsite well until well after the 10,000 year evaluation, no illustration is provided.

It is evident from these results that the performance of the disposal facility depends on the functional relationship between the cover system and the concrete vaults themselves. That is, while the presence of the concrete vaults helps in minimizing the percolation of water through the waste and, hence, the release of contaminants, the importance of these effects is ultimately dependent upon facility hydraulic properties after failure. These properties are determined by the performance of the earthen cover.

The interrelationship of the cover and the vaults can, perhaps, be better appreciated if the components are considered separately. In the absence of concrete vaults, the most mobile contaminants leached from the waste would arrive at the offsite well within 5,500 and 210 years for the 0.1-cm/yr and 2.8-cm/yr percolation rates, respectively. Conversely, waste disposed of in concrete vaults would not reach the well until after 5,000 years, regardless of the performance of the cover system.

From these data, it is evident that the presence of the concrete vaults is relatively more important as the performance of the cover system degrades. For highly impermeable cover systems, as typified by the 0.1-cm/yr percolation rate, the very long contaminant travel times

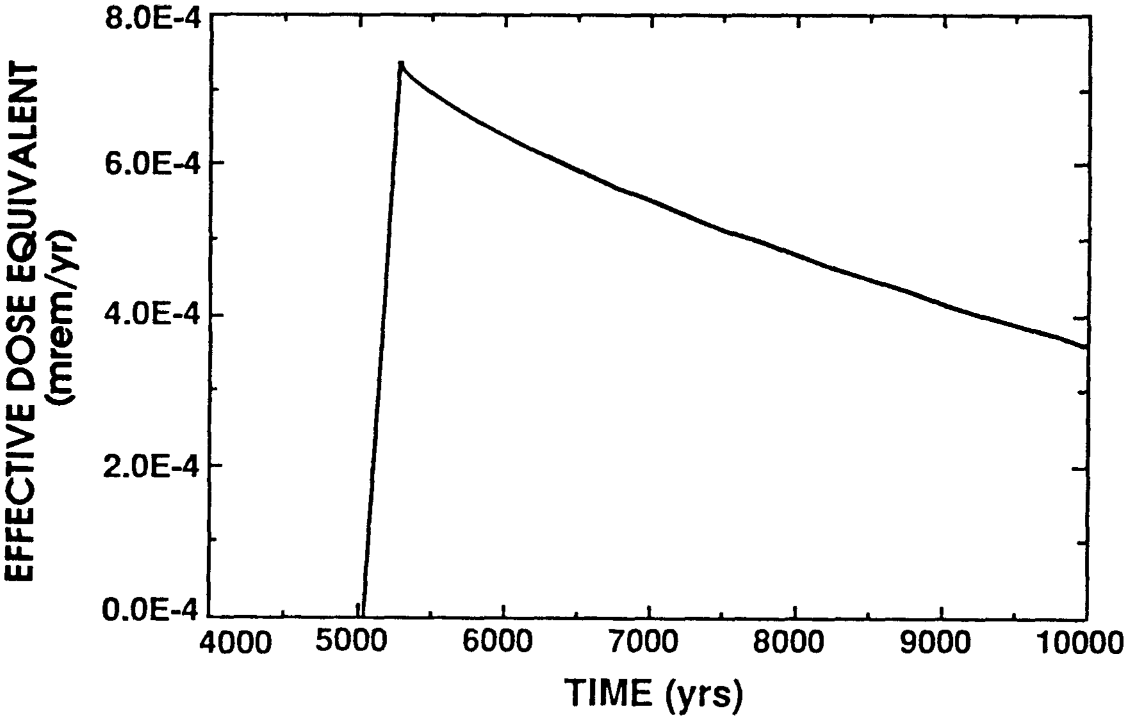

Figure 4-1. Doses for the adjacent farmer scenario as a function of time (2.8 cm/yr infiltration rate).

reduce the significance of the benefits gained from the structures. Under these conditions, the approximately 5,000-year delay gained through the use of vaults is matched by the travel times due to the cover system alone. For the higher percolation rate, however, the minimum delay caused by the vaults exceeds contaminant travel times due to the cover alone by about 24 times.

These comparisons pertain specifically to the hypothetical AGEMCV disposal facility analyzed and consider only the most mobile contaminants. In terms of long-lived, immobile radionuclides, the importance of the benefits gained through the use of concrete vaults diminishes dramatically. While contaminant travel times increase significantly, for either post-failure percolation rate, the use of concrete vaults still provides a maximum of 5,000 years delay time.

It should be evident from this discussion that the performance of the earthen cover system is an important part of overall facility performance. The performance of the cover system will depend on the materials and methods used in its construction, and the underlying support conditions. A major strength of the AGEMCV facility lies in the use of the tightly packed, grouted waste form to provide uniform support for the vault roofs and overlying cover system.

4.3 Protection of the Inadvertent Intruder

The maximum doses (effective dose equivalent) for the intruder exposure scenarios for each post-failure percolation rate are given in Table 4-2. Doses for the intruder-explorer and intruder-construction scenarios fall well below the acute exposure limit of 500 mrem. Similarly, continuous exposures for the intruder-agriculture scenario are much less than the applicable 100-mrem/yr standard.

The maximum doses for the intruder-construction and intruder-explorer scenarios occur at that time when each scenario is first considered to be feasible. Following these times, doses for these scenarios decline due to decay of the waste radionuclides.

For the intruder-explorer scenario, the time of maximum exposure corresponds with the end of the institutional control period. While the intruder-construction scenario can also occur at the end of the institutional period, no exposures will be realized from this scenario until the roof of each vault has lost its structural integrity. Prior to that time, the intruder would not be

TABLE 4-2. RADIONUCLIDE DOSE SUMMARY FOR THE INTRUDER EXPOSURE SCENARIOS

Exposure Scenario	Dose Summary Post-Failure Percolation Rate 0.1 cm/yr	 2.8 cm/yr
Intruder-Explorer		
Year of maximum dose	100	100
Maximum effective dose equivalent (mrem/yr)	1.3E-13	1.3E-13
Dominant pathway	Gamma Radiation	Gamma Radiation
Dominant nuclide	Tl-208	Tl-208
Intruder-Construction		
Year of maximum dose	5,008	5,008
Maximum effective dose equivalent (mrem/yr)	1.7E-04	1.7E-04
Dominant pathway	Dust Inhalation	Dust Inhalation
Dominant nuclide	U-238	U-238
Intruder-Agriculture		
Year of maximum dose	5,008	5,204
Maximum effective dose equivalent (mrem/yr)	5.8E-04	1.3E-03
Dominant pathway	Dust Inhalation	Ingestion
Dominant nuclide	U-238	C-14

able to drill a well into the waste. While the foundation for the house could be excavated, the depth of the earthen cover (about 4.0 m) would preclude contacting the waste.

Exposures for the intruder-explorer and intruder-construction scenarios are unaffected by the post-failure percolation rate. This is because they occur before, or at the time of, vault failure.

Similar to the intruder-construction scenario, maximum exposures for the intruder-agriculture scenario do not occur until the vault roofs have failed. In contrast, projected exposures for the intruder-agriculture scenario are affected by changes in post-failure percolation rates. At the lower rate of post-failure percolation (0.1 cm/yr), all exposures to the agricultural intruder arise through dust inhalation, direct radiation, and ingestion of contaminated food. No doses are received through the consumption of contaminated water because contaminant travel times preclude the arrival of radionuclides at the well within 10,000 years. As discussed earlier, these travel times are significantly reduced at the higher percolation rate (2.8 cm/yr). Consequently, projected doses increase, reflecting the ingestion of contaminated water.

5. CONCLUSIONS

The contributions of the waste form, vault, and cover system to the performance of the AGEMCV are as follows:

1. The use of tightly packed, grouted waste forms provides uniform support for the vault roof and the overlying cover system, effectively eliminating subsidence and subsidence-induced degradation of the roof and cover system.
2. The AGEMCV provides just over 5,000 years delay in the time at which radionuclides begin to move through the environment.
3. The AGEMCV delays inadvertent intrusion for just over 5,000 years, barring a catastrophic disruption of the structure.
4. After the 5000+ years of delay, the more permeable cover system (2.8 cm/yr) provides a transit time of 210 years from the vault to the adjacent farmer well for the most mobile radionuclides in the waste inventory.
5. After the 5000+ years of delay, the less permeable cover system (0.1 cm/yr) provides a 5,500-year transit time (vault to well) for the most mobile radionuclides.

Based on the above contributions, the AGEMCV, as analyzed in this report, more than satisfies the DOE performance objectives for protection of the public and inadvertent intruders. Therefore, to the extent that the facility is accurately portrayed by the input data and assumptions, no design changes are required to meet said objectives.

The maximum calculated dose (effective dose equivalent) to a member of the public occurs 5,249 years after site closure and is 7.4E-04 mrem/yr, in excess of 30,000 times less than the DOE performance objectives (see References 2 and 8). This dose is a result of the ingestion of C-14 and occurs for a facility using a cover system that allows 2.8 cm/yr infiltration. No dose whatsoever is imposed on the public within the 10,000-year analysis period when the less permeable cover system (0.1 cm/yr) is used.

The maximum dose to an inadvertent intruder never approaches the chronic exposure limit of 100 mrem/yr or the acute exposure limit of 500 mrem. The maximum dose occurs 5,204 years after site closure at a magnitude of 1.3E-03 mrem/yr. This dose, which pertains to the intruder-agriculture scenario and results from ingestion of C-14, is in excess of 70,000 times less than the 100-mrem/yr DOE performance objective. Doses for the intruder-construction and intruder-explorer scenarios are smaller still, falling below regulatory requirements by a factor of more than 100,000.

The hypothetical AGEMCV performance reported above represents a significant improvement over the performance of the abovegrade vault (AGV) concept that was modeled previously (see Reference 2). While the performance of AGEMCV and the AGV cannot be quantitatively compared due to differences in waste source term and leaching characteristics, and due to the lack of a detailed analysis of concrete performance for the AGV (vault failure was assumed to occur 500 years after site closure), a qualitative comparison of facility performance can be made. The AGV facility design did not provide uniform support conditions for the vault roof and did not employ an earthen cover over the disposal vaults. Consequently, when the roof of each AGV facility failed, disposed waste was exposed to the environment. The waste was readily suspended into the atmosphere and transported away from the facility with surface runoff.

The greatly improved performance of the AGEMCV over the AGV is based on a combination of several design features which were not included in the AGV. The design features most critical to the improved performance concern the support conditions for the AGEMCV's roof and the use of an earthen cover system. The engineered earthen cover and the unique support conditions used in the design of the AGEMCV facility act together to negate the major exposure pathways calculated for the AGV. The grade of the cover and the establishment of vegetation minimizes erosive processes, while the support conditions for the concrete roof minimize the potential for localized failure of the cover system. Further, upon failure of the vault, the waste within remains covered by several meters of cover. These features act to ensure the isolation of the waste even after many thousands of years. Additionally, the virtual elimination of organics in the waste greatly reduces the potential for gas generation within the waste stack.

Despite the relative lack of a common basis on which to make a quantitative comparison of the two facilities, it is clear that the previously calculated performance of the AGV facility cannot be construed as applicable to all abovegrade disposal strategies. On the contrary, the analysis of the AGEMCV disposal facility provides strong evidence of the viability of this mode of LLW disposal.

6. REFERENCES

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APPENDIX A

ABOVEGRADE EARTH-MOUNDED CONCRETE VAULT PERFORMANCE ASSESSMENT INPUT DATA

APPENDIX A

ABOVEGRADE EARTH-MOUNDED CONCRETE VAULT PERFORMANCE ASSESSMENT INPUT DATA

Appendix A contains the input data used for the analysis of the hypothetical AGEMCV facility. The data have been divided into a number of categories based on the aspect of the disposal system to which they apply. The first of these aspects, concrete structural data, describes key operating assumptions about the facility and provides the structural basis for the AGEMCV. Concrete design data provide the mix characteristics of the concrete used in vault construction.

Disposal site data include parameters that describe miscellaneous features of facility operations. Disposal environment and exposure pathway data supply characteristics of the disposal site, excluding the vaults, and provide information which allows modeling of the exposures to human receptors. Waste form data characterize the properties of the waste prior to, and following, disposal. Finally, all data that are nuclide-specific in nature are listed in a series of tables. These data encompass a broad range of items, from inventories to biotransfer factors to dose conversion factors.

The data used in the analysis are tabulated in the following ten tables. Each table includes a description of the parameter, the value suggested for use in the analysis, and a reference indicating its origin. A reference of "RAE" means that the value was selected by Rogers and Associates based on best scientific and engineering judgment. A list of all other references is provided at the end of the appendix. Further discussion of the basis of a given parameter value is supplied as necessary.

Concrete structural design data are listed in Table A-1. These data are used in assessing the performance of the facility over time using the BARRIER code. The basis of the design is that found in Appendix A of Reference 1. Construction details of the AGEMCV were modified to reflect optimum engineering design practices for the specified structure. These modifications, detailed in Appendix B, are marked with the reference "APP B" in the table below.

TABLE A-1. CONCRETE STRUCTURAL DESIGN INPUT DATA

Variable Description	Value	Reference
Concrete cover thickness over steel reinforcement (cm):		APP B
Upper face of roof	11.4	
Lower face of roof	8.9	
Upper face of floor	8.9	
Lower face of floor	11.4	
Radius of steel reinforcement (cm):		APP B
Upper face of roof	1.3	
Lower face of roof	1.3	
Upper face of floor	1.3	
Lower face of floor	1.3	
Spacing of steel reinforcement (cm):		APP B
Upper face of roof	10.2	
Lower face of roof	10.2	
Upper face of floor	10.2	
Lower face of floor	10.2	
Average thickness of cover (soil plus concrete) over waste (m)	5.1	1
Thickness of walls of waste overpack (cm)	3.2E-1	1
Corrosion rate of waste overpack (cm/yr)	1.2E-3	2
Minimum thickness of roof (cm)	91.4	APP B
Maximum thickness of roof (cm)	21.9	APP B
Thickness of floor (cm)	106.7	APP B
Number of disposal cells across each vault	2	1
Number of disposal cells along length of each vault	1	1
Length of disposal cell (m)	70.1	1
Width of disposal cell (m)	7.9	1
Height of disposal cell (m)	7.3	1
Thickness of external walls (cm)	106.7	APP B
Thickness of internal wall (cm)	15.2	1
Length of floor overhang (cm)	.0	APP B
Static load on roof of vault (psi)	13.6	1
Friction angle of waste backfill (deg)	54.	1
Friction angle of soil backfill around vault (deg)	16.	1
Modulus of the subgrade reaction (Kci)	300.	APP B
Density of soil backfill around vault (g/cm^3)	1.8	RAE

Concrete design information, also used in the assessment of vault performance with time, is listed in Table A-2. The data reflect the properties of high-quality, Type-V concrete. The chemical exposure conditions outside of the vault are considered representative of the facility locale.[3]

Chloride ion concentrations inside the vault are estimated using available information from Reference 1 on PVC processing operations. Average Cl- concentrations in the waste were calculated, a portion of which is assumed to be leached from the waste annually. Concentrations of Mg++, and SO_4-- are assumed to be equivalent to groundwater concentrations upon failure of the waste overpacks. Prior to this time, concentrations of these ions are considered negligible.

Data describing assorted aspects of disposal site operation are listed in Table A-3. These data are used for a variety of aspects of the performance assessment.

Site environmental data are included in Table A-4. These data are used in modeling the release and transport of contaminants from the facility and, subsequently, exposures to human receptors.

Waste characteristics, listed in Table A-5, are used to model the deterioration of the solidified waste form employed at the disposal facility. The solidified waste is modeled as an equivalent cylindrical container which, upon corrosion of the overpack, would undergo sulfate attack at a rate determined by groundwater concentrations of Mg++ and SO_4-- ions.

Tables A-6 through A-9 include nuclide-specific data necessary for the performance assessment of the AGEMCV. Distribution coefficients required for model calculations are listed in Table A-6. Surface, vertical, and aquifer coefficients are used to calculate contaminant transport in surface soil, below the vault, and within the aquifer, respectively. Waste distribution coefficients are used to calculate radionuclide release rates. These coefficients are the same as those used in Reference 7 for nuclides in common between the two assessments. For radionuclides not considered in the earlier analysis, data were taken from Reference 9.

TABLE A-2. CONCRETE DESIGN INPUT DATA

Variable Description	Value	Reference
Weight percent of C3A in unhydrated cement	3.0	RAE
Weight percent of C3A in unhydrated grout used for waste solidification	8.0	RAE
Average $Ca(OH)_2$ concentration in concrete (mole/L)	4.0	3
Average $Ca(OH)_2$ concentration in pore fluid of concrete (mole/L)	2.0E-2	3
Grain diameter of concrete (cm)	1.0E-3	3
Water-to-cement ratio	4.0E-1	3
Coefficient 'a' in concrete compressive strength equation	1.02E+1	4, 5
Coefficient 'b' in concrete compressive strength equation	6.0E-1	4, 5
Compressive strength of concrete at 28 days (psi)	5,000.	RAE
Modulus of elasticity of steel reinforcement (kg/cm^2)	2.0E+6	6
Yield strength of steel reinforcement (kg/cm^2)	4.2E+3	RAE
Diffusion coefficients in concrete (m^2/s):		
$Ca(OH)_2$	1.0E-10	3
O_2	1.0E-10	3
SO_4--	3.0E-11	3
Chemical exposure conditions prior to vault failure (mg/l):		
Upper face of roof-		
Cl-	4.8	3
Mg++	5.8	3
SO_4--	300.	3
O_2--	10.	3
Lower face of roof-		
Cl-	2.	1
Mg++	5.8	3
SO_4--	300.	3
O_2--	10.	3
Upper face of floor-		
Cl-	2.	1
Mg++	5.8	3
SO_4--	300.	3
O_2--	10.	3
Lower face of floor-		
Cl-	4.8	3
Mg++	5.8	3
SO_4--	300.	3
O_2--	10.	3

TABLE A-3. DISPOSAL SITE CHARACTERISTICS

Variable Description	Value	Reference
Disposal site operational period (yr)	30.	1
Number of years of active site maintenance after closure (yr)	0.	1
Total volume of waste disposed (m^3)	2.2E+4	1

TABLE A-4. DISPOSAL ENVIRONMENT AND EXPOSURE PATHWAY INPUT DATA

Variable Description	Value	Reference
Fraction of irrigation water supplied by contaminated water from:		7
Well	0.	
Stream	0.1	
Fraction of animal drinking water supplied by contaminated water from:		7
Well	0.5	
Stream	0.5	
Fraction of human drinking water supplied by contaminated water from:		7
Well	1.0	
Stream	0.	
Distance from bottom of vault to aquifer (m)	28.	7
Distance from center of vault to well (m)	108.	7
Aquifer velocity (m/yr)	8.5	7
Thickness of aquifer (m)	30.0	7
Aquifer dispersion angle (rad)	0.1	7
Aquifer porosity	2.5E-1	7
Aquifer density (g/cm^3)	1.4	7
Longitudinal dispersivity of aquifer (m)	10.8	8
Aquifer transverse dispersion coefficient (m^2/yr)	0.	7
Sub-vault porosity	4.8E-1	7
Sub-vault permeability (m/yr)	10.	7
Disposal vault area (m^2)	3.59E+3	7
Annual infiltration for non-cap portions of disposal site (m)	7.3E-1	7
Annual percolation through waste (cm):		
Prior to vault failure	1.0E-2	calculated by HELP
Following vault failure	1.0E-1	1
	2.8E+0	calculated by HELP
Fraction of saturation below vault	3.8E-1	7
Residual saturation below vault	8.0E-2	7
Absolute humidity of atmosphere (g/m^3)	6.4	7
Atmospheric source height (m)	1.	7
Settling velocity due to gravity (m/s)	1.0E-2	7
Annual average wind speed (m/s)	5.0	7
Deposition velocity (m/s)	1.0E-2	7
Distance from vault to atmospheric receptor location (m)	200.	7
Height of inversion layer or lid (m)	300.	7
Hosker's roughness factor (m)	0.01	7
Fraction of the time the wind blows toward the receptor location	1.06E-1	7

TABLE A-4. DISPOSAL ENVIRONMENT AND EXPOSURE PATHWAY INPUT DATA (Continued)

Variable Description	Value	Reference
Factors used in resuspension rate equation:	1.0E-6 -1.5E-1 1.0E-10	7
Dust loading for inadvertent intruder (kg/m^3):		
Intruder-Agriculture	1.0E-7	7
Intruder-Construction	5.0E-7	7
Fraction of the year inadvertent intruder is exposed to dust:		7
Intruder-explorer	1.1E-1	
Intruder-Construction	5.7E-2	
Intruder-Agriculture	7.1E-1	
Pasquill stability category	4	7
Rainfall factor (R/yr)	100.	7
Soil-erodibility factor (tons/acre-R)	1.9E-1	7
Slope steepness-length factor	5.4E-1	7
Crop management factor	1.0E-1	7
Erosion control practices factor	1.	7
Sediment delivery ratio	1.	7
Porosity of surface soil	4.3E-1	7
Bulk density of soil (g/cm^3)	1.4	7
River/stream flow rate (m^3/yr)	3.65E+8	7
Cross slope extent of the surface region contaminated by operational spillage	2.10E+2	7
Active depth of soil in surface-contaminated region (m)	0.1	7
Distance from nearest edge of vault to river/stream (m)	2.5E+2	7
Total annual precipitation (m)	1.0	7
Fraction of annual precipitation that becomes deep infiltration at site	1.0E-3 2.8E-2	1 calculated by HELP
Fraction of annual precipitation that runs off	0.	7
Agricultural productivity for pasture grass (kg/m^3)	3.4E-1	7
Agricultural productivity for other vegetation (kg/m^3)	5.6E-1	7
Weathering removal constant for vegetation (L/hr)	2.1E-3	7
Radionuclide retention fractions:		7
Air	2.0E-1	
Irrigation	2.5E-1	

TABLE A-4. DISPOSAL ENVIRONMENT AND EXPOSURE PATHWAY INPUT DATA (Continued)

Variable Description	Value	Reference
Period of time crops exposed to contaminated air during growing season (hr):		7
Pasture grass	720.	
Leafy vegetables	1,440.	
Delay between harvest and consumption (hr):		7
Pasture grass	330.	
Stored feed	2,160.	
Leafy vegetables	24.	
Produce	336.	
Fraction of year animals graze on pasture grass	2.7E-1	7
Fraction of animal's daily feed that is pasture grass for time spent in pasture	0.1	7
Daily consumption of feed by cattle (kg)	50.	7
Transport time from animal feed to milk (hr)	48.	7
Delay time between animal slaughter and meat consumption (hr)	336.	7
Fraction of the year crops are irrigated	8.0E-2	7
Irrigation rate (L/m^3-hr)	4.2E-2	7
Time of irrigation (hr):		7
Pasture grass	720.	
Other vegetation	1,440.	
Daily water consumption of milk cows (L)	60.	7
Daily water consumption of cattle (L)	50.	7
Annual human consumption rates:		7
Leafy vegetables (kg)	13.	
Produce (kg)	84.	
Milk (L)	112.	
Meat (kg)	62.	
Drinking water (L)	391.	
Fraction of food eaten which is grown over waste site (Intruder-Agriculture scenario)	0.5	7
Fraction of year spent in direct radiation field:		7
Intruder-Explorer	1.1E-1	
Intruder-Construction	5.7E-2	
Intruder-Agriculture	7.1E-1	
Local population	1.	7
Adult breathing rate (m^3)	8,035.	7
Fractional equilibrium ratio for C-14	1.	7

TABLE A-5. RADIOACTIVE WASTE CHARACTERISTICS

Variable Description	Value	Reference
Density of waste (g/cm^3)	3.4	1
Equivalent height of waste overpack (m)	1.2	1
Equivalent radius of waste overpack (m)	0.6	1
Porosity of solidified waste	0.3	RAE
Moisture content of grouted waste	0.12	RAE
Diffusion coefficient of SO_4^{--} in grouted waste-form (m^2/s)	3.0E-11	3
Chemical exposure conditions (mg/L):		3
Mg^{++}	5.8	
SO_4^{--}	300.	

TABLE A-6. RADIONUCLIDE DISTRIBUTION COEFFICIENTS

Nuclide	Surface Kd	Waste Kd	Vertical Kd	Aquifer Kd
H-3	.01	.3	.01	.01
C-14	.01	60.	.01	.01
Mn-54	150.	50.	150.	150.
Fe-55	1,500.	50.	1,500.	1,500.
Ni-59	150.	50.	150.	150.
Co-60	40.	50.	40.	40.
Ni-63	150.	50.	150.	150.
Sr-90	30.	30.	30.	30.
Y-90	30.	30.	30.	30.
Nb-95	350.	70.	350.	350.
Zr-95	350.	70.	350.	350.
Tc-99	.03	.03	.03	.03
Rh-106	220.	70.	220.	220.
Ru-106	220.	70.	220.	220.
Sb-125	45.	45.	45.	45.
Te-125m	45.	45.	45.	45.
Cs-134	250.	2,000.	250.	250.
Cs-137	250.	2,000.	250.	250.
Ba-137M	250.	2,000.	250.	250.
Eu-152	4,300.	2,000.	4,300.	4,300.
Tl-208	a	a	a	a
Bi-210	220.	220.	220.	220.
Pb-210	220.	220.	220.	220.
Po-210	220.	220.	220.	220.
Bi-212	a	a	a	a
Pb-212	a	a	a	a
Po-212	a	a	a	a
Bi-214	220.	220.	220.	220.
Pb-214	220.	220.	220.	220.
Po-214	220.	220.	220.	220.
Po-216	a	a	a	a
Rn-220	a	a	a	a
Rn-222	220.	220.	220.	220.
Ra-224	a	a	a	a
Ra-226	220.	220.	220.	220.
Ac-228	60,000.	60,000.	60,000.	60,000.
Ra-228	60,000.	60,000.	60,000.	60,000.
Th-228	a	a	a	a
Th-232	60,000.	60,000.	60,000.	60,000.
Th-234	50.	3,000.	50.	30,00.
U-232	50.	3,000.	50.	50.
U-234	50.	3,000.	50.	50.
U-235	50	3,000.	50.	50.
Np-237	5.	5.	5.	5.
U-238	50.	3,000.	50.	50.
Pu-238	1,800.	700.	1,800.	1,800.
Pu-239	1,800.	700.	1,800.	1,800.
Pu-240	1,800.	700.	1,800.	1,800.

TABLE A-6. RADIONUCLIDE DISTRIBUTION COEFFICIENTS (Continued)

Nuclide	Surface Kd	Waste Kd	Vertical Kd	Aquifer Kd
Am-241	4,700.	80.	4,700.	4,700.
Pu-241	1,800.	700.	1,800.	1,800.
Pu-242	1,800.	700.	1,800.	1,800.
Am-243	4,700.	80.	4,700.	4,700.

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a. Radionuclide is a daughter of U-232 and Th-232. That portion of the nuclide inventory resulting from U-232 has a waste Kd of 3,000, while all other Kds are 50. All Kds for daughters of Th-232 are 60,000.

TABLE A-7. RADIONUCLIDE INVENTORIES, LEACH RATES, AND SOLUBILITIES

		Leach Fraction (L/yr)			
		Initial	Final		
Nuclide	Inventory[a] (Ci)		0.1 cm/yr	2.8 cm/yr	Solubility (mole/L)
H-3	4.7E+01	1.1E-05	1.1E-04	3.2E-03	0.0E+00
C-14	1.2E-02	6.8E-08	6.8E-07	1.9E-05	0.0E+00
Mn-54	5.0E+04	8.1E-08	8.1E-07	2.3E-05	0.0E+00
Fe-55	1.1E+03	8.1E-08	8.1E-07	2.3E-05	0.0E+00
Ni-59	5.4E+00	8.1E-08	8.1E-07	2.3E-05	1.0E-02
Co-60	1.6E+04	8.1E-08	8.1E-07	2.3E-05	1.0E-02
Ni-63	3.3E+03	8.1E-08	8.1E-07	2.3E-05	1.0E-02
Sr-90	3.0E+01	1.4E-07	1.4E-06	3.8E-05	0.0E+00
Y-90	1.8E+01	1.4E-07	1.4E-06	3.8E-05	0.0E+00
Nb-95	5.5E+00	5.8E-08	5.8E-07	1.6E-05	0.0E+00
Zr-95	5.5E+00	5.8E-08	5.8E-07	1.6E-05	0.0E+00
Tc-99	1.0E-06	4.6E-05	4.6E-04	1.3E-02	0.0E+00
Rh-106	1.8E+01	1.5E-10	1.5E-09	4.1E-08	1.0E-10
Ru-106	1.8E+01	1.5E-10	1.5E-09	4.1E-08	1.0E-10
Sb-125	7.8E+00	9.0E-08	9.0E-07	2.5E-05	1.0E-04
Te-125m	7.8E+00	9.0E-08	9.0E-07	2.5E-05	1.0E-04
Cs-134	1.2E+00	2.0E-09	2.0E-08	5.7E-07	0.0E+00
Cs-137	2.0E+01	2.0E-09	2.0E-08	5.7E-07	0.0E+00
Ba-137m	2.0E+01	2.0E-09	2.0E-08	5.7E-07	0.0E+00
Eu-152	1.0E-05	2.0E-09	2.0E-08	5.7E-07	0.0E+00
Tl-208	7.9E-01	b	b	b	b
Bi-210	1.0E-01	1.8E-08	1.8E-07	5.2E-06	1.0E-08
Pb-210	1.0E-01	1.8E-08	1.8E-07	5.2E-06	1.0E-08
Po-210	1.0E-01	1.8E-08	1.8E-07	5.2E-06	1.0E-08
Bi-212	2.2E+00	b	b	b	b
Pb-212	2.2E+00	b	b	b	b
Po-212	1.4E+00	b	b	b	b
Bi-214	1.0E-01	1.8E-08	1.8E-07	5.2E-06	1.0E-08
Pb-214	1.0E-01	1.8E-08	1.8E-07	5.2E-06	1.0E-08
Po-214	1.0E-01	1.8E-08	1.8E-07	5.2E-06	1.0E-08
Po-216	2.2E+00	b	b	b	b
Rn-220	2.2E+00	b	b	b	b
Rn-222	1.0E-01	1.8E-08	1.8E-07	5.2E-06	1.0E-08
Ra-224	2.2E+00	b	b	b	b
Ra-226	1.0E-01	1.8E-08	1.8E-07	5.2E-06	1.0E-08
Ac-228	1.8E-04	6.8E-11	6.8E-10	1.9E-08	1.0E-04
Ra-228	1.8E-04	6.8E-11	6.8E-10	1.9E-08	1.0E-04
Th-228	2.2E+00	b	b	b	b
Th-232	1.8E-04	6.8E-11	6.8E-10	1.9E-08	1.0E-04
Th-234	3.6E-01	1.4E-09	1.4E-08	3.8E-07	0.0E+00
U-232	2.2E+00	1.4E-09	1.4E-08	3.8E-07	0.0E+00
U-234	7.6E-08	1.4E-09	1.4E-08	3.8E-07	0.0E+00
U-235	1.8E-02	1.4E-09	1.4E-08	3.8E-07	0.0E+00
Np-237	4.9E-05	8.0E-07	8.0E-06	2.2E-04	1.0E+01

TABLE A-7. RADIONUCLIDE INVENTORIES, LEACH RATES, AND SOLUBILITIES (Continued)

Nuclide	Inventory[a] (Ci)	Leach Fraction (L/yr) Initial	Final 0.1 cm/yr	Final 2.8 cm/yr	Solubility (mole/L)
U-238	3.6E-01	1.4E-09	1.4E-08	3.8E-07	0.0E+00
Pu-238	2.1E-04	6.4E-11	6.4E-10	1.8E-08	1.0E-13
Pu-239	1.8E-02	6.4E-11	6.4E-10	1.8E-08	1.0E-13
Pu-240	1.6E-03	6.4E-11	6.4E-10	1.8E-08	1.0E-13
Am-241	3.5E-03	5.1E-08	5.1E-07	1.4E-05	1.0E-01
Pu-241	2.1E-02	6.4E-11	6.4E-10	1.8E-08	1.0E-13
Pu-242	4.1E-05	6.4E-11	6.4E-10	1.8E-08	1.0E-13
Am-243	2.0E-04	5.1E-08	5.1E-07	1.4E-05	1.0E-01

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a. Inventory reflects omission of several short-lived radionuclides and the ingrowth of daughter products (discussed in main report).

b. Radionuclide is a daughter of U-232 and Th-232. That portion of the nuclide inventory resulting from U-232 has a solubility of 0.0E+00 and an initial leach rate of 1.4E-09, and final leach rates of 1.4E-08 and 3.8E-07 for 0.1 and 2.8 cm/yr percolation, respectively. Daughters of Th-232 have a solubility of 1.0E-04 and an initial leachrate of 6.8E-11. Final leach rates are 6.8E-10 and 1.9E-08 for 0.1 and 2.8 cm/yr percolation, respectively.

TABLE A-8. RADIONUCLIDE BIOTRANSFER DATA

	Soil-To-Plant Uptake Factors (dry weight basis)		Transfer Factors	
Nuclide	Vegetation	Grain	Forage-to-Milk (day/L)	Forage-to-Beef (day/L)
H-3	4.8E+0	4.8E-1	1.0E-2	1.2E-2
C-14	5.5E+0	5.5E-1	1.2E-2	3.1E-2
Mn-54	2.5E-1	5.0E-2	3.5E-4	4.0E-4
Fe-55	4.0E-3	1.0E-3	2.5E-4	2.0E-2
Ni-59	6.0E-2	6.0E-2	1.0E-3	6.0E-3
Co-60	2.0E-2	7.0E-3	2.0E-3	2.0E-2
Ni-63	6.0E-2	6.0E-2	1.0E-3	6.0E-3
Sr-90	2.5E+0	2.5E-1	1.5E-3	3.0E-4
Y-90	1.5E-2	6.0E-3	2.0E-5	3.0E-4
Nb-95	2.0E-2	5.0E-3	2.0E-2	2.5E-1
Zr-95	2.0E-3	5.0E-4	3.0E-5	5.5E-3
Tc-99	9.5E+0	1.5E+0	1.0E-2	8.5E-3
Rh-106	1.5E-1	4.0E-2	1.0E-2	2.0E-3
Ru-106	7.5E-2	2.0E-2	6.0E-7	2.0E-3
Sb-125	2.0E-1	3.0E-2	1.0E-4	1.0E-3
Te-125m	2.5E-2	4.0E-3	2.0E-4	1.5E-2
Cs-134	8.0E-2	3.0E-2	7.0E-3	2.0E-2
Cs-137	8.0E-2	3.0E-2	7.0E-3	2.0E-2
Ba-137m	1.5E-1	1.5E-2	3.5E-4	1.5E-4
Eu-152	1.0E-2	4.0E-3	2.0E-5	5.0E-3
Tl-208	4.0E-3	4.0E-4	2.0E-3	4.0E-2
Bi-210	3.5E-2	5.0E-3	5.0E-4	4.0E-4
Pb-210	4.5E-2	9.0E-3	2.5E-4	3.0E-4
Po-210	2.5E-3	4.0E-4	3.5E-4	9.5E-5
Bi-212	3.5E-2	5.0E-3	5.0E-4	4.0E-4
Pb-212	4.5E-2	9.0E-3	2.5E-4	3.0E-4
Po-212	2.5E-3	4.0E-4	3.5E-4	9.5E-5
Bi-214	3.5E-2	5.0E-3	5.0E-4	4.0E-4
Pb-214	4.5E-2	9.0E-3	2.5E-4	3.0E-4
Po-214	2.5E-3	4.0E-4	3.5E-4	9.5E-5
Po-216	2.5E-3	4.0E-4	3.5E-4	9.5E-5
Rn-220	0.0E+0	0.0E+0	0.0E+0	0.0E+0
Rn-222	0.0E+0	0.0E+0	0.0E+0	0.0E+0
Ra-224	1.5E-2	1.5E-3	4.5E-4	2.5E-4
Ra-226	1.5E-2	1.5E-3	4.5E-4	2.5E-4
Ac-228	3.5E-3	3.5E-4	2.0E-5	2.5E-5
Ra-228	1.5E-2	1.5E-3	4.5E-4	2.5E-4
Th-228	8.5E-4	8.5E-5	5.0E-4	6.0E-6
Th-232	8.5E-4	8.5E-5	4.5E-4	6.0E-6
Th-234	8.5E-4	8.5E-5	4.5E.4	6.0E-6
U-232	8.5E-3	4.0E-3	6.0E-4	2.0E-4
U-234	8.5E-3	4.0E-3	6.0E-4	2.0E-4
U-235	8.5E-3	4.0E-3	6.0E-4	2.0E-4

TABLE A-8. RADIONUCLIDE BIOTRANSFER DATA (Continued)

	Soil-To-Plant Uptake Factors (dry weight basis)		Transfer Factors	
Nuclide	Vegetation	Grain	Forage-to-Milk (day/L)	Forage-to-Beef (day/L)
Np-237	1.0E-1	1.0E-2	5.0E-6	5.5E-5
U-238	8.5E-3	4.0E-3	6.0E-4	2.0E-4
Pu-238	4.5E-4	4.5E-5	1.0E-7	5.0E-7
Pu-239	4.5E-4	4.5E-5	1.0E-7	5.0E-7
Pu-240	4.5E-4	4.5E-5	1.0E-7	5.0E-7
Am-241	5.5E-3	2.5E-4	4.0E-7	3.5E-6
Pu-241	4.5E-4	4.5E-5	1.0E-7	5.0E-7
Pu-242	4.5E-4	4.5E-5	1.0E-7	5.0E-7
Am-243	5.5E-3	2.5E-4	4.0E-7	3.5E-6

TABLE A-9. RADIONUCLIDE DOSE CONVERSION FACTORS

			Direct Radiation	
Nuclide	Ingestion (mrem/pCi)	Inhalation (mrem/pCi)	Ground Surface (mrem-m^2/pCi/hr)	Air Immersion (mrem-m^3/pCi/hr)
H-3	6.3E-08	6.3E-08	0.0E-00	0.0E-00
C-14	2.1E-06	2.1E-06	0.0E-00	0.0E-00
Mn-54	2.7E-06	6.4E-06	9.6E-09	5.0E-07
Fe-55	5.8E-07	2.6E-06	2.5E-12	1.3E-11
Ni-59	2.0E-07	2.7E-06	4.8E-12	2.2E-11
Co-60	2.6E-05	1.5E-04	2.6E-08	1.5E-06
Ni-63	5.4E-07	6.3E-06	0.0E+00	0.0E+00
Sr-90	1.3E-04	1.3E-03	0.0E+00	0.0E+00
Y-90	1.0E-05	8.2E-06	0.0E+00	0.0E+00
Nb-95	2.2E-06	4.5E-06	8.9E-09	4.5E-07
Zr-95	3.4E-06	1.9E-05	8.5E-09	4.4E-07
Tc-99	1.3E-06	7.5E-06	7.2E-15	3.0E-13
Rh-106	0.0E-00	0.0E-00	2.4E-09	1.2E-07
Ru-106	2.1E-05	4.4E-04	0.0E+00	0.0E+00
B-125	2.6E-06	9.8E-06	5.1E-09	2.4E-07
Te-125m	3.4E-06	6.7E-06	2.4E-10	5.5E-09
Cs-134	7.4E-05	4.7E-05	1.8E-08	9.1E-07
Cs-137	5.0E-05	3.2E-05	0.0E-00	0.0E-00
Ba-137M	0.0E-00	0.0E-00	7.0E-09	3.5E-07
Eu-152	6.0E-06	2.2E-04	1.3E-08	6.7E-07
Tl-208	0.0E+00	0.0E+00	3.4E-08	2.3E-06
Bi-210	5.9E-06	1.3E-05	0.0E+00	0.0E+00
Pb-210	5.1E-03	1.3E-02	3.4E-11	7.6E-10
Po-210	1.6E-03	8.1E-03	9.8E-14	5.1E-12
Bi-212	9.9E-07	2.1E-05	2.0E-09	1.1E-07
Pb-212	4.1E-05	1.6E-04	1.9E-09	8.4E-08
Po-212	0.0E+00	0.0E+00	1.9E-09	0.0E+00
Bi-214	2.4E-07	6.3E-06	1.8E-08	9.2E-07
Pb-214	5.8E-07	6.7E-06	3.1E-09	1.4E-07
Po-214	0.0E+00	0.0E+00	9.6E-13	5.0E-11
Po-216	0.0E+00	0.0E+00	1.7E-13	8.6E-12
Rn-220	0.0E+00	0.0E+00	6.1E-12	3.0E-10
Rn-222	0.0E+00	0.0E+00	4.6E-12	2.2E-10
Ra-224	3.3E-04	2.9E-03	1.2E-10	5.8E-09
Ra-226	1.1E-03	7.9E-03	8.7E-11	3.9E-09
Ac-228	2.1E-06	2.9E-04	1.0E-08	5.5E-07
Ra-228	1.2E-03	4.2E-03	7.2E-18	3.6E-17
Th-228	3.8E-04	3.1E-01	3.2E-11	1.1E-09
Th-232	2.8E-03	1.6E+00	7.6E-12	1.1E-10
Th-234	1.3E-05	3.3E-05	1.2E-10	4.4E-09
U-232	1.3E-03	6.7E-01	1.2E-11	1.5E-10
U-234	2.6E-04	1.3E-01	9.2E-12	8.7E-11
U-235	2.5E-04	1.2E-01	2.0E-09	8.8E-08
Np-237	3.9E-03	4.9E-01	3.7E-10	1.3E-08

TABLE A-9. RADIONUCLIDE DOSE CONVERSION FACTORS (Continued)

			Direct Radiation	
Nuclide	**Ingestion (mrem/pCi)**	**Inhalation (mrem/pCi)**	**Ground Surface (mrem-m²/ pCi/hr)**	**Air Immersion (mrem-m³/ pCi/hr)**
U-238	2.3E-04	1.2E-01	7.4E-12	5.9E-11
Pu-238	3.8E-03	4.6E-01	9.8E-12	5.0E-11
Pu-239	4.3E-03	5.1E-01	4.3E-12	4.7E-11
Pu-240	4.3E-03	5.1E-01	9.4E-12	4.9E-11
Am-241	4.5E-03	5.2E-01	3.4E-10	1.1E-08
Pu-241	8.6E-05	1.0E-02	0.0E+00	0.0E+00
Pu-242	4.1E-03	4.8E-01	7.8E-12	4.2E-11
Am-243	4.5E-03	5.2E-01	7.6E-10	2.9E-08

Annual nuclide inventories, leach rates, and solubilities are included in Table A-7. Radionuclide inventories are derived from correspondence with EG&G Idaho.[10] The basis of the final source term is discussed in the main body of the report.

All leach fractions are calculated using the BARRIER code and the data included therein. The initial leach fractions are used after the carbon steel waste overpacks have completely corroded and before failure of the vault roof occurred. Prior to overpack failure, no release of contaminants is assumed to occur. Following corrosion of the overpacks, degradation of the solidified waste form begins, causing leach rates to change as more of the waste becomes accessible to infiltrating water. The final leach rates, following total waste form degradation, are listed in Table A-7. Leach rates are provided for both post-failure percolation rates considered in the simulation.

Radionuclide solubilities are used to limit contaminant releases to levels soluble in the volume of water percolating through the waste. Releases for nuclides with solubilities equal to zero were not considered to be so limited. Solubility limits are taken from Reference 11.

Biotransfer factors used to model foodchain transport of waste radionuclides are included in Table A-8. These factors are based on Reference 12.

Dose conversion factors are listed in Table A-9. These factors are taken from References 13 and 14.

Gamma attenuation coefficients and weighted averages of the gamma ray energies are listed in Table A-10. The former were taken from the Radiological Health Handbook,[15] while average gamma energies can be found in References 15 and 16.

TABLE A-10. RADIONUCLIDE GAMMA RADIATION DATA

Nuclide	Gamma Attenuation Factor (m^{-1})	Weighted Average Gamma Energy (MeV)
H-3	0.0E+00	0.0E+00
C-14	0.0E+00	0.0E+00
Mn-54	1.1E+01	8.3E-01
Fe-55	5.0E+01	1.0E-02
Ni-59	5.0E+01	1.0E-02
Co-60	9.2E+00	1.3E+00
Ni-63	0.0E+00	0.0E+00
Sr-90	0.0E+00	0.0E+00
Y-90	0.0E+00	0.0E+00
Nb-95	1.2E+01	7.7E-01
Zr-95	1.2E+01	7.4E-01
Tc-99	0.0E+00	0.0E+00
Rh-106	1.3E+01	6.1E-01
Ru-106	0.0E+00	0.0E+00
Sb-125	1.4E+01	4.6E-01
Tc-125m	2.2E+01	1.6E-01
Cs-134	1.2E+01	7.0E-01
Cs-137	0.0E+00	0.0E+00
Ba-137m	1.2E+01	6.6E-01
Eu-152	1.2E+01	7.2E-01
Tl-208	8.4E+00	1.5E+00
Bi-210	0.0E+00	0.0E+00
Pb-210	6.0E+01	5.0E-02
Po-210	1.1E+01	8.0E-01
Bi-212	1.0E+01	9.3E-01
Pb-212	1.9E+01	2.4E-01
Po-212	0.0E+00	0.0E+00
Bi-214	9.7E+00	1.1E+00
Pb-214	1.7E+01	3.3E-01
Po-214	1.1E+01	8.0E-01
Po-216	0.0E+00	0.0E+00
Rn-220	1.3E+01	5.5E-01
Rn-222	1.4E+01	5.1E-01
Ra-224	1.9E+01	2.4E-01
Ra-226	2.1E+01	1.9E-01
Ac-228	1.1E+01	7.8E-01
Ra-228	0.0E+00	0.0E+00
Th-228	2.2E+01	1.5E-01
Th-232	4.0E+01	6.0E-02
Th-234	3.1E+01	8.0E-02
U-232	3.0E+01	8.3E-02
U-234	1.5E+01	4.0E-01
U-235	2.1E+01	1.8E-01
Np-237	2.2E+01	1.5E-01
U-238	5.0E+01	5.0E-02
Pu-238	1.4E+01	5.0E-01

TABLE A-10. RADIONUCLIDE GAMMA RADIATION DATA (Continued)

Nuclide	Gamma Attenuation Factor (m^{-1})	Weighted Average Gamma Energy (MeV)
Pu-239	2.7E+01	1.0E-01
Pu-240	2.2E+01	1.6E-01
Am-241	1.4E+01	5.0E-01
Pu-241	0.0E+00	0.0E+00
Pu-242	5.0E+01	2.0E-02
Am-243	2.2E+01	1.5E-01

APPENDIX A REFERENCES

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APPENDIX B

STRUCTURAL ANALYSES
FOR
ABOVEGRADE EARTH-MOUNDED CONCRETE VAULT

APPENDIX B

STRUCTURAL ANALYSES FOR ABOVEGRADE EARTH-MOUNDED CONCRETE VAULT

Appendix B contains the detailed engineering analysis for the AGEMCV facility. This information is presented in a series of tables. Tables B-1 and B-2 address the loading and soil conditions for the disposal facility, respectively. Properties of the concrete used in construction and the chemical environment to which the facility is exposed are outlined in Tables B-3 and B-4. Table B-5 includes the design criteria used in the engineering analysis.

The structural analysis of the facility is addressed in Tables B-6 through B-8, including analyses of the roof, exterior walls, and floor of the AGEMCV. Design of the steel reinforcement used in vault construction is outlined in TAble B-9. Finally, strength, stress, and crack width analyses for the disposal facility are given in Tables B-10 through B-12.

TABLE B-1. LOADING CONDITIONS FOR THE AGEMCV

Minimum Service Life (yr) :						500
Loads:						
	Dead Loads					
		Reinforced concrete density (lb/ft3)				150
	Live Loads					
		Gravity Loads				
			Average weight of waste & containers (lb/ft3)			210
			Average density of cover system (lb/ft3)			110
			Snow (lb/ft3)			50
			Uniform construction load (lb/ft2)			150
		or	Linear construction load over 7-ft length (k/ft)			7
			Concentrated load over 5-ft square (k)			50
		Lateral Soil Pressure				
			Equivalent liquid density of waste and sand inside the cell			
				Before waste container failure (lb/ft3)		0
				After waste container failure (lb/ft3)		40
			Equivalent liquid density of exterior soil backfill			80
	Wind Load - Base wind speed (mph)					70
	Seismic					
		Maximum horizontal acceleration (ft/sec2)				0.2 g
		Maximum vertical acceleration (ft/sec2)				0.1 g
	Thermal Load					
		Assumed differential temperatures				
		Elements		Thickness (ft)	Working condition	Diff.temperature (degr.F)
		Roof		3.0 to 4.0	with cover system	0
		Roof		3.0 to 4.0	without cover system	15
		Ext.Wall		3.0 to 3.5	one side exposed to air	15
		Ext.Wall		3.0 to 3.5	two sides same condition	0
		Int.Wall		0.6 to 1.0	two sides same condition	0
		Floor Mat		3.5 to 4.0	with cover system	0
		Floor Mat		3.5 to 4.0	without cover system	20
	Coefficient of thermal expansion of concrete (1/deg.F)					5.5 E-6

TABLE B-1. (Continued)

Loading Combinations:

The factored loading combinations for which moments and forces were analyzed are those specified in ACI 349-80.

U1 = 1.4D + 1.7L + 1.7H + 1.7E
U2 = 1.4D + 1.7L + 1.7H + 1.7W
U3 = D + L + H + E + T
U4 = D + L + H + W + T

For normal service load, Unfactored U = D+L+H

where:

U = required strength to resist factored loads or related internal factored moments and forces
D = dead load, or related internal moment and forces
E = seismic load, or related internal moment and forces
H = lateral earth pressure, or related internal moment and forces
L = live load, or related internal moment and forces
T = thermal load, or related internal moment and forces
W = wind load, or related internal moment and forces

For the above load combinations, where any load reduces the effects of other loads, the corresponding coefficient for that load should be taken as 0.9 if it can be demonstrated that the load is always present or occurs simultaneously with the other loads. Otherwise, the coefficient for that load should be taken as zero.

TABLE B-2. SOIL CONDITIONS FOR THE AGEMCV

Assumed Subgrade Conditions:	
Modulus of subgrade reaction, K, for floor mat foundation design	
Native soil, K (kci)	100
used roll compact concrete, K (kci)	300
Allowable net soil bearing (lb/ft2)	3000
Allowable vertical displacement (in.)	2
Allowable differential displacement (in.)	0.5
Coefficient of friction against sliding	0.4
Extreme Frost Penetration (in.)	35

TABLE B-3. CONCRETE PROPERTIES FOR THE AGEMCV

Reinforced Concrete Properties:			
	Portland Cement		Type V
	Specified compressive strength of concrete (fc') at 28-day		
		Roof, Floor, Interior wall, fc' (psi)	5000
		Exterior wall, fc' (psi)	6000
	Poisson's ratio of concrete		0.15 to 0.20
	Maximum water-cement ratio for concrete		0.4
	Maximum concrete permeability (cm/sec)		1.0E-11
	Maximum diffusion coefficient in concrete (m2/sec)		
		Ca(OH)2	1.0E-10
		O2	1.0E-10
		SO4	3.0E-11
	Specified yield strength of reinforcement, fy (ksi)		60
	All reinforcing steel should be epoxy coated and sould conform to ASTM A775 & ASTM D3963/D3963M-87.		
	Aggregates are shown by service records or laboratory examination to result in no alkali-silica reaction, cement-aggregate reaction or expansive alkali carbonate reaction.		
	Maximum sulfate and sulfide content in aggregate and sand of concrete shall be less than 0.05 percent by weight of cement.		
	Maximum total chloride content in aggregate and sand of concrete shall be less than 0.05 percent by weight of cement.		
	Maximum silt, clay and dust content of aggregate shall be less than 0.5 percent by weight of aggregate.		
	Concrete will not be vulnerable to less than 300 freeze/thaw cycle in accordance with ASTM C666, ASTM C671 and ASTM C682.		
	Air-entraining admixtures should conform to ASTM C260.		

TABLE B-4. ENVIRONMENTAL CONDITIONS FOR THE AGEMCV DISPOSAL SITE

Chemical Attack Of Reinforced Concrete		
	Concentration of chloride ions in native soil (ppm)	4.8
	Concentration of sulfate in native soil (ppm)	300
	Concentration of magnesium in native soil (ppm)	5.8
	Calcium hydroxide Ca(OH)2 in concrete (mole/liter)	4
	Calcium hydroxide Ca(OH)2 in pore fluid of concrete (mole/liter)	0.02
	Tricalcium aluminate C3A in cement (%)	3
	Oxygen in solution (ppm)	10

TABLE B-5. DESIGN CRITERIA FOR THE AGEMCV

Allowable Maximum Stresses :	
The vault is intended to be a water tight structure. The allowable concrete and steel stresses for roof, exterior wall and floor design at service loads are presented in ACI 350R-83.	
The recommended service load stresses shall not exceed the following:	
Concrete in flexure compression (psi))	0.45*fc'
Shear stress carried by concrete (psi)	1.1*fc'^0.5
Bearing on loaded area (psi)	0.3* fc'
Reinforcing steel in tension (ksi)	0.4*fy
Control Of Cracking For Reinforced Concrete Elements:	
ACI 349-80, ACI 224R-80, ACI 350R-83 are general guides for controlling of cracking in flexural elements.	
The tolerable crack width at the tensile face of reinforced concrete structures for typical conditions is :	
Index of crack control, Z, limiting distribution of reinforcement (kip/in.)	
Normal exposure condition	115
Severe exposure condition	95
Maximum crack width	
Dry air or protective membrane (in.)	0.016
Moist soil environment (in.)	0.012
Maximum Roor Displacement Over Span	1/360
Safety Factors For Stability Of Structure	
Resistance to overturning	2
Resistance to sliding	1.5

TABLE B-6. STRUCTURAL ANALYSIS OF THE ROOF OF THE AGEMCV

	General Condition :	After construction of the roof and earthen cover system					
		Span length, L (ft)			26		
		Clear span, Ln (ft)			24		
		Roof thickness, h (in.)			36	@ end of exterior wall, ha	
					48	@ end of interior wall, hb	
					42	@ midspan or average	
		Concrete cover over steel (in.)			4.5	@ external face	
					3.5	@ internal face	
		Assumed sulfate attack layer (in.)			1.5	@ external face	
					0.5	@ internal face	
		Effective thickness, he (in.)			34	@ end of exterior wall	
					46	@ end of interior wall	
					40	@ midspan or average	
		Effective depth, d (in.)			31	@ end of exterior wall, da	
					43	@ end of interior wall, db	
					37	@ midspan or average	
		Average soil cover system (ft)			13		
		Average soil weight (lb/ft3)			110		
	Calculation Formulas :	(Taking Unit Width b=1 ft)					
		Roof is considered as a one-way slab because the longitudinal dimension of the roof					
		is much greater than transverse dimension of the roof					
	Uniform Load, q (ksf)		M=(Coeff.M)*q*L**2			(k-ft/ft)	
			R=(Coeff.R)*q*L			(k/ft)	
			V=(Coeff.R)*q*Ln-q*d/12			(k/ft)	
		Reference "Statically Indeterminate Structures" 2nd edition					
			- by Lawrence C. Maugh, John Wiley & Sons, Inc., New York 1964				
		Continuous beam, peaked roof :					
			@ continuous end		ha/hb =	0.75	
			@ hinged end F.E.M coeff.		fb =	0.098	
					fa =	0.07	
			Carry over factor		Cab	0.62	
			@ continuous end		Coeff.M =	0.1414	
					Coeff.R =	0.6414	
			@ hinged end		Coeff.M =	0	
					Coeff.R =	0.3586	
		Simple support beam :					
			@ midspan		Coeff.M =	0.125	
			@ hinged end		Coeff.R =	0.5	

TABLE B-6. (Continued)

	The waste in the vault may expand or subside depending upon how the waste and/or containers are placed						
	and the amount of original void space.						
	There are two posible loading conditions and the critical one will be used for design of the structural members.						
(1) Assume roof will subside due to waste settlement or compaction :							
	Long-Term Deflection Analysis of Roof with Simple Support Condition						
	Loading :	Unit					
	Roof weigth	ksf	0.525				
	Soil weight on top of roof	ksf	1.430				
	Summary uniform load, q	ksf	1.955				
	Section properties :						
	Span length of roof, L	ft	26				
	Unit width, b	in.	12				
	Average roof thickness, h	in.	42				
	Effective roof thickness, he	in.	40				
	d=h - concrete cover	in.	37				
	Disposal vault roof will be closed	day	28				
	Minimum strength, fc', after one year	psi	7962				
	Modulus of elasticity, Ec	ksi	5086				
	Poisson's ratio of concrete, u		0.15				
	Moment Inertia (Gross), Ig	in.4	74088				
	Moment Inertia (Cracked), Icr	in.4	17270				
	fr=7.5 SQRT(fc')	psi	669				
	Mcr=(fr*Ig/0.5h)/12000	k-ft	206.59				
	Ma=0.125 q*l^2	k-ft	165.20				
	If section cracked @ midspan ?		NO				
	Ie=(Mcr/Ma)^3*Ig+(1-(Mcr/Ma)**3)*Icr<or=Ig	in.4	74088				
	Deflection, Do= (5/384)*q*b*L^4*12^2/(Ec*Ie)	in.	0.053				

TABLE B-6. (Continued)

	Long-Term Deflection Analysis of Roof with simple support Condition (continued)						
	Creep effect :						
	Aging correction factor						
	C1=1.25/((365)^0.118)		0.62				
	Time for completed corrosion of overpack, t	day	79570				
	Time correction factor						
	C2=t^0.6/(10+t^0.6)		0.99				
	Compression steel effect						
	C3=0.85-0.45(As'/As)		0.40				
	Creep coefficient						
	Ct=2.35 C1*C2*C3		0.58				
	Creep deflection, Dcr=Ct*Do	in.	0.031				
	Shrinkage effect:						
	Shringkage correction factor, C4		0.68				
	Time correction factor						
	C5=t/(35+t)		1.00				
	Shringkage strain						
	Esh=(7.8*E-4)*C4*C5		5.30E-04				
	Shrinkage curvature=0.7 Esh/d	1/in.	1.00E-05				
	Shrinkage deflection						
	Dsh=0.125* L^2*144*curvature	in.	0.122				
	Total deflection=Do+Dcr+Dsh	in.	0.206				
	12*L/Total deflection		1512				
	Total deflection/(12 L)		1/1512				

TABLE B-6. (Continued)

(2) The waste container may expand due to corrosion of steel :

In accordance with letter from G. Ross Darnell INEL May 5, 1989 it was assumed that ferrous metal in the waste will not cause a rise in the waste stack; the waste containers may expand and rise in vertical plane only due to oxidation of the steels.

Thickness of wall of overpack (in.)	0.109
Vertical stacking of overpack (ea.)	6
Total thickness of 12 layers of steel, t (in.)	1.308
Corrosion rate of waste overpack (in./yr)	5.00E-04
Time for complected corrosion of waste overpack (yr)	218
Thickness of steel after total oxidation, ti (in.)	1.740
Total free rise in the waste stack, tf (in.)	0.432
Minimum strength, fc', after one year (psi)	7962
Asummed modulus of elasticity of concrete & grouting, Ec (ksi)	5086
Cell height, L (ft)	24.00

An equivalent uniform load against free expansion q = tf/(12*L)*Ec*144

1098.60 (k/ft2)

It is almost imposible to design the structural member to resist this expansion load, the roof will crack and the exterior wall will be stretched upward due to expansion of containers.

If all the support walls crack : Total tension strain in the walls = tf/(12*L)

= 0.0015

Tesional stress in exterior wall reinforcement, fs = strain * Es

= 43.50 (ksi)

It was assumed there is no gap under the roof. Therefore, a gap space inside containers or compactable material layers between containers should be provided to allow containers expansion without stretching the walls and pushing the roof upward.

The downward loads on the roof, q = roof weight+soil weight+ construction loads

= 2.11 (k/ft^2)

This downward load will be balanced with upward reaction .

It is conservative to use this downward load for conceptual design of roof structure

The BARRIER code will consider degradation of concrete and will project the time of structural failure and analyze the migration of radiocontaminants through the structure.

The safety of structures will be checked by BARRIER code analysis hereafter.

TABLE B-6. (Continued)

	Working Condition :	After construction of the roof and earthen cover system					
		Uniform Load (ksf)	Moment @ Top Mt (k-ft/ft)	Moment @ Bottom Mb (k-ft/ft)	Shear @ Hinged end V1 (k/ft)	Shear @ Continuous end V2 (k/ft)	Axial Force Pmax (k/ft)
	Vertical Loads:						
	DL (Dead load)						
D:1	Roof weight	0.525	50.18	44.36	4.94	6.73	0.00
	DL Summary	0.525	50.18	44.36	4.94	6.73	0.00
	LL (Live loads)						
L:1	Soil	1.430	136.69	120.84	13.47	18.32	0.00
L:2	Snow	0.050	4.78	4.23	0.47	0.64	0.00
L:3	Construction	0.150	14.34	12.68	1.41	1.92	0.00
	LL Summary	1.630	155.81	137.74	15.35	20.88	0.00
	H (Lateral soil pressure)						
	Reaction from exterior wall	0.000	0.00	0.00	0.00	0.00	17.80
	W (Wind)	0.000	0.00	0.00	0.00	0.00	0.00
	E (Seismic)	0.196	18.69	16.52	1.84	2.50	8.55
	T (Thermal)	0.000	0.00	0.00	0.00	0.00	0.00
	Loading Combination:						
U:1	1.4D+1.7L+1.7H+1.7E	3.838	366.89	324.34	36.14	49.17	44.79
U:2	1.4D+1.7L+1.7H+1.7W	3.506	335.13	296.26	33.01	44.91	30.26
U:3	D+L+H+E+T	2.351	224.68	198.62	22.13	30.11	26.35
U:4	D+L+H+W+T	2.155	205.99	182.10	20.29	27.61	17.80
	Service loads D+L+H	2.155	205.99	182.10	20.29	27.61	17.80

TABLE B-7. STRUCTURAL ANALYSIS OF THE EXTERIOR WALLS OF THE AGEMCV

General Condition :	After construction of the roof and earthen cover system:							
	Wall height, L (ft)					24		
	Average wall thickness, ho (in.)					42		
	Concrete cover over steel (in.)					4.5	@ external face	
						3.5	@ internal face	
	Assumed sulfate attack layer (in.)					1.5	@ external face	
						0.5	@ internal face	
	Effective thickness, he (in.)					40		
	Effective depth, d (in.)					37	Tension @ exterior face	
						37	Tension @ interior face	
	Average roof thickness (in.)					42		
	Average soil cover system depth (ft)					13		
	Average soil density (pcf)					110		
	Lateral soil pressure equivalent liquid density (pcf)					80		
	Waste & container weight (lb/ft3)					210		
	Lateral pressure equivalent liquid density of waste (pcf)					0	Before container failure	
						40	After container failure	
Calculation Formulas:	(Taking unit width b=1 ft)							
	Bottom fixed & top hinged							
Uniform Load, q1 (ksf)		Moment	M=(Coeff.M)*q1*L**2			(k-ft/ft)		
		Reaction	R=(Coeff.R)*q1*L			(k/ft)		
		Shear	V= R - q1*d/12			(k/ft)		
		@ Bottom		Coeff.M=	0.1250			
		@ 0.375*L from top		Coeff.M=	0.0703			
		@ Bottom		Coeff.R=	0.6250			
		@ Top		Coeff.R=	0.3750			
Triangular Load, q2 (ksf)		Moment	M=(Coeff.M)*q2*L**2			(k-ft/ft)		
		Reaction	R=(Coeff.R)*q2*L			(k/ft)		
	@ Bottom	Shear	V= R - q2*(d/12-(d/12)^2/2L)			(k/ft)		
	@ Top	Shear	V= R - q2*((d/12)^2/2L)			(k/ft)		
		@ Bottom		Coeff.M=	0.0667			
		@ 0.447*L from top		Coeff.M=	0.0298			
		@ Bottom		Coeff.R=	0.4000			
		@ Top		Coeff.R=	0.1000			

TABLE B-7. (Continued)

Wall Weight	Axial compression force (kips/ft)	P=0.15*(ho/12)*height from top		
Vertical Loads from Roof, q (ksf)	Axial compression force (kips/ft)	P=0.3586	*q* Roof span (Continuous beam)	
		P=0.5000	*q* Roof span (Simple support Beam)	
Seismic Loads	It is assumed that a shear wall system will be provided to carry the seismic force from the roof diaphram.			
	The local seismic loads will be analyzed only.			
Due to Wall Weight:	The lateral seismic load was assumed to be 20 percent of the weight of the structural elements.			
		Uniform Load q1=0.15*(ho/12)*0.2=	0.105	(ksf)
	The formulas used to calculate the maximum moment & shear forces due to uniform load are applicable.			
Due to Soil Pressure:	Dynamic increment soil pressure may be calculated according to H. Bolton Seed and Robert V. Whiteman			
	"Design of Earth Retaining Structures For Dynamic Loads".			
		Dynamic increment in earth pressure Pi= dK *(0.5* r*L^2)		
	Where :	Pi = Dynamic increment in earth pressure (lb)		
		r = Unit weight of soil (lb/ft3)		
		L = Height of wall (ft)		
		Kh = Horizontal ground acceleration / g =	0.2	
		g = Gravity acceleration (ft/sec2)		
		dK = Dynamic increment in earth pressure coefficient, dK=0.75Kh =	0.15	
	Dynamic component of earth pressure acting at a height of 2/3 height of wall above the base.			
	Therefore the dynamic increment soil pressure will be divided by two components :			
		Uniform distributed pressure q1 = dk r*L		(ksf)
		Triangular distributed pressure q2 = -dk r*L		(ksf)
	The formulas used to calculate the maximum moment & shear forces			
	due to uniform load and triangular load are applicable.			
Differential Temperature,T (deg F)	@ Midspan or midheight	M=Ec*ho**2*a*T/24		
	@ Fixed support	M=Ec*ho**2*a*T/12		
		V=0.1942 Ec*a*ho**2*T/Lx		

TABLE B-7. (Continued)

	Working Condition :	After construction of the roof and earthen cover system:							
		Uniform	Triangular	Moment	Axial Compr.	Shear	Moment	Axial Compr.	Shear
		q1	q2	M	P	V	Mc *	Pc *	V'
		T & Bott	Bottom	Fixed end	Fixed end	Fixed end	Midheight	Midheight	Hinged end
	Vertical Loads :	ksf	ksf	k-ft/ft	k/ft	k/ft	k-ft/ft	k/ft	k/ft
	DL (Dead load)								
D:1	Roof weight	0.525		0.00	5.81	0.00	0.00	5.81	0.00
D:2	Wall weight	0.525		0.00	12.60	0.00	0.00	6.30	0.00
	DL Summary	1.050	0.000	0.00	18.41	0.00	0.00	12.11	0.00
	LL (Live load)								
L:1	Soil Weight	1.430		0.00	15.84	0.00	0.00	15.84	0.00
L:2	Snow	0.050		0.00	0.55	0.00	0.00	0.55	0.00
L:3	Construction	0.150		0.00	1.66	0.00	0.00	1.66	0.00
	LL Summary	1.630	0.000	0.00	18.05	0.00	0.00	18.05	0.00
	H (Lateral soil pressure)								
H:1	Soil above the wall	1.320		95.04	0.00	15.73	53.45	0.00	7.81
	Soil against the wall		1.920	73.76	0.00	12.89	32.96	0.00	4.23
H:2	Snow	0.036		2.62	0.00	0.43	1.47	0.00	0.22
H:3	Construction	0.109		7.85	0.00	1.30	4.42	0.00	0.65
	H Summary	1.465	1.920	179.28	0.00	30.36	92.30	0.00	12.90
H:4	Waste & container		-0.960	-36.88	0.00	-6.45	-16.48	0.00	-2.11
	W (Wind)	0.000		0.00	0.00	0.00	0.00	0.00	0.00
	E (Seismic)								
E1	Wall	0.105		7.56	0.00	1.25	4.25	0.00	0.62
E2	Soil against the wall	0.396	-0.396	13.30	0.00	2.06	9.24	0.00	1.47
E3	Waste & container	0.756	-0.756	25.39	0.00	3.93	54.01	0.00	2.81
	E Summary	1.257	-1.152	46.25	0.00	7.24	67.50	0.00	4.90
	T (Thermal)			0.00	0.00	0.00	0.00	0.00	0.00
	Loading Combinations :								
U:1	0.9D+0.9L+0.9H4+1.7H+1.7E	7.040	0.442	350.19	32.82	58.12	256.82	27.15	28.36
U:2	0.9D+0.9L+0.9H4+1.7H+1.7W	4.903	2.400	271.58	32.82	45.80	142.07	27.15	20.02
U:3	0.9D+0.9L+0.9H4+H+E+T	5.134	-0.096	192.33	32.82	31.80	144.97	27.15	15.90
U:4	0.9D+0.9L+0.9H4+H+W+T	3.877	1.056	146.08	32.82	24.55	77.47	27.15	11.00
	D+L+H4+H	4.145	0.960	142.40	36.46	23.91	75.82	30.16	10.78
	* Note: Maximum moments appeared in different sections of the wall, it is conservative to combine these moments.								

TABLE B-7. (Continued)

	Probable Maximum Reaction Calculations in Exterior Wall								
	(Taking Unit Width b=1 ft)								
	The wall is fixed at bottom & hinged at top, the roof will be simple support								
		Uniform	Triangular	Horizontal	Horizontal	Vertical	Vertical		
		Load	Load	Reaction	Reaction	Axial Force	Axial Force		
		q1	q2	R	R	P	Pc		
				Bottom	Top	Bottom	Midheight		
		ksf	ksf	k/ft	k/ft	k/ft	k/ft		
	Vertical Loads								
	DL (Dead load)								
D:1	Roof weight	0.525		0.00	0.00	6.83	3.41		
D:2	Wall weight	0.525		0.00	0.00	12.60	6.30		
	DL Summary	1.050	0.000	0.00	0.00	19.43	9.71		
	LL (Live load)								
L:1	Soil weight	1.430		0.00	0.00	18.59	9.30		
L:2	Snow	0.050		0.00	0.00	0.65	0.33		
L:3	Construction	0.150		0.00	0.00	1.95	0.98		
	LL Summary	1.630	0.000	0.00	0.00	21.19	10.60		
	Lateral Soil Pressure								
	H Summary	1.465	1.920	40.41	17.80	0.00	0.00		
	W (Wind)	0.000		0.00	0.00	0.00	0.00		
	E Summary	1.257	-1.152	7.80	8.55	0.00	0.00		
	T (Thermal)			0.00	0.00	0.00	0.00		
	Loading Combinations :								
U:0	1.4D+1.7L+1.7H	6.732	3.264	68.70	30.26	63.22	31.61		
U:1	1.4D+1.7L+1.7H+1.7E	8.869	1.306	81.96	44.79	63.22	31.61		
U:2	1.4D+1.7L+1.7H+1.7W	6.732	3.264	68.70	30.26	63.22	31.61		
U:3	D+L+H+E+T	5.402	0.768	48.21	26.35	40.62	20.31		
U:4	D+L+H+W+T	4.145	1.920	40.41	17.80	40.62	20.31		
	D+L+H	4.145	1.920	40.41	17.80	40.62	20.31		

TABLE B-8. STRUCTURAL ANALYSIS OF THE FLOOR OF THE AGEMCV

General Condition :	After construction of the roof and earthen cover system		
	Span length, L (ft)	26	
	Clear span, Ln (ft)	24	
	Number of span, No.	2	
	Floor thickness, h (in.)	42	
	Concrete cover over steel (in.)	3.5	@ Top face
		4.5	@ Bottom face
	Assumed sulfate attack layer (in.)	0.5	@ Top face
		1.5	@ Bottom face
	Effective thickness, he (in.)	40	
	Effective depth, d (in.)	37	Tension @ Top face
		37	Tension @ Bottom face
	Average soil cover system depth (ft)	13	
	Average soil density (lb/ft3)	110	
	Waste & container weight (lb/ft3)	210	
	Average roof thickness (in.)	42	
	Average interior wall thickness (in.)	6	
	Average exterior wall thickness, ho (in.)	42	
	Wall height (ft)	24	
	Overhang from center of exterior wall, lo (ft)	1.75	
	Modulus of subgrade reaction, k (pci)	300	
	Minimum compression strength of concrete, fc' (psi)	5000	
Calculation Formulas :	(Taking unit width, b =1 ft)		
	Floor is considered as a one-way slab because the longitudinal dimension of the floor		
	is much greater than transverse dimension of the floor.		
	In BARRIER the floor will be analyzed as a mat on elastic foundation.		
	The axial force in the floor will be neglected in analysis.		
	No*L =	52	ft
	l = No*L+2*lo =	55.50	ft
	Floor thickness, h (ft)	3.50	ft
	Elastic modulus of concrete, E=57*SQRT(fc')*144 =	580393	k/ft2
	Moment inertia, I = b*h^3/12 =	3.57	ft4
	Modulus of subgrade reaction, K=k*12^3/1000	518.4	k/ft3

TABLE B-8. (Continued)

Reference from "Elastic Analysis Of Soil-Foundation Interaction" by A.P.S. Selvadurai,
Elsevier Scientific Publishing Company , New York 1979

In the region x<= a of the finite beam, subjected to a concentrated force P and moment M

Moment Mx = P*Coeff.1p + M*Coeff.1m
Shear Vx = P*Coeff.2p + M*Coeff.2m

Coeff.1p = I1p/(2*Lm*CH)
Coeff.1m = I1m/CH
Coeff.2p = - I2p/CH
Coeff.2m = I2m*Lm/CH

Lm = 12*(b*K/(4*E*I))^0.25 = 0.0889 1/ft
CH = (Sinh(Lm*l))^2-(Sin(Lm*l))2 = 4830.67

I1p=2*Sinh(Lm*X)*Sin(Lm*X)*A1-(Sinh(Lm*X)*Cos(Lm*X)-Cosh(Lm*X)*Sin(Lm*X))*(A2+A3)
I2p=(Cosh(Lm*X)*Sin(Lm*X)+Sinh(Lm*X)*Cos(Lm*X))*A1+Sinh(Lm*X)*Sin(Lm*X)*(A2+A3)
I1m=Sinh(Lm*X)*Sin(Lm*X)*(B1+B2)+(Sinh(Lm*X)*Cos(Lm*X)-Cosh(Lm*X)*Sin(Lm*X))*B3
I2m=(Cosh(Lm*X)*Sin(Lm*X)+Sinh(Lm*X)*Cos(Lm*X))*(B1+B2)-2*Sinh(Lm*X)*Sin(Lm*X))*B3

TABLE B-8. (Continued)

	Concentrated loads located at distance from left , a =					1.75	ft		
	Distance	X (ft)	Lm*X	Sinh(Lm*X)	Sin(Lm*X)	Cosh(Lm*x)	Cos(Lm*x)		
	l =	55.50	4.935	69.5099	-0.9754	69.5171	0.2205		
	a =	1.75	0.156	0.1562	0.1550	1.0121	0.9879		
	c =	53.75	4.779	59.4926	-0.9978	59.5010	0.0666		
		A1=Sinh(Lm*l)*Cos(Lm*a)*Cosh(Lm*c)-Sin(Lm*l)*Cosh(Lm*a)*Cos(Lm*c) =						4086.010	
		A2=Sinh(Lm*l)*Sin(Lm*a)*Cosh(Lm*c)-Sinh(Lm*l)*Cos(Lm*a)*Sinh(Lm*c) =						-3444.423	
		A3=Sin(Lm*l)*Sinh(Lm*a)*Cos(Lm*c)-Sin(Lm*l)*Cosh(Lm*a)*Sin(Lm*c) =						-0.995	
		B1=Sinh(Lm*l)*(Cos(Lm*l)*Sinh(Lm*c)*Cos(Lm*c)+Sin(Lm*a)*Cosh(Lm*c)) =						701.689	
		B2=Sin(Lm*l)*(Cosh(Lm*l)*Cosh(Lm*c)*Sin(Lm*c)+Sinh(Lm*a)*Cos(Lm*c)) =						4025.597	
		B3=Sinh(Lm*l)*Cos(Lm*a)*Cosh(Lm*c)+Sin(Lm*l)*Cosh(Lm*a)*Cos(Lm*c) =						4085.878	
x (ft)	Lm*X	Sinh(Lm*X)	Sin(Lm*X)	Cosh(Lm*X)	Cos(Lm*X)	Coeff.1p	Coeff.1m	Coeff.2p	Coeff.2m
0.00	0.000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000	0.000
Left 1.75	0.156	0.1562	0.1550	1.0121	0.9879	0.220	0.022	-0.246	0.023
Right 1.75	NA	NA	NA	NA	NA	0.220	-0.978	0.754	0.023
4.35	NA	NA	NA	NA	NA	-1.332	-0.886	0.452	0.045
6.95	NA	NA	NA	NA	NA	-2.196	-0.752	0.224	0.056
9.55	NA	NA	NA	NA	NA	-2.553	-0.604	0.061	0.057
12.15	NA	NA	NA	NA	NA	-2.562	-0.460	-0.047	0.053
14.75	NA	NA	NA	NA	NA	-2.349	-0.330	-0.110	0.046
17.35	NA	NA	NA	NA	NA	-2.016	-0.220	-0.141	0.038
19.95	NA	NA	NA	NA	NA	-1.635	-0.132	-0.148	0.030
22.55	NA	NA	NA	NA	NA	-1.257	-0.066	-0.140	0.022
25.15	NA	NA	NA	NA	NA	-0.914	-0.019	-0.123	0.015
Left 27.75	NA	NA	NA	NA	NA	-0.622	0.012	-0.101	0.009
Right 27.75	NA	NA	NA	NA	NA	-0.622	0.012	-0.101	0.009
30.35	NA	NA	NA	NA	NA	-0.388	0.031	-0.079	0.005
32.95	NA	NA	NA	NA	NA	-0.211	0.039	-0.057	0.002
35.55	NA	NA	NA	NA	NA	-0.088	0.040	-0.038	-0.001
38.15	NA	NA	NA	NA	NA	-0.009	0.037	-0.023	-0.002
40.75	NA	NA	NA	NA	NA	0.034	0.031	-0.011	-0.003
43.35	NA	NA	NA	NA	NA	0.050	0.023	-0.002	-0.003
45.95	NA	NA	NA	NA	NA	0.047	0.016	0.004	-0.003
48.55	NA	NA	NA	NA	NA	0.033	0.009	0.006	-0.002
51.15	NA	NA	NA	NA	NA	0.016	0.004	0.006	-0.002
Left 53.75	NA	NA	NA	NA	NA	0.003	0.001	0.003	-0.001
Right 53.75	NA	NA	NA	NA	NA	0.003	0.001	0.003	-0.001
55.50	NA	NA	NA	NA	NA	0.000	0.000	0.000	0.000

TABLE B-8. (Continued)

Concentrated loads located at distance from left , a = 27.75 ft

Distance	X (ft)	Lm*X	Sinh(Lm*X)	Sin(Lm*X)	Cosh(Lm*x)	Cos(Lm*x)
l =	55.50	4.935	69.5099	-0.9754	69.5171	0.2205
a =	27.75	2.467	5.8531	0.6243	5.9379	-0.7812
c =	27.75	2.467	5.8531	0.6243	5.9379	-0.7812

A1=Sinh(Lm*l)*Cos(Lm*a)*Cosh(Lm*c)-Sin(Lm*l)*Cosh(Lm*a)*Cos(Lm*c) =	-326.946
A2=Sinh(Lm*l)*Sin(Lm*a)*Cosh(Lm*c)-Sinh(Lm*l)*Cos(Lm*a)*Sinh(Lm*c) =	575.499
A3=Sin(Lm*l)*Sinh(Lm*a)*Cos(Lm*c)-Sin(Lm*l)*Cosh(Lm*a)*Sin(Lm*c) =	8.076
B1=Sinh(Lm*l)*(Cos(Lm*l)*Sinh(Lm*c)*Cos(Lm*c)+Sin(Lm*a)*Cosh(Lm*c)) =	187.619
B2=Sin(Lm*l)*(Cosh(Lm*l)*Cosh(Lm*c)*Sin(Lm*c)+Sinh(Lm*a)*Cos(Lm*c)) =	-246.909
B3=Sinh(Lm*l)*Cos(Lm*a)*Cosh(Lm*c)+Sin(Lm*l)*Cosh(Lm*a)*Cos(Lm*c) =	-317.897

	x (ft)	Lm*X	Sinh(Lm*X)	Sin(Lm*X)	Cosh(Lm*X)	Cos(Lm*X)	Coeff.1p	Coeff.1m	Coeff.2p	Coeff.2m
	0.00	0.000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000	0.000
Left	1.75	0.156	0.1562	0.1550	1.0121	0.9879	-0.017	0.000	0.018	0.000
Right	1.75	0.156	0.1562	0.1550	1.0121	0.9879	-0.017	0.000	0.018	0.000
	4.35	0.387	0.3965	0.3772	1.0757	0.9261	-0.088	0.001	0.034	0.001
	6.95	0.618	0.6580	0.5794	1.1971	0.8151	-0.183	0.006	0.037	0.003
	9.55	0.849	0.9549	0.7507	1.3827	0.6606	-0.269	0.018	0.026	0.007
	12.15	1.080	1.3030	0.8821	1.6425	0.4711	-0.308	0.041	0.001	0.011
	14.75	1.311	1.7211	0.9666	1.9905	0.2564	-0.259	0.077	-0.041	0.017
	17.35	1.543	2.2316	0.9996	2.4454	0.0282	-0.080	0.129	-0.100	0.023
	19.95	1.774	2.8618	0.9795	3.0315	-0.2016	0.275	0.199	-0.177	0.030
	22.55	2.005	3.6457	0.9072	3.7803	-0.4207	0.854	0.286	-0.271	0.037
	25.15	2.236	4.6252	0.7867	4.7321	-0.6173	1.699	0.388	-0.381	0.042
Left	27.75	2.467	5.8531	0.6243	5.9379	-0.7812	2.843	0.500	-0.500	0.044
Right	27.75	NA	NA	NA	NA	NA	2.843	-0.500	0.500	0.044
	30.35	NA	NA	NA	NA	NA	1.699	-0.388	0.381	0.042
	32.95	NA	NA	NA	NA	NA	0.854	-0.286	0.271	0.037
	35.55	NA	NA	NA	NA	NA	0.275	-0.199	0.177	0.030
	38.15	NA	NA	NA	NA	NA	-0.080	-0.129	0.100	0.023
	40.75	NA	NA	NA	NA	NA	-0.259	-0.077	0.041	0.017
	43.35	NA	NA	NA	NA	NA	-0.308	-0.041	-0.001	0.011
	45.95	NA	NA	NA	NA	NA	-0.269	-0.018	-0.026	0.007
	48.55	NA	NA	NA	NA	NA	-0.183	-0.006	-0.037	0.003
	51.15	NA	NA	NA	NA	NA	-0.088	-0.001	-0.034	0.001
Left	53.75	NA	NA	NA	NA	NA	-0.017	0.000	-0.018	0.000
Right	53.75	NA	NA	NA	NA	NA	-0.017	0.000	-0.018	0.000
	55.50	NA	NA	NA	NA	NA	0.000	0.000	0.000	0.000

TABLE B-8. (Continued)

	Case (I) - Consider lateral forces and moment from walls								
	Loads On Floor Mat								
	Working Condition :	After construction of the roof and earthen cover system							
	Loads :	Uniform	Concent.	Concent.	Concent.	Moment	Moment	Moment	Axial
		q	P1	P2	P3	M1	M2	M3	Force
			Exterior	Interior	Exterior	Exterior	Interior	Exterior	
	DL (Dead load)	ksf	k/ft	k/ft	k/ft	k-ft/ft	k-ft/ft	k-ft/ft	k/ft
D:1	Roof weight		5.81		5.81				
D:2	Exterior wall weight		12.60		12.60				
D:3	Interior wall weight			1.80					
D:4	Floor weight	0.525							
	DL Summary	0.525	18.41	1.80	18.41	0.00	0.00	0.00	0.00
	LL (Live load)								
L:1	Soil weight		15.84		15.84				
L:2	Snow		0.55		0.55				
L:3	Construction		1.66		1.66				
L:4	Waste & Container	5.040	-17.64	-2.52	-17.64				
	LL Summary	5.040	0.41	-2.52	0.41	0.00	0.00	0.00	0.00
	H (Lateral soil pressure)								
H:1	Soil above the wall					95.04		-95.04	15.73
	Soil against the wall					73.76		-73.76	12.89
H:2	Snow					2.62		-2.62	0.43
H:3	Construction					7.85		-7.85	1.30
	H Summary	0.000	0.00	0.00	0.00	179.28	0.00	-179.28	30.36
H:4	Waste & container					-36.88	0.00	36.88	-6.45
	W (Wind)	0.000				0.00	0.00	0.00	0.00
	E (Seismic)								
E1	Wall					7.56	1.08	7.56	1.25
E2	Soil against the wall					13.30	0.00	0.00	2.06
	Waste & container					0.00	25.39	25.39	3.93
	E Summary	0.000	0.00	0.00	0.00	20.86	26.47	32.95	7.24
	T (Thermal)	0.000				0.00	0.00	0.00	0.00
	Loading Combinations :								
U:1	1.4D+1.7L+0.9H4+1.7H+1.7E	9.303	26.48	-1.76	26.48	307.04	44.99	-215.57	58.12
U:2	1.4D+1.7L+0.9H4+1.7H+1.7W	9.303	26.48	-1.76	26.48	271.58	0.00	-271.58	45.80
U:3	D+L+0.9H4+H+E+T	5.565	18.82	-0.72	18.82	166.94	26.47	-113.14	31.80
U:4	D+L+0.9H4+H+W+T	5.565	18.82	-0.72	18.82	146.08	0.00	-146.08	24.55
	D+L+H4+H	5.565	18.82	-0.72	18.82	142.40	0.00	-142.40	23.91

TABLE B-8. (Continued)

	Concentrated loads located at distance from left , a =					53.75	ft		
	Distance	X (ft)	Lm*X	Sinh(Lm*X)	Sin(Lm*X)	Cosh(Lm*x)	Cos(Lm*x)		
	l =	55.50	4.935	69.5099	-0.9754	69.5171	0.2205		
	a =	53.75	4.779	59.4926	-0.9978	59.5010	0.0666		
	c =	1.75	0.156	0.1562	0.1550	1.0121	0.9879		
		A1=Sinh(Lm*l)*Cos(Lm*a)*Cosh(Lm*c)-Sin(Lm*l)*Cosh(Lm*a)*Cos(Lm*c) =						62.024	
		A2=Sinh(Lm*l)*Sin(Lm*a)*Cosh(Lm*c)-Sinh(Lm*l)*Cos(Lm*a)*Sinh(Lm*c) =						-70.920	
		A3=Sin(Lm*l)*Sinh(Lm*a)*Cos(Lm*c)-Sin(Lm*l)*Cosh(Lm*a)*Sin(Lm*c) =						-48.334	
		B1=Sinh(Lm*l)*(Cos(Lm*l)*Sinh(Lm*c)*Cos(Lm*c)+Sin(Lm*a)*Cosh(Lm*c)) =						-67.832	
		B2=Sin(Lm*l)*(Cosh(Lm*l)*Cosh(Lm*c)*Sin(Lm*c)+Sinh(Lm*a)*Cos(Lm*c)) =						-67.963	
		B3=Sinh(Lm*l)*Cos(Lm*a)*Cosh(Lm*c)+Sin(Lm*l)*Cosh(Lm*a)*Cos(Lm*c) =						-52.648	
x (ft)	Lm*X	Sinh(Lm*X)	Sin(Lm*X)	Cosh(Lm*X)	Cos(Lm*X)	Coeff.1p	Coeff.1m	Coeff.2p	Coeff.2m
0.00	0.000	0.0000	0.0000	1.0000	1.0000	0.000	0.000	0.000	0.000
Left 1.75	0.156	0.1562	0.1550	1.0121	0.9879	0.003	-0.001	-0.003	-0.001
Right 1.75	0.156	0.1562	0.1550	1.0121	0.9879	0.003	-0.001	-0.003	-0.001
4.35	0.387	0.3965	0.3772	1.0757	0.9261	0.016	-0.004	-0.006	-0.002
6.95	0.618	0.6580	0.5794	1.1971	0.8151	0.033	-0.009	-0.006	-0.002
9.55	0.849	0.9549	0.7507	1.3827	0.6606	0.047	-0.016	-0.004	-0.003
12.15	1.080	1.3030	0.8821	1.6425	0.4711	0.050	-0.023	0.002	-0.003
14.75	1.311	1.7211	0.9666	1.9905	0.2564	0.034	-0.031	0.011	-0.003
17.35	1.543	2.2316	0.9996	2.4454	0.0282	-0.009	-0.037	0.023	-0.002
19.95	1.774	2.8618	0.9795	3.0315	-0.2016	-0.088	-0.040	0.038	-0.001
22.55	2.005	3.6457	0.9072	3.7803	-0.4207	-0.211	-0.039	0.057	0.002
25.15	2.236	4.6252	0.7867	4.7321	-0.6173	-0.388	-0.031	0.079	0.005
Left 27.75	2.467	5.8531	0.6243	5.9379	-0.7812	-0.622	-0.012	0.101	0.009
Right 27.75	2.467	5.8531	0.6243	5.9379	-0.7812	-0.622	-0.012	0.101	0.009
30.35	2.699	7.3951	0.4287	7.4624	-0.9034	-0.914	0.019	0.123	0.015
32.95	2.930	9.3341	0.2103	9.3875	-0.9776	-1.257	0.066	0.140	0.022
35.55	3.161	11.7742	-0.0193	11.8166	-0.9998	-1.635	0.132	0.148	0.030
38.15	3.392	14.8463	-0.2478	14.8799	-0.9688	-2.016	0.220	0.141	0.038
40.75	3.623	18.7153	-0.4632	18.7420	-0.8863	-2.349	0.330	0.110	0.046
43.35	3.854	23.5890	-0.6539	23.6102	-0.7565	-2.562	0.460	0.047	0.053
45.95	4.086	29.7289	-0.8099	29.7457	-0.5866	-2.553	0.604	-0.061	0.057
48.55	4.317	37.4646	-0.9227	37.4780	-0.3854	-2.196	0.752	-0.224	0.056
51.15	4.548	47.2115	-0.9865	47.2221	-0.1638	-1.332	0.886	-0.452	0.045
Left 53.75	4.779	59.4926	-0.9978	59.5010	0.0666	0.220	0.978	-0.754	0.023
Right 53.75	NA	NA	NA	NA	NA	0.220	-0.022	0.246	0.023
55.50	NA	NA	NA	NA	NA	0.000	0.000	0.000	0.000

TABLE B-8. (Continued)

Case (I) - Consider lateral forces and moment from walls									
Factored Moment and Forces Calculation									
Working Condition :	After construction of the roof and earthen cover system								
Due to Factored Load	Force	Force	Force	Moment	Moment	Moment	Summary	Positive	Negative
	P1 =	P2 =	P3 =	M1 =	M2 =	M3 =	Factored	Factored	Factored
	26.48	-1.76	26.48	307.04	44.99	-215.57	Moment	Moment	Moment
	k/ft	k/ft	k/ft	k-ft/ft	k-ft/ft	k-ft/ft	k-ft/ft	k-ft/ft	k-ft/ft
Load Location, a (ft)	1.75	27.75	53.75	1.75	27.75	53.75		(Top)	(Bottom)
Factored Moment (k-ft/ft)								12.70	305.80
X=0.00 , Mux =	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
X=1.75 , Mux = (Left)	5.83	0.03	0.08	6.62	-0.01	0.14	12.70		
X=1.75 , Mux = (Right)	5.83	0.03	0.08	-300.41	-0.01	0.14	-294.34		
X=4.35 , Mux =	-35.26	0.15	0.43	-271.97	0.03	0.82	-305.80		
X=6.95 , Mux =	-58.14	0.32	0.88	-230.97	0.25	1.94	-285.71		
X=9.55 , Mux =	-67.60	0.47	1.24	-185.55	0.81	3.39	-247.24		
X=12.15 , Mux =	-67.82	0.54	1.33	-141.19	1.84	5.00	-200.31		
X=14.75 , Mux =	-62.20	0.46	0.91	-101.28	3.47	6.60	-152.04		
X=17.35 , Mux =	-53.38	0.14	-0.23	-67.55	5.82	7.92	-107.27		
X=19.95 , Mux =	-43.30	-0.49	-2.32	-40.59	8.95	8.65	-69.08		
X=22.55 , Mux =	-33.29	-1.51	-5.60	-20.20	12.87	8.38	-39.34		
X=25.15 , Mux =	-24.19	-3.00	-10.27	-5.70	17.47	6.59	-19.09		
X=27.75 , Mux = (Left)	-16.46	-5.02	-16.46	3.83	22.50	2.69	-8.91		
X=27.75 , Mux = (Right)	-16.46	-5.02	-16.46	3.83	-22.50	2.69	-53.91		
X=30.35 , Mux =	-10.27	-3.00	-24.19	9.39	-17.47	-4.00	-49.53		
X=32.95 , Mux =	-5.60	-1.51	-33.29	11.94	-12.87	-14.18	-55.51		
X=35.55 , Mux =	-2.32	-0.49	-43.30	12.33	-8.95	-28.50	-71.23		
X=38.15 , Mux =	-0.23	0.14	-53.38	11.28	-5.82	-47.42	-95.42		
X=40.75 , Mux =	0.91	0.46	-62.20	9.40	-3.47	-71.11	-126.01		
X=43.35 , Mux =	1.33	0.54	-67.82	7.13	-1.84	-99.13	-159.80		
X=45.95 , Mux =	1.24	0.47	-67.60	4.82	-0.81	-130.27	-192.14		
X=48.55 , Mux =	0.88	0.32	-58.14	2.76	-0.25	-162.17	-216.59		
X=51.15 , Mux =	0.43	0.15	-35.26	1.16	-0.03	-190.95	-224.49		
X=53.75 , Mux = (Left)	0.08	0.03	5.83	0.20	0.01	-210.92	-204.77		
X=53.75 , Mux = (Right)	0.08	0.03	5.83	0.20	0.01	4.65	10.80		
X=55.50 , Mux =	0.00	0.00	0.00	0.00	0.00	0.00	0.00		

TABLE B-8. (Continued)

Case (I) - Consider lateral forces and moment from walls								
Factored Shear Calculation								
Working Condition :	After construction of the roof and earthen cover system							
Due to Factored Load	Force	Force	Force	Moment	Moment	Moment	Summary	Maximum
	P1 =	P2 =	P3 =	M1 =	M2 =	M3 =	Factored	Factored
	26.48	-1.76	26.48	307.04	44.99	-215.57	Shear	Shear
	k/ft	k/ft	k/ft	k-ft/ft	k-ft/ft	k-ft/ft	k/ft	k/ft
Load Location, a (ft)	1.75	27.75	53.75	1.75	27.75	53.75		Ext.Supp
Factored Shear (k/ft)								27.19
X=0.00 , Vux =	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
X=1.75 , Vux = (Left)	-6.51	-0.03	-0.09	7.20	0.00	0.16	0.72	
X=1.75 , Vux = (Right)	19.96	-0.03	-0.09	7.20	0.00	0.16	27.19	
X=4.35 , Vux =	11.98	-0.06	-0.17	13.97	0.04	0.35	26.11	
X=6.95 , Vux =	5.93	-0.07	-0.17	17.05	0.14	0.50	23.39	
X=9.55 , Vux =	1.62	-0.05	-0.10	17.54	0.30	0.60	19.91	
X=12.15 , Vux =	-1.23	0.00	0.05	16.36	0.50	0.63	16.32	
X=14.75 , Vux =	-2.92	0.07	0.28	14.23	0.76	0.58	13.00	
X=17.35 , Vux =	-3.74	0.18	0.61	11.68	1.05	0.42	10.19	
X=19.95 , Vux =	-3.93	0.31	1.02	9.07	1.36	0.12	7.95	
X=22.55 , Vux =	-3.71	0.48	1.52	6.66	1.65	-0.36	6.23	
X=25.15 , Vux =	-3.26	0.67	2.08	4.56	1.87	-1.05	4.88	
X=27.75 , Vux = (Left)	-2.68	0.88	2.68	2.84	1.97	-1.99	3.69	
X=27.75 , Vux = (Right)	-2.68	-0.88	2.68	2.84	1.97	-1.99	1.93	
X=30.35 , Vux =	-2.08	-0.67	3.26	1.50	1.87	-3.20	0.67	
X=32.95 , Vux =	-1.52	-0.48	3.71	0.51	1.65	-4.67	-0.79	
X=35.55 , Vux =	-1.02	-0.31	3.93	-0.17	1.36	-6.37	-2.58	
X=38.15 , Vux =	-0.61	-0.18	3.74	-0.60	1.05	-8.20	-4.79	
X=40.75 , Vux =	-0.28	-0.07	2.92	-0.83	0.76	-9.99	-7.49	
X=43.35 , Vux =	-0.05	0.00	1.23	-0.90	0.50	-11.49	-10.70	
X=45.95 , Vux =	0.10	0.05	-1.62	-0.85	0.30	-12.32	-14.35	
X=48.55 , Vux =	0.17	0.07	-5.93	-0.72	0.14	-11.97	-18.24	
X=51.15 , Vux =	0.17	0.06	-11.98	-0.50	0.04	-9.81	-22.02	
X=53.75 , Vux = (Left)	0.09	0.03	-19.96	-0.22	0.00	-5.05	-25.12	
X=53.75 , Vux = (Right)	0.09	0.03	6.51	-0.22	0.00	-5.05	1.35	
X=55.50 , Vux =	0.00	0.00	0.00	0.00	0.00	0.00	0.00	

TABLE B-8. (Continued)

Case (I) - Consider lateral forces and moment from walls									
Moment At Service Loads Calculation									
Working Condition :	After construction of the roof and earthen cover system								
Due to Service Loads	Force	Force	Force	Moment	Moment	Moment	Summary	Positive	Negative
	P1 =	P2 =	P3 =	M1 =	M2 =	M3 =	Service	Service	Service
	18.82	-0.72	18.82	142.40	0.00	-142.40	Moment	Moment	Moment
	k/ft	k/ft	k/ft	k-ft/ft	k-ft/ft	k-ft/ft	k-ft/ft	k-ft/ft	k-ft/ft
Load Location, a (ft)	1.75	27.75	53.75	1.75	27.75	53.75		(Top)	(Bottom)
Unfactored Moment (k-ft/ft)								7.38	150.29
X=0.00 , Mx =	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
X=1.75 , Mx = (Left)	4.15	0.01	0.06	3.07	0.00	0.09	7.38		
X=1.75 , Mx = (Right)	4.15	0.01	0.06	-139.32	0.00	0.09	-135.01		
X=4.35 , Mx =	-25.07	0.06	0.31	-126.13	0.00	0.54	-150.29		
X=6.95 , Mx =	-41.33	0.13	0.63	-107.12	0.00	1.28	-146.41		
X=9.55 , Mx =	-48.06	0.19	0.88	-86.05	0.00	2.24	-130.80		
X=12.15 , Mx =	-48.22	0.22	0.94	-65.48	0.00	3.30	-109.23		
X=14.75 , Mx =	-44.22	0.19	0.65	-46.97	0.00	4.36	-86.00		
X=17.35 , Mx =	-37.95	0.06	-0.16	-31.33	0.00	5.23	-64.15		
X=19.95 , Mx =	-30.78	-0.20	-1.65	-18.82	0.00	5.72	-45.74		
X=22.55 , Mx =	-23.67	-0.61	-3.98	-9.37	0.00	5.54	-32.10		
X=25.15 , Mx =	-17.20	-1.22	-7.30	-2.64	0.00	4.36	-24.01		
X=27.75 , Mx = (Left)	-11.70	-2.05	-11.70	1.78	0.00	1.78	-21.90		
X=27.75 , Mx = (Right)	-11.70	-2.05	-11.70	1.78	0.00	1.78	-21.90		
X=30.35 , Mx =	-7.30	-1.22	-17.20	4.36	0.00	-2.64	-24.01		
X=32.95 , Mx =	-3.98	-0.61	-23.67	5.54	0.00	-9.37	-32.10		
X=35.55 , Mx =	-1.65	-0.20	-30.78	5.72	0.00	-18.82	-45.74		
X=38.15 , Mx =	-0.16	0.06	-37.95	5.23	0.00	-31.33	-64.15		
X=40.75 , Mx =	0.65	0.19	-44.22	4.36	0.00	-46.97	-86.00		
X=43.35 , Mx =	0.94	0.22	-48.22	3.30	0.00	-65.48	-109.23		
X=45.95 , Mx =	0.88	0.19	-48.06	2.24	0.00	-86.05	-130.80		
X=48.55 , Mx =	0.63	0.13	-41.33	1.28	0.00	-107.12	-146.41		
X=51.15 , Mx =	0.31	0.06	-25.07	0.54	0.00	-126.13	-150.29		
X=53.75 , Mx = (Left)	0.06	0.01	4.15	0.09	0.00	-139.32	-135.01		
X=53.75 , Mx = (Right)	0.06	0.01	4.15	0.09	0.00	3.07	7.38		
X=55.50 , Mx =	0.00	0.00	0.00	0.00	0.00	0.00	0.00		

TABLE B-8. (Continued)

Case (I) - Consider lateral forces and moment from walls								
Shear At Service Loads Calculation								
Working Condition :	After construction of the roof and earthen cover system							
Due to Service Load	Force	Force	Force	Moment	Moment	Moment	Summary	Maximum
	P1 =	P2 =	P3 =	M1 =	M2 =	M3 =	Service	Service
	18.82	-0.72	18.82	142.40	0.00	-142.40	Shear	Shear
	k/ft	k/ft	k/ft	k-ft/ft	k-ft/ft	k-ft/ft	k/ft	k/ft
Load Location, a (ft)	1.75	27.75	53.75	1.75	27.75	53.75		Ext.Supp
Unfactored Shear (k-ft/ft)								17.56
X=0.00 , Vx =	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
X=1.75 , Vx = (Left)	-4.63	-0.01	-0.06	3.34	0.00	0.10	-1.27	
X=1.75 , Vx = (Right)	14.19	-0.01	-0.06	3.34	0.00	0.10	17.56	
X=4.35 , Vx =	8.52	-0.02	-0.12	6.48	0.00	0.23	15.09	
X=6.95 , Vx =	4.22	-0.03	-0.12	7.91	0.00	0.33	12.31	
X=9.55 , Vx =	1.15	-0.02	-0.07	8.14	0.00	0.40	9.59	
X=12.15 , Vx =	-0.88	0.00	0.04	7.59	0.00	0.42	7.17	
X=14.75 , Vx =	-2.08	0.03	0.20	6.60	0.00	0.38	5.14	
X=17.35 , Vx =	-2.66	0.07	0.43	5.42	0.00	0.28	3.54	
X=19.95 , Vx =	-2.79	0.13	0.72	4.21	0.00	0.08	2.34	
X=22.55 , Vx =	-2.64	0.20	1.08	3.09	0.00	-0.24	1.48	
X=25.15 , Vx =	-2.31	0.27	1.48	2.11	0.00	-0.70	0.86	
X=27.75 , Vx = (Left)	-1.91	0.36	1.91	1.32	0.00	-1.32	0.36	
X=27.75 , Vx = (Right)	-1.91	-0.36	1.91	1.32	0.00	-1.32	-0.36	
X=30.35 , Vx =	-1.48	-0.27	2.31	0.70	0.00	-2.11	-0.86	
X=32.95 , Vx =	-1.08	-0.20	2.64	0.24	0.00	-3.09	-1.48	
X=35.55 , Vx =	-0.72	-0.13	2.79	-0.08	0.00	-4.21	-2.34	
X=38.15 , Vx =	-0.43	-0.07	2.66	-0.28	0.00	-5.42	-3.54	
X=40.75 , Vx =	-0.20	-0.03	2.08	-0.38	0.00	-6.60	-5.14	
X=43.35 , Vx =	-0.04	0.00	0.88	-0.42	0.00	-7.59	-7.17	
X=45.95 , Vx =	0.07	0.02	-1.15	-0.40	0.00	-8.14	-9.59	
X=48.55 , Vx =	0.12	0.03	-4.22	-0.33	0.00	-7.91	-12.31	
X=51.15 , Vx =	0.12	0.02	-8.52	-0.23	0.00	-6.48	-15.09	
X=53.75 , Vx = (Left)	0.06	0.01	-14.19	-0.10	0.00	-3.34	-17.56	
X=53.75 , Vx = (Right)	0.06	0.01	4.63	-0.10	0.00	-3.34	1.27	
X=55.50 , Vx =	0.00	0.00	0.00	0.00	0.00	0.00	0.00	

TABLE B-8. (Continued)

	Case (2) - Assume lateral forces and moment = 0 from walls								
	Loads On Floor Mat								
	Working Condition :	After construction of the roof and earthen cover system							
	Loads :	Uniform	Concent.	Concent.	Concent.	Moment	Moment	Moment	Axial
		q	P1	P2	P3	M1	M2	M3	Force
			Exterior	Interior	Exterior	Exterior	Interior	Exterior	
	DL (Dead load)	ksf	k/ft	k/ft	k/ft	k-ft/ft	k-ft/ft	k-ft/ft	k/ft
D:1	Roof weight		5.81		5.81				
D:2	Exterior wall weight		12.60		12.60				
D:3	Interior wall weight			1.80					
D:4	Floor weight	0.525							
	DL Summary	0.525	18.41	1.80	18.41	0.00	0.00	0.00	0.00
	LL (Live load)								
L:1	Soil weight		15.84		15.84				
L:2	Snow		0.55		0.55				
L:3	Construction		1.66		1.66				
L:4	Waste & container	5.040	-17.64	-2.52	-17.64				
	LL Summary	5.040	0.41	-2.52	0.41	0.00	0.00	0.00	0.00
	H (Lateral soil pressure)								
H:1	Soil above the wall					0.00		0.00	0.00
	Soil against the wall					0.00		0.00	0.00
H:2	Snow					0.00		0.00	0.00
H:3	Construction					0.00		0.00	0.00
	H Summary	0.000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H:4	Waste & container					0.00	0.00	0.00	0.00
	W (Wind)	0.000				0.00	0.00	0.00	0.00
	E (Seismic)								
E1	Wall					0.00	0.00	0.00	0.00
E2	Soil against the wall					0.00	0.00	0.00	0.00
	Waste & container					0.00	0.00	0.00	0.00
	E Summary	0.000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	T (Thermal)	0.000				0.00	0.00	0.00	0.00
	Loading Combinations :								
U:1	1.4D+1.7L+0.9H4+1.7H+1.7E	9.303	26.48	-1.76	26.48	0.00	0.00	0.00	0.00
U:2	1.4D+1.7L+0.9H4+1.7H+1.7W	9.303	26.48	-1.76	26.48	0.00	0.00	0.00	0.00
U:3	D+L+0.9H4+H+E+T	5.565	18.82	-0.72	18.82	0.00	0.00	0.00	0.00
U:4	D+L+0.9H4+H+W+T	5.565	18.82	-0.72	18.82	0.00	0.00	0.00	0.00
	D+L+H4+H	5.565	18.82	-0.72	18.82	0.00	0.00	0.00	0.00

TABLE B-8. (Continued)

Case (2) - Assume lateral forces and moment = 0 from walls									
Factored Moment and Forces Calculation									
Working Condition :	After construction of the roof and earthen cover system								
Due to Factored Load	Force	Force	Force	Moment	Moment	Moment	Summary	Positive	Negative
	P1 =	P2 =	P3 =	M1 =	M2 =	M3 =	Factored	Factored	Factored
	26.48	-1.76	26.48	0.00	0.00	0.00	Moment	Moment	Moment
	k/ft	k/ft	k/ft	k-ft/ft	k-ft/ft	k-ft/ft	k-ft/ft	k-ft/ft	k-ft/ft
Load Location, a (ft)	1.75	27.75	53.75	1.75	27.75	53.75		(Top)	(Bottom)
Factored Moment (k-ft/ft)								5.94	65.95
X=0.00 , Mux =	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
X=1.75 , Mux = (Left)	5.83	0.03	0.08	0.00	0.00	0.00	5.94		
X=1.75 , Mux = (Right)	5.83	0.03	0.08	0.00	0.00	0.00	5.94		
X=4.35 , Mux =	-35.26	0.15	0.43	0.00	0.00	0.00	-34.67		
X=6.95 , Mux =	-58.14	0.32	0.88	0.00	0.00	0.00	-56.93		
X=9.55 , Mux =	-67.60	0.47	1.24	0.00	0.00	0.00	-65.88		
X=12.15 , Mux =	-67.82	0.54	1.33	0.00	0.00	0.00	-65.95		
X=14.75 , Mux =	-62.20	0.46	0.91	0.00	0.00	0.00	-60.83		
X=17.35 , Mux =	-53.38	0.14	-0.23	0.00	0.00	0.00	-53.46		
X=19.95 , Mux =	-43.30	-0.49	-2.32	0.00	0.00	0.00	-46.10		
X=22.55 , Mux =	-33.29	-1.51	-5.60	0.00	0.00	0.00	-40.40		
X=25.15 , Mux =	-24.19	-3.00	-10.27	0.00	0.00	0.00	-37.46		
X=27.75 , Mux = (Left)	-16.46	-5.02	-16.46	0.00	0.00	0.00	-37.94		
X=27.75 , Mux = (Right)	-16.46	-5.02	-16.46	0.00	0.00	0.00	-37.94		
X=30.35 , Mux =	-10.27	-3.00	-24.19	0.00	0.00	0.00	-37.46		
X=32.95 , Mux =	-5.60	-1.51	-33.29	0.00	0.00	0.00	-40.40		
X=35.55 , Mux =	-2.32	-0.49	-43.30	0.00	0.00	0.00	-46.10		
X=38.15 , Mux =	-0.23	0.14	-53.38	0.00	0.00	0.00	-53.46		
X=40.75 , Mux =	0.91	0.46	-62.20	0.00	0.00	0.00	-60.83		
X=43.35 , Mux =	1.33	0.54	-67.82	0.00	0.00	0.00	-65.95		
X=45.95 , Mux =	1.24	0.47	-67.60	0.00	0.00	0.00	-65.88		
X=48.55 , Mux =	0.88	0.32	-58.14	0.00	0.00	0.00	-56.93		
X=51.15 , Mux =	0.43	0.15	-35.26	0.00	0.00	0.00	-34.67		
X=53.75 , Mux = (Left)	0.08	0.03	5.83	0.00	0.00	0.00	5.94		
X=53.75 , Mux = (Right)	0.08	0.03	5.83	0.00	0.00	0.00	5.94		
X=55.50 , Mux =	0.00	0.00	0.00	0.00	0.00	0.00	0.00		

TABLE B-8. (Continued)

Case (2) - Assume lateral forces and moment = 0 from walls								
Factored Shear Calculation								
Working Condition :	After construction of the roof and earthen cover system							
Due to Factored Load	Force	Force	Force	Moment	Moment	Moment	Summary	Maximum
	P1 =	P2 =	P3 =	M1 =	M2 =	M3 =	Factored	Factored
	26.48	-1.76	26.48	0.00	0.00	0.00	Shear	Shear
	k/ft	k/ft	k/ft	k-ft/ft	k-ft/ft	k-ft/ft	k/ft	k/ft
Load Location, a (ft)	1.75	27.75	53.75	1.75	27.75	53.75		Ext.Supp
Factored Shear (k/ft)								19.84
X=0.00 , Vux =	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
X=1.75 , Vux = (Left)	-6.51	-0.03	-0.09	0.00	0.00	0.00	-6.63	
X=1.75 , Vux = (Right)	19.96	-0.03	-0.09	0.00	0.00	0.00	19.84	
X=4.35 , Vux =	11.98	-0.06	-0.17	0.00	0.00	0.00	11.75	
X=6.95 , Vux =	5.93	-0.07	-0.17	0.00	0.00	0.00	5.70	
X=9.55 , Vux =	1.62	-0.05	-0.10	0.00	0.00	0.00	1.47	
X=12.15 , Vux =	-1.23	0.00	0.05	0.00	0.00	0.00	-1.18	
X=14.75 , Vux =	-2.92	0.07	0.28	0.00	0.00	0.00	-2.57	
X=17.35 , Vux =	-3.74	0.18	0.61	0.00	0.00	0.00	-2.96	
X=19.95 , Vux =	-3.93	0.31	1.02	0.00	0.00	0.00	-2.60	
X=22.55 , Vux =	-3.71	0.48	1.52	0.00	0.00	0.00	-1.72	
X=25.15 , Vux =	-3.26	0.67	2.08	0.00	0.00	0.00	-0.50	
X=27.75 , Vux = (Left)	-2.68	0.88	2.68	0.00	0.00	0.00	0.88	
X=27.75 , Vux = (Right)	-2.68	-0.88	2.68	0.00	0.00	0.00	-0.88	
X=30.35 , Vux =	-2.08	-0.67	3.26	0.00	0.00	0.00	0.50	
X=32.95 , Vux =	-1.52	-0.48	3.71	0.00	0.00	0.00	1.72	
X=35.55 , Vux =	-1.02	-0.31	3.93	0.00	0.00	0.00	2.60	
X=38.15 , Vux =	-0.61	-0.18	3.74	0.00	0.00	0.00	2.96	
X=40.75 , Vux =	-0.28	-0.07	2.92	0.00	0.00	0.00	2.57	
X=43.35 , Vux =	-0.05	0.00	1.23	0.00	0.00	0.00	1.18	
X=45.95 , Vux =	0.10	0.05	-1.62	0.00	0.00	0.00	-1.47	
X=48.55 , Vux =	0.17	0.07	-5.93	0.00	0.00	0.00	-5.70	
X=51.15 , Vux =	0.17	0.06	-11.98	0.00	0.00	0.00	-11.75	
X=53.75 , Vux = (Left)	0.09	0.03	-19.96	0.00	0.00	0.00	-19.84	
X=53.75 , Vux = (Right)	0.09	0.03	6.51	0.00	0.00	0.00	6.63	
X=55.50 , Vux =	0.00	0.00	0.00	0.00	0.00	0.00	0.00	

TABLE B-8. (Continued)

Case (2) - Assume lateral forces and moment = 0 from walls									
Moment At Service Loads Calculation									
Working Condition :	After construction of the roof and earthen cover system								
Due to Service Loads	Force	Force	Force	Moment	Moment	Moment	Summary	Positive	Negative
	P1 =	P2 =	P3 =	M1 =	M2 =	M3 =	Service	Service	Service
	18.82	-0.72	18.82	0.00	0.00	0.00	Moment	Moment	Moment
	k/ft	k/ft	k/ft	k-ft/ft	k-ft/ft	k-ft/ft	k-ft/ft	k-ft/ft	k-ft/ft
Load Location, a (ft)	1.75	27.75	53.75	1.75	27.75	53.75		(Top)	(Bottom)
Unfactored Moment (k-ft/ft)								4.22	47.06
X=0.00 , Mx =	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
X=1.75 , Mx = (Left)	4.15	0.01	0.06	0.00	0.00	0.00	4.22		
X=1.75 , Mx = (Right)	4.15	0.01	0.06	0.00	0.00	0.00	4.22		
X=4.35 , Mx =	-25.07	0.06	0.31	0.00	0.00	0.00	-24.70		
X=6.95 , Mx =	-41.33	0.13	0.63	0.00	0.00	0.00	-40.58		
X=9.55 , Mx =	-48.06	0.19	0.88	0.00	0.00	0.00	-46.99		
X=12.15 , Mx =	-48.22	0.22	0.94	0.00	0.00	0.00	-47.06		
X=14.75 , Mx =	-44.22	0.19	0.65	0.00	0.00	0.00	-43.39		
X=17.35 , Mx =	-37.95	0.06	-0.16	0.00	0.00	0.00	-38.05		
X=19.95 , Mx =	-30.78	-0.20	-1.65	0.00	0.00	0.00	-32.63		
X=22.55 , Mx =	-23.67	-0.61	-3.98	0.00	0.00	0.00	-28.26		
X=25.15 , Mx =	-17.20	-1.22	-7.30	0.00	0.00	0.00	-25.72		
X=27.75 , Mx = (Left)	-11.70	-2.05	-11.70	0.00	0.00	0.00	-25.45		
X=27.75 , Mx = (Right)	-11.70	-2.05	-11.70	0.00	0.00	0.00	-25.45		
X=30.35 , Mx =	-7.30	-1.22	-17.20	0.00	0.00	0.00	-25.72		
X=32.95 , Mx =	-3.98	-0.61	-23.67	0.00	0.00	0.00	-28.26		
X=35.55 , Mx =	-1.65	-0.20	-30.78	0.00	0.00	0.00	-32.63		
X=38.15 , Mx =	-0.16	0.06	-37.95	0.00	0.00	0.00	-38.05		
X=40.75 , Mx =	0.65	0.19	-44.22	0.00	0.00	0.00	-43.39		
X=43.35 , Mx =	0.94	0.22	-48.22	0.00	0.00	0.00	-47.06		
X=45.95 , Mx =	0.88	0.19	-48.06	0.00	0.00	0.00	-46.99		
X=48.55 , Mx =	0.63	0.13	-41.33	0.00	0.00	0.00	-40.58		
X=51.15 , Mx =	0.31	0.06	-25.07	0.00	0.00	0.00	-24.70		
X=53.75 , Mx = (Left)	0.06	0.01	4.15	0.00	0.00	0.00	4.22		
X=53.75 , Mx = (Right)	0.06	0.01	4.15	0.00	0.00	0.00	4.22		
X=55.50 , Mx =	0.00	0.00	0.00	0.00	0.00	0.00	0.00		

TABLE B-8. (Continued)

Case (2) - Assume lateral forces and moment = 0 from walls								
Shear At Service Loads Calculation								
Working Condition :	After construction of the roof and earthen cover system							
Due to Service Load	Force	Force	Force	Moment	Moment	Moment	Summary	Maximum
	P1 =	P2 =	P3 =	M1 =	M2 =	M3 =	Service	Service
	18.82	-0.72	18.82	0.00	0.00	0.00	Shear	Shear
	k/ft	k/ft	k/ft	k-ft/ft	k-ft/ft	k-ft/ft	k/ft	k/ft
Load Location, a (ft)	1.75	27.75	53.75	1.75	27.75	53.75		Ext.Supp
Unfactored Shear (k/ft)								14.12
X=0.00 , Vx =	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
X=1.75 , Vx = (Left)	-4.63	-0.01	-0.06	0.00	0.00	0.00	-4.71	
X=1.75 , Vx = (Right)	14.19	-0.01	-0.06	0.00	0.00	0.00	14.12	
X=4.35 , Vx =	8.52	-0.02	-0.12	0.00	0.00	0.00	8.37	
X=6.95 , Vx =	4.22	-0.03	-0.12	0.00	0.00	0.00	4.07	
X=9.55 , Vx =	1.15	-0.02	-0.07	0.00	0.00	0.00	1.06	
X=12.15 , Vx =	-0.88	0.00	0.04	0.00	0.00	0.00	-0.84	
X=14.75 , Vx =	-2.08	0.03	0.20	0.00	0.00	0.00	-1.85	
X=17.35 , Vx =	-2.66	0.07	0.43	0.00	0.00	0.00	-2.16	
X=19.95 , Vx =	-2.79	0.13	0.72	0.00	0.00	0.00	-1.94	
X=22.55 , Vx =	-2.64	0.20	1.08	0.00	0.00	0.00	-1.37	
X=25.15 , Vx =	-2.31	0.27	1.48	0.00	0.00	0.00	-0.56	
X=27.75 , Vx = (Left)	-1.91	0.36	1.91	0.00	0.00	0.00	0.36	
X=27.75 , Vx = (Right)	-1.91	-0.36	1.91	0.00	0.00	0.00	-0.36	
X=30.35 , Vx =	-1.48	-0.27	2.31	0.00	0.00	0.00	0.56	
X=32.95 , Vx =	-1.08	-0.20	2.64	0.00	0.00	0.00	1.37	
X=35.55 , Vx =	-0.72	-0.13	2.79	0.00	0.00	0.00	1.94	
X=38.15 , Vx =	-0.43	-0.07	2.66	0.00	0.00	0.00	2.16	
X=40.75 , Vx =	-0.20	-0.03	2.08	0.00	0.00	0.00	1.85	
X=43.35 , Vx =	-0.04	0.00	0.88	0.00	0.00	0.00	0.84	
X=45.95 , Vx =	0.07	0.02	-1.15	0.00	0.00	0.00	-1.06	
X=48.55 , Vx =	0.12	0.03	-4.22	0.00	0.00	0.00	-4.07	
X=51.15 , Vx =	0.12	0.02	-8.52	0.00	0.00	0.00	-8.37	
X=53.75 , Vx = (Left)	0.06	0.01	-14.19	0.00	0.00	0.00	-14.12	
X=53.75 , Vx = (Right)	0.06	0.01	4.63	0.00	0.00	0.00	4.71	
X=55.50 , Vx =	0.00	0.00	0.00	0.00	0.00	0.00	0.00	

TABLE B-9. STEEL REINFORCEMENT DESIGN FOR THE AGEMCV

Element		Roof	Roof	Roof	Floor	Floor	Ext Wall	Ext Wall
		Top	Bottom	Bottom	Top	Bottom	Ext. Face	Int. Face
	Unit	Continuous end	Midspan	Hinged end	Midspan	Support wall	Floor Supp	Midheight
Comp. strength of concrete, fc'	ksi	5	5	5	5	5	6	6
Yield strength of steel, fy	ksi	60	60	60	60	60	60	60
Unit width of element, b	in.	12	12	12	12	12	12	12
Original thickness of element	in.	48.00	42.00	36.00	42.00	42.00	42.00	42.00
Effective thickness, h	in.	46.00	40.00	34.00	40.00	40.00	40.00	40.00
Effective cover of concrete, dc	in.	3.00	3.00	3.00	3.00	3.00	3.00	3.00
d=h-dc	in.	43.00	37.00	31.00	37.00	37.00	37.00	37.00
Factored moment, Mu	k-ft	366.89	324.34	0.00	12.70	305.80	350.19	256.82
Factored compression, Pu(min)	k	0.00	0.00	0.00	0.00	0.00	32.82	27.15
Factored compression, Pu(max)	k	44.79	44.79	44.79	58.12	58.12	63.22	31.61
Factored shear, Vu	k	49.17	0.00	36.14	27.19	27.19	58.12	0.00
Mus=Mu+Pu(d-0.5h)/12	k-ft	366.89	324.34	0.00	12.70	305.80	396.69	295.28
0.1fc'bh	k	276.00	240.00	204.00	240.00	240.00	288.00	288.00
PHI=0.9-0.2Pu/0.1fc'bh		0.90	0.90	0.90	0.90	0.90	0.88	0.88
Kns=12000 Mus/b d**2	psi	198	237	0	9	223	290	216
Modified Kn=0.9 Kns/PHI	psi	198	237	0	9	223	297	220
required steel ratio by bending, p		0.0038	0.0046	0	0	0.0043	0.0058	0.0041
As(req)= p b d-Pu/(PHI*fy)	si	1.96	2.04	0.00	0.00	1.91	1.95	1.31
Ab= 87*0.85 d/(87+fy)	in.	21.63	18.61	15.59	18.61	18.61	18.61	18.61
Pb= 0.85 fc'b*Ab-As*fy	k	985.57	826.73	795.34	949.28	834.72	1022.03	1060.72
Minimum reinforcement, p(min)		0.0012	0.0012	0.0012	0.0012	0.0012	0.0012	0.0012
As(min)=p(min)*b*d		0.69	0.60	0.52	0.60	0.60	0.60	0.60
Reinforcement size & space		#8@4"	#8@4"	#8@4"	#8@4"	#8@4"	#8@4"	#8@6"
Provided As in tension	si/ft	2.37	2.37	2.37	2.37	2.37	2.37	1.58
Reinforcement size & space		#8@4"	#8@4"	#8@4"	#8@4"	#8@4"	#8@6"	#8@8"
Provided As' in compression	si/ft	2.37	2.37	2.37	2.37	2.37	1.58	1.19
Reinforcement size & space		#6@6"	#6@6"	#6@6"	#6@6"	#6@6"	#6@6"	#6@6"
Provided longitudinal steel, As	si/ft	0.88	0.88	0.88	0.88	0.88	0.88	0.88
Is steel adequate ?		YES	YES	YES	YES	YES	YES	YES

TABLE B-10. STRENGTH CALCULATIONS FOR THE AGEMCV

Element		Roof	Roof	Roof	Floor	Floor	Ext Wall	Ext Wall
		Top	Bottom	Bottom	Top	Bottom	Ext. Face	Int. Face
	Unit	Continuous end	Midspan	Hinged end	Midspan	Support wall	Floor Supp	Midheight
Comp. strength of concrete, fc'	ksi	5	5	5	5	5	6	6
Yield strengh of steel, fy	ksi	60	60	60	60	60	60	60
Unit width of element, b	in.	12	12	12	12	12	12	12
Original thickness of element	in.	48.00	42.00	36.00	42.00	42.00	42.00	42.00
Effective thickness, h	in.	46.00	40.00	34.00	40.00	40.00	40.00	40.00
Effective cover of concrete, dc	in.	3.00	3.00	3.00	3.00	3.00	3.00	3.00
d=h-dc	in.	43.00	37.00	31.00	37.00	37.00	37.00	37.00
Span length or height	ft	18.30	18.30	18.30	18.30	18.30	18.30	18.30
Factored moment, Mu	k-ft	366.89	324.34	0.00	12.70	305.80	350.19	256.82
Factored compression, Pu(min)	k	0.00	0.00	0.00	0.00	0.00	32.82	27.15
Factored compression, Pu(max)	k	44.79	44.79	44.79	58.12	58.12	63.22	31.61
Factored shear, Vu	k	49.17	0.00	36.14	27.19	27.19	58.12	0.00
Steel area in tension, As	si	2.37	2.37	2.37	2.37	2.37	2.37	1.58
Steel area in compression, As'	si	2.37	2.37	2.37	2.37	2.37	1.58	1.19
Ab=87*0.85d/(87+fy)	in.	21.63	18.61	15.59	18.61	18.61	18.61	18.61
assumed fs'	ksi	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pb=0.85fc'b Ab+As'fs'-Asfy	k	961.01	807.08	653.14	807.08	807.08	996.93	1044.33
PHI		0.90	0.90	0.90	0.90	0.90	0.88	0.88
Let Pn=Pu(min)/PHI	k	0.00	0.00	0.00	0.00	0.00	37.41	30.81
a=(Pn+Asfy-As'fs')/(0.85fc'b)	in.	2.79	2.79	2.79	2.79	2.79	2.93	2.05
c= a/0.85	in.	3.28	3.28	3.28	3.28	3.28	3.45	2.41
fs'=(c-dc)*87/c must > or = 0	ksi	0.00	0.00	0.00	0.00	0.00	0.00	0.00
a=(Pn+Asfy-As'fs')/(0.85fc'b)	in.	2.79	2.79	2.79	2.79	2.79	2.93	2.05
Strength calculations:								
PHI*Mn=PHI((As*fy)*(d-0.5h)								
+0.85fc'ab(0.5h-0.5a))/12	k-ft	443.73	379.74	315.75	379.74	379.74	420.04	293.34
0.85Vc=1.7b d(1000fc')**0.5/1000	k	62.03	53.37	44.72	53.37	53.37	58.47	58.47
0.7 Pnw= 0.385 fc'b h								
*(1-(12L/32h)^2)	k	913.17	794.06	674.95	794.06	794.06	952.88	952.88
Are strengths adequate ?		YES	YES	YES	YES	YES	YES	YES

TABLE B-11. STRESS CALCULATIONS FOR THE AGEMCV

Element		Roof	Roof	Roof	Floor	Floor	Ext Wall	Ext Wall
		Top	Bottom	Bottom	Top	Bottom	Ext. Face	Int. Face
	Unit	Continuous end	Midspan	Hinged end	Midspan	Support wall	Floor Supp	Midheight
Comp. strength of concrete, fc'	psi	5000	5000	5000	5000	5000	6000	6000
Yield strength of steel, fy	ksi	60	60	60	60	60	60	60
Unit width of element, b	in.	12	12	12	12	12	12	12
Effective thickness, h	in.	46.00	40.00	34.00	40.00	40.00	40.00	40.00
Effective cover of concrete, dc	in.	3.00	3.00	3.00	3.00	3.00	3.00	3.00
d=h-dc	in.	43.00	37.00	31.00	37.00	37.00	37.00	37.00
n=Es/Ec		7	7	7	7	7	7	7
Moment, M	k-ft	205.99	182.10	0.00	7.38	150.29	142.40	75.82
Compression force, P	k	0.00	0.00	0.00	0.00	0.00	36.46	30.16
Shear force, V	k	27.61	0.00	20.29	0.00	17.56	23.91	0.00
Steel area in tension, As	si	2.37	2.37	2.37	2.37	2.37	2.37	1.58
Steel area in compression, As'	si	2.37	2.37	2.37	2.37	2.37	1.58	1.19
At=bh+(n-1)(As+As')	si	580.44	508.44	436.44	508.44	508.44	503.70	496.62
Equation 6X**2+BX-C=0								
B= n As+(n-1)As'	si	30.81	30.81	30.81	30.81	30.81	26.07	18.20
C= n As*d+(n-1)As'*dc	si	756.03	656.49	556.95	656.49	656.49	642.27	430.64
X=(B**2+24 C)**0.5/12	in.	11.52	10.77	9.97	10.77	10.77	10.57	8.61
Icr=4 X**3+n As(d-X)**2								
+(n-1)As'(X-dc)**2	in.4	23584	17270	11993	17270	17270	16857	11691
Calculated stresses:								
fc=12000 MX/I+1000P/At	psi	1207	1363	0	55	1125	1144	731
Allow compression in concrete	psi	2250	2250	2250	2250	2250	2700	2700
fs=12n M(d-X)/I-n P/At	ksi	23.10	23.23	0.00	0.94	19.17	18.25	15.04
Allowable tension in steel	ksi	24.00	24.00	24.00	24.00	24.00	24.00	24.00
v=1000 V/bd	psi	54	0	55	0	40	54	0
Allowable shear in concrete	psi	78	78	78	78	78	85	85
Are stresses adequate ?		YES	YES	YES	YES	YES	YES	YES

TABLE B-12. CRACK WIDTH ANALYSIS FOR THE AGEMCV

Element		Roof	Roof	Roof	Floor	Floor	Ext Wall	Ext Wall	
		Top	Bottom	Bottom	Top	Bottom	Ext. Face	Int. Face	
	Unit	Continuous end	Midspan	Hinged end	Midspan	Support wall	Floor Supp	Midheight	
Provided reinforcement		#8@4"	#8@4"	#8@4"	#8@4"	#8@4"	#8@4"	#8@6"	
Steel diameter, db	in.	0.875	0.75	0.75	0.875	0.875	0.875	0.875	
Steel space, S	in.	6.00	6.00	6.00	6.00	6.00	6.00	6.00	
Reinforcing steel stress, fs	ksi	23.10	23.23	0.00	0.94	19.17	18.25	15.04	
Effective thickness, h	in.	46.00	40.00	34.00	40.00	40.00	40.00	40.00	
Net concrete cover	in.	2.56	2.63	2.63	2.56	2.56	2.56	2.56	
dc=Cover+0.5db	in.	3.00	3.00	3.00	3.00	3.00	3.00	3.00	
d=h-dc	in.	43.00	37.00	31.00	37.00	37.00	37.00	37.00	
B=(h-X)/(d-X)		1.10	1.11	1.14	1.11	1.11	1.11	1.11	
Max. dc in equation	in	2.44	2.38	2.38	2.44	2.44	2.44	2.44	
A=2dc*S	si	29.25	28.50	28.50	29.25	29.25	29.25	29.25	
Z=fs(dc A)**0.333	k/in.	96	95	0	4	79	76	62	
Allowable Z	k/in.	115	115	115	115	115	115	115	
Probable maximum crack width									
W1=0.076B Z/1000	in.	7.96E-03	8.01E-03	0.00E+00	3.30E-04	6.72E-03	6.39E-03	5.23E-03	
Allowable crack width	in.	1.20E-02	1.20E-02	1.20E-02	1.20E-02	1.20E-02	1.20E-02	1.20E-02	
Is crack control adequate ?		YES	YES	YES	YES	YES	YES	YES	