9.1.2 New and Spent Fuel Storage

The NFSF and SFSF are both located within the reinforced concrete structure of the Fuel Building (see Section 3.8.4). The NFSF provides onsite dry storage for new fuel assemblies required for refueling the reactor. The SFSF provides onsite underwater storage for spent fuel assemblies and optional underwater storage of some of the new fuel assemblies. The SFSF provides storage locations for a maximum of 1247 spent fuel assemblies in a single fuel storage pool, which is constructed of reinforced concrete with a stainless steel lining. A net of 96 fuel assemblies are offloaded into the spent fuel pool (SFP) during an 18-month fuel cycle, and 140 fuel assemblies during a 24-month fuel cycle.

All spent fuel storage racks will be installed in the SFP prior to the introduction of any fuel assemblies.

9.1.2.1 Design Bases

The functions of the NFSF and SFSF are to maintain new and spent fuel in a safe and subcritical array during all anticipated operating and accident conditions and to limit offsite exposures in the event of release of radioactive materials from the fuel. The spent fuel facility will also keep spent fuel assemblies adequately cooled during all anticipated operating and accident conditions. The requirements related to the general design criteria (GDC) are as follows:

1. The NFSF and SFSF are protected from the effects of natural phenomena, including earthquakes, tornadoes, hurricanes, floods, and external missiles (GDC 2). The facility components meet the guidance presented in RG 1.13, positions C.1 and C.2, RG 1.29, RG 1.117, Reference 2, and Reference 1 as applicable to GDC 2 compliance.

2. The NFSF and SFSF will remain functional after an SSE and will perform their intended function following postulated hazards such as fires, internal missiles, or pipe break (GDC 4). The facility components meet the guidance presented in RG 1.13, positions C.2 and C.3, RG 1.115, and RG 1.117.

3. Structures, systems, and components of the NFSF and SFSF that are important to safety are not shared with other units (GDC 5).

4. The NFSF and SFSF are designed with the capability to permit periodic inspections (GDC 61). The NFSF meets the applicable design requirements of Reference 1 as applicable to GDC 4 compliance. The SFSF meets the applicable design guidance of RG 1.13 and the design requirements of Reference 2 as applicable to GDC 4 compliance.

5. The depth of shielding water over the spent fuel will be sufficient to limit the radiation dose to acceptable levels (GDC 61). Details of the dose assessment are provided in Section 12.3.5.

6. The NFSF and SFSF provide appropriate containment, confinement, and filtering capability (GDC 61).

7. The SFSF provides adequate residual heat removal capability having reliability and testability that reflects the importance to safety of decay heat and other residual heat removal (GDC 61).

8. Fuel pool radiation, water level, and water temperature monitoring are provided for the protection of personnel and to detect conditions that could result in the loss of decay heat removal capabilities. Alarms and communication systems are provided to alert personnel in fuel storage areas of excessive radiation levels (GDC 63). The SFSF meets position C.7 of RG 1.13 and the design requirements of Reference 2 as applicable to GDC 63 compliance. For the NFSF, the design prevents an increase in effective multiplication factor (k_{eff}) beyond safe limits based on the requirements in 10 CFR 50.68(b). (See Section 9.1.1.1).

9. The new and spent fuel storage racks are designed to Seismic Category I requirements and to meet the stress limits of ASME BPVC, Section III, Division I, Subsection NF – Supports, Class 3. The design, fabrication, and examination of the racks are performed in accordance with guidance from NF-3000 (design), NF-4000 (fabrication) and NF-5000 (examination) of ASME BPVC, Section III, Division I, Subsection NF – Supports, Class 3. New and spent fuel storage racks are corrosion-resistant. Section 9.1.1.1 provides the design basis quantities of fuel to be stored in the new fuel and spent fuel storage facilities.

10. The SFSF is designed to prevent the loss of cooling water within the pool that could uncover the stored fuel assemblies or prevent cooling capability (GDC-61). A redundant Seismic Category I emergency makeup water supply is provided.

11. The new fuel and spent fuel storage rack design precludes the placement of more than one fuel assembly in a single storage cell or inserting a fuel assembly between two storage cells.

Other important non-safety related design criteria for the NFSF and SFSF are also included, as discussed below:

- In accordance with the requirements of 10 CFR 20.1101(b), engineering controls are provided to keep radiation doses in the NFSF and SFSF to as low as reasonably achievable (ALARA) levels. Refer to Section 12.1 for further ALARA design details. A discussion of how the design meets the requirements of RG 8.8, section C.2, with regard to provisions for decontamination is provided in Section 12.3.1.

- Gaseous radioactivity above the SFP is maintained below the limits as defined in 10 CFR 20, Appendix B, Table 1, Column 3.

- A leak chase and collection system is provided for the detection of leaks in the spent fuel pool liner plate.

9.1.2.2 Facilities Description

9.1.2.2.1 New Fuel Storage

The Fuel Building is enclosed by a hardened concrete protection shield, which prevents damage to the building from external hazards. The Fuel Building interior structures, systems, and components are further protected from impact forces of an aircraft hazard by structural decoupling from the outer hardened walls above the basemat elevation.

The NFSF is approximately 18 feet deep, dry, unlined and enclosed by the reinforced concrete structure of the Fuel Building. New fuel storage racks are located in the new fuel dry storage room inside the Fuel Building. These racks are designed to provide storage of new fuel assemblies, either with or without rod cluster control assemblies.

Two rack modules (one 7x8 module and one 8x8 module) with a total capacity of 120 fuel assemblies are provided in the NFSF for receiving and storing new fuel in a dry environment. Figure 9.1.2-1 provides a sketch of a typical new fuel rack array with the dry new fuel storage rack layout as shown in Figure 9.1.2-2. The new fuel storage rack modules are composed of a rectangular grid of connected cells, each cell designed to store a single fuel assembly. Figure 9.1.2-4 shows a cross-section of the new fuel storage racks. Center-to-center spacing of the assemblies in the new fuel racks is provided in TN-Rack.0101, "U.S. EPR New and Spent Fuel Storage Rack Technical Report" (Reference 3). The new fuel storage racks are vertically supported by the concrete floor of the new fuel storage room and laterally supported against the walls of the new fuel storage room. The NFSF includes solid hatch cover designed so that they do not fall and damage the fuel or fuel rack during a seismic event.

Building features such as door thresholds, curbs, and floor openings are provided to prevent entry of water or other moderation media into the new fuel storage room.

The new fuel storage room is provided with a drain system connected to the NI drain and vent sumps. The floor drains in the NIDVS have the capacity to accommodate the maximum expected flow rate from a rupture of the largest water pipe in the NFSF area. Refer to Section 9.3.3.1. The new fuel storage cells are each designed with an opening in the bottom of the cell in the base plate which can drain unanticipated water sources.

Table 3.2.2-1 provides the seismic and other design classifications for the new fuel racks. Non-safety-related equipment or structures not designed to Seismic Category I criteria that are located in the vicinity of the NFSF are evaluated to confirm that their failure could not cause an increase in the k_{eff} value beyond the maximum allowable.

9.1.2.2.2 Spent Fuel Storage

The spent fuel pool provides storage space for a minimum of 10 years worth of irradiated fuel assemblies, plus the capability for a full core offload from the reactor. The spent fuel storage racks provide a maximum storage capacity of 1247 fuel assemblies. The pool is a reinforced concrete structure (refer to Section 3.8.4) with a stainless steel liner having a nominal depth of 47 feet, 3 inches (approximately 29 feet above the tops of the stored fuel assemblies). Borated water is used in the spent fuel pool and is maintained at greater than or equal to 1700 ppm boron isotopically enriched to ≥ 37 percent B-10. The concentration required for sub-criticality for spent fuel is approximately 582 ppm boron isotopically enriched to ≥ 37 percent B-10. Figure 3.8-42 through Figure 3.8-46 and Figure 3.8-50 through Figure 3.8-52 show the spent fuel pool and other related fuel handling areas. A simplified cross-section of the spent fuel pool showing elevations is provided in Figure 9.1.2-3. Fresh unirradiated fuel assemblies are either stored in the NFSF or in the fuel storage pool (or both). Unirradiated rod control clusters and thimble plug assemblies are normally stored in the fuel assemblies in the SFP.

Prior to refueling, water from the boric acid storage tank (BAST) is injected into the RCS and the refueling cavity is filled. Consequently, water stored in the BAST could mix with the SFP inventory due to fluid interchange between the SFP and refueling cavity during fuel movement. Therefore, before borating the RCS to the refueling concentration, the BAST enrichment is verified to be 40 percent +/- 1.0 percent by performing testing in accordance with Section 14.2 (test abstract #051). This test demonstrates that the addition of borated water from the BAST will not reduce the average boron enrichment of the SFP.

The underwater fuel storage racks are located in the spent fuel storage pool inside the Fuel Building. The racks meet Seismic Category I requirements. Spent fuel rack materials are compatible with the pool storage environment. Rack structural materials are corrosion-resistant and compatible with the expected water chemistry of the SFP.

The spent fuel storage racks consist of an assembly of tubes with neutron absorber plates sandwiched between the tubes. The tube assembly is supported by a stainless steel frame structure consisting of a base plate, four corner angles, bottom horizontal bands, three sets of intermediate horizontal bands equally spaced along the rack's length, and top support and bottom support grid assemblies which are welded to the external frame structure. The top and bottom grid assemblies provide lateral restraint to the tube assembly. The top grid assembly also provides axial restraint to the tubes and neutron absorber plates. Each rack module is vertically supported by 6 legs on the SFP floor without anchoring. The grid structures are designed so that a fuel assembly cannot be inserted between the cells.

Low density storage (Region 1 racks) will be used for freshly discharged fuel. There are 382 available storage cells in the low density storage racks in the spent fuel pool arranged in five 10x8 free standing modules divided into arrays of 9 inch ID square tubes. Figure 9.1.2-4 shows a cross-section of the Region 1 storage racks. Region 2 racks use the same tubes surrounded by poison material, but no flux traps, and a reduced assembly pitch (see Reference 3) to provide 865 usable storage spaces provided by 12 free-standing modular racks of varying size. Figure 9.1.2-5 shows a cross section of the Region 2 storage racks. If freshly discharged fuel is required to be stored in the high density storage racks (Region 2), the assemblies are required to be stored in a checkerboard or other pattern that confirms that adequate cooling can be maintained consistent with Technical Specification restrictions.

Figure 9.1.2-6 provides an illustration of a typical spent fuel rack array with the spent fuel storage rack layout as shown in Figure 9.1.2-7. The spent fuel storage rack modules are composed of a rectangular grid of connected cells, each cell designed to store a single fuel assembly. Center-to-center spacing of the assemblies in the spent fuel racks is provided in Reference 3. Section 9.1.1.1 provides the design basis quantities of fuel to be stored.

The design of the SFP is such that inadvertent draining of water from the pool is prevented (see Section 9.1.3). The concrete structures for the SFP, SFP liner, and fuel transfer canal are designed in accordance with the criteria for Seismic Category I structures contained in Section 3.7 and Section 3.8. As such, they are designed to maintain leak-tight integrity to prevent the loss of cooling water from the pool. In addition, all piping penetrations into the pool are designed to preclude draining the pool down to an unacceptable limit, as described in Section 9.1.3.

The spent fuel pool liner leak chase system consists of half pipes, structural steel or concrete channels, or similar configurations embedded in the concrete, segregated into sectors, and interconnected to the exterior side of the pool liner. Leakage, if any, from the stainless steel pool liner is monitored and routed to collection areas to determine the amount of leakage, its leakage channel location, and proper disposal. The design of the system is such that it provides accessibility for inspections, removal of blockages, and testing. The stainless steel liner plate welds are inspected during fabrication and tested for leak-tightness after erection. The liner plates and fuel racks are arranged so that the maximum horizontal displacement of the fuel racks under all loading conditions, including the safe shutdown earthquake, will not result in the rack bearing plates contacting an area of the pool liner that is backed by a leak chase channel.

Borated demineralized reactor makeup water is used to fill and to supplement water inventory in the spent fuel pool.

Adjacent to the SFP is a separate spent fuel cask loading pit. This pit is used when the spent fuel is to be shipped offsite. Figure 9.1.2-8—Fuel Storage and Handling Areas

Layout illustrates the fuel storage and handling areas layout. Also adjacent to the SFP is a transfer compartment. The transfer compartment is used to transfer fuel assemblies between the Fuel Building and the Reactor Building. The fuel transfer tube is fitted with a blind flange on the Reactor Building side and a gate valve on the Fuel Building side.

Two stainless steel gates separate the cask loading pit from the SFP and two stainless steel gates separate the transfer compartment from the SFP. Figure 9.1.2-9—Cask Loading Pit Gates shows the cask loading pit gates. The gates allow isolation of the adjacent pits from the SFP so that they can be drained. The gates are designed to Seismic Category I criteria and are designed to maintain leak-tight integrity to prevent the loss of cooling water from the SFP. The gates are equipped with radiation resistant seals. The gates and the weirs, shown in Figure 3.8-52, are arranged so that the bottoms of the gates are higher than the top of the stored fuel assemblies. The combined volume of the adjacent pits is limited so that leakage into these areas while drained will not reduce the SFP inventory to less than 10 feet above the top of the fuel assemblies.

The Fuel Pool Cooling and Purification System (FPCPS) functions to limit the spent fuel storage pool temperature to 140°F during non-refueling plant conditions, and to remove impurities from the water to improve visual clarity. A description of the FPCPS is provided in Section 9.1.3.

During fuel handling operations, a controlled and monitored ventilation system removes gaseous radioactivity from the atmosphere above the spent fuel pool and processes it through high efficiency particulate air (HEPA) filters and charcoal adsorber units to the unit vent. Refer to Section 9.4.2 for a description of the spent fuel pool area ventilation system operation and to Section 11.5 for the process ventilation monitors.

Table 3.2.2-1 provides the seismic and other design classifications for the spent fuel racks. Non-safety-related equipment or structures not designed to Seismic Category I criteria that are located in the vicinity of the SFSF will be evaluated to confirm that their failure could not cause an increase in the k_{eff} value beyond the maximum allowable k_{eff}.

Refer to Section 12.3.6.5.1 for fuel handling and storage system design features which demonstrate compliance with the requirements of 10 CFR 20.1406.

9.1.2.2.3 New Fuel Rack and Spent Fuel Storage Rack Design

Structural design and stress analysis of the new and spent fuel storage racks are evaluated in accordance with Seismic Category I requirements of RG 1.29. The dynamic and stress analyses are performed and described in Reference 3. Loads and

load combinations considered in the structural design and stress analysis are provided in Table 9.1.2-1 based on SRP Section 3.8.4, Appendix D. Uplift force analysis is also performed for new and spent fuel racks design, and described in Reference 3. Each rack is evaluated to withstand a maximum uplift force of 5,000 pounds based on the lifting capacity of the suspension hoist and the fuel handling machine. Structural analysis is performed to verify that resultant stress in the critical part of the rack is within acceptable stress limits and deformation of the rack array is limited to maintain a subcritical array.

Fuel assembly drop analysis is performed for each spent fuel rack to demonstrate that the racks maintain a subcritical array and that the pool liner will not be perforated. Drop weight is determined from the maximum weight of the fuel assembly of 2,044 lbs and drop height is determined from the design height for handling fuel above each rack. Two drop cases are postulated: (1) a shallow drop on the top of the rack, and (2) a deep drop through the empty cell. The analysis is also provided in Reference 3.

Materials and the material properties to be used in the design of the neutron absorber plates are as follows: borated stainless steel ASTM A887, Type 304B to 304B7; or boron carbide/aluminum metal matrix composite supported by corrosion, mechanical, and neutronic testing for the proposed service. The neutron absorber used in the spent fuel racks is a metal matrix composite (MMC) consisting of aluminum alloy and boron carbide with no polymer or organic components. The minimum B-10 areal density is 28 mg/cm^2. The manufacturer shall specify the chemical composition of the matrix and the boron carbide.

9.1.2.3 Safety Evaluation

The safety evaluation that follows corresponds to the requirements associated with the GDCs in Section 9.1.2.1:

1. The NFSF and SFSF are located within the Fuel Building, a Seismic Category I structure. The Fuel Building is designed to withstand shipping, handling and normal operating loads, as well as the effects of external hazards such as earthquakes, tornadoes, hurricanes, floods, and external missiles. Section 3.3, Section 3.4, Section 3.5, Section 3.7, and Section 3.8 provide the bases for the adequacy of the structural design of the building.

2. The NFSF and SFSF are designed to remain functional after an SSE. Section 3.7 and Section 3.9 provide the design loads that were applied. The results of the hazards analyses are presented in Section 9.5.1 (fire), Section 3.5, and Section 3.6 and show that the NFSF and SFSF can perform their intended function following postulated internal hazards.

3. The NFSF and SFSF are capable of storing the required number of fuel assemblies, in accordance with the design basis. Structures, systems and components (SSC) are not shared with other units.

4. The NFSF does not require any shielding and is accessible for periodic inspections. Access to the SFSF is provided for periodic inspection as shown in Figure 3.8-42 through Figure 3.8-46 and Figure 3.8-50 through Figure 3.8-52.

5. A minimum of 23 feet of water above the tops of the spent fuel pool assemblies in the spent fuel racks provides sufficient shielding to limit radiation doses to personnel in the spent fuel pool area to minimal values in keeping with the ALARA approach described in Section 12.1.

6. Containment and confinement are provided in the SFSF by the spent fuel pool liner and by the ventilation system for the Fuel Building (see Section 9.4.2). The joint welds that require initial testing and subsequent monitoring of weld integrity are provided with a leak chase system. A monitoring system is provided for the leak chase system. Any water collected is directed to the floor and equipment drain system and transferred to the liquid radwaste system for processing. Filtering of the spent fuel pool water is provided by the FPCPS (see Section 9.1.3). For the NFSF, appropriate confinement of the new fuel assemblies is provided by the new fuel storage racks located inside the concrete structure of the new fuel room.

7. The design and density storage arrangement of the spent fuel racks provide adequate natural coolant circulation to remove the residual heat from spent fuel stored in the spent fuel rack, in combination with the FPCPS. The FPCPS maintains the spent fuel pool water temperature and water level within prescribed limits by removing decay heat generated by the stored spent fuel assemblies (see Section 9.1.3).

8. Instrumentation is provided to monitor the pool water level and water temperature (see Section 9.1.3) to provide indication of the loss of decay heat removal and to warn personnel of potentially unsafe conditions. In addition, area radiation monitors are provided near the SFP which will provide a distinct audible and visual alarm to alert personnel in the vicinity of the need to take appropriate action. Refer to Section 12.3.4 for further details on the area radiation monitors.

9. The new and spent fuel racks are Seismic Category I structures and are designed to withstand normal and postulated dead loads, live loads, loads resulting from thermal effects, and loads caused by an SSE event. See Section 9.1.2.2.3 for information on structural and stress analyses for new and spent fuel racks.

10. The spent fuel is stored within a stainless steel lined concrete pool which has no penetrations that can result in an unacceptable loss of water. As described in Section 9.1.3, the FPCPS provides makeup water for the SFP. The concrete structures for the SFP and fuel transfer canal are designed to maintain leak-tight integrity to prevent the loss of cooling water from the pool. All piping penetrations into the pool are designed to preclude draining the pool down to an unacceptable limit, as described in Section 9.1.3.

11. The design of the new and spent fuel racks confirms that only one fuel assembly can be inserted into a single storage cell.

12. The spent fuel pool and cooling systems are designed so that in the event of failure of inlets, outlets, piping, or drains, the pool level will not be inadvertently drained below a level approximately 3 meters (10 feet) above the top of the active fuel. The spent fuel pool does not include piping that extends below this elevation. The water level in the spent fuel pool can be affected by leaks in the cask loading pit (CLP) and spent fuel cask transfer facility (SFCTF). Refer to Section 9.1.4.3.4 for a discussion concerning the prevention, detection, and mitigation of leaks in the CLP and SFCTF.

9.1.2.4 Inspection and Testing Requirements

Refer to Section 14.2 (test abstract #038) for initial plant startup test program related to the proper operation of the fuel handling equipment, including the spent fuel storage rack positions.

A coupon surveillance program monitors the MMC neutron absorber over the lifetime of the racks to verify its integrity. The coupons are taken from the same production lot as that used for construction of the racks. Prior to immersion in the racks, the coupons are characterized for comparison with subsequent measurements. At least one archive specimen will be retained for later comparison with the irradiated coupons.

A minimum of 12 coupons are immersed in the storage racks into the spent fuel pool. Additional coupons may be used to address potential license extensions and post-shutdown fuel storage. The size of each coupon will be large enough to obtain a tensile test specimen (approximately 1 x 8 inches) and a specimen for B-10 areal density testing (approximately 2 inches square). The coupons are located adjacent to freshly discharged irradiated fuel in an empty fuel compartment in Region 2. The coupons are placed at a depth in the region of the center of the active zone of a fuel assembly, plus or minus five feet.

The recommended schedule for coupon monitoring is to remove and examine one coupon at approximately 2, 4, 6, 8, 10, 15, 20, 25, 30, 40, 50, and 60 years from the first insertion of irradiated fuel into the racks. Coupons are measured and visually examined to monitor changes in the physical properties of the MMC material. B-10 areal density will also be measured. Coupons that are not destroyed may be returned to the pool for continued use in the surveillance program.

Qualification Program for the MMC Neutron Absorber

Any differences between the manufacturing of qualification test materials and the full scale manufacturing methods will be evaluated to verify that there is no non-conservative effect on the applicability of the test results to production material. The potential environmental deterioration mechanism is corrosion. Corrosion testing will be performed and evaluated. The neutron absorber material must have sufficient strength and ductility for handling and fabrication and to support its own weight in the rack.

9.1.2.5 Instrumentation Requirements

Instrumentation is provided to monitor the pool water level and water temperature (see Section 9.1.3) to provide indication of the loss of water and degradation of the decay heat capability. As described in Section 12.3.4, area radiation monitors are placed near the NFSF and the SFSF which provide a clear audible and visual alarm to alert personnel in the vicinity of abnormal radiation levels and the need to evacuate the area.

9.1.2.6 References

1. ANSI/ANS-57.3-1983: "Design Requirements for New Fuel Storage Facilities at Light Water Reactor Plants," American National Standards Institute/American Nuclear Society, 1983.

2. ANSI/ANS-57.2-1983: "Design Requirements for Light Water Reactor Spent Fuel Storage Facilities at Nuclear Power Plants," American National Standards Institute/American Nuclear Society, 1983.

3. TN-Rack.0101, Revision 0, "U.S. EPR New and Spent Fuel Storage Rack Technical Report," AREVA Transnuclear Inc., December 2009.

Table 9.1.2-1—Fuel Rack Design Loads and Load Combinations

Load Combinations	Acceptable Limit (ASME Section III, Division 1, Subsection NF, Article NF-3000)
D+L	Level A service limits
$D+L+T_o$	
$D+L+T_o+E$	
$D+L+T_a+E$	Level B service limits
$D+L+T_o+P_f$	
$D+L+T_a+E'$	Level D service limits The functional capability of the fuel racks should be demonstrated
$D+L+F_d$	

Notes:

1. T_a is defined as the highest temperature associated with the postulated abnormal design conditions.
2. T_o is defined as the thermal effects and load during normal operating or shutdown conditions, based on the most critical transient or steady state condition.
3. F_d is the force caused by the accidental drop of the heaviest load from the maximum possible height.
4. P_f is the upward force on the racks caused by a postulated stuck fuel assembly.
5. D is defined as Dead Load and their related internal forces and moments.
6. L is defined as Live Load due to moving objects in the racks.
7. E is defined as Load generated by the OBE.
8. E' is defined as Load generated by the SSE.

Deformation limits specified by the design specification limits should be satisfied, and such deformation limits should preclude damage to the fuel assemblies.

Figure 9.1.2-1—Typical New Fuel Rack Array

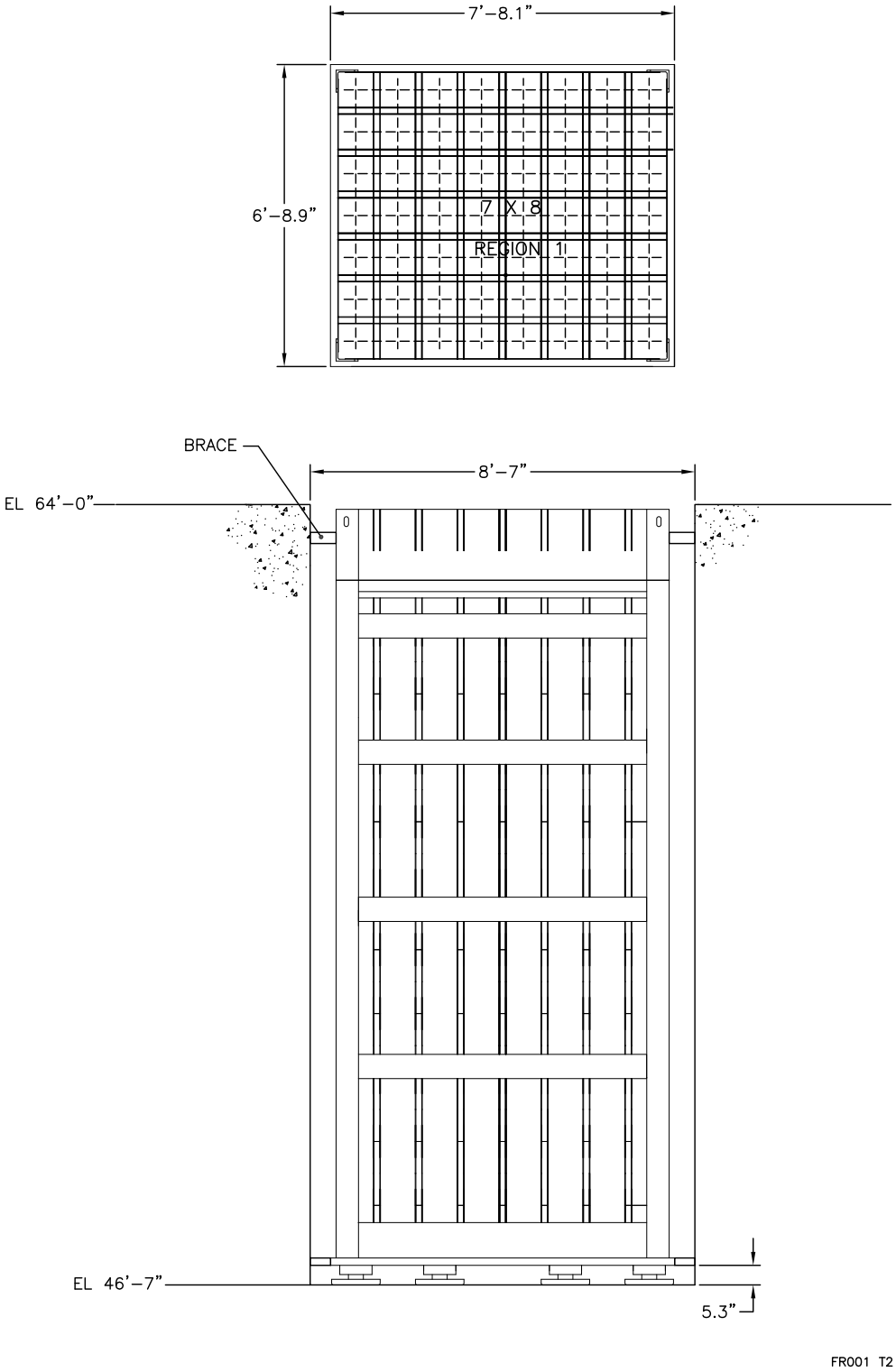
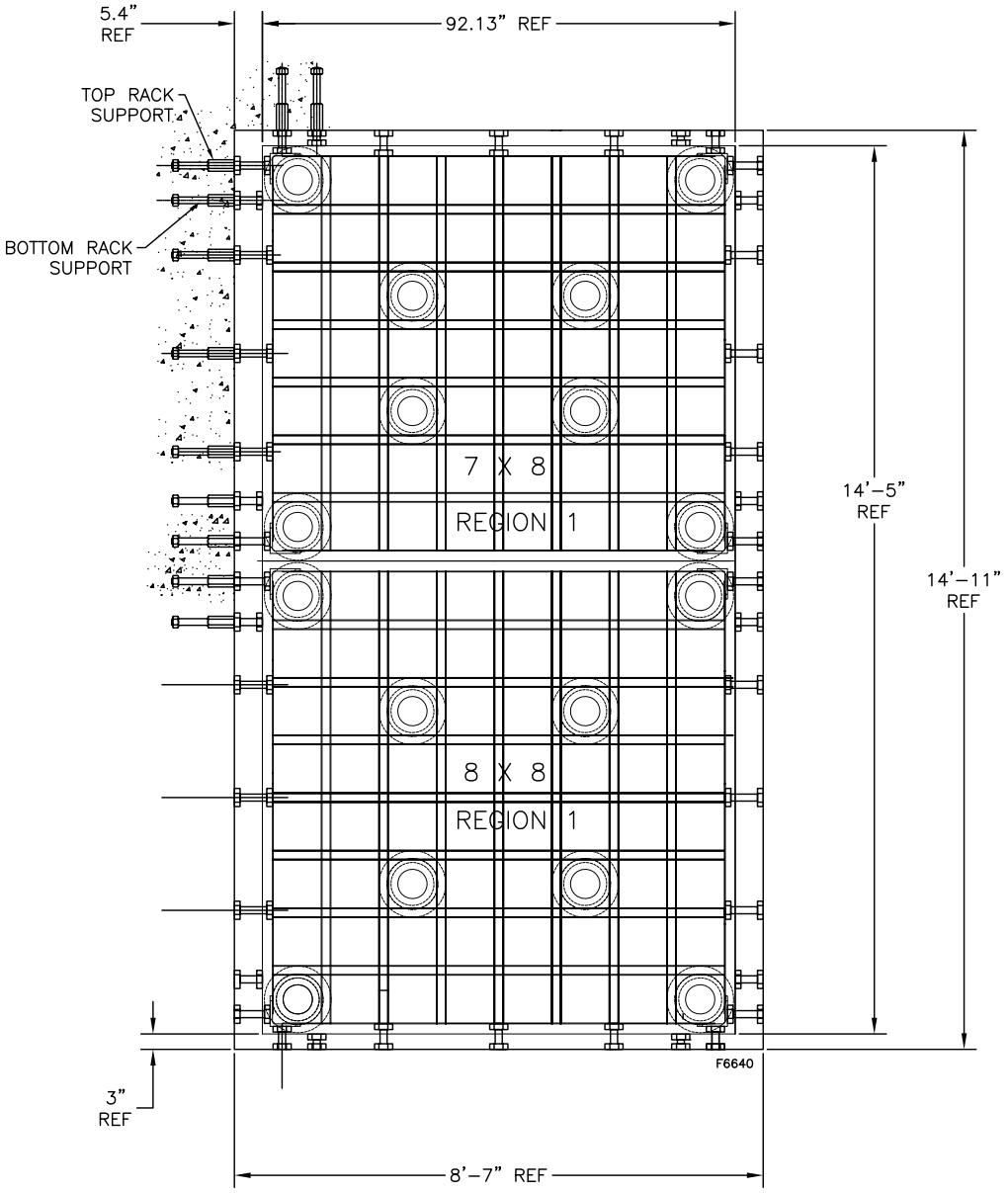


Figure 9.1.2-2—Dry New Fuel Storage Racks



NOTE: GAP DIMENSIONS SHOWN APPLY AT EDGE OF RACK BASE PLATES.

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Figure 9.1.2-3—Spent Fuel Pool Elevation

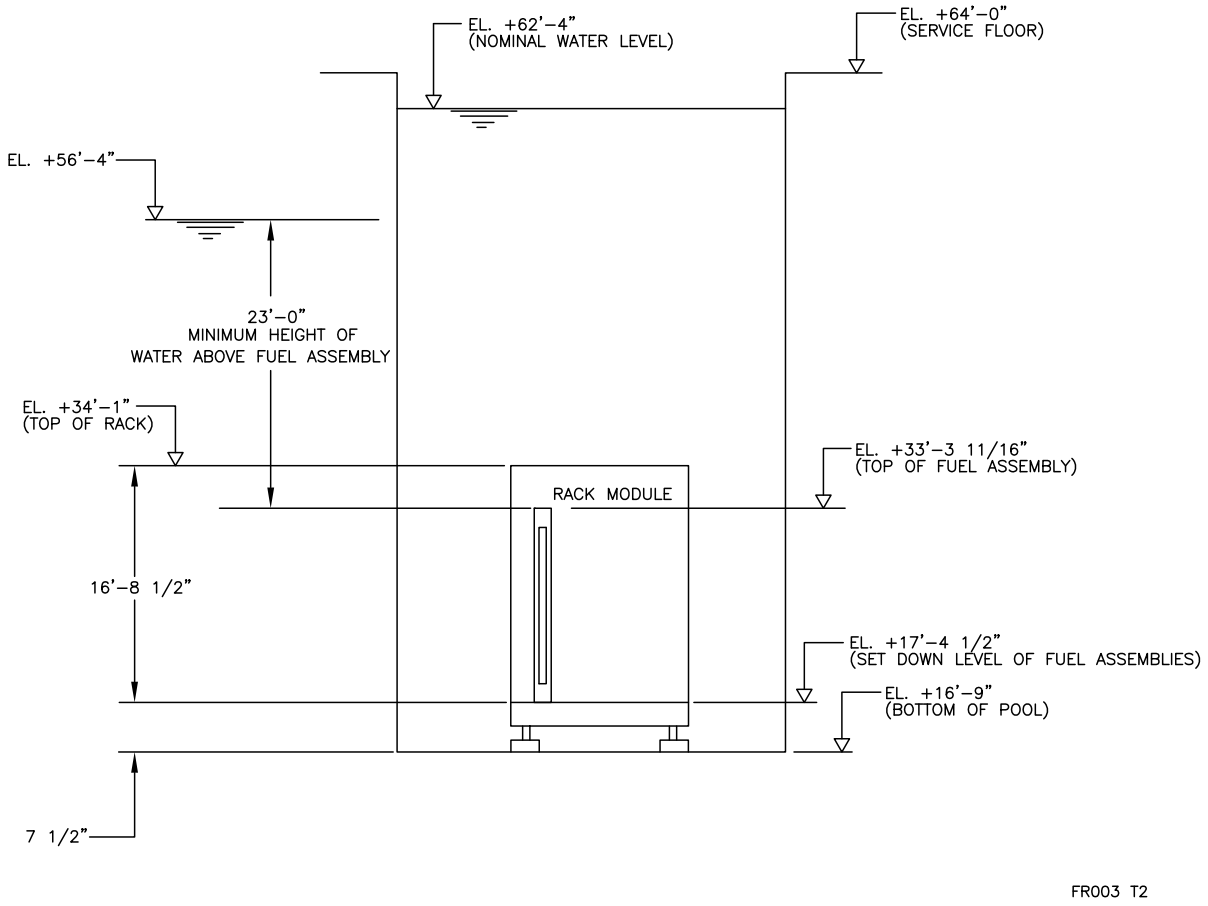


Figure 9.1.2-4—New Fuel and Region 1 Spent Fuel Storage Rack Cross-Section

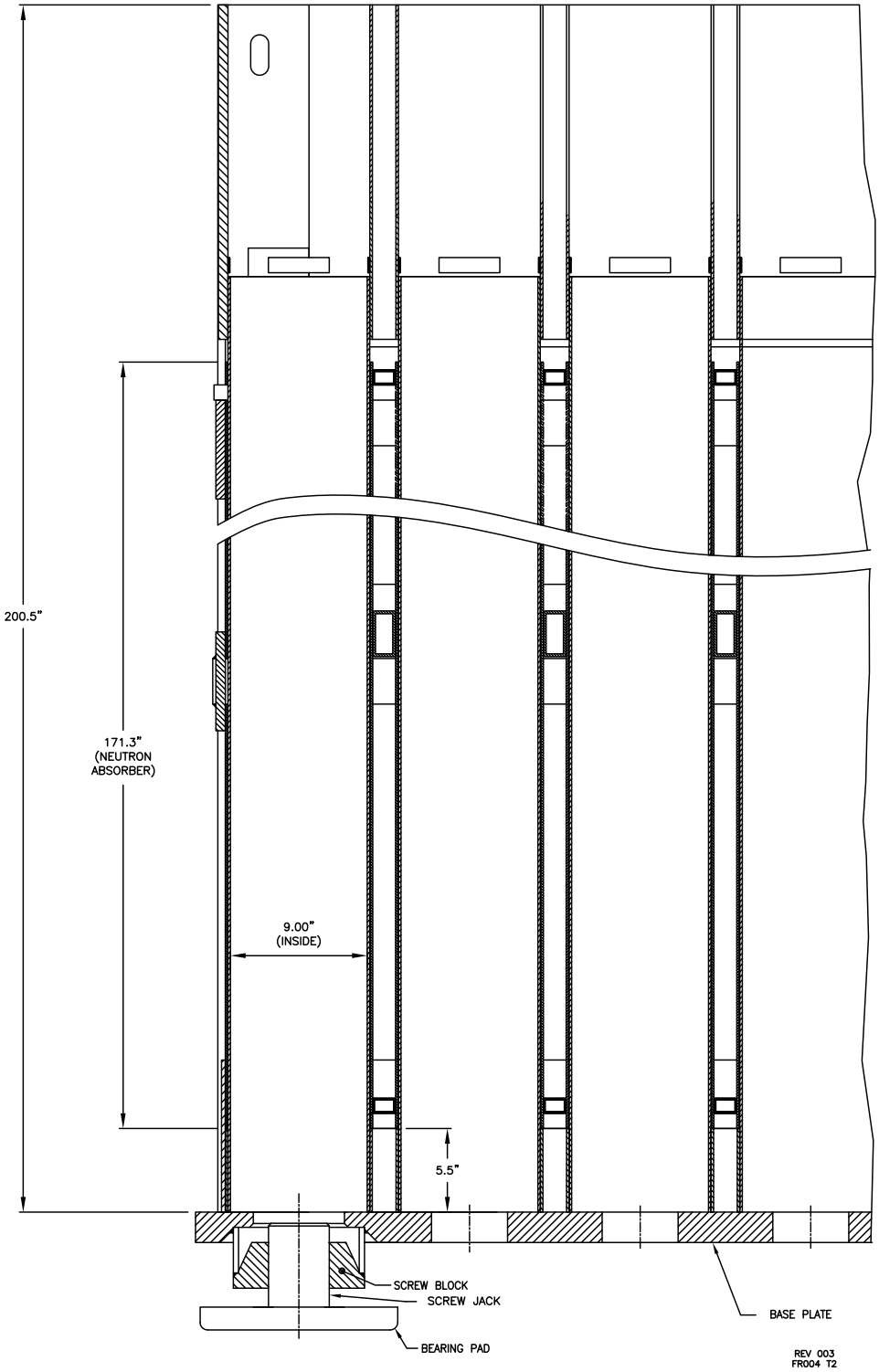


Figure 9.1.2-5—Region 2 Spent Fuel Storage Rack Cross-Section

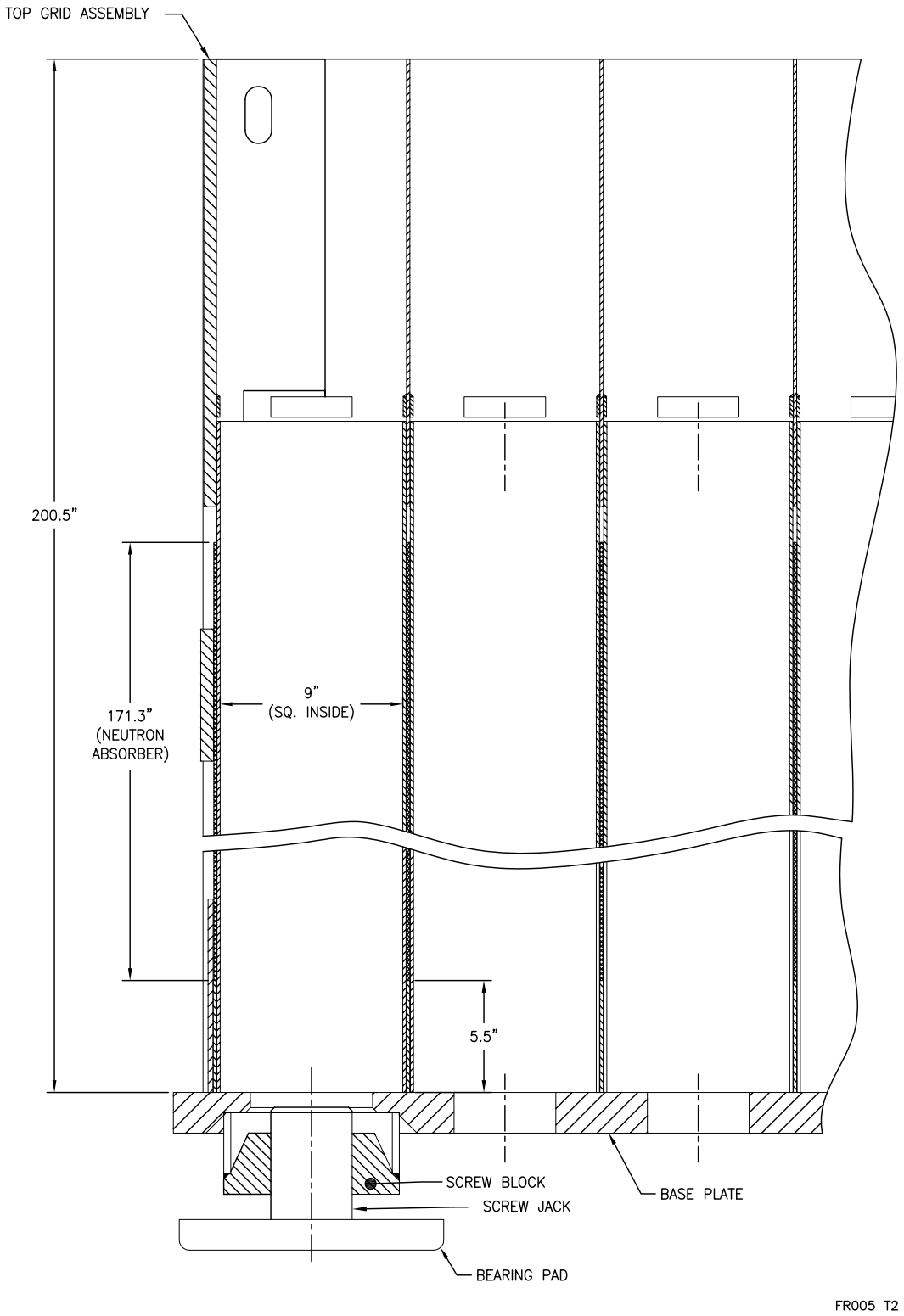


Figure 9.1.2-6—Typical Spent Fuel Rack Array

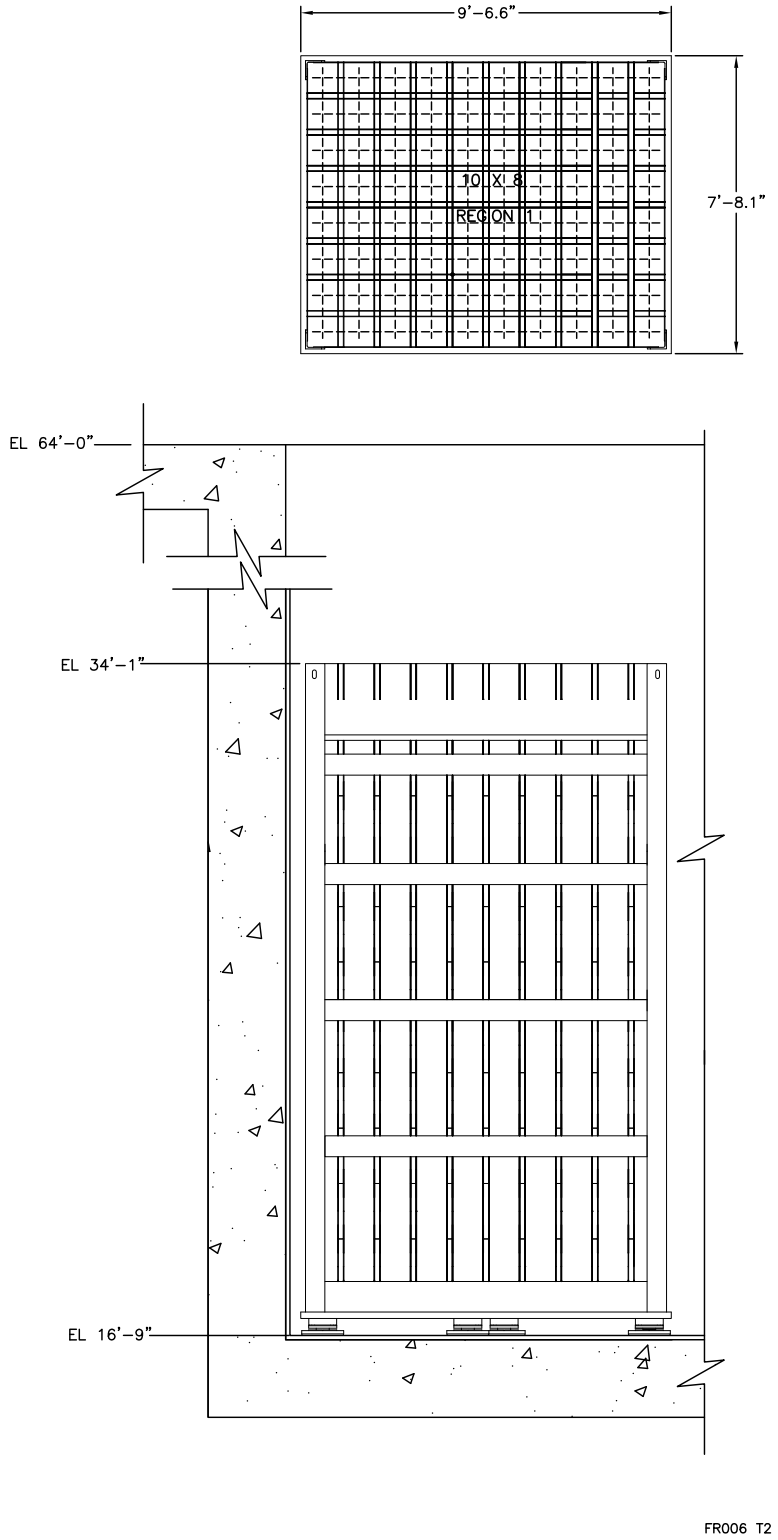


Figure 9.1.2-7—Spent Fuel Storage Pool Layout

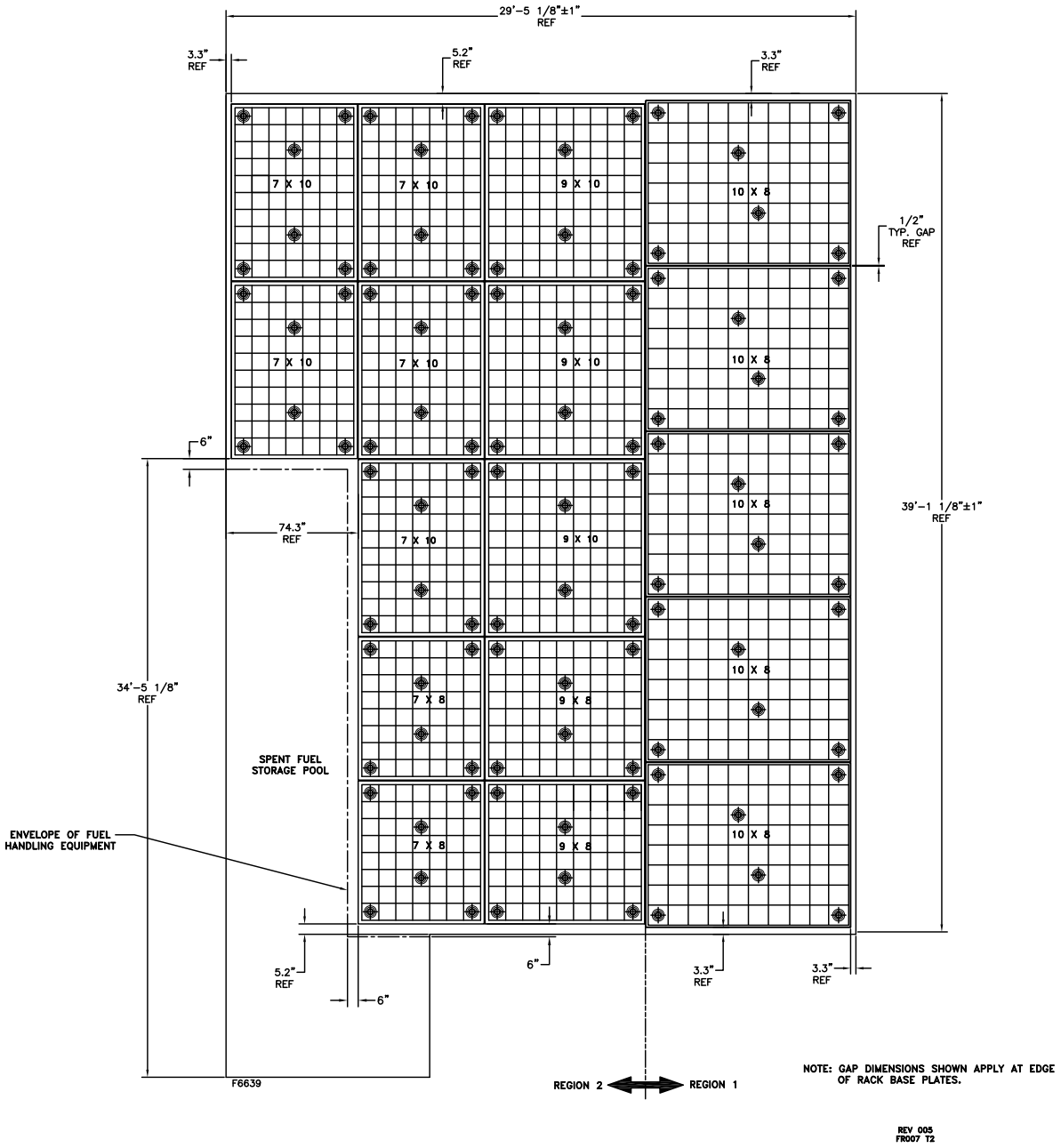


Figure 9.1.2-8—Fuel Storage and Handling Areas Layout

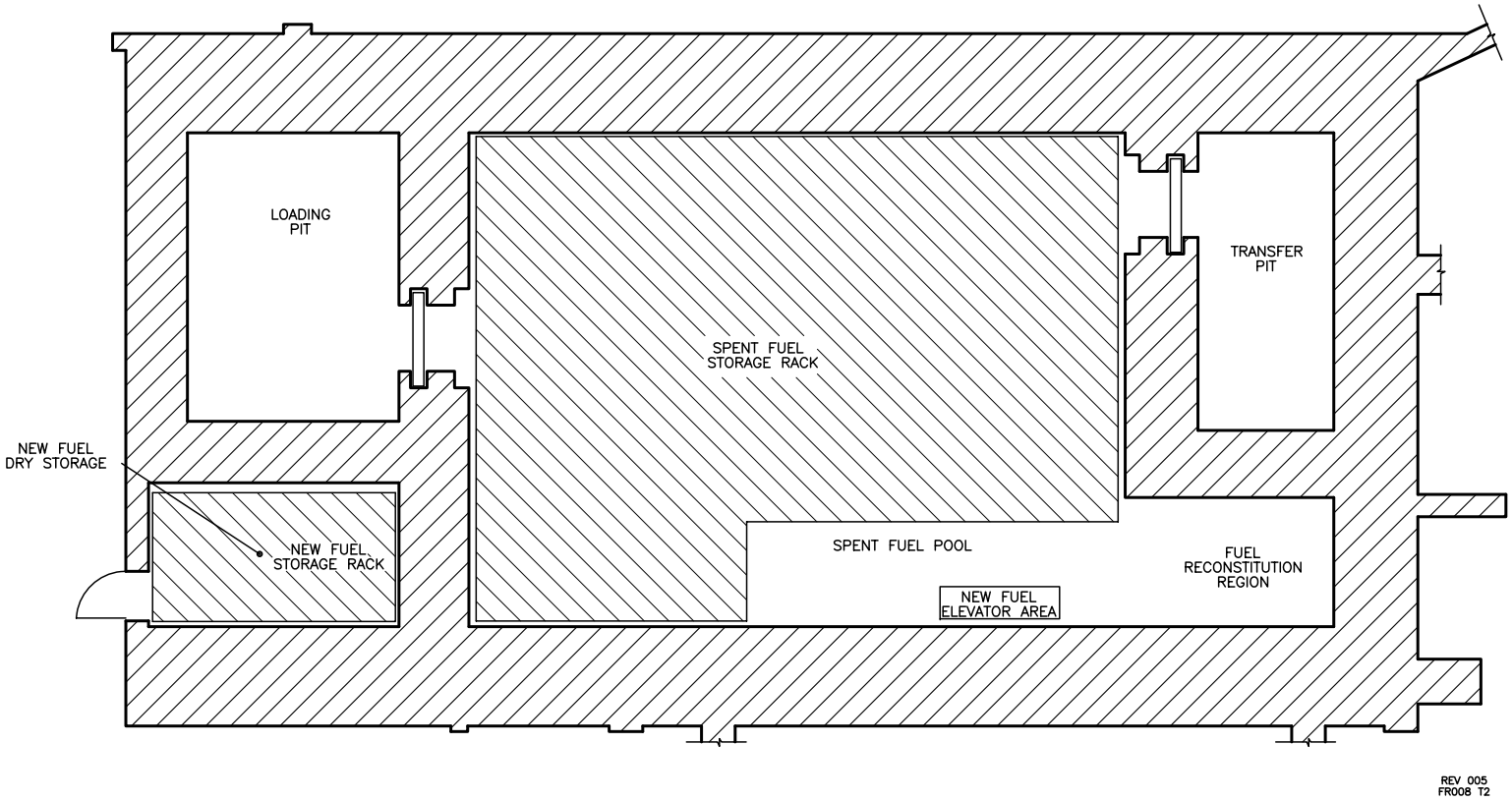
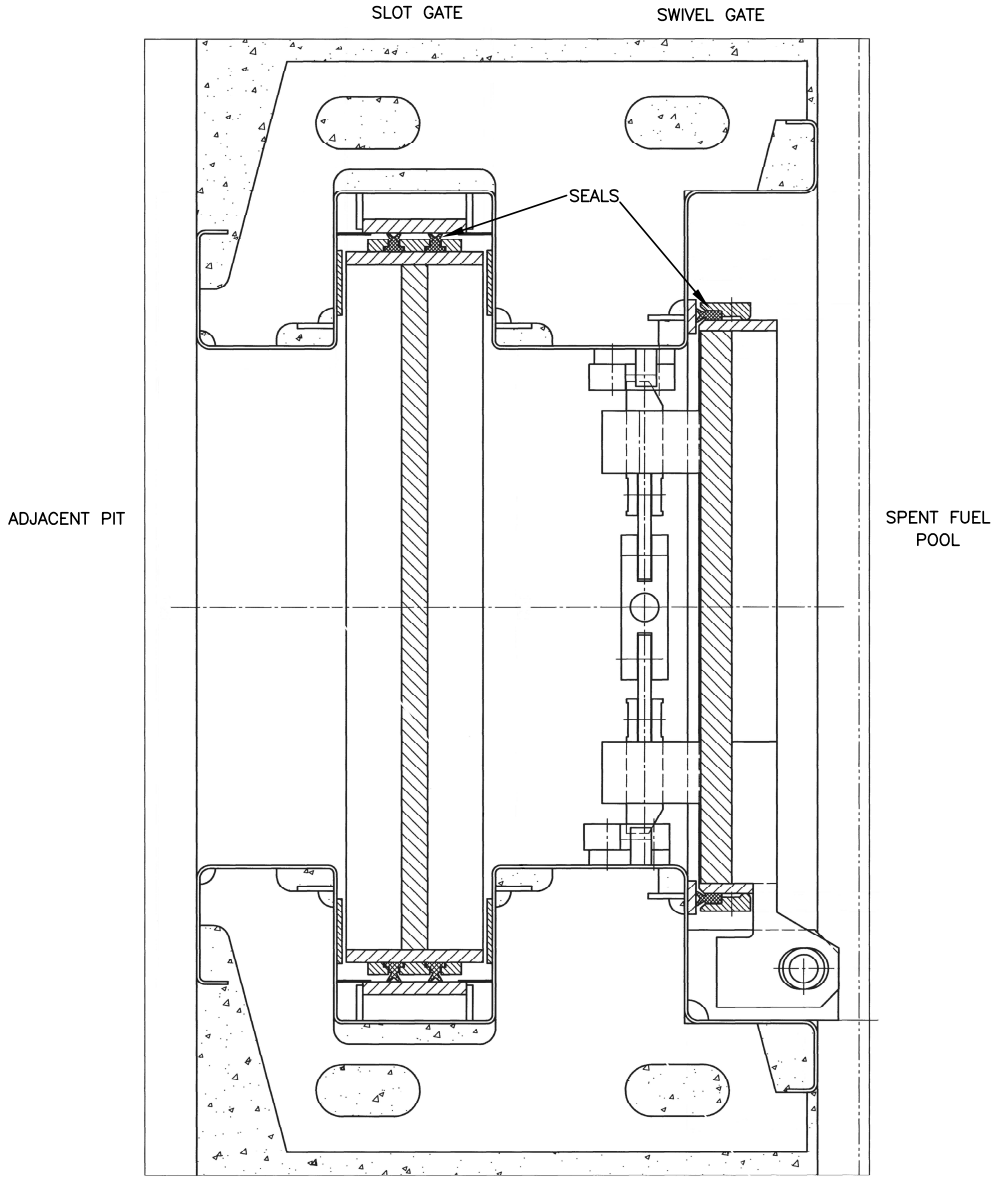


Figure 9.1.2-9—Cask Loading Pit Gates



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