9.1.4 Fuel Handling System

The fuel handling system (FHS) provides a safe means for handling and performance monitoring of fuel assemblies and control components from the time of receipt of new fuel assemblies to the storage of spent fuel. This includes installing and removing fuel assemblies in the reactor vessel, transferring irradiated fuel assemblies from the reactor vessel to the spent fuel pool (SFP), and storage of irradiated fuel assemblies. The system also provides a means of safely receiving, inspecting, storing, and handling new fuel.

The FHS design maintains occupational radiation exposures as low as is reasonably achievable (ALARA) during transportation and handling.

9.1.4.1 Design Bases

The following major components are safety-related and designed to Seismic Category I requirements:

- New and spent fuel storage racks.
- Transfer tube, isolation devices, and expansion joints.
- Spent Fuel Cask Transfer Facility loading pit penetration and cover.

The design basis requirements and design criteria are as follows:

The FHS components are located inside the Reactor Building (RB) and Fuel Building (FB) structures, which are designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods and external missiles (GDC 2).

The seismic design of the system components meets the guidance of RG 1.29 (Position C1 for safety-related portions and Position C2 for non-safety-related portions).

The FHS components are not shared among nuclear power units (GDC 5).

The design of the FHS includes the safe handling and storage of fuel under both normal and accident conditions (GDC 61).

The design of the FHS prevents inadvertent criticality (GDC 62). The fuel racks (FR) are designed to store fuel assemblies in an appropriate manner during normal operation and the safe shutdown earthquake (SSE) so that criticality accidents are avoided, and the fuel racks are not damaged by overloading or overheating.

The FHS is designed and arranged so that dropped loads do not result in fuel damage that would release radioactivity in excess of 10 CFR 100 guidelines or impair the safe shutdown of the plant.

The fuel transfer tube facility (FTTF) provides containment isolation so that offsite dose limits are not exceeded during a design basis accident (DBA).

9.1.4.2 System Description

FHS equipment is needed to perform the following functions:

- New fuel handling and storage.
- Refueling.
- Spent fuel storage and activities during plant normal operation.

This equipment consists of fuel assembly handling devices such as the refueling machine, FTTF, new fuel elevator, spent fuel machine, auxiliary crane, Spent Fuel Cask Transfer Facility, and fuel racks. The areas associated with the fuel handling equipment are the refueling cavity consisting of the reactor cavity, the core internal storage area and the reactor building transfer compartment, and the fuel pool consisting of the transfer pit, the loading pit and the spent fuel storage pool, and the new fuel storage area. Figures showing the overall system arrangement in the Reactor Building and Fuel Building are provided in Section 3.8.

9.1.4.2.1 General Description

The fuel handling equipment can handle a fuel assembly under water from the time a new fuel assembly is lowered into the underwater fuel storage area until the irradiated fuel assembly is placed in a spent fuel cask for shipment from the site. Underwater transfer of spent fuel assemblies provides radiation shielding and cooling for removal of decay heat. The boric acid concentration in the water is sufficient to preclude criticality.

The reactor cavity, the core internal storage compartment, and the Reactor Building Pool Transfer Compartment are flooded only for refueling during plant shutdowns. The SFP remains full of water and is always accessible to operating personnel.

New Fuel Handling and Storage

New fuel containers are received in the FB loading bay. Typically, each container carries two fuel assemblies. The new fuel assemblies are moved from the loading bay to the new fuel assembly examination facility. After examination, the accepted new fuel assemblies are placed either in the new fuel dry storage area or lowered into the spent fuel storage pool for underwater storage via the new fuel elevator. The new fuel assemblies placed in the new fuel dry storage will be moved to underwater storage prior to the refueling outage. From the spent fuel storage racks, the fuel assemblies are transferred under water until loaded into the reactor.

Refueling Procedure

Refueling operations are started after the reactor coolant system (RCS) is borated as specified in the Technical Specifications and cooled down to refueling shutdown conditions.

The refueling operation is divided into five major evolutions: (1) RCS and refueling system preparation, (2) disassembly of the reactor, (3) fuel handling during refueling operations, (4) reassembly of the reactor, and (5) preoperational checks and startups. A general description of a typical refueling operation through these evolutions is provided below.

RCS and Refueling System Preparation

The reactor is shut down, borated, and cooled to refueling conditions. After an initial radiation survey, access to the reactor vessel head is allowed. The coolant level in the reactor vessel is lowered to a point slightly below the vessel flange. The fuel transfer tools and equipment are checked, inspected and tested for operation.

Disassembly of the Reactor

Mechanical and instrumentation connections to the reactor pressure vessel are disconnected to allow removal of the vessel head. The refueling cavity is prepared for flooding by checking the underwater lights, and tools; closing the refueling cavity drain lines; and removing the blind flange from the fuel transfer tube. With the refueling cavity prepared for flooding, the vessel head is unseated and raised above the vessel flange using the reactor building polar crane (refer to Section 9.1.5 for equipment handling heavy loads). Water from the in-containment refueling water storage tank (IRWST) is directed into the reactor coolant system in order to fill the RB refueling cavity. The vessel head is lifted and placed on the head stand. When the RB refueling cavity water level reaches the specified depth for shielding and the water level in the FB transfer pit is equalized to the refueling cavity level, the fuel transfer tube isolation valve is opened. The refueling machine is positioned over the core and the control rod drive shafts are disconnected. Once the control rod shafts are disconnected, the internals lifting rig is installed. The upper internals are removed from the vessel and stored in the refueling canal in a designated area located away from the fuel load path. The refueling machine is indexed over the core and tested underwater. The core is ready for refueling when all fuel handling prerequisites have been met.

Fuel Handling during Refueling Operations

The refueling sequence begins in the RB with the refueling machine. Spent fuel assemblies are removed; and partially irradiated fuel assemblies are relocated in the core per the refueling plan and new fuel assemblies are added to the core. The general fuel handling sequence for a full core off load or a core fuel shuffle are essentially the same, except for the number of fuel assemblies removed from the reactor vessel.

The general fuel handling sequence for refueling involving moving the fuel assembly from the reactor vessel to the SFP is as follows:

1. The refueling machine is automatically or manually positioned over a fuel assembly in the core. Once the refueling machine mast is positioned over the selected fuel assembly; the fuel assembly gripper is lowered and engages the fuel assembly.

2. The refueling machine withdraws the selected fuel assembly from the core and raises it to a predetermined height sufficient to clear the vessel flange. The maximum height of the fuel assembly is limited to provide sufficient water covering the fuel assembly. The fuel assembly is then transported to the fuel transfer tube facility area of the reactor building refueling cavity.

3. The fuel transfer system conveyor car is positioned in the fuel transfer tube facility area of the refueling cavity, and the fuel container is in the vertical position.

4. The refueling machine is positioned to line up the fuel assembly over the empty fuel container. The fuel assembly is lowered and placed into the empty fuel container of the conveyor car. The upender pivots the fuel container to the horizontal position and is transported by the conveyor car to the SFP side of the fuel transfer tube facility. The upender then pivots the fuel container to the vertical position.

5. The spent fuel machine is positioned over the fuel assembly then it latches and withdraws the assembly from the fuel container. The spent fuel machine then transports the fuel assembly to a predetermined location in the SFP where it is lowered into the fuel rack location and unlatched.

The general fuel handling sequence for refueling involving moving the fuel assembly from the SFP to the reactor vessel is as follows:

1. A fuel assembly is taken from a specified location in the SFP storage rack and loaded into the empty fuel container of the conveyor car by the spent fuel machine.

2. The upender pivots the fuel container to the horizontal position and the conveyor car moves the fuel assembly through the fuel transfer tube to the fuel transfer tube facility area in the RB. The upender then pivots the fuel container back to the vertical position.

3. The refueling machine is then located over the fuel assembly and withdraws it from the fuel container. The refueling machine then transports the fuel assembly over the core area and inserts it into a specified location in the core.

The foregoing procedures are repeated until the reactor vessel refueling is completed.

Reassembly of the Reactor

After the core mapping is complete, the reactor vessel is reassembled. The spent fuel pool is isolated from the refueling cavity and the RB refueling cavity water level is lowered to just below the reactor vessel flange and the vessel head is installed. The mechanical and instrumentation connections are reinstalled.

Pre-operational Checks and Startup

In the final phase, the blind flange on the fuel transfer tube is re-installed and the fuel handling areas inside the reactor building are cleaned and restored.

Spent Fuel Storage and Activities During Plant Normal Operation

Spent fuel is stored in the fuel storage racks in the spent fuel storage pool. The fuel pool cooling system removes the decay heat from the spent fuel assemblies stored in the pool (refer to Section 9.1.3). After sufficient decay, spent fuel assemblies may be removed from the SFP.

During normal operation, handling activities related to rearrangement and inspection of the spent and new fuel assemblies in the fuel storage pool and in the new fuel dry storage area take place. The spent fuel machine and auxiliary crane are used to relocate fuel and fuel assembly inserts.

Prior to initiating these activities in the SFP, the following checks are made:

- Verification of the SFP readiness, including lighting.
- Verification that the fuel pool cooling and purification system and support systems are available and capable of handling the expected spent fuel heat load.
- Verification of SFP boron concentration to maintain subcriticality of the fuel assemblies.
- Verification of water level in the SFP to keep the radiation levels within acceptable limits when the fuel assemblies are relocated in SFP.
- Verification of the SFP gates integrity to make sure there is no unexpected loss of SFP water level during fuel movement operations.

Other than the handling of fuel and fuel assembly inserts, the inspection and testing of the fuel handling tools and accessible components and equipment are also carried out during the plant normal operation. The calibration of instruments and circuits, and the testing of electrically operated equipment and components, including the checking for proper operation of interlocks, are accomplished.

Fuel Handling Administrative Controls and Programs

The fuel handling operations are performed per approved plant procedures, which cover administrative, operating, emergency, testing and maintenance aspects.

The administrative control procedure and checklists are developed from a review of fuel handing related safety analysis and the fuel handling operations. The checklists assist in providing assurance that fuel handing safety analysis assumptions and initial conditions are not violated during the refueling and other fuel handling operations.

Administrative controls for fuel handling operations include the following:

1. Movement of the fuel assemblies from the core shall be started only after allowing for sufficient decay after the reactor shutdown.
2. The spent fuel cask loading pit gate shall be retained closed during refueling operations.
3. Manual control of the handling equipment, such as, Refueling Machine, Spent Fuel Machine, New Fuel Elevator, and Auxiliary Crane shall be put under administrative control.
4. The spent fuel cask loading pit penetration cover shall be kept closed.

9.1.4.2.2 Component Description

The major components of the FHS are described in the following paragraphs. Refer to Section 3.2 for the seismic and system quality group classification of these components. The FHS is designed in accordance with ANS 57.1 (Reference 1), ANS 57.2 (Reference 2), and ANS 57.3 (Reference 3). The transfer tube components are designed per ASME Boiler and Pressure Vessel Code, III (Reference 4).

Refueling Machine

The refueling machine (RM) moves fuel assemblies both within the reactor vessel and between the reactor vessel and the fuel transfer tube facility during outages. The RM is primarily designed for the underwater handling of fuel assemblies between the FTTF and the core during outages. The RM also provides access to fuel assemblies for detecting fuel cladding ruptures, visual core mapping, an operational platform for handling control rod drive shafts and instrumentation, and access to the upper internals of the reactor vessel.

The main components of the RM are shown in Figure 9.1.4-1—Refueling Machine.

A conceptual drawing of the fuel assembly hoisting mechanism is shown in Figure 9.1.4-2—Fuel Assemblies Hoisting Mechanism.

Fuel Transfer Tube Facility

The main purpose of the FTTF is to transfer fuel between the SFP and the refueling cavity. The fuel transfer tube is fitted with a blind flange on the Reactor Building side to provide containment isolation during power operations and with a manual gate valve on the Fuel Building side to allow isolation of the SFP from the refueling cavity. The fuel transfer tube is provided with expansion joints on the RB and FB side to accommodate the differential movement and provide leak tight sealing. An underwater conveyor car carries the fuel assemblies in a fuel container through the tube. Upenders provide the capability to tilt the fuel container.

The main components of the FTTF are shown in Figure 9.1.4-3—Fuel Transfer Tube Facility, Reactor Building and Figure 9.1.4-4—Fuel Transfer Tube Facility, Fuel Building.

New Fuel Elevator

The primary purpose of the new fuel elevator (NFE) is to lower new fuel assemblies to the bottom of the spent fuel storage pool for transfer via the spent fuel machine. The NFE supports and rotates the fuel assemblies, protects them from shock, and provides a means to inspect fuel assemblies when they are underwater.

The main components of the NFE are shown in Figure 9.1.4-5—New Fuel Elevator.

Spent Fuel Machine

The spent fuel machine (SFM) is primarily designed for the underwater handling of fuel assemblies between the SFP and the FTTF. The SFM permits access to the fuel assemblies to detect fuel cladding ruptures. It also enables the loading of spent fuel into the shipping casks.

The main components of the SFM are shown in Figure 9.1.4-6—Spent Fuel Machine.

Auxiliary Crane

The auxiliary crane is used to handle new fuel containers, container covers, protection lids, new fuel assemblies, erection opening covers, canisters, slot gates, swivel gates, tilting basket, along with miscellaneous handling operations. The auxiliary crane is designed with buffers and shock-absorbing devices. The auxiliary crane bridge hoist uses the new fuel handling tool to handle new fuel assemblies for operations in air. For further details on the auxiliary crane, refer to Section 9.1.5.

Fuel Racks

The fuel racks are located under water for irradiated fuel storage, and above water for new fuel storage. The racks are designed to store fuel in a manner that precludes criticality and maintains the irradiated fuel in a coolable geometry. Refer to Section 9.1.2 for the design of the new and spent fuel storage racks.

Spent Fuel Cask Transfer Facility

A penetration is located in the bottom of the cask loading pit to enable loading of spent fuel assemblies into a spent fuel cask after a sufficient decay period in the spent fuel pool. The penetration assembly maintains leak-tightness during fuel loading into the cask to maintain fuel integrity. A Seismic Category I penetration cover with double seals in the bottom of the loading pit seals the penetration to maintain the water inventory in the loading pit when the cover is closed. The cover is maintained closed.

9.1.4.3 Safety Evaluation

- The safety-related portions of the FHS are located in the RB and FB. These buildings are designed to withstand the effects of earthquakes, tornadoes, hurricanes, floods, external missiles, and other similar natural phenomena. 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 these buildings.

- The safety-related portions of the FHS are designed to remain intact after an SSE. Section 3.7 provides the design loading conditions that were considered. Section 3.5, Section 3.6, and Appendix 9A provide the required hazards analysis. The refueling machine, fuel transfer tube facility, NFE, and SFM are designed to hold their maximum load during an SSE. See Section 9.1.5.2.3 for auxiliary crane design requirements.

- The portions of the FHS that provide containment boundary and containment isolation functions are safety related. The fuel transfer tube penetrates the primary containment and is equipped with a blind flange in the Reactor Building that is closed during power operations. The leak-tight function of the fuel transfer tube is tested in accordance with 10 CFR 50, Appendix J programmatic requirements (refer to Section 6.2.6).

- The spent fuel assemblies and their inserts are handled with sufficient water cover to provide adequate shielding. Movement of fuel assemblies that could result in assembly grid contact or contact with other fuel assemblies takes place at low speed. Details regarding the specific assumptions, sequences, and analyses of fuel handling accidents are provided in Section 15.0.3.10.

Details regarding criticality prevention measures for new and spent fuel storage are provided in Section 9.1.1.

The FHS is designed and arranged so that there are no loads which, if dropped, could result in damage leading to the release of radioactivity in excess of 10 CFR 100 guidelines, or impair the capability to safely shut down the plant. All spent fuel cask handling activities are performed below the SFP in the loading hall located at the ground elevation of the FB. Any lifting of a spent fuel cask is performed outside of the

FB using appropriate handling equipment and lifting height limitations. At all times during spent fuel cask handling inside the FB, the cask height will not exceed 30 feet based on the design of the FB. The cask drop accident is addressed in Section 15.0.3.10. Details regarding new and spent fuel storage are provided in Section 9.1.1 and Section 9.1.2. Details regarding the specific assumptions, sequences, and analyses of fuel handling accidents are provided in Section 15.0.3.10.

9.1.4.3.1 Safety Provisions for the Major Fuel Handling System Components

Refueling Machine

The refueling machine (RM) hoisting mechanism is equipped with an operational brake, an auxiliary brake, and a safety brake which acts on the drum in case of overspeed detection, chain failure, or reverse rotation. The brakes are designed to engage when de-energized. They engage in case of a malfunction of the loop drive train configuration.

The gripper mast assembly is suspended via two cables, with an equalizing system and break detector. A limit switch stops the lifting movement when the telescopic gripper mast reaches its upper end position. A load cell measures the weight of the suspended load and control circuits associated with the load cell allow for the brake actuation.

A load limiting device protects the fuel assembly during normal lifting movements in the core when contact occurs between two fuel assemblies. It limits the loads applied to the grids of the fuel assemblies and to the nozzles of the fuel assemblies.

During normal operation, the refueling machine can only travel within a defined "travel route", thereby avoiding the possibility of inadvertent contacts. This route is determined by encoders and limit switches.

The RM is provided with a dose rate measurement device, and lifting is stopped in case of exceeding the allowable dose rate limit.

The RM is provided with interlocks related to:

- Traveling or traversing.
- Lowering or lifting.
- Engaging or disengaging of the latches.
- Travel from one compartment of the pool to another.
- Preventing interference with the FTTF.

Fuel Transfer Tube Facility

The transfer tube is attached to the RB internal containment wall by means of a rigid and leak tight connection so as not to affect containment integrity. A metal expansion bellows welded to the transfer tube and to the frames of the building structure is provided at each end of the transfer tube. The bellows form close concentric volumes, which are equipped with a sensor for detecting leaks from the expansion joints. The sensors provide an alarm in the main control room.

The fuel transfer tube facility hoisting mechanism is equipped with an operational brake and a safety brake, which acts on the drum in case of overspeed, chain failure or reverse rotation. The winch is equipped with redundant cables that preclude the falling of a lifting frame to its horizontal position in the event of a cable failure. The brakes are designed to engage when de-energized. They engage in case of malfunction of the loop drive train configuration.

In case of an abnormal situation during fuel assembly transfer, the fuel assembly can be placed in a safe position. The fuel assembly can be moved by using either manual devices (hand wheels at the drives) or via the backup horizontal movement system of the conveyor car in case of an electrical or mechanical failure to place it in a safe state. The backup horizontal movement system can be used to return the conveyor car to the FB from any position in its normal travel in the event of control system malfunction. After returning the conveyor car, the fuel transfer tube gate valve can be closed manually.

A load cell is also provided, which prevents operation in the event of overloading or in case of a slack cable.

Each control desk is equipped with a manual switch which trips the main circuit breakers should the operator note a malfunction.

In addition to limit switches, the fuel transfer tube facility is provided with the following interlocks related to:

- Horizontal movement of the FTTF conveyor car.
- Tilting of the fuel container.

Spent Fuel Machine

The SFM hoisting mechanism is equipped with an operational brake, an auxiliary brake, and a safety brake, which acts on the drum in case of overspeed, chain failure or reverse rotation. The brakes are designed to be engaged when de-energized. They engage in case of malfunction of the loop drive train configuration.

The gripper mast assembly is suspended via two cables with an equalizing system and break detector. A limit switch stops the lifting movement when the telescopic gripper mast reaches the upper end position. A load cell prevents hoisting operation in the event of overload.

The spent fuel machine travel is limited to avoid a fuel assembly contacting the SFP walls, the FB transfer pit walls, and the loading pit walls.

The limit switch prevents further lifting such that personnel exposure from an irradiated fuel assembly will not be >2.5 mrem/hour. The SFM is provided with a dose rate measurement device and the lifting is stopped in case of exceeding the allowable dose rate limit.

The SFM is provided with interlocks related to:

- Traveling or traversing.
- Lowering or lifting.
- Engaging or disengaging of the latches.
- Functioning of the FTTF, auxiliary crane, and NFE.
- Access to the fuel pool transfer pit.

New Fuel Elevator

The NFE hoisting mechanism is equipped with an operational brake, and a safety brake on the drum. The brakes are designed to be engaged when de-energized. The hoisting mechanism is provided with a cable equalizing system and a cable break detector. The movement is stopped if a cable break is detected. The hoisting mechanism is equipped with a load detection device and the movement is stopped in the event of a threshold overrun.

The NFE is designed to accommodate only one fuel assembly at a time and is provided with a radiation monitor that stops the NFE in the event of exceeding the radiation limits.

The NFE is provided with interlocks related to:

- Lowering or lifting.
- Functioning of the SFM.

Auxiliary Crane

Refer to Section 9.1.5 for safety provisions incorporated in the auxiliary crane.

Spent Fuel Cask Transfer Facility

When the Spent Fuel Cask Transfer Facility is not operated, the loading pit is isolated from the SFP by two gates. The loading pit may be empty or contain water for SFP makeup, as described in Section 9.1.3. The leak tightness of the SFP loading pit penetration is monitored and an alarm is transmitted to the main control room.

The single failure criterion is applied to the components of the facility performing safety functions, failure of which may lead to abnormal levels of occupational radiation exposure. The safe position is assured by the mechanical components in case of electrical failure.

9.1.4.3.2 Refueling Cavity Draindown Events

Rapid draindown of the refueling cavity resulting in fuel uncovery during refueling is not a credible event. The reactor vessel cavity ring is a permanently installed stainless steel assembly welded to the reactor vessel and the refueling cavity liner to prevent water leakage from the refueling cavity. The passive cavity ring design does not rely on active components such as pneumatic seals and is not susceptible to gross failure. Seals for openings in the refueling cavity liner do not rely on active components and do not pose a risk for rapid cavity draining.

Inadvertent draining of the refueling cavity is addressed by plant procedures. Refer to Section 13.5 for plant procedure information.

Any credible drainage from the refueling cavity will be detected visually or by installed instrumentation in adequate time to place a handled fuel assembly, if necessary, in a safe storage location. The safe storage location is either in the reactor core or in the fuel transfer facility, where it can be positioned horizontally to increase shielding depth or can be transferred to the Fuel Building. Weirs in the Reactor Building and Fuel Building pools limit the loss of water in pool areas separated from the drain path by the weirs.

9.1.4.4 Inspection and Testing Requirements

The safety-related components are located to permit preservice and inservice inspections. The FHS containment isolation function is testable. Refer to Section 14.2 (test abstracts #038 and #039) for initial plant testing of the FHS components. The performance and structural integrity of system components is demonstrated by continuous operation.

9.1.4.5 Instrumentation Requirements

In general, mechanical or electrical interlocks are provided, when required, to provide reasonable assurance of the proper and safe operation of the fuel handling equipment. The intent is to prevent a situation which could endanger the operator or damage the fuel assemblies and control components. The interlocks, setpoints, rules for handling fuel assemblies, and other devices that restrict undesired or uncontrolled movement are incorporated in the design. The RM, SFM and NFE are provided with an arrangement, on the respective control desk, for an emergency shutdown of movements. As a minimum, the interlocks specified in Table 1 of Reference 1 will be provided.

9.1.4.6 References

1. ANSI/ANS-57.1-1992; R1998; R2005 (R=Reaffirmed): "Design Requirements for Light Water Reactor Fuel Handling Systems," American National Standards Institute/American Nuclear Society, 2005.

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. 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.

4. ASME Boiler and Pressure Vessel Code, Section III, "Rules for Construction of Nuclear Facility Components," The American Society of Mechanical Engineers, 2004.

Figure 9.1.4-1—Refueling Machine

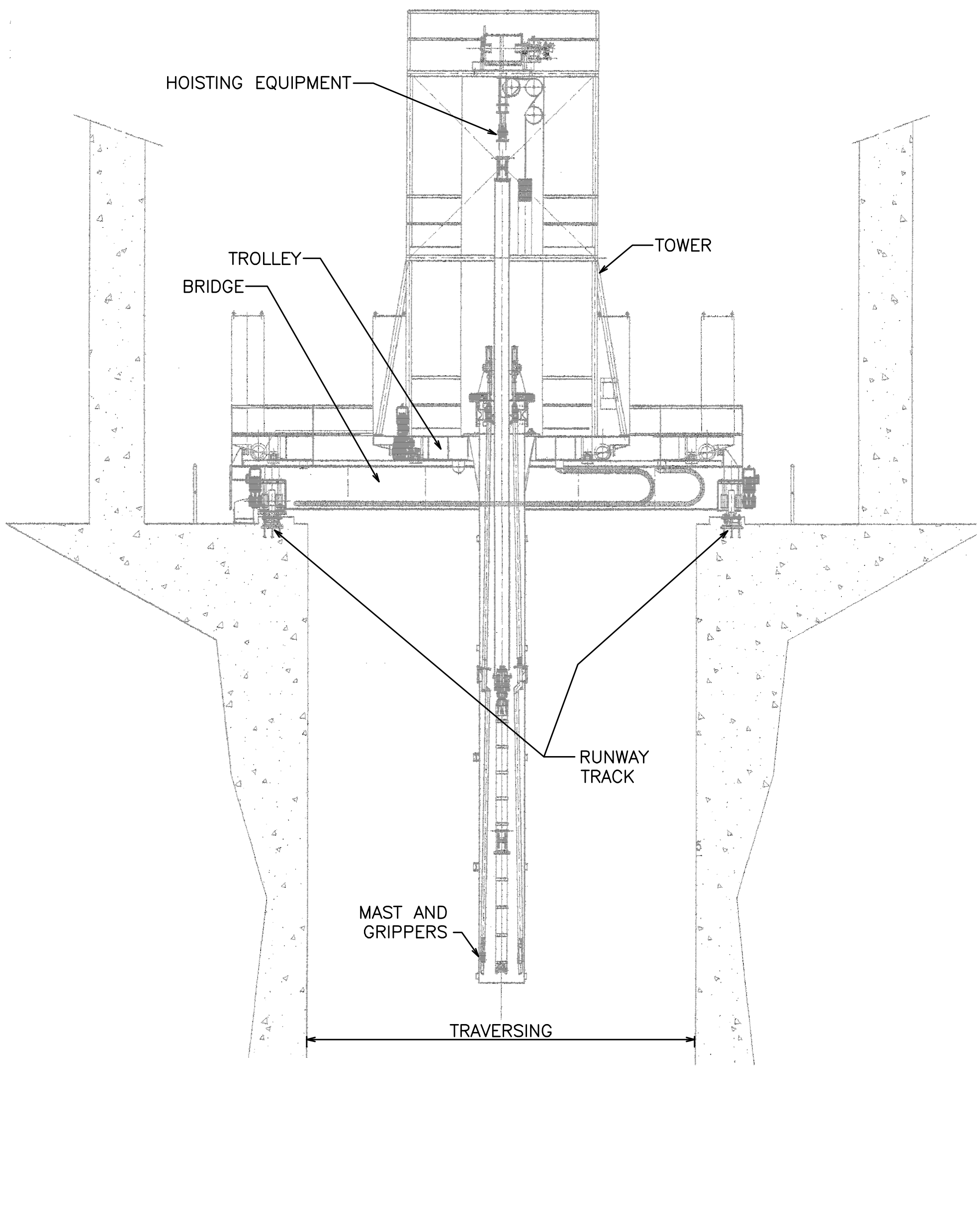

Figure 9.1.4-2—Fuel Assemblies Hoisting Mechanism

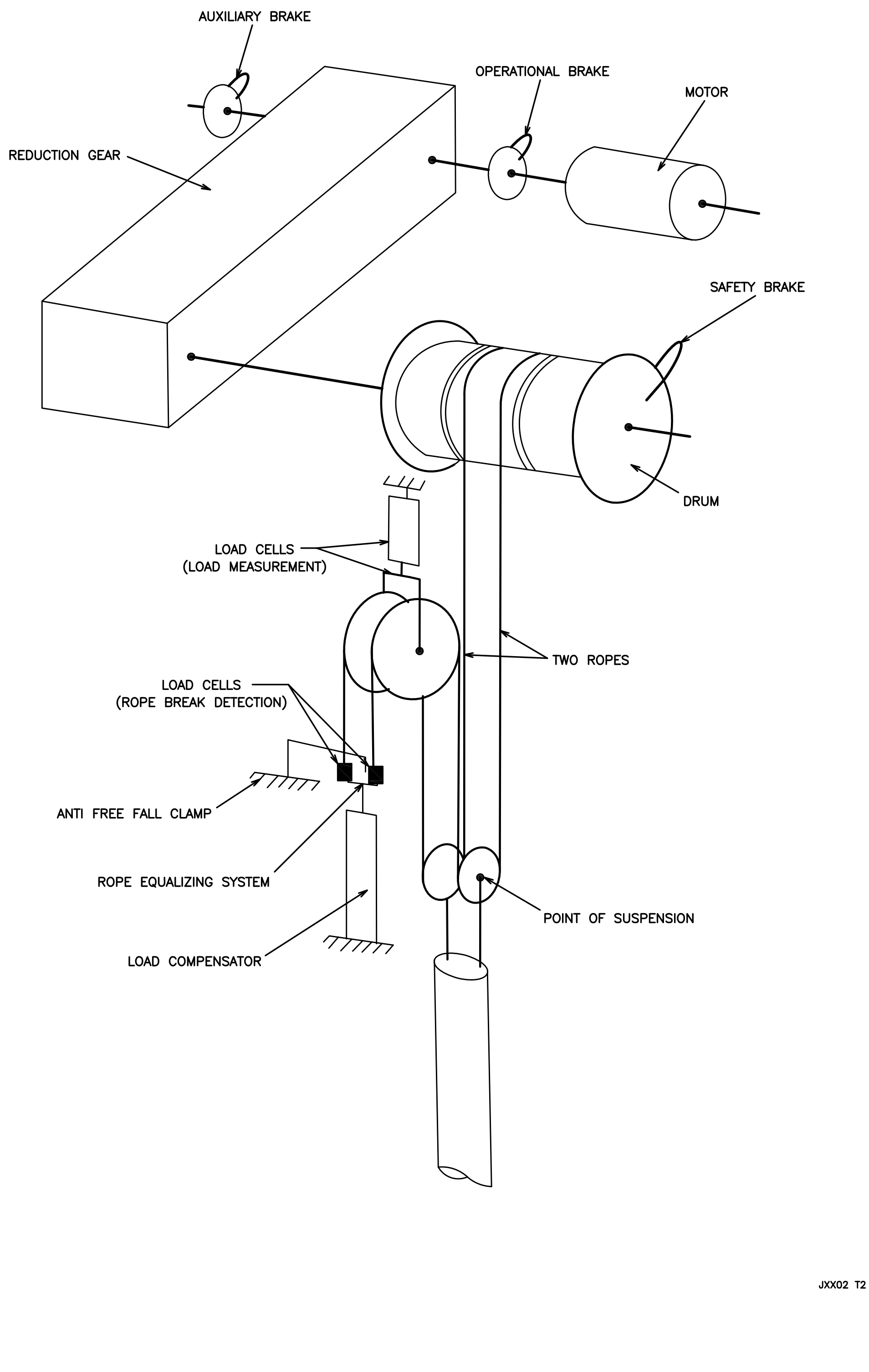

Figure 9.1.4-3—Fuel Transfer Tube Facility, Reactor Building

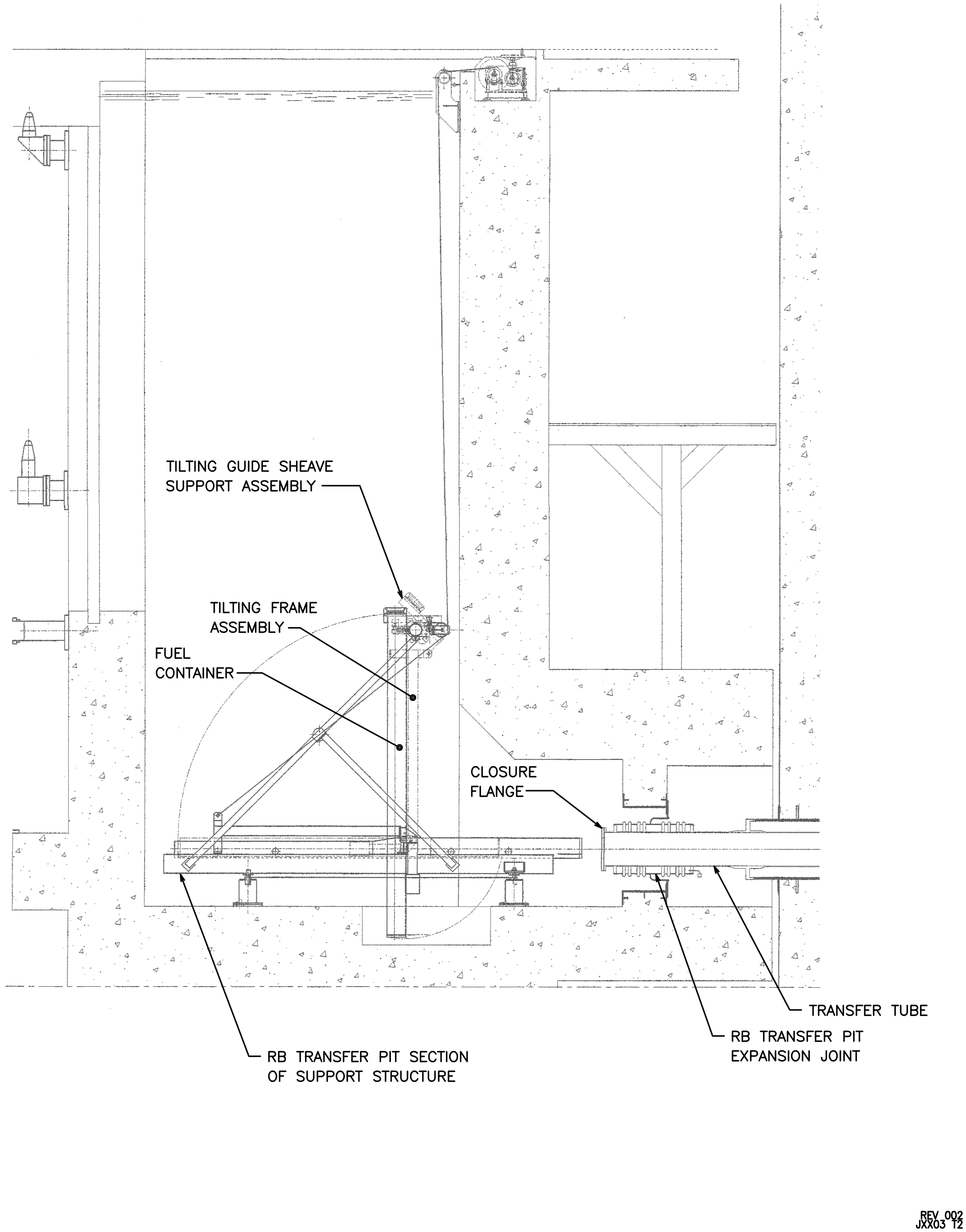

Figure 9.1.4-4—Fuel Transfer Tube Facility, Fuel Building

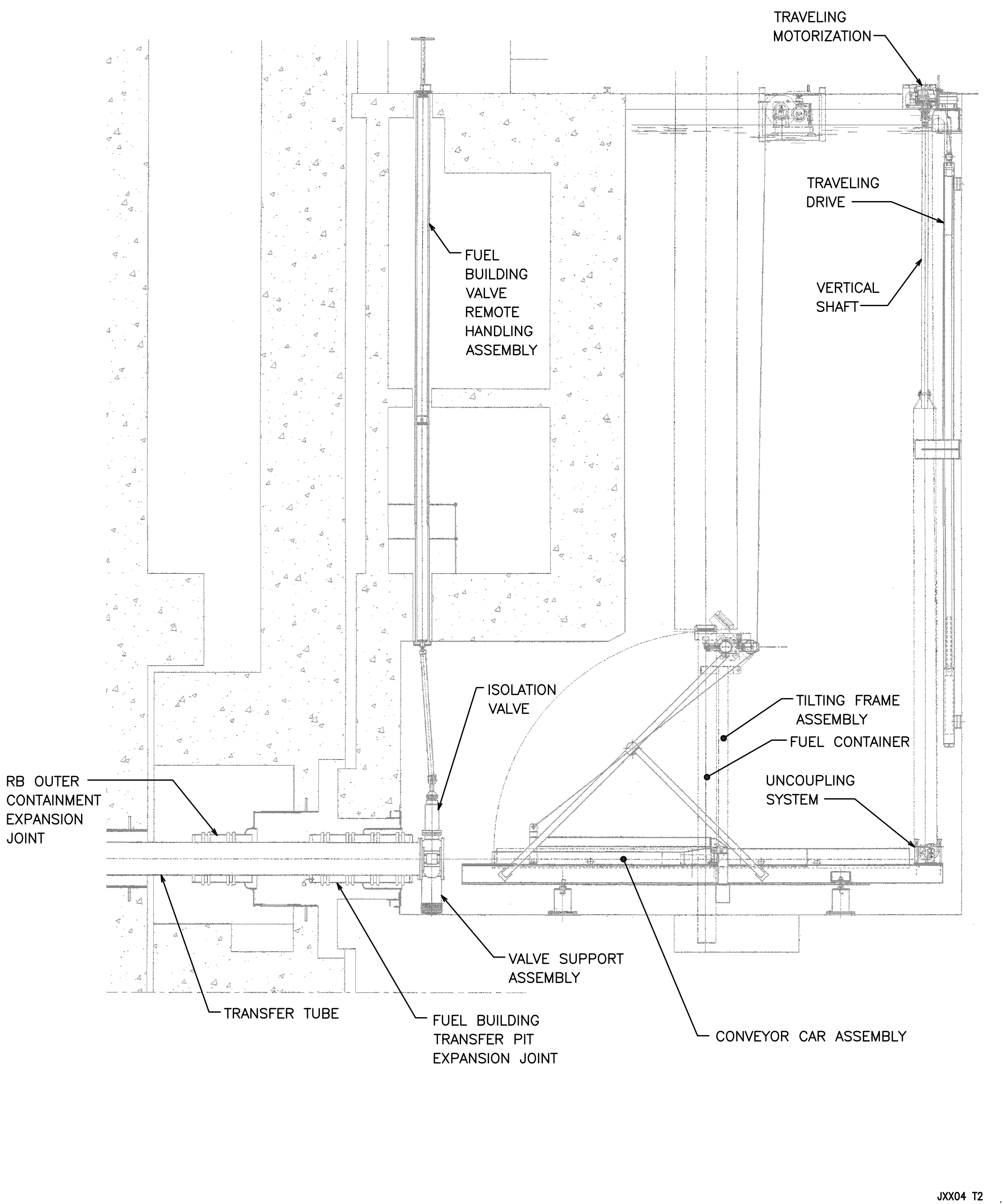

Figure 9.1.4-5—New Fuel Elevator

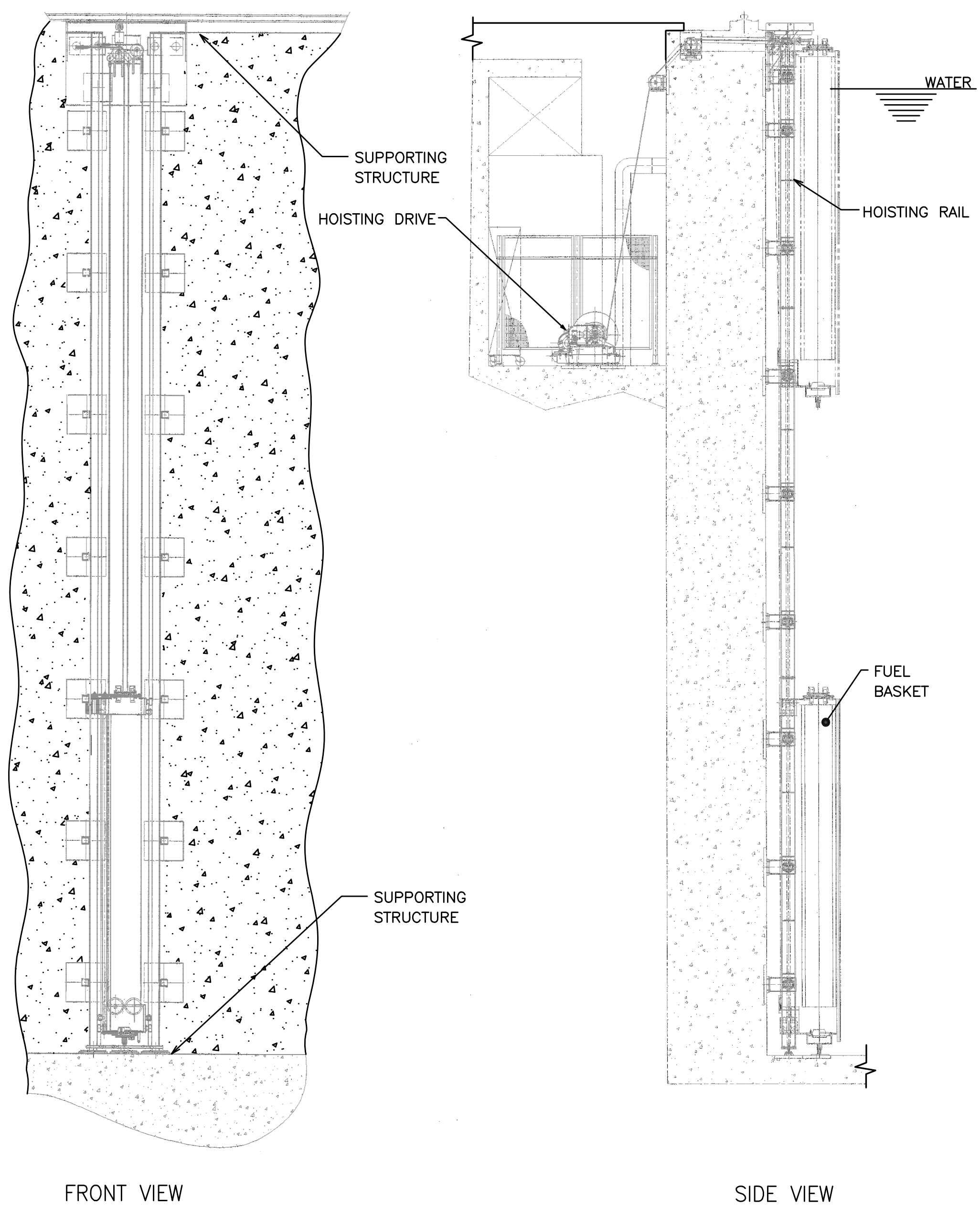

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Figure 9.1.4-6—Spent Fuel Machine

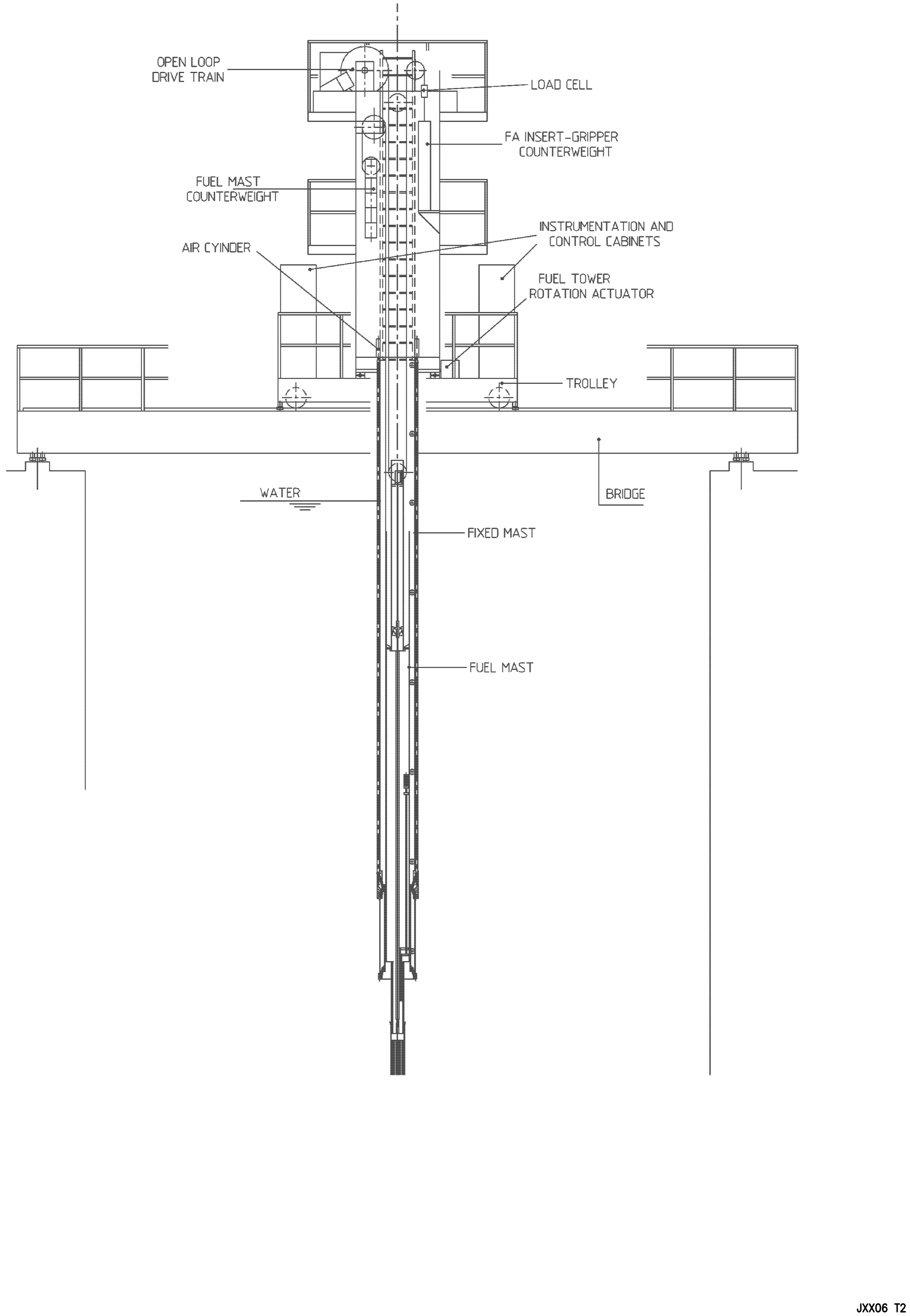

Figure 9.1.4-7—Figure Deleted

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