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TECHNICAL EVALUATION REPORT

CONTROL OF HEAVY LOADS (C-10)

TENNESSEE VALLEY AUTHORITY
BROWNS FERRY NUCLEAR PLANT

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FOREWORD

This Technical Evaluation Report was prepared by Franklin Research Center under a contract with the U.S. Nuclear Regulatory Commission (Office of Nuclear Reactor Regulation, Division of Operating Reactors) for technical assistance in support of NRC operating reactor licensing actions. The technical evaluation was conducted in accordance with criteria established by the NRC.

Mr. I. H. Sargent contributed to the technical preparation of this report through a subcontract with WESTEC Services, Inc.

1. INTRODUCTION

1.1 GENERIC ISSUE BACKGROUND

In order to ensure adequate safety for fuel storage and handling systems that can cause a direct or indirect release of radioactivity, the NRC has established guidelines for design and manufacture of single-failure-proof cranes. These criteria were originally stated in Regulatory Guide 1.13, "Spent Fuel Storage Facility Design Basis" [1]. As a consequence of this regulatory guide, a series of standards were issued (including Regulatory Guide 1.104 [2] and Branch Technical Position APCSB 9-1 [3]) which further defined single-failure-proof crane criteria and identified acceptable alternatives for existing handling systems to comply with staff requirements. NUREG-0554 [4], "Single-Failure-Proof Cranes for Nuclear Power Plants," consolidated these various documents into one standard for evaluation of fuel handling systems. The criteria of NUREG-0554 provided the basis for NUREG-0612 [5], "Control of Heavy Loads at Nuclear Power Plants," which in turn provided equivalent alternative designs or interim measures for cranes manufactured and in use before implementation of NUREG-0554.

1.2 SPECIFIC ISSUE BACKGROUND

In the initial design of the Browns Ferry reactor building crane, the Tennessee Valley Authority (TVA) recognized the need for material handling safety and attempted to comply with then-issued standards to provide a single-failure-proof crane. Initial compliance with the staff guidelines established in BTP APCSB 9-1 was noted in the Licensee's June 30, 1976 letter [6] to the NRC. On August 4, 1980 [7], the NRC requested additional information from TVA to determine the extent of compliance with NUREG-0554. In a letter dated February 10, 1981 [8], TVA provided additional information concerning the design of these cranes, the results of additional crane analysis, and several modifications and tests proposed to meet the intent of NUREG-0554. This response was modified by subsequent transmittals dated March 11 and May 27, 1981 [9,10].

1.3 PURPOSE OF THE REVIEW

This review provides a basis for determining if the reactor building cranes at the Browns Ferry plant, upon completion of the modifications and testing proposed in Reference 9, satisfy the requirements for a single-failure-proof crane considering the criteria of NUREG-0554.

2. NRC CRITERIA

Current criteria for a single-failure-proof crane are provided in NUREG-0554. This document, supplemented by exceptions identified in NUREG-0612, Appendix C, for cranes constructed prior to the publication of NUREG-0554, forms the basis for this evaluation.

3. TECHNICAL EVALUATION

3.1 SPECIFIC ISSUES

Table 3.1 provides a detailed comparison of the Browns Ferry cranes, based on Licensee-provided information, with the criteria of NUREG-0554. An assessment of the extent of compliance for each specific criterion is provided supplemented by explanatory comments where appropriate.

The following notations are used to specify the extent of compliance indicating that the specific requirement of NUREG-0554:

[C] - has been complied with by the Licensee.

[T] - has been complied with by actions or an adequate design which are technically equivalent to the specified requirement.

[P] - has been partially complied with by the Licensee with the exception of those items noted.

[N] - has not been complied with by the Licensee.

[R] - Will be complied with upon completion of tests or modifications proposed by the Licensee.

Table 3.1 Single-Failure-Proof Crane Compliance Matrix

NUREG-0554 Requirement	Licensee's Response	Evaluation/Comment
2. Specification and Design Criteria		
2.1 Construction and Operating Periods		
1. When an overhead crane handling system will be used during the plant construction phase, separate performance specifications may be needed to reflect the duty cycles and loading requirements for each service.	Performance specifications for construction and plant use were identical.	[C] - Separate performance specifications are not required by the Licensee since the requirements for construction and plant use are identical.
2. The allowable design stress limits for the crane intended for plant operation should be those indicated in Table 3.3.3.1.3-1 of CMAA Specification #70 and reflecting the appropriate duty cycle in CMAA Specification #70.	A direct comparison of the allowable stresses provided in Tables 12.2-14 and 12.2-15 of the Browns Ferry FSAR with those given in CMAA 70-1975 cannot be made since they are interrelated through actual design factors such as the the ratio of the trolley weight to hook load. In order to assess the degree to which actual design stresses comply with the allowable stresses given in CMAA 70-1975, the crane was reanalyzed using the load combination given in CMAA 70-1975. The results of this analysis as shown below indicate that the CMAA 70-1975 allowable stresses are not exceeded for the structures in question.	[T]

	Maximum Actual Stress (ksi)	CMAA Allowable Stress (ksi)
Box girder:		
tension	12.2	17.6
compression	11.6	17.6
shear	2.6	13.2
End trucks:		
tension	7.8	14.4
compression	7.8	14.4
shear	3.2	10.8
Trolley frame:		
tension	13.5	14.4
compression	13.5	14.4
shear	1.9	10.8

Table 3.1 (Cont.)

NUREG-0554 Requirement	Licensee's Response	Evaluation/Comment
3. The sum total of simultaneously applied loads (static and dynamic) should not result in stress levels causing permanent deformation other than localized strain concentration.		[C] - Acceptable based upon FSAR Table 12.2-14 and 12.2-15.
4. The effects of cyclic loading induced by jogging or plugging an uncompensated hoist control system should be included in the design specification.	The electrical features designed into the General Electric stepless DC adjustable voltage drive systems for the main hoist, auxiliary hoist, bridge, and trolley effectively ensure smooth acceleration and deceleration regardless of the operator's movement of the controls. The major features involved in this acceleration control process are: a. Timed acceleration - The rate of change of the speed reference voltage is limited through a resistor-capacitor network. This softens any abrupt control movement by the operator. b. Armature voltage sensing - When a stop is made by returning the control to the "off" position, an armature voltage relay will prevent the brake from setting until the motor back emf and hence speed drops to a preset level. Initial slowing is provided by the much smother regenerative braking feature whereby the kinetic energy of the moving parts is converted to electrical energy and pumped back into the electrical system. c. Current limit - The static SCR voltage regulators incorporate current limiting circuits set at the following percentages of rated armature currents; main and auxiliary hoists 200 percent, bridge and trolley 150 percent. This limits the torque available for acceleration and thereby smooths speed changes.	[T] - The Licensee's drive system is a compensated stepless DC adjustable voltage drive system. This system eliminates the effects of cyclic loading through use of acceleration control. Therefore, no design specification is required and the Licensee complies with this requirement.

Table 3.1 (Cont.)

NUREG-0554 Requirement	Licensee's Response	Evaluation/Comment
	d. Static reversing - Reversing of all drives is accomplished through static SCR voltage regulators which effect a smooth voltage reversal instead of the abrupt reversal found in magnetic contactor controls. This eliminates the possibility of plugging and jogging in the usual sense of applying full power (forward or reverse) to promote limited movement. e. Load float - Each hoist is provided with a load float feature actuated from a thumb switch on the master switch control. Operation of this switch holds the brake off independent of the hoist or lower switch and limits the speed reference voltage to 25 percent of its full value. This allows a load to be accurately positioned (up and/ or down) without the shock producing effect of the brakes setting and releasing as the load is maneuvered. f. Drift point - The bridge and trolley drives are provided with a drift point feature which operates essentially the same as described under 2(e) above for "Load float." g. Slow-down limit switches - The bridge and trolley are provided with a set of limit switches which are actuated before reaching the maximum travel limit switches. Actuation of these switches automatically limits the speed reference voltage to 25 percent of its full value. This provides an automatic slowdown feature which limits deceleration produced by actuation of maximum travel limit switches or contact of bumpers with their stops. The hoist brakes are electrically connected so as to release only when the motor is energized. From a stopped condition, the hoist brakes are actually prevented from releasing until the motor is producing torque. This is accomplished through a torque proving relay which senses armature loop current and delays release of the brakes until a preset level of current is reached. This prevents shock producing load sag on initiation of the hoisting motion.	

Table 3.1 (Cont.)

NUREG-0554 Requirement	Licensee's Response	Evaluation/Comment
	The bridge and trolley brakes are electrically connected so as to release only when the motor is energized for normal operation. It is possible to release these brakes by actuating the "drift point" switch with the motor deenergized. This is not regarded as a safety hazard since no movement of the load is involved in the brake release.	
2.2 Maximum Critical Load		
1. The crane should be designed to handle the maximum critical load (MCL) that will be imposed.	The maximum critical load (MCL) which will be imposed on the crane is the reactor vessel head which with its lifting device will weigh 105 tons.	[C]
2. A slightly higher design load should be selected for component parts that are subject to degradation due to wear and exposure. An increase of approximately 15% of the design load for these component parts would be a reasonable margin.	The design rated load (DRL) to which the crane will be maintained and tested is 125 tons. The MCL, which is actually the maximum working load (MWL), is 84 percent of the DRL. This margin of capacity provides for any degradation of components which might not be detected through our preventive maintenance program. Devices which limit the hoist motor torque output and thus the load on mechanical components are: a. Inverse time delay overload relay on MG set AC motor - This relay is set at 150 percent of full load current and limits sustained overloads. b. Hoist motor current limit circuit - This electronic torque limit is set at 200 percent of full load current and represents the upper limit of torque production of the motor. c. Instantaneous overcurrent relay - This relay is set to trip at 250 percent of full load current for the hoist motor and serves as a back up to the current limit circuit described in (b).	[C]

Table 3.1 (Cont.)

NUREG-0554 Requirement	Licensee's Response	Evaluation/Comment
	A more direct and flexible system for limiting the load on the crane is in the process of design at this time. This consists of a load cell load detector with digital readouts and variable trip points. With this system a trip point may be selected slightly above the load to be lifted which if exceeded would stop the motor and set the brakes. This system will effectively limit the stress experienced by the hoisting system components and protect the load from load hang-up conditions.	
3. The MCL rating should be clearly marked on the crane.	Only one contractor name plate was provided, which states only the design rated load for the main and auxilary hoist. This is a 12-inch by 13-inch sign located near the center of the bridge.	[N] - MCL rating should be clearly marked on the crane.
4. The DRL rating should be marked on the crane separately from the MCL marking.		[C]
2.3 Operating Environment		
1. The operating environment, including maximum and minimum pressure, maximum rate of pressure increase, temperature, humidity, and emergency corrosive or hazardous conditions, should be specified for the crane and lifting fixtures.	The possibility of extensive surface condensation was provided for by cleaning, priming, and painting all structural insulation surfaces in an approved manner, using non-hygroscopic electrical insulation, plating critical mechanical parts and terminals of electrical devices, and installing motor space heaters.	[T]
For cranes inside the containment structure, the closed box sections of the crane structure should be vented to avoid collapse during containment pressurization. Drainage should be provided.	The crane is located in a nonpressure confining part of the reactor building. The girders were of a sealed design with no need for venting or drainage provisions (BWR).	[T] - Since the crane is limited to use outside of pressure boundaries, the Licensee technically complies with this requirement.
2.4 Material Properties		
1. The crane and lifting fixtures for crane already fabricated or operating may be subjected to a cold-proof test consisting of a single dummy load test as follows:	The cold-proof test of the crane and nondestructive examination of critical welds will be performed by NUC PR under the direction of EN DES. However, these activities must be scheduled at the convenience of other critical refuel floor activities.	[R] - The Licensee has indicated that a cold-proof test of the crane will be performed. Verification that all requirements of this item will be included as part of this test should be provided.

Table 3.1 (Cont.)

NUREG-0554 Requirement	Licensee's Response	Evaluation/Comment
a. Metal temperature of the structural members essential to the structural integrity of the crane handling system should be at below the minimum operating temperature.		
b. The corresponding dummy load should be equal to 1.25 times the MCL.		
c. The cold-proof test should be followed by a nondestructive examination of welds whose failure could result in the drop of a critical load.		
d. The nondestructive examination of critical areas should be repeated at 4-yr intervals or less.		
2. Cranes and lifting fixtures made of low-alloy steel such as ASTM A514 should be cold-proof tested in any case.	Cold-proof test of the crane and NDE of critical welds will be performed.	[R] - The Licensee has agreed to cold-proof test the crane.
3. Cast iron should not be used for load-bearing components.	Cast iron was not used for load-bearing components as required by NUREG-0554.	[C]
2.5 Seismic Design		
1. The crane should be designed and constructed in accordance with regulatory position 2 of Regulatory Guide 1.29.	The seismic analysis of the reactor building crane was performed by idealizing the crane as a lumped-mass mathematical model. The stiffness of the model is the stiffness of the crane girders. The trolley was assumed to be rigid and was idealized in the mathematical model as rigid links connecting the crane girders. The trolley was assumed to be pinned to the crane girders in order to maximize the inertial effects of the trolley. The maximum load on the crane during a seismic event was assumed to be 150 kips, which is 60 percent of the design rated load.	[C]

Table 3.1 (Cont.)

NUREG-0554 Requirement	Licensee's Response	Evaluation/Comment
	A modal analysis was performed for motion transverse to the crane girders. The analysis considered two cases of trolley position; one case for the trolley at the centerline of the girders and one for the trolley at the end. Seismic responses were calculated for each case by use of the response spectrum method of analysis. Acceleration response spectra at the elevation of the runway were taken from the seismic analysis of the reactor building and used as input to the mathematical model. A damping value of one percent of critical damping was used in the response analysis for both the operating base earthquake and design base earthquake events. In the both the longitudinal and vertical directions, the crane was designed for pseudostatic seismic loads caused by the zero period acceleration (ZPA) of the acceleration response spectrum at the evaluation of the crane runway. The seismic loads were combined on an absolute basis with other loads in the appropriate loading combinations. Seismic loads from only one horizontal direction at a time were considered to occur simultaneously with the vertical direction.	
2. The MCL plus operational and seismically induced pendulum and swinging load effects on the crane should be considered in the design of the trolley, and they should be added to the trolley weight for the design of the bridge.		[N] - The seismic analysis assumed only an underhook load of approximately 71% of MCL.
2.6 Lamellar Tearing		
1. All weld joints whose failure could result in the drop of a critical load should be nondestructively examined.	No nondestructive examination (NDE) of welds was made at the time of fabrication. Subsequent load testing at 125% of rated capacity has proved their soundness.	[P] - The Licensee has suggested that the 125% load test be substituted for nondestructive examination of load-bearing welds. Typically the soundness of critical welds is established on the basis of either a volumetric examination or a proof-test followed by a surface examination.

Table 3.1 (Cont.)

NUREG-0554 Requirement	Licensee's Response	Evaluation/Comment
2. If any of these weld joint geometries would be susceptible to lamellar tearing, the base metal at the joints should be nondestructively examined.	At the time of design and fabrication of the reactor building crane, lamellar tearing was not considered. A review of actual fabrication drawings indicates that structural and welding details were used which would neither be expected to cause nor be vulnerable to lamellar tearing. The design is such that tee and corner welded connections in the main structural members are loaded primarily in shear or compression and are made with fillet welds of 5/16-inch or smaller. There is no evidence or suggestion in available technical literature to indicate that welds of this size would induce sufficient shrinkage stress to create lamellar tearing.	[T] - The Licensee review of structural details provides an adequate basis for eliminating lamellar tearing as a significant potential contributor to structural failure.
2.7 Structural Fatigue		
1. A fatigue analysis should be considered for the critical load-bearing structures and components of the crane handling system. The cumulative fatigue usage factors should reflect effects of the cyclic loading from both the construction and operating periods.	The critical load bearing rotating parts listed below were analyzed for cumulative damage from fatigue. The endurance limit was taken as a conservative 40 percent of tensile strength. Since the maximum stress for each part is less than one-half the endurance limit, no fatigue damage is indicated.	[C] - The Licensee also states in the FSAR that "stresses in all structural and mechanical parts will be far below the endurance limits for infinite life of the various materials for both the rated crane capacity and the test load of 125% capacity. All loads to be handled are below rated capability. Therefore, stresses should never reach allowable working stresses. Loads on the structural parts will vary but will not reverse. The only critical parts with stress reversals will be the rotating parts, and these are provided with single failure protection. Since the crane is to operate under normal temperature conditions and since the stress levels are below the endurance limit for infinite life, testing of the crane to 125% of rated capacity provides reasonable as assurance that the crane will not fail while handling a spent fuel cask." The Licensee has also demonstrated that the maximum stress experienced by critical parts is less than 1/2 the endurance limit.

Part	Material	Maximum Stress (ksi)	Endurance Limit (ksi)
Drum	A36	10.9	23.2
Drum Shaft	4140	22.0	44.0
Ring Gear	4140	20.0	44.0
Pinion	4340	29.5	72.0
Pinion Gear Shaft	C1140	21.0	44.8

Table 3.1 (Cont.)

NUREG-0554 Requirement	Licensee's Response	Evaluation/Comment
2.8 Welding Procedures		
1. Preheat temperatures and postweld heat-treatment (stress relief) temperatures for all weldments should be specified in the weld procedure.	All welding was done in accordance with the AWS D1.1 Standard Code for Welding in Building Construction. All welds requiring preheat and post-heat were done by procedures which specified the required temperature.	[C]
2. Welds described in the recommendations of Section 2.6 should be postweld heat treated in accordance with Subarticle 3.9 of AWS D1.1, "Structural Welding Code."	The welds whose failure could result in the drop of a critical load were not postweld heat treated. The only examination made for these welds was visual. The 125 percent overload test and conservative stress levels were used to ensure adequate design.	[T] - Although the 125 percent overload test did not provide the stress relief inherent in postweld heat treatments, the fact that the crane is made of carbon steel, has been installed in a moderate environment, and has been operated for about 10 years supports the conclusion that little can be gained in the way of further residual stress relief.
3. Safety Features		
3.1 General		
3.2 Auxiliary Systems		
1. All auxiliary hoisting systems of the main crane handling system that are employed to lift or assist in handling critical loads should be single failure proof.	The auxiliary hoist is used in handling some critical loads. The maximum criteria load (MCL) handled by the auxiliary hoist is limited by the Browns Ferry Technical Specification to 1,000 pounds over spent fuel assemblies in the spent fuel storage pool. The design rated load (DRL) and maximum working load (MWL) is 5 tons. The auxiliary hoist is designed as a single-failure-proof lifting system except for attachment points. The following features are included: a. There are two independent hoisting ropes each terminating at a crosshead at the hook (one-part double reeving). b. The drum is provided with structural devices to limit the drop and prevent disengagement from braking system should the drum, shaft, or bearings fail.	[T] - The Licensee has indicated that several additional features contributing to preventing load drop following a single failure have been applied to the auxiliary hoists. In addition, the Licensee has committed to limiting loads carried over the spent fuel pool on this hoist to less than 1,000 lb.

Table 3.1 (Cont.)

NUREG-0554 Requirement	Licensee's Response	Evaluation/Comment
	c. The hoist is equipped with two spring set electrically released brakes connected to the drum through mechanically separate gear trains. Each brake is sized for 125 percent of the full load motor torque at the point of application. d. Two independent overhoist limit switches of different design are provided to prevent "two blocking."	
2. Auxiliary systems or dual components should be provided for the main hoisting mechanism so that, in case of subsystem or component failure, the load will be retained and held in a stable or immobile safe position.	See FSAR paragraph 12.2.2.5.2 for details of compliance.	[C] - Licensee responses contained in FSAR paragraph 12.2.2.5.2 and responses to items 3.3, 4.1, 4.2, 4.3, 4.5 and 4.7 demonstrate compliance for the auxiliary systems and dual components.
3.3 Electric Control Systems		
1. The automatic controls and limiting devices should be designed so that, when disorders due to inadvertent operator action, component malfunction, or disarrangement of subsystem control functions occur singly or in combination during the load handling, and assuming no components have failed in any subsystems, these disorders will not prevent the handling system from stopping and holding the load.	See FSAR paragraph 12.2.2.5.2 for details of compliance.	[T] - Although the Licensee has not explicitly stated compliance with this requirement, it is implicit in the response to APCSB 9-1 and in the FSAR that the automatic controls and limiting devices are properly designed.
2. An emergency stop button should be added at the control station to stop all motion.	All limit switches, overspeed switches, overcurrent relays, etc., are provided as safety backup devices and are not intended for normal operating use.	[T] - FSAR Sections 12.2.2.5.2.j & k state that the crane is provided with a manual (-magnetic) main power supply contactor that can be operated manually from the cab, by a pushbutton in the cab, and by pushbutton on the pendant control. This contactor controls the power supply motions. for all motions. A second and separate contactor, or circuit breaker, is provided in the power supply to the main crane feed rails, which can be operated by three emergency stop pushbuttons on the operating floor (elev. 664' 0").

Table 3.1 (Cont.)

NUREG-0554 Requirement	Licensee's Response	Evaluation/Comment
3.4 Emergency Repairs		
1. Means should be provided for using the devices required in repairing, adjusting, or replacing the failed component(s) or subsystem(s) when failure of an active component or subsystem has occurred and the load is supported and retained in the safe position with the handling system immobile.	An extensive inventory of spare parts and standard plant maintenance equipment will allow in-place repairs to be made of any credible component failure. Separate Licensee responses (see 4.9-4 and 5.1-5 following) indicate that manual operation of brakes is available.	[P] - The intent of the NUREG is to provide a means for emergency repair, not just to have an "extensive spare parts inventory." As an alternative to repairing in place, means may be provided for safely moving the immobilized handling system with load to a safe laydown area that has been designed to accept the load while repairs are being made.
4. Hoisting Machinery		
4.1 Reeving System		
1. Design of the rope reeving system(s) should be dual with each system providing separately the load balance on the head and load blocks through the configuration of ropes and rope equalizer(s).	Both the head and load block have physically separate sheave systems for the two ropes. A load balance is thus established on that portion of the block associated with the unfailed rope system.	[T] - The rope reeving system is redundant and meets the intent of NUREG-0554. Refer to FSAR Figure 12.2-2 12.2-22d.
2. The maximum load (including static and inertia forces) on each individual wire rope in the dual reeving system with the MCL attached should not exceed 10% of the manufacturer's published breaking strength.	For a MCL of 105 tons for the main hoist the maximum dynamic rope stress is 15.14 percent of the breaking strength. This is with 15 percent impact. The 15.6 percent given in response to to APCSB 9-1 did not include impact. For a MCL of 1,000 pounds for the auxiliary hoist the maximum dynamic rope stress is 2.08 percent of the breaking strength.	[N] - The maximum dynamic rope stress identified by the Licensee exceeds the maximum allowed by NUREG-0554.
3. The maximum fleet angle from drum to lead sheave in the load block or between individual sheaves should not exceed 0.061 rad (3 1/2°) at any point during hoisting except that for the last 1 meter of maximum lift elevation the fleet angle may increase slightly. The use of reverse bends for running wire ropes should be limited.	The maximum fleet angle from drum to lead sheave is 2.86°. In the high hook position the maximum fleet angle between sheaves is 4.15 degrees. This angle decreases to the suggested 1.5 degrees within 8 feet 3 inches of hook travel. A minimum amount of handling is done near the high hook position. No reverse bends are used in this reeving system.	[T] - The Licensee's response is acceptable. The Licensee has indicated that the maximum fleet angle between sheaves is 4.15° and decreases to 1.5° within 8 feet 3 inches. The NUREG limit is 3.5° (3 ft). The distance associated with 3.5° equals 3.5' or 1.06 meters. Therefore, the intent of NUREG-0554 is satisfied.

Table 3.1 (Cont.)

NUREG-0554 Requirement	Licensee's Response	Evaluation/Comment
4. The equalizer for stretch and load on the rope reeving system may be of either beam or sheave type or combinations thereof. A dual rope reeving system with individual attaching points and means for balancing or distributing the load between the two operating rope reeving systems will permit either rope system to hold the critical load and transfer the critical load without excessive shock in the case of failure of the other rope system.	The equalizing device is a double-ended hydraulic cylinder as shown in Figure 12.2-22d of the FSAR. This is a modified beam type with internal damping. The equalization rate is limited to 6 inches per minute by a velocity fuse arrangement in the case of a rope break.	[C] - The equalizing device shown in FSAR Figure 12.2-22d satisfies the NUREG requirement.
5. The pitch diameter of running sheaves and drums should be selected in accordance with the recommendations of CMAA Specification #70.	The running sheaves are 27.3 and 24.1 times the rope diameter and the equalizing sheaves are 20.1 times the rope diameter. This is in accordance with CMAA Spec #70 which allows ratios of 24 to 1 and 12 to 1, respectively. The ratio of the main hoist drum diameter to the rope diameter is 49.6:1. The ratio of the auxiliary hoist drum diameter to the rope diameter is 38.4:1. These exceed the requirements of the CMAA 70.	[C]
6. The dual reeving system may be a single rope from each end of a drum terminating at one of the blocks or equalizer with provisions for equalizing beam-type load and rope stretch, with each rope designed for the total load. Alternately, a 2-rope system may be used from each drum or separate drums using a sheave equalizer or beam equalizer or any other combination that provides two separate and complete reeving systems.	The redundant reeving system is shown in Figure 12.2-22d of the FSAR.	[C]

NUREG-0554 Requirement	Licensee's Response	Evaluation/Comment
4.2 Drum Support		
1. The load hoisting drum on the trolley should be provided with structural and mechanical safety devices to limit the drop of the drum and thereby prevent it from disengaging from its holding brake system if the drum shaft or bearings were to fail or fracture.	See paragraph 12.2.2.5.2.c and 12.2.2.5.2.d of the FSAR for statement of compliance.	[T] - Paragraph 12.2.2.5.2.c of the FSAR states that safety plates are provided at each end and at the center of the drum. The Licensee claims that these plates will limit the drum movement in the horizontal or vertical directions to 1/4-inch. Although no positive statement has been made that these plates prevent the drum from disengaging from its holding brake system, it is judged that a 1/4-inch limit is acceptable and satisfies the intent of the NUREG.
4.3 Head and Load Blocks		
1. The head and load blocks should be designed to maintain a vertical load balance about the center of lift from load block through head block and have a reeving system of dual design.	The reeving system for the main hoist shown in Figure 12.2-22d of the FSAR is dual and maintains vertical balance and alignment with both ropes intact.	[C]
2. The load-block assembly should be provided with two load-attaching points (hooks or other means) so designed that each attaching point will be able to support a load of three times the load (static and dynamic) being handled without permanent deformation of any part of the load-block assembly other than localized strain concentration in areas for which additional material has been provided for wear.	The spent fuel cask is the only load for which dual attaching points from the lower block are provided. The load-block assembly illustrated in Figure 12.2-22d is schematic to the extent that the safety cables are actually safety links that were made from alloy steel bars (ASTM A322). These links can support three times the weight of the critical load they handle. These links were designed with a safety factor of 5.1 based on the critical load they handle. The links are not loaded during normal cask handling but are pinned to the redundant lifting beam. With the pin connection the impact would be negligible in case of a hook failure. The redundant links were tested to 127 percent of their design rated load. Dual attaching points from the lower block are not provided for any other critical loads and the safety factor for the attaching slings varies from 4.86 to 7.13. There are critical loads that are handled that are above 10 percent of the load-carrying capability of the hook.	[N] - The Licensee does not comply with this requirement in that the load block assembly has only one attachment point (i.e., lower block hook). Only one load (spent fuel cask) has been provided with dual attachment points. In lieu of redundant attachment points, the staff has accepted (NUREG-0612, Appendix C) a single attachment point if the safety factor is increased to 10:1 to compensate for loss of the single-failure-proof feature.

Table 3.1 (Cont.)

NUREG-0554 Requirement	Licensee's Response	Evaluation/Comment
3. The individual components of the vertical hoisting system components, which include the head block, rope reeving system, load block, and dual load-attaching device, should each be designed to support a static load of 200% of the MCL.	As shown in Table 12.2-15 of the FSAR, all mechanical parts are designed with a safety factor of 5 under normal conditions.	[C] - The Licensee's response is acceptable because the vertical hoisting system is designed to handle greater than 5 times the MCL.
4. A 200% static-type load test should be performed for each load-attaching hook. Measurements of the geometric configuration of the hooks should be made before and after the test and should be followed by a nondestructive examination that should consist of volumetric and surface examinations to verify the soundness of fabrication and ensure the integrity of the hooks. The load blocks should be nondestructively examined by surface and volumetric techniques.	The hooks were proof tested to 200% rated capacity with subsequent magnetic particle examination prior to installation. After installation, a complete 125% load test was performed on the crane. No static load tests were performed on the reeving system at the manufacturer's plant. The load blocks were not nondestructively examined by surface and volumetric techniques.	[P] - The Licensee has indicated that the hook has been static load tested to 200% and then magnetic particle tested. The Licensee has not stated that the safety lines (used in lieu of redundant hook) have been static load tested to 200%. Surface and volumetric NDE of the load blocks have not been performed.
4.4 Hoisting Speed		
1. Maximum hoisting speed for the critical load should be limited to that given in the "slow" column of Figure 70-6 of CMAA Spec # 70. Conservative industry practice limits the rope line speed to 1/4 m/s (50 fpm) at the drum.	The maximum full load hoisting speeds are: main hook 5.33 fpm and auxiliary hook 22.6 fpm. Empty hook speeds of 275% of these values are provided by the tapered speed load characteristics of the GE maxspeed drives. The line speeds for full load hoisting are: main hoist 32 fpm and auxiliary hoist 22.6 fpm. Each of these speeds can increase by a factor of 2.75 with empty hook conditions.	[C] - The Licensee's maximum full load hoisting speed of 5.33 fpm meets the intent of the NUREG and only represents a 7% decrease in reaction time (time for corrective action for hoisting movement and the potential behavior of failed rope). The line speed is below that recommended during handling of MCL (i.e., 32 fpm versus 50 fpm recommended). Therefore, the Licensee's response is considered adequate to satisfy the NUREG-0554 requirement.
4.5 Design Against Two-Blocking		
1. The mechanical and structural components of the complete hoisting system should have the required strength to resist failure if the hoisting system should "two-block" or if "load hangup" should occur during hoisting.		The Licensee has opted for the alternatives provided in NUREG-0554 (see 4.5-2 below).

Table 3.1 (Cont.)

NUREG-0554 Requirement	Licensee's Response	Evaluation/Comment
2. As an alternative, the protective control system to prevent the hoisting system from two blocking should include as a minimum: o Two independent travel-limit devices of different designs and activated by separate mechanical means. o These devices should de-energize the hoist drive motor and main power supply.	Redundant limit switches of different designs are provided to stop the upward motion of the hook in the event of operator negligence. The travel limit switches are inspected and tested in accordance with ANSI B30.2.0-1976. Frequent and periodic inspection requirements have been imposed through NUC PR Division Procedures Manual N74M15.	[P] - The Licensee has indicated that redundant limit switches of different design are provided to stop the upward motion of the hook to prevent "two blocking." No verification has been made that the limit switches are activated by separate mechanical means or that they operate to deenergize the hoist drive motor and main power supply.
3. The protective control system for load hangup, a part of the overload protection system, should consist of load cell systems in the drive train or motor-current-sensing devices or mechanical load-limiting devices.	Load hangup is conservatively provided for by designing for 275% full load motor torque at stall while the actual value is 200 percent. Concerning the testing of the current-limiting device on the hoist motor, the current limit should be set at 200 percent current rating; this value should be verified on the hoist regulator. The instantaneous overcurrent relays and the overload relays should also be tested. NUC PR will revise the associated electrical maintenance instructions to include these tests.	[T] - With respect to load hangup, the Licensee in FSAR Paragraph 12.2.2.5.2 has indicated that the torque of all motors is limited by the current-limiting device to 200% rated for the hoists. In addition, overload protection is by instantaneous overcurrent relays on the dc motors set at about 250% rated current and by inverse time delay overload devices on the ac motors of the m-g set to trip at 150% full load current. Taking into consideration that the mechanical and structural parts were designed to 275% full load motor torque under stall conditions, the NUREG-0554 requirement is satisfied.
4. The mechanical holding brakes and their controls should include the capability to withstand the maximum torque of the driving motor if a malfunction occurs and power to the driving motor cannot be shut off.		[C]
5. The auxiliary hoist should be equipped with two independent travel-limit switches to prevent two-blocking.	The auxiliary handling system has part direct lift or whip style reeving that requires no lower or upper block. This system is provided with two up-travel limit switches to stop the hoist, set the brakes, and prevent hook over travel.	[T]

Table 3.1 (Cont.)

NUREG-0554 Requirement	Licensee's Response	Evaluation/Comment
4.6 Lifting Devices		
1. Lifting devices should be conservatively designed with a dual or auxiliary device or combination thereof. Each device should be designed or selected to support a load of three times the load (static and dynamic) being handled without permanent deformation.	Several slings are provided for handling various covers and shield plugs. The minimum safety factor for these slings is 4.86 based on the actual load to be lifted. Redundant design was not used since none of the loads using slings are handled over the open reactor vessel.	Information provided by the Licensee is insufficient for an evaluation in this area. No information has been provided concerning special lifting devices other than the reactor pressure vessel head strongback. In the latter case the fact that this device has a "factor of safety of 4 based on rated capacity" does not address the issue of design with respect to material yield stress or permanent deformation.
	There are two lifting devices that may be used with the reactor building crane over an open reactor pressure vessel. These devices are the dryer-separator sling and the reactor pressure vessel head strongback. The dryer-separator sling has a safety factor of 5.55 based on rated capacity. The reactor pressure vessel head strong-back has a safety factor of 4 based on rated capacity. Both devices have been tested to 125% of their rated capacity.	Information provided concerning slings is also inadequate. The fact that slings are not used over the open reactor vessel is not sufficient justification for a lack of a "dual or auxiliary device" since the requirements of NUREG-0554 are based on loads lifted over objects other than the reactor vessel (e.g., spent fuel in the fuel pool). Proof testing of slings in accordance with ANSI B30.9 (physical testing of a sling at twice rated capacity) does not address the question of design.
	All special lifting devices used with this crane were purchased on the NSSS contract; therefore, they will have to be analyzed by the General Electric Company to determine conformance with ANSI N14.6-1978.	The issue of design requirements for slings and special lifting devices is addressed in more detail in the guidelines of NUREG-0612. This issue should be separated from the basic question of single-failure-proof crane design.
	All slings used on the refuel floor have been proof-load tested as specified in ANSI B30.9-1971. Some slings used on the refuel floor are not tagged for intended use.	
4.7 Wire Rope Protection		
1. If sideldads cannot be avoided, the reeving system should be equipped with a guard that would keep the wire rope properly located in the grooves on the drum.	Both main and auxiliary hoist drums are provided with guards to prevent the hoisting ropes from leaving the grooves on the drum.	[C]

Table 3.1 (Cont.)

NUREG-0554 Requirement	Licensee's Response	Evaluation/Comment
4.8 Machinery Alignment		
1. Where gear trains are interposed between the holding brakes and the hoisting drum, these gear trains should be single failure proof and should be of dual design.		[C] - Review of Figure 12.2-22d of the FSAR shows that the gear trains are interposed between the holding brakes and the hoisting drums. FSAR paragraph 12.2.2.5.2d describes these gears as two separate gearing systems, each with its own spring-set electrically released brake. Each gearing system consists of a ring gear and pinion mounted at one end of the drum and a gear reducer. Therefore, the design is single failure proof and satisfies the NUREG requirement.
4.9 Hoist Braking System		
1. The minimum hoisting braking system should include one power control braking system (not mechanical or drag brake type) and two holding brakes. The holding brakes should be applied when power is off and should be automatically applied on overspeed to the full holding position if a malfunction occurs. Each holding brake should have a torque rating not less than 125% of the full-load hoisting torque at point of application.	All aspects of these criteria are complied with.	[C] - The Licensee has indicated that all aspects of the criteria are complied with. Documentation of the hoisting braking system in the FSAR indicates the following. 1. From paragraph 12.2.2.5.2.d of FSAR - The (hoist holding) brake has sufficient torque capacity to stop and hold a rated crane capacity load lowering at 125% of rated top speed. 2. From paragraph 12.2.2.5.2.i of FSAR - All motions are provided by dc motors driven from m-g sets with regenerative braking under normal operation. Emergency automatic dynamic braking provides controlled lowering of the load upon loss of electrical power together with failure of both brakes to set. 3. From paragraph 12.2.2.5.2.r of FSAR - A mechanical overspeed switch is provided on the main and auxiliary hoist drive motors to trip at 125% of top rated speed in either direction to stop the hoist motor and set the holding brakes on the drum.

Table 3.1 (Cont.)

NUREG-0554 Requirement	Licensee's Response	Evaluation/Comment
2. The minimum number of braking systems that should be operable for emergency lowering after a single brake failure should be two holding brakes for stopping and controlling drum rotation.	See 4.9-1 above.	[C] - Single failure of the regenerative braking system will result in two holding brakes for stopping and controlling the load.
3. The holding brake system should be single failure proof; i.e. any component or gear train should be dual if interposed between the holding brakes and the hoisting drums.		[C] - See 4.8-1 above.
4. Provision for manual operation of the hoisting brakes should be included in the design conditions.	See 4.9-1 above.	[C] - The Licensee has indicated that this NUREG requirement is satisfied but no details are provided.
5. Bridge and Trolley		
5.1 Braking Capacity		
1. The maximum torque capability of the driving motor and gear reducer for trolley motion and bridge motion of the overhead bridge crane should not exceed the capability of gear train and brakes to stop the trolley or bridge from the maximum speed with the DRL attached. Control and holding brakes should each be rated at 100% of maximum drive torque that can be developed at the point of application.	The next larger standard size motor above that calculated was selected. Travel drive sizes are based on acceleration time as well as running torque. As stated in our response to APCSB 9-1, the bridge and trolley brakes are not rated for maximum motor torque and the bridge has only one brake for each driving motor. Presently the bridge is provided with one 50 percent brake for normal stopping and a 100 percent torque brake for holding. Both trolley brakes are 75% torque brakes. These brakes' torque ratings are generally in accordance with CMAA Specification #70 when it is considered this crane is both a floor and cab controlled machine.	[R] - Present crane design does not comply with this requirement. The Licensee has agreed to a braking system modification which will result in compliance with the requirement.

Table 3.1 (Cont.)

NUREG-0554 Requirement	Licensee's Response	Evaluation/Comment
	However to satisfy the requirement the trolley braking system will be upgraded by increasing the torque rating of each brake to the maximum torque rating of the motor, and the bridge braking system will be upgraded by relocating each bridge drive motor and adding an additional brake between the drive motor and its reducer. Each of two drive brakes for each drive motor on the bridge or trolley should be rated for 100% of maximum driving torque of its respective motor.	
2. If two mechanical brakes, one for control and one for holding, are provided, they should be adjusted with one brake in each system leading the other and should be activated by release or shutoff of power. This applies to both trolley and bridge.	An adjustable time delay is provided for each backup brake. All brakes are actuated on interruption of power for any reason.	[C]
3. The brakes should also be mechanically tripped to the "on" or "holding" position in the event of a malfunction in the power supply or an overspeed condition.	All brakes are actuated on interuption of power for any reason.	[P] - The Licensee has not verified that the brakes are mechanically tripped to preclude movement by the trolley or bridge if power is restored.
4. Provisions should be made for manual emergency operation of the brakes.	All brakes have provisions for manual operation and none are foot operated.	[C]
5. The holding brake should be designed so that it cannot be used as a foot-operated slowdown brake.	See 5.1-4 above.	[C]
6. Drag brakes should not be used.	No drag brakes are used.	[C]
7. Opposite-driven wheels on bridge or trolley that support bridge or trolley on their runways should be matched and should have identical diameters.	All bridge wheels and all trolley wheels are within a machine tolerance of $\pm$0.010 inch of the same diameter.	[C]
8. Trolley and bridge speed should be limited. The speed limits indicated for slow operating speeds for trolley and bridge in Spec. CMAA #70 are recommended for handling MCLs.	The maximum trolley speed is 30.35 fpm, and the maximum bridge speed is 54.1 fpm.	[T] - CMAA Spec. #70 for 125 ton MCL limits the trolley speed to 30 to 50 fpm while the bridge speed is limited to 50 fpm. The maximum bridge speed of 54.1 fpm is judged satisfactory.

Table 3.1 (Cont.)

NUREG-0554 Requirement	Licensee's Response	Evaluation/Comment
5.2 Safety Stops		
1. Limiting devices, mechancial and/or electrical, should be provided to control or prevent overtravel and overspeed of the trolley and bridge. Buffers for bridge and trolley travel should be included at the end of the rails.	The bridge and trolley are provided with two limit switches wired in series which decelerate the drives to creep speed between the limit switch actuators and the maximum travel. Four bridge bumpers and two trolley bumpers of the spring type are provided.	[C]
2. Safety devices such as limit-type switches provided for malfunction, inadvertent operation action, or failure should be in addition to and separate from the limiting means or control devices provided for operation.	All limit switches, overspeed switches, overcurrent relays, etc., are provided as safety backup devices and are not intended for normal operating use.	[C]
6. Drivers and Controls		
6.1 Driver Selection		
1. The maximum torque capability of the electric motor drive for hoisting should not exceed the rating or capability of the individual component of the hoisting system required to hoist the MCL at the maximum design hoist speed.	The calculated power requirement and the motor rating for the main hoist are identical at 50 horsepower. The auxiliary hoist motor is rated at 7.5 H.P. while the calculated requirement is 7.45, an oversize of 1.1%.	[C] - The Licensee's response complies with the NUREG requirement for the main hoist. For the auxiliary hoist the intent was satisfied by providing an oversize of 1.1%.
2. A maximum hoisting movement of 8 cm (3 in) would be an acceptable stopping distance.	The Division of Nuclear Power (NUC PR) will perform a field test of the overspeed control device as delineated in Item 6.2 of the scoping document for Preoperational Test No. TVA-2 as recommended by EN DES.	[P] - The Licensee has agreed to perform a field test. It is not clear that this test will demonstrate compliance with this suggestion.
3. For elaborate control systems, radio control, or ultimate control under unforeseen conditions of distress, an "emergency stop button" should be placed at ground level to remove power from the crane independently of the crane controls.		[T] - The Licensee states in FSAR paragraph 12.2.2.5.2k that a circuit breaker can be operated to interrupt the power supply to the main crane feed rails. Three emergency stop pushbuttons are located on the operating floor.

NUREG-0554 Requirement	Licensee's Response	Evaluation/Comment
6.2 Driver Control Systems		
1. The control system(s) provided should include consideration of the hoisting (raising and lowering) of all loads, including the rated load, and the effects of the inertia of the rotating hoisting machinery such as motor armature, shafting and coupling, gear reducer, and drum.	The control system complies fully with Item 6.2 of NUREG-0554.	[C]
2. If the crane is to be used for lifting spent fuel elements, the control system should be adaptable to include interlocks that will prevent trolley and bridge movements while the load is being hoisted free of a reactor vessel or a storage rack, as may be recommended in Reg. Guide 1.13.	The reactor building crane is not used to handle individual spent fuel elements, therefore, interlocks as recommended in Regulatory Guide 1.13 are not included in the design.	[C] - The crane is not intended for use to lift spent fuel elements (Ref. FSAR paragraph 12.2.2.5.1).
6.3 Malfunction Protection (Drivers)		
1. Means should be provided in the motor control circuits to sense and respond to such items as excessive electric current, excessive motor temperature, overspeed, overload, and overtravel.	The intent of these criteria is met by the safety features listed in paragraph 12.2.2.5.2 of FSAR.	[C]
2. Controls should be provided to absorb the kinetic energy of the rotating machinery and stop the hoisting movement reliably and safely through a combination of electrical power controls and mechanical braking systems and torque controls if one rope or one of the dual reeving systems should fail or if overloading or an overspeed condition should occur.	See 6.3-1 above.	[C]
6.4 Slow Speed Drives		
1. If jogging or plugging is to be used, the control circuit should include features to prevent abrupt change in motion.	These features are inherent in the General Electric Company's maxspeed DC adjustable voltage systems used on both hoist and travel drives.	[C] See Assessment 2.1-4.

NUREG-0554 Requirement	Licensee's Response	Evaluation/Comment
2. Drift point in the electric power system when provided for bridge or trolley movement should be provided only for the lowest operating speeds.	Same as 6.4-1 above.	[C] See Assessment 2.1-4.
6.5 Safety Devices		
1. Safety devices such as limit-type switches provided for malfunction, inadvertent operator action, or failure should be in addition to and separate from the limiting means or control devices provided for operation.	See 5.2 above.	[C]
6.6 Control Stations		
1. The complete operating control system and provisions for emergency controls for the overhead crane handling system should preferably be located in a cab on the bridge.	The bridge mounted cab has complete operating and emergency controls.	[C]
2. Additional operator stations should have control systems similar to the main station.	A duplicate set of controls for all functions except the main hoist is provided on a bridge mounted retractable pendant.	[C]
3. Manual controls for hoisting and trolley movement may be provided on the trolley, while manual controls for the bridge may be located on the bridge.		Not addressed by the Licensee; however, this is not a requirement.
4. Cranes that use more than one control station should be provided with electrical interlocks that permit only one control station to be operable at any one time.	Interlocks were provided that permit only one control station to be operable at any one time.	[C]
7. Installation Instructions		
7.1 General		
1. Installation instructions provided by the manufacturer should include a full explanation of the crane handling system, its controls, and the limitations for the system and should cover the requirements for installation, testing, and preparations for operation.	An operating and maintenance manual satisfying the intent of this paragraph was supplied by the crane manufacturer.	[C]

Table 3.1 (Cont.)

NUREG-0554 Requirement	Licensee's Response	Evaluation/Comment
7.2 Construction and Operating Periods		
1. After construction use, the crane should be thoroughly inspected by nondestructive examination and load tested for the operating phase. The extent of nondestructive examination, the procedures used, and the acceptance criteria should be defined in the design specification.	The construction and permanent plant requirements were the same. A thorough performance test and 125% capacity load test were made prior to use as permanent plant equipment. Visual inspection was the only NDE process used on the crane after it was erected.	[P] - The Licensee indicated that visual inspection was the only NDE process used. Article 2.6 states that all weld joints whose failure could result in the drop of a critical load should be nondestructively examined.
2. If allowable design stress limits for the plant operating service are to be exceeded during the construction phase, added inspection supplementing that described in Section 2.6 should be specified and developed.		[C] - The Licensee's response that the allowable design stress limits for plant operating service were not exceeded.
8. Testing and Preventive Maintenance		
8.1 General		
1. Information concerning proof testing on components and subsystems that was required and performed at the manufacturer's plant to verify the ability of components or subsystems to perform should be available for the checking and testing performed at the place of installation of the crane system.	Records of proof test on hooks are maintained in the permanent records file at the plant.	[T]
8.2 Static and Dynamic Load Tests		
1. The crane system should be static load tested at 125% of the MCL. The tests should include all positions generating maximum strain in the bridge and trolley structures and other positions as recommended by the designer and manufacturer.	The acceptance tests included complete performance tests at no load, 50%, 100%, and 125% rated capacity.	[C]
2. The crane handling system should be given full performance tests with 100% of the MCL for all speeds and motions for which the system is designed.	See 8.2-1 above.	[C]

Table 3.1 (Cont.)

NUREG-0554 Requirement	Licensee's Response	Evaluation/Comment
3. The features provided for manual lowering of the load and manual movement of the bridge and trolley during an emergency should be tested with the MCL attached to demonstrate the ability to function as intended.		[N] - No information has been provided by the Licensee to verify that these features were tested during acceptance testing.
8.3 Two-Block Test		
1. When equipped with an energy-controlling device between the load and head blocks, the complete hoisting machinery should be allowed to two-block during the hoisting test (load block limit and safety devices are bypassed).	Two-blocking is protected against by redundant overhoist limit switches and is not considered a credible occurrence.	[P] - The Licensee in response to 4.5-2 has furnished the crane with two independent travel limit switches which is an acceptable alternative in accordance with NUREG-0612 Appendix C. The Licensee, however, should commit to verification of proper functioning of these switches to comply with the requirements of Appendix C.
2. The complete hoisting machinery should be tested for ability to sustain a load hangup condition by a test in which the load-block-attaching points are secured to a fixed anchor or an excessive load.	No load hangup test was performed. This possibility was provided for by designing the structural and mechanical parts of the crane for 275% of motorfull load torque at stall. The allowable stress for this condition was 0.9 yield which gives a safety factor of more than 2 based on ultimate. (See Section 4.5-3.)	[P] - The Licensee has indicated interlock circuitry will prevent this. The Licensee has agreed to perform testing (Licensee's response, Section 4.5-3) of interlock circuitry which will result in compliance with the acceptable alternative of Appendix C, NUREG-0612.
8.4 Operational Tests		
1. Operational tests of crane systems should be performed to verify the proper functioning of limit switches and other safety devices and the ability to perform as designed.		[C] - The Licensee states in FSAR Section 12.2.2.5.3 that "operational tests and visual inspections are to be made at periodic intervals during the life of the crane to demonstrate its ability to safely perform its intended functions."
8.5 Maintenance		
1. The MCL rating of the crane should be established as the rated load capacity, and the design rating for the degradable portion of the handling system should be identified to obtain the margin available for the maintenance program.	The MCL capacity will be maintained at 100% of DRL capacity.	[C] - This response is inconsistent with that provided concerning Item 22-2 and must be clarified.

Table 3.1 (Cont.)

NUREG-0554 Requirement	Licensee's Response	Evaluation/Comment
2. The MCL should be plainly marked on each side of the crane for each hoisting unit.	Only one contractor nameplate was provided. This stated the design rated load for the main and auxiliary hoist. This is a 12-inch by 18-inch sign located near the center of the bridge.	[N]
9. Operating Manual		
1. The crane designer and manufacturer should provide a manual of information and procedures for use in checking, testing, and operating the crane.	Ederer Incorporated provided TVA with electrical equipment and mechanical maintenance manuals specifying lubrication, inspection, and preventive maintenance requirements; however, an operating manual as described in Item 9.0 of NUREG-0554 was not supplied.	[N] Compliance with this item could be demonstrated.
2. The operating requirements for all travel movements (vertical and horizontal movements or rotation, singly or in combination) incorporated in the design for permanent plant cranes should be clearly defined in the operating manual for hoisting and for trolley and bridge travel.		
10. Quality Assurance		
1. A quality assurance program should be established to the extent necessary to include the recommendations of this report for the design, fabrication, installation, testing, and operation of crane handling systems for safe handling of critical loads.	The reactor building crane is listed as a CSSC item in Appendix A of the Browns Ferry Nuclear Plant Operational Quality Assurance Manual. Therefore, all inspection, testing, and operational requirements, as listed in the Division Procedures Manuals N78S2 and N745M15, are auditable by NUC PR Quality Assurance Staff.	[T] - The Licensee cannot provide full compliance with this item since the crane was designed, fabricated, installed, and tested prior to the issuance of NUREG-0554.

4. CONCLUSIONS

This summary is provided to consolidate the evaluation of Section 3 to identify additional Licensee actions necessary to achieve verbatim compliance with the provisions of NUREG-0554 [1], and to provide an overall evaluation and recommendation concerning the load-handling reliability of the Browns Ferry reactor building crane.

4.1 PARTIAL COMPLIANCE ITEMS

The Browns Ferry reactor building crane partially satisfies the following specific guidelines of NUREG-0554. Actions necessary to achieve verbatim compliance with these criteria are noted.

NUREG-0554 Item	Verbatim Compliance Actions
2.4-1 (cold-proof testing)	Perform cold-proof test of the crane, including verification that all items listed in Section 2.4-1 of NUREG-0554 are complied with.
2.4-2 (cold-proof test, low-alloy steels)	Perform cold-proof test of crane appropriate lifting devices.
2.6-1 (weld joint examination)	Perform surface examination of weld joints where failure could result in the drop of a critical load.
3.4-1 (emergency repairs)	Demonstrate that the crane will hold critical loads while repairs are effected or that alternative means of transferring the load to a safe laydown area are available.
4.3-4 (static test of load attaching hooks)	Perform surface and volumetric nondestructive examination of load blocks.
4.5-2 (two blocking-protective control systems)	Provide verification that limit switches are activated by separate mechanical means and function to deenergize the hoist drive motor and main power supply.

NUREG-0554 Item	Verbatim Compliance Actions
5.1-3 (braking system, loss of power	Demonstrate that braking systems are mechanically tripped to preclude movement of the trolley or bridge when power is restored.
6.1-2 (hoist stopping distance)	Perform a field test of the crane to establish if the hoisting system achieves an acceptable stopping distance.
7.2-1 (post-construction period inspection)	Perform nondestructive examination of all accessible weld joints whose failure could result in a drop of a critical load.
8.3-1 (two blocking test)	Perform testing of over hoist limit switches to verify operability to prevent a two blocking event.
8.3-2 (load hangup test)	Perform testing of instantaneous overcurrent relays and the overload relays of the hoisting machinery to demonstrate the ability to sustain a load hangup condition.

4.2 NON-COMPLIANCE ITEMS

The Browns Ferry reactor building crane does not comply with the following specific guidelines of NUREG-0554. Actions necessary to achieve verbatim compliance with the guidelines are noted.

NUREG-0554 Item	Verbatim Compliance Actions
2.2-3 (MCL identification)	Mark the crane MCL clearly on the crane.
2.5-2 (design load effects)	Provide seismic and operational analyses to demonstrate that use of 100% MCL will not exceed the design cri- teria of the trolley and bridge (original analysis assumed an under-hook load of approximately 71% of MCL).

NUREG-0554 Item	Verbatim Compliance Actions
4.1-2 (maximum wire rope load)	Replace the wire rope with one that has suitable breaking strength such that the maximum load (static and inertia force) with MCL attached will not exceed 10% of the manufacturer's published breaking strength.
4.3-2 (load block attaching points)	Provide dual attachment points for all loads, or if single attachment is used, increase the safety factor to 10:1 to equal the safety factor required for the wire rope.
8.2-3 (hoist-manual lowering test)	Demonstrate, by actual operational test with MCL attached, manual lowering of the load and movement of the bridge and trolley.

4.3 OVERALL EVALUATION AND RECOMMENDATIONS

The reactor building crane at the Browns Ferry Unit 1 does not fully comply with the requirements of NUREG-0554 [1] for a "single-failure-proof" crane. It is, however, designed with substantial consideration for the prevention of a load-handling accident and could be found by the staff to satisfy the intent of the general requirement for the provision of a specially designed, highly reliable handling system for loads less than 75 tons upon implementation of the following:

Brake modifications. Bridge and trolley braking systems should be modified, as proposed by the Licensee, to provide control and holding brakes rated at 100% of maximum motor torque.

Test program. The Licensee has agreed to perform a cold-proof test of the crane to satisfy NUREG-0554 requirements pertaining to brittle fracture. An expanded test program should be conducted which includes the verification of other aspects of crane design. Such a test should address:

1. Acceptable protection against brittle fracture by complying with the provisions of NUREG-0612, Article 2.4.1.

2. Verification that, following the failure of an active component of the drive system (bridge, trolley, or hoist drive motor or brake), either

suitable procedures and physical features are available to repair or replace the failed component while the MCL is maintained in a stable condition or that, without repair, the MCL can be moved and placed in a safe laydown area. (Articles 3.4-1 and 8.2-3)

3. Verification of redundancy of electrical components (limit switches, relays) provided to prevent two-blocking and overload in the event of a load hangup. (Article 4.5-2)

4. Verification that maximum hoist stopping distance is acceptable (approximately 3 in). (Article 6.1-2)

5. Verification that braking system design precludes inadvertent bridge, trolley, or hoist motions upon restoration of electrical power following an electrical power failure. (Article 5.1-3)

Post-test examination. Following the operational/cold-proof test, a one time examination should be conducted to increase the assurance of future integrity of critical structural elements including the following:

1. A surface examination of accessible weldments in load-bearing joints.

2. A surface examination of the hook assembly to detect flaws affecting structural integrity.

Routine inspection. The Licensee should institute an inspection program complying with the requirements of ANSI B30.2-1976, Chapter 2-2, enhanced to compensate for variations from NUREG-0554 requirements in certain areas.

1. Rope replacement criteria of ANSI B30.2-1976, Article 2-2.4.2, should be made more stringent to accommodate the differential between the NUREG-0554 requirement concerning the ratio of maximum load to breaking strength and that provided in the Browns Ferry crane.

2. The periodic inspection requirements of ANSI B30.2-1976, Article 2-2.1.3, should be enhanced to include a visual inspection of accessible welded joints associated with load-bearing members to detect cracking in areas subject to potentially high residual stresses.

Lifting devices. The acceptability of lifting devices, both those specially designed and general purpose devices (e.g., slings) should be established on the basis of conformance with ANSI N14.6-1978 or ANSI B30.9-1971, as appropriate, in accordance with the requirement of NUREG-0612. Dual attachment points should be provided for loads which, if dropped, could result in effects in excess of the criteria provided in NUREG-0612.

Miscellaneous

1. A label plate should be provided on the crane to clearly identify the MCL.

The Browns Ferry Unit 1 crane cannot be found to satisfy single-failure-proof criteria for loads in excess of approximately 75 tons due to the lack of seismic analysis for such loads. The acceptability of this situation should be evaluated on the basis of additional information which should be required of the Licensee to identify:

- o The weights of each load in excess of 75 tons expected to be carried.
- o The duty cycle, or hours per year, each load in excess of 75 tons is expected to be carried.
- o The estimated total duty cycle of the crane (i.e., hours/year the crane is expected to be under load).
- o The accleration forces or recurrence interval associated with the seismic event during which the crane has been evaluated to be capable of carrying the MCL.

5. REFERENCES

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   Regulatory Guide 1.13

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4. "Single-Failure-Proof Cranes for Nuclear Power Plants"
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5. "Control of Heavy Loads at Nuclear Power Plants"
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7. T. M. Novak (NRC)
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8. L. M. Mills (TVA)
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9. L. M. Mills (TVA)
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