U.S. NUCLEAR REGULATORY COMMISSION

February 1976

REGULATORY GUIDE

OFFICE OF STANDARDS DEVELOPMENT

REGULATORY GUIDE 1.104
OVERHEAD CRANE HANDLING SYSTEMS FOR NUCLEAR POWER PLANTS

A. INTRODUCTION

General Design Criterion 1, "Quality Standards and Records," of Appendix A, "General Design Criteria for Nuclear Power Plants," to 10 CFR Part 50, "Licensing of Production and Utilization Facilities," requires that structures, systems, and components important to safety be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety function to be performed. General Design Criterion 2, "Design Bases for Protection Against Natural Phenomena," requires that structures, systems, and components important to safety be designed to withstand the effects of natural phenomena such as earthquakes. General Design Criterion 5, "Sharing of Structures, Systems, and Components," prohibits the sharing of structures, systems, and components important to safety among nuclear power units unless it can be shown that such sharing will not significantly impair their ability to perform their safety functions. In addition, General Design Criterion 61, "Fuel Storage and Handling and Radioactivity Control," requires, in part, that fuel storage and handling systems be designed to ensure adequate safety under normal accident conditions.

Regulatory Guide 1.13, "Spent Fuel Storage Facility Design Basis," describes methods acceptable to the NRC staff for complying with the Commission's regulations with regard to the construction of spent fuel storage facilities and load handling systems.

Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," to 10 CFR Part 50 requires, in part, that measures be established to ensure control of design, materials, fabrication, special processes, installation, testing, and operation of structures, systems, and components important to safety, including crane handling systems. Section 50.55a, "Codes and Standards," of 10 CFR Part 50 requires that design, fabrication, installation, testing, or inspection of certain specified systems or components be in accordance with generally recognized codes and standards. This guide describes methods acceptable to the NRC staff for complying with the Commission's regulations with regard to the design, fabrication, and testing of overhead crane systems used for reactor refueling and spent fuel handling operations. This guide applies to all nuclear power plants for which the applicants elect to provide a single-failure-proof overhead crane handling system.

B. DISCUSSION

The safe handling of critical loads can be accomplished by adding safety features to the handling equipment, by adding special features to the structures and areas over which the critical load is carried, or a combination of the two, thus enabling these areas to withstand the effects of a load drop in case the handling equipment fails. This guide covers critical load handling equipment for those plants where reliance for safe handling of critical loads will be placed on the overhead crane system by making it single failure proof.

Overhead crane handling systems are often used for handling critical items at nuclear power plants. The handling of critical loads such as a spent fuel cask raises the possibility of damage to the safety-related systems, structures, and equipment under and adjacent to the path on which it is transported should the handling system suffer a breakdown or malfunction during this handling period. Definitions of critical items or critical loads should be submitted in the PSAR.

Design Criteria

To provide a consistent basis for selecting equipment and components for the handling of critical loads, a list of codes, standards, and recommended practices generally available to industry is appended to this guide. The applicable requirements of these standards and recommendations should be used to the maximum extent practical to obtain quality construction. Where differences or conflicts in interpretation exist between the codes, standards, or recommendations, use of the most stringent requirement is recommended. However, special features should be added to prevent and control or stop inadvertent operation and malfunction of the load-supporting and -moving components of the handling system.

When an overhead crane handling system will be used during the plant construction phase prior to its intended service in the operating plant, separate performance specifications are needed to reflect the duty cycles and loading requirements for each service. At the end of the construction period, changes to the crane system may be required to reflect the specifications for the permanent operating plant condition. For example, if the specifications for the size of the hoist drive motor differ sufficiently for the two applications, the motor and the affected control equipment would have to be replaced or changed for the operating plant phase. Features and functions needed for the cranes during the plant construction period are not considered in this guide except where the use of the crane may influence its design and operation for the permanent plant operation.

Overhead cranes may be operating at the time when an earthquake occurs. Therefore. the cranes should be designed to retain control of and hold the load, and the bridge and trolley should be designed to remain in place on their respective runways with their wheels prevented from leaving the tracks during a seismic event. If a seismic event comparable to a safe shutdown earthquake (SSE) occurs, the bridge should remain immobile on the runway, and the trolley with load should remain immobile on the crane girders.

Since all the crane loading cycles will produce cyclic stress, it may be necessary to investigate the potential for failure of the metal due to fatigue. When a crane will be used for the construction period, it will experience additional cyclic loading, and these loads should be added to the expected cyclic loading for the permanent plant operation for the fatigue evaluation.

Materials and Fabrication

Bridge and trolley structures are generally fabricated by welding structural shapes together. Problems have been experienced with weld joints between rolled structural members. Specifically, subsurface lamellar tearing has occurred at the weld joints during fabrication and the load-bearing capacity of the joint has thus been reduced. Radiography or ultrasonic inspection, as appropriate, of all load-bearing weld joints would help to ensure the absence of lamellar tearing in the base metal and the soundness of the weld metal. Other problems with welding of low-alloy steels can occur if the base metal temperature is not properly controlled during welding and the postweld heat treatment. Regulatory Guide 1.50, "Control of Preheat Temperature for Welding of Low-Alloy Steel," identifies this potential problem and indicates an acceptable procedure for obtaining sound welds in low-alloy steels.

Cranes are generally fabricated from structural shapes and plate rolled from mild steel or low-alloy steel. Some of these steel parts exceed ½ inch in thickness and may have brittle-fracture tendencies during some of the intended operating temperatures, so that testing of the material toughness becomes necessary. Specifically, the nil-ductility transition temperature (NDTT) should be determined.

Safety Features

General. Numerous applications have been reviewed by the staff, and the need for inclusion of certain safety features and the magnitudes of specific operational limits to provide adequate safety have been determined.

It is important to prevent the release of radioactivity in case of failure, inadvertent operation, malfunction, or loss of load, and it may be necessary to include special features and provisions to preclude system incidents that would result in release of radioactivity.

A crane that has been immobilized because of malfunction or failure of controls or components while holding a critical load should be able to set the load down while repairs or adjustments are made. This can be accomplished by inclusion of features that will permit manual operation of the hoisting system and the bridge and trolley transfer mechanisms by means of ancillary, auxiliary, or emergency devices.

A crane handling system includes all the structural, mechanical, and electrical components that are needed to lift and transfer a load from one location to another. Primary or principal load-bearing components, equipment, and subsystems such as the driving equipment, drum, rope reeving system, control systems, and braking means should receive special attention.

All auxiliary hoisting systems of the main crane handling system that are employed to lift or assist in handling critical loads should be provided with the same safety features as the rest of the main crane handling system.

Hoisting Machinery. Proper support of the rope drums is necessary to ensure that they would be retained and prevented from falling or disengaging from their braking and control system in case of a shaft or bearing failure. Two mechanical holding brakes in the hoisting system (raising and lowering) that are automatically activated when electric power is off or when mechanically tripped by overspeed devices or overload devices in the hoisting system will help ensure that a critical load will be safely held or controlled in case of failure in the individual load-bearing parts of the hoisting machinery.

Each holding brake should have more than full-load stopping capacity but should not have excessive capacity that could cause damage through sudden stopping of the hoisting machinery. A brake capacity of 125% to 150% of the breakdown torque developed by the motor at the point of brake application has been determined to be acceptable.

Manual operation of the hoisting brakes may be necessary during an emergency condition, and provision for this should be included in the design conditions. Adequate heat dissipation from the brake should be ensured so that damage does not occur if the lowering velocity is permitted to increase excessively. Features should be included in the manual control of the brake to limit the lowering speed. A limiting velocity of 3.5 fpm has been determined to be acceptable for trouble-free operation.

Component parts of the vertical hoisting mechanism are important. Specifically, the rope and reeving system deserves special consideration during design of the system. The selection of the hoisting rope which is a "running rope" should include consideration of size, construction, lay, and means of lubrication to provide for the efficient working of the strands and individual wires. The load-carrying rope will suffer accelerated wear if it rubs excessively on the sides of the grooves in the drum and sheaves due to improper alignment or large fleet angles between the grooves. The load-carrying rope will furthermore suffer shock loading if it is partly held by friction on the groove wall and then suddenly released to enter the bottom of the groove. The rope can be protected by the selection of conservative fleet angles. Ropes may also suffer damage due to excessive strain developed if the cable construction and the pitch diameter of the sheaves are not properly selected. Fatigue stress in ropes can be minimized when the pitch diameter of the sheaves are selected large enough to produce only nominal stress levels. The pitch diameter of the sheaves should be larger for ropes moving at the highest velocity near the drum and can be smaller for sheaves used as equalizers where the rope is stationary.

Equalizers for stretch and load on the rope reeving system may be of either beam or sheave type. 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 maintain balance in case of failure of the other rope system.

Selection of hoisting speed is influenced by such items as reaction time for corrective action for the hoisting movement and the potential behavior of a failed rope. To prevent or limit damaging effects that may result from dangerous rope spinoff in case of a rope break, the hoisting speed should be limited. A 5 fpm hoisting speed limit is an acceptable limit. The rope traveling speed at the drum is higher than at other points in the reeving system, and the potential for damage due to rope flailing and interference with other parts of the system should be considered. Conservative industry practice limits the rope line speed to 50 fpm at the drum as a conservative approach.

Power transmission gear trains are often supported by fabricated weldments of structural parts. The proper alignment of shafts and gears depends on the adequacy of bearings and their supports to maintain correct alignment of all components. The proper functioning of the hoisting machinery during load handling can best be ensured by providing adequate support strength and proper alignment of the individual component parts and the welds or bolting that binds them together.

Bridge and Trolley. Failure of the bridge and trolley travel to stop when power is shut off could result in uncontrolled incidents. This would be prevented if both bridge and trolley drives are provided with control and holding braking systems which will be automatically applied when the power is shut off or if an overspeed or overload condition occurs because of malfunction or failure in the drive system. Sufficient braking capacity would be needed to overcome torque developed by the drive motor and the power necessary to decelerate the bridge or trolley with the attached load to a complete stop. A holding or control capacity of 100 percent of the maximum torque developed at the point of brake application would be an acceptable capacity for each braking system. Drag-type brakes are subject to excessive wear, and the need for frequent service and repair tends to make this type of brake less reliable; they therefore should not be used to control movements of the bridge and trolley.

The travel speed of the trolley and bridge will influence the operation of the crane as well as the equipment design and selection. Numerous crane applications have been studied and it has been concluded that the travel speed for nuclear power plant application should be conservatively selected. Trolley and bridge speed limits of 30 fpm and 40 fpm, respectively, have been determined to be acceptable.

Drivers and Controls. Of the basic types of electric drive motors available for crane operation, the series-wound a.c. or d.c. motors or shunt-wound d.c. motors are readily adaptable to various control systems, and either of these types would be acceptable. Compound-wound motors should not be used because of difficulty in control of the breakdown torque. The horsepower rating of the driving motor should be matched with the calculated requirement that considers the design load and acceleration to the design hoisting speed. Overpowering of the hoisting equipment would impose additional strain on the machinery and load-carrying devices by increasing the hoisting acceleration rate. A motor rating limited to 110% of the design rating would provide adequate power without loss of flexibility and would be acceptable.

Normally, a crane system is equipped with mechanical and electrical limiting devices to shut off power to driving motors when the crane hook, trolley, and bridge approach the end of travel or when other parts of the crane system would be damaged if power was not shut off. It is prudent to include safety devices in the control system for the crane, in addition to the limiting devices, for the purpose of ensuring that the controls will return to or maintain a safe holding position in case of malfunction, inadvertent operation or failure, or overspeed and overtorque conditions. Overpower and overspeed conditions should be considered an operating hazard as they may increase the hazard of malfunction or inadvertent operation. It is essential that the controls be capable of stopping the hoisting movement within amounts of movement that damage would not occur. A 3-inch maximum hoisting movement would be an acceptable stopping distance.

Operational Tests

Operational tests of crane systems should be performed to verify the proper functioning of limit switches and safety devices and the ability to perform as designed. However, special arrangements may have to be made to test overload and overspeed sensing devices.

Existing Handling Systems

It may be necessary to determine the extent to which an existing handling system and the areas in which the load is transported may require that the crane handling system be single failure proof. Therefore, a detailed inspection may be necessary to determine the condition of each crane prior to its continued use and to define the portion of the system that may need alteration, addition, or replacement in order to ensure its ability to perform acceptable handling of critical loads.

Quality Assurance

Although crane handling systems for critical loads are not required for the direct operation of a nuclear power plant, the nature of their function makes it necessary to ensure that the desired quality level is attained. A quality assurance program should be established to the extent necessary to include the recommendations of this guide for the design, fabrication, installation, testing, and operation of crane handling systems for safe handling of critical loads.

C. REGULATORY POSITION

When an applicant chooses to provide safe handling of critical loads by making the overhead crane handling system single-failure proof rather than by adding special features to the structures and areas over which the critical load is carried, the system should be designed so that a single failure will not result in loss of the capability of the handling system to perform its safety functions.

Overhead crane handling systems used for handling critical loads (following construction) such as loads during reactor refueling and spent fuel handling should be designed, fabricated, installed, inspected, tested, and operated in accordance with the following:

1. Performance Specification and Design Criteria

a. Separate performance specifications that are required to develop design criteria should be prepared for a permanent crane that is to be used for construction prior to use for plant operation. The allowable design stress limits should be identical for both cases, and the sum total of simultaneously applied loads should not result in stress levels causing permanent deformation other than localized strain concentration in any part of the handling system.

b. The operating environment, including maximum and minimum pressure, temperature, humidity, and emergency corrosive or hazardous conditions, should be specified for the crane and lifting fixtures.

(1) Closed box sections of the crane structure should be vented to avoid collapse during containment pressurization. Drainage should be provided to avoid standing water in the crane structure.

(2) Minimum operating temperatures should be specified in order to reduce the possibility of brittle fracture of the ferritic load-carrying members of the crane. Materials for structural members essential to structural integrity should be impact tested unless exempted by the provisions of paragraph AM-218 of the ASME Code, Section VIII, Division 2. However, the "minimum design temperature" as used therein should be defined as 60°F below the minimum operating temperature. Either drop weight test per ASTM E-208 or Charpy tests per ASTM A-370 may be used for impact testing. The minimum drop weight test requirement should be nil-ductility transition temperature (NDTT) not less than 60°F below the minimum operating temperature. Minimum Charpy V-notch impact test requirements should be those given in Table AM 211.1 of the ASME Code, Section VIII, Division 2, which should be met at a temperature 60°F below the minimum operating temperature. Alternative methods of fracture analysis that achieve an equivalent margin of safety against fracture may be used if they include toughness measurements on each heat of steel used in structural members

essential to structural integrity. In addition, the fracture analysis that provides the basis for setting minimum operating temperatures should include consideration of stress levels; quality control; the mechanical checking, testing, and preventive maintenance program; and the temperatures at which the design rated load test is run relative to operating temperature.

(3) As an alternative to the recommendations of regulatory position C.1.b.2, the crane and lifting fixtures may be subjected to a cold proof test as described in regulatory position C.4.d.

(4) Cranes and lifting fixtures made of low-alloy steel such as ASTM A514 should be subjected to the cold proof test described in regulatory position C.4.d.

c. The crane should be classified as Seismic Category I and should be capable of retaining the maximum design load during a safe shutdown earthquake (SSE), although the crane may not be operable after the seismic event. The bridge and trolley should be provided with means for preventing them from leaving their runways with or without the design load during operation or under any seismic excursions. The design rated load 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.

d. All weld joints for load-bearing structures including those susceptible to lamellar tearing should be inspected, including nondestructive examination for soundness of the base metal and weld metal.

e. 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.

f. Preheat and postheat treatment (stress relief) temperatures for all weldments should be specified in the weld procedure. For low-alloy steel, the recommendations of Regulatory Guide 1.50, "Control of Preheat Temperature for Welding of Low-Alloy Steels," should be applied.

2. Safety Features

a. The automatic controls and limiting devices should be designed so that, when disorders due to inadvertent operation, component malfunction, or disarrangement of subsystem control functions occur singly or in combination during the load handling and failure has not occurred in either subsystems or components, these disorders will not prevent the handling system from being maintained at a safe neutral holding position.

b. Auxiliary systems, dual components, or ancillary systems should be provided so that. in case of subsystem or component failure, the load will be retained and held in a stable or immobile safe position.

c. 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 (temporary) position with the handling system immobile. As an alternative to repairing the crane 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 the repairs are being made.

d. The design of the crane and its operating area should include provisions that will not impair the safe operation of the reactor or release radioactivity when corrective repairs, replacements, and adjustments are being made to place the crane handling system back into service after component failure(s).

3. Equipment Selection

a. Dual load attaching points (redundant design) should be provided as part of the load block assembly which is designed so that each attaching point will be able to support a static load of 3W (W is weight of the design rated load) 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.

b. Lifting devices that are attached to the load block such as lifting beams, yokes, ladle or trunnion type hooks, slings, toggles, and clevises should be of redundant design with dual or auxiliary device or combinations thereof. Each device should be designed to support a static load of 3W without permanent deformation.

c. The vertical hoisting (raising and lowering) mechanism which uses rope and consists of upper sheaves (head block), lower sheaves (load block), and rope reeving system, should provide for redundantly designed dual hoisting means. Maximum hoisting speed should be no greater than 5 fpm.

d. 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 load block should maintain alignment and a position of stability with either system being able to support 3W within the breaking strength of the rope and maintain load stability and vertical alignment from center of head block through all hoisting components through the center of gravity of the load.

e. 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 configuration of ropes and rope equalizer(s). Selection of the hoisting rope or running rope should include consideration of the size, construction, lay, and means or type of lubrication to maintain efficient working of the individual wire strands when each section of rope passes over the individual sheaves during the hoisting operation. The effects of impact loadings, acceleration, and emergency stops should be included in selection of rope and reeving systems. The wire rope should be 6 x 37 IWRC (iron wire rope core) or comparable classification. The lead line stress to the drum during hoisting (dynamic) at the maximum design speed with the design rated load should not exceed 20% of the manufacturer's published rated strength. Line speed during hoisting (raising or lowering) should not exceed 50 fpm.

f. The maximum fleet angle from drum to lead sheave in the load block should not exceed 3-½ degrees at any one point during hoisting and should have only one 180-degree reverse bend for each rope leaving the drum and reversing on the first or lead sheave on the load block with no other reverse bends other than at the equalizer if a sheave equalizer is used. The fleet angles between individual sheaves for rope should not exceed 1-½ degrees. Equalizers may be of the beam or sheave type or combinations thereof. For the recommended 6 x 37 IWRC classification wire rope, the pitch diameter of the lead sheave should be 30 times the rope diameter for the 180-degree reverse bend, 26 times the rope diameter for running sheaves and drum, with 13 times the rope diameter for equalizers. The pitch diameter is measured from the center of the rope on the drum or sheave groove through the center of the drum or sheave to the center of the rope on the opposite side. 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, or a 2-rope system may be used from each drum or separate drums using a sheave equalizer or beam equalizer, or any other combination which provides two separate and complete reeving systems.

g. The portions 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 sustain a test load of 200% of the design rated load. Each reeving system and each one of the load-attaching devices should be assembled with approximately a 6-inch clearance between head and load blocks and should support 200% of the design rated load without permanent deformation other than localized strain concentration or localized degradation of the components. A 200% static-type load test should be performed for each reeving system and a load-attaching point at the manufacturer's plant. Measurements of the geometric configuration of the attaching points should be made before and after the test and should be followed by a nondestructive examination that should consist of combinations of magnetic particle, ultrasonic, radiograph, and dye penetrant examinations to verify the soundness of fabrication and ensure the integrity of this portion of the hoisting system. The results of examinations should be documented and recorded for the hoisting system for each overhead crane.

h. Means should be provided to sense such items as electric current, temperature, overspeed, overloading, and overtravel. Controls should be provided to absorb the kinetic energy of the rotating machinery and stop the hoisting movement within a maximum of 3 inches of vertical travel through a combination of electrical power controls and mechanical braking systems and torque controls if one rope or one of the dual reeving system should fail or if overloading or an overspeed condition should occur.

i. The control systems should be designed as a combination of electrical and mechanical systems and may include such items as contactors, relays, resistors, and thyristors in combination with mechanical devices and mechanical braking systems. The electric controls should be selected to provide a maximum breakdown torque limit of 175% of the required rating for a.c. motors or d.c. motors (series or shunt wound) used for the hoisting drive motor(s). Compound wound d.c. motors should not be used. The control system(s) provided should include consideration of the hoisting (raising and lowering) of all loads, including the maximum design rated load, and the effects of the inertia of the rotating hoisting machinery such as motor armature, shafting and coupling, gear reducer, and drum.

j. 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"[1] or if "load hangup"[2] should occur during hoisting. The designer should provide means within the reeving system located on the head or on the load block combinations to absorb or control the kinetic energy of rotating machinery prior to the incident of two blocking or load hangup. The location of mechanical holding brakes and their controls should provide positive, reliable, and capable means to stop and hold the hoisting drum(s) for the conditions described in the design specification and regulatory positions 1 and 2. This should include the maximum torque of the driving

[1]"Two blocking" is the act of continued hoisting in which the load block and head block assemblies are brought into physical contact, thereby preventing further movement of the load block and creating shock loads to rope and reeving system.

[2]"Load hangup" is the act in which the load block and/or load is stopped during hoisting by entanglement with fixed objects, thereby overloading the hoisting system.

motor cannot be shut off.

k. The load hoisting drum on the trolley should be provided with structural and mechanical safety devices to prevent the drum from dropping, disengaging from its holding brake system, or rotating, if the drum or any portion of its shaft or bearings should fail or fracture.

l. To preclude excessive breakdown torque, the horsepower rating of the electric motor drive for hoisting should not exceed 110% of the calculated design horsepower required to hoist the design rated load at the maximum design hoist speed.

m. The minimum hoisting braking system should include one power control braking system (not mechanical or drag brake type) and two mechanical holding brakes. The holding brakes should be activated when power is off and should be automatically mechanically tripped on overspeed to the full holding position if malfunction occurs in the electrical brake controls. Each holding brake should be designed to 125%-150% of the maximum developed torque at point of application (location of the brake in the mechanical drive). The minimum design requirements for braking systems that will be operable for emergency lowering after a single brake failure should be two holding brakes for stopping and controlling drum rotation. Provisions should be made for manual operation of the holding brakes. Emergency brakes or holding brakes which are to be used for manual lowering should be capable of operation with full load and at full travel and provide adequate heat dissipation. Design for manual brake operation during emergency lowering should include features to limit the lowering speed to less than 3.5 fpm.

n. The dynamic and static alignment of all hoisting machinery components including gearing, shafting, couplings, and bearings should be maintained throughout the range of loads to be lifted, with all components positioned and anchored on the trolley machinery platform.

o. Increment drives for hoisting may be provided by stepless controls or inching motor drive. Plugging[3] should not be permitted. Controls to prevent plugging should be included in the electrical circuits and the control system. Floating point[4] in the electrical power system when required for bridge or trolley movement should be provided only for the lowest operating speeds.

p. To avoid the possibility of overtorque within the control system, the horsepower rating of the motion of the overhead bridge crane should not exceed 110% of the calculated horsepower requirement at maximum speed with design rated load attached. Incremental or fractional inch movements, when required, should be provided by such items as variable speed or inching motor drives. Control and holding brakes should each be rated at 100% of maximum drive torque at the point of application. If two mechanical brakes, one for control and one for holding, are provided, they should be adjusted with one brake in each system for both the trolley and bridge leading the other and should be activated by release or shutoff of power. 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. Provisions should be made for manual operation of the brakes. The holding brake should be designed so that it cannot be used as a foot-operated slowdown brake. Drag brakes should not be used. Opposite wheels on bridge or trolley that support bridge or trolley on their runways should be matched and have identical diameters. Trolley and bridge speed should be limited. A maximum speed of 30 fpm for the trolley and 40 fpm for the bridge is recommended.

q. The complete operating control system and provisions for emergency controls for the overhead crane handling system should be located in the main cab on the bridge. Additional cabs located on trolley or lifting devices should have complete control systems similar to the bridge cab. Manual controls for hoisting and trolley movement may be provided on the trolley. Manual controls for the bridge may be located on the bridge. Remote control or pendant control for any of these motions should be identical to those provided on the bridge cab control panel. Provisions and locations should be provided in the design of the control systems for devices for emergency control or operations. Limiting devices, mechanical and electrical, should be provided to indicate and control or prevent overtravel and overspeed of hoist (raising or lowering) and for both trolley and bridge travel movements. Buffers for bridge and trolley travel should be included.

r. Safety devices such as limit type switches provided for malfunction, inadvertent operation, or failure should be in addition to and separate from the limiting means or devices provided for operation in the aforementioned. These would include buffers, bumpers, and devices or means provided for control of malfunction(s).

s. 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. The designer should establish the maximum working load (MWL). The MWL should not be less than 85% of the design rated load (DRL) capacity for

[3]Plugging is the momentary application of full line power to the drive motor for the purpose of promoting a limited movement.

[4]That point in the lowest range of movement control at which power is on, brakes are off, and motors are not energized.

the new crane at time of operation. The redundancy in design, design factors, selection of components, and balance of auxiliary-ancillary and dual items in the design and manufacture will provide or dictate the maximum working load for the critical load handling crane systems. The MWL should not exceed the DRL for the Overhead Crane Handling System.

t. When the permanent plant crane is to be used for construction and the operating requirements for construction are not identical to those required for premanent plant service, the construction operating requirements should be completely defined separately. The crane should be designed structurally and mechanically for the construction loads, plant service loads, and their functional performance requirements. At the end of the construction period, the crane handling system should be adjusted for the performance requirements of the nuclear power plant service. The design requirements for conversion or adjustment may include the replacement of such items as motor drives, blocks, and reeving system. After construction use, the crane should be thoroughly inspected by nondestructive examination and performance tested. If allowable design stress limits are to be exceeded during the construction phase, added inspection supplementing that of regulatory position C.1.d should be considered. If the load and performance requirements are different for construction and plant service periods, the crane should be tested for both phases. Its integrity should be verified by designer and manufacturer with load testing to 125% of the design rated load required for the operating plant before it is used as permanent plant equipment.

u. Installation instructions should be provided by the manufacturer. These 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.

4. Mechanical Check, Testing, and Preventive Maintenance

a. A complete mechanical check of all the crane systems as installed should be made to verify the method of installation and to prepare the crane for testing.

During and after installation of the crane the proper assembly of electrical and structural components should be verified. The integrity of all control, operating, and safety systems should be verified as to satisfaction of installation and design requirements.

The crane designer and crane manufacturer should provide a manual of information and procedures for use in checking, testing, and operating the crane. The manual should also describe a preventive maintenance program based on the approved test results and information obtained during the testing; it should include such items as servicing, repair and replacement requirements, visual examinations, inspections, checking, measurements, problem diagnosis, nondestructive examination, crane performance testing, and special instructions.

Information concerning proof testing on components and subsystems as 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.

b. The crane system should be prepared for the static test of 125% of the design rated load. The tests should include all positions of hoisting, lowering, and trolley and bridge travel with the 125% rated load and other positions as recommended by the designer and manufacturer. After satisfactory completion of the 125% static test and adjustments required as a result of the test, the crane handling system should be given full performance tests with 100% of the design rated load for all speeds and motions for which the system is designed. This should include verifying all limiting and safety control devices. The crane handling system with the design rated load should demonstrate its ability to lower and move the load by manual operation and with the use of emergency operating controls and devices that have been designed into the handling system.

The complete hoisting machinery should be allowed to "two block" during the hoisting test (load block limit and safety devices are bypassed). This test, conducted at slow speed without load, should provide assurance of the integrity of the design, the equipment, the controls, and the overload protection devices. The test should demonstrate that the maximum torque that can be developed by the driving system, including the inertia of the rotating parts at the overtorque condition, will be absorbed or controlled prior to two-blocking. 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 excessive load. The drum should be capable of one full revolution before starting the hoisting test.

c. The preventive maintenance program recommended by the designer and manufacturer should also prescribe and establish the MWL for which the crane will be used. The maximum working load should be plainly marked on each side of the crane for each hoisting unit. It is recommended that the critical load handling cranes should be continuously maintained at DRL capacity.

d. The cold proof test provided for in regulatory positions C.1.b.3 and 4 should consist of a periodic dummy load test as follows: Metal temperature of the structural members essential to the structural integrity of the crane handling system should be at or below the minimum operating temperature. The corresponding dummy load should be equal to 1.25 times the maximum working load (MWL). If it is not feasible to achieve the minimum operating temperature during the test, the dummy load should be increased beyond the design rated load 1.5 percent per degree F temperature difference. Test frequency should be approximately 40 months or less; however, crane handling systems that are used less frequently than once every 40 months may be given a cold proof test prior to each use. The cold proof test should be followed by a nondestructive examination of critical areas for cracks.

5. Quality Assurance

a. To the extent necessary, applicable procurement documents should require the crane manufacturer to provide a quality assurance program consistent with the pertinent provisions of Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," to 10 CFR Part 50.

b. The program should also address each of the recommendations in regulatory positions C.1, C.2, C.3, and C.4.

D. IMPLEMENTATION

The purpose of this section is to provide information to applicants and licensees regarding the NRC staff's plans for using this regulatory guide.

1. Except in those cases in which the applicant proposes an alternative method for complying with specified portions of the Commission's regulations, this guide will be used in the evaluation of design, fabrication, assembling, and use of crane systems for critical load handling ordered after September 1, 1976.

2. For crane handling systems ordered prior to September 1, 1976:

a. Regulatory positions C.1, C.2, C.3, and C.4 will be used in evaluating crane handling systems that have been ordered but are not yet assembled.

b. All regulatory positions except C.1.f; C.3.c, f, and q will be used in evaluating crane handling systems that have been assembled or may have been used for handling heavy loads during plant construction. Regulatory positions C.1.f; C.3.c, f, and q will be used by the NRC staff to determine the extent of changes or modifications necessary.

c. All regulatory positions except C.1.f; C.2.a, b, c, and d; C.3.a, b, c, e, f, g, j, n, o, p, q, r, and t will be used in evaluating crane handling systems that will be or are being used to handle heavy loads that are defined as critical. Regulatory positions C.1.f; C.2.a, b, c, and d; C.3.a, b, c, e, f, g, j, n, o, p, q, r, and t will be used by the NRC staff to determine the extent of changes or modifications necessary to meet the intent of the regulatory positions.

APPENDIX
ENGINEERING, MANUFACTURING, AND OPERATING STANDARDS, PRACTICES, AND REFERENCES

AISE *Association of Iron and Steel Engineers (Std. No. 6)*
General items for overhead cranes and specifically for drums, reeving systems, blocks, controls, and electrical, mechanical, and structural components.
Copies may be obtained from the Association at 3 Gateway Center, Pittsburgh, Pennsylvania 15222.

AISC *American Institute of Steel Construction, Manual of Steel Construction.*
Runway bridge design loadings for impact and structural supports.
Copies may be obtained from the Institute at 101 Park Avenue, New York, New York 10017.

ASME *American Society of Mechanical Engineers*
References for testing, materials, and mechanical components.
Copies may be obtained from the Society at United Engineering Center, 345 East 47th Street, New York, New York 10017.

ASTM *American Society for Testing and Materials*
Testing and selection of materials.
Copies may be obtained from the Society at 1916 Race Street, Philadelphia, Pennsylvania 19103.

ANSI *American National Standards Institute (A10, B3, B6, B15, B29, B30, and N45 series)*
N series of ANSI standards for quality control. ANSI consensus standards for design, manufacturing, and safety.
Copies may be obtained from the Institute at 1430 Broadway, New York, New York 10018.

IEEE *Institute of Electrical and Electronics Engineers*
Electrical power and control systems.
Copies may be obtained from the Institute at United Engineering Center, 345 East 47th Street, New York, New York 10017.

AWS *American Welding Society (D1.1.72 - 73/74 revisions)*
Fabrication requirements and standards for crane structure and weldments.
Copies may be obtained from the Society at 2501 NW 7th Street, Miami, Florida 33125.

EEI *Edison Electrical Institute*
Electrical Systems.
Copies may be obtained from the Institute at 90 Park Avenue, New York, New York 10016.

SAE *Society of Automotive Engineers, "Standards and Recommended Practices"*
Recommendations and practices for wire rope, shafting, lubrication, fasteners, materials selection, and load stability.
Copies may be obtained from the Society at 400 Commonwealth Drive, Warrendale, Pennsylvania 15096.

CMAA *Crane Manufacturers Association of America (CMAA 70)*
Guide for preparing functional and performance specification and component selection.
Copies may be obtained from the Association at 1326 Freeport Road, Pittsburgh, Pennsylvania 15238.

NEMA *National Electrical Manufacturers Association*
Electrical motor, control, and component selections.
Copies may be obtained from the Association at 155 East 44th Street, New York, New York 10017.

WRTB *Wire Rope Technical Board* and their manufacturing members for selection of rope, reeving system, and reeving efficiencies.
Copies may be obtained from the Board at 1625 1st Street, NW., Washington, D.C. 20006.

MHI *Materials Handling Institute* and their member associations such as American Gear Manufacturing Association for gears and gear reducers, Antifriction Bearing Manufacturers Association for bearing selection, etc.
Copies may be obtained from the Institute at 1326 Freeport Road, Pittsburgh, Pennsylvania 15238.

WRC *Welding Research Council, "Control of Steel Construction to Avoid Brittle Fracture."*
Copies may be obtained from the Council at United Engineering Center, 345 East 47th Street, New York, New York 10017.

WRC *Welding Research Council, Bulletin #168, "Lamellar Tearing."*
Copies may be obtained from the Council at United Engineering Center, 345 East 47th Street, New York, New York 10017.

Regulatory Guide 1.50, "Control of Preheat Temperature for Welding of Low-Alloy Steel."

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