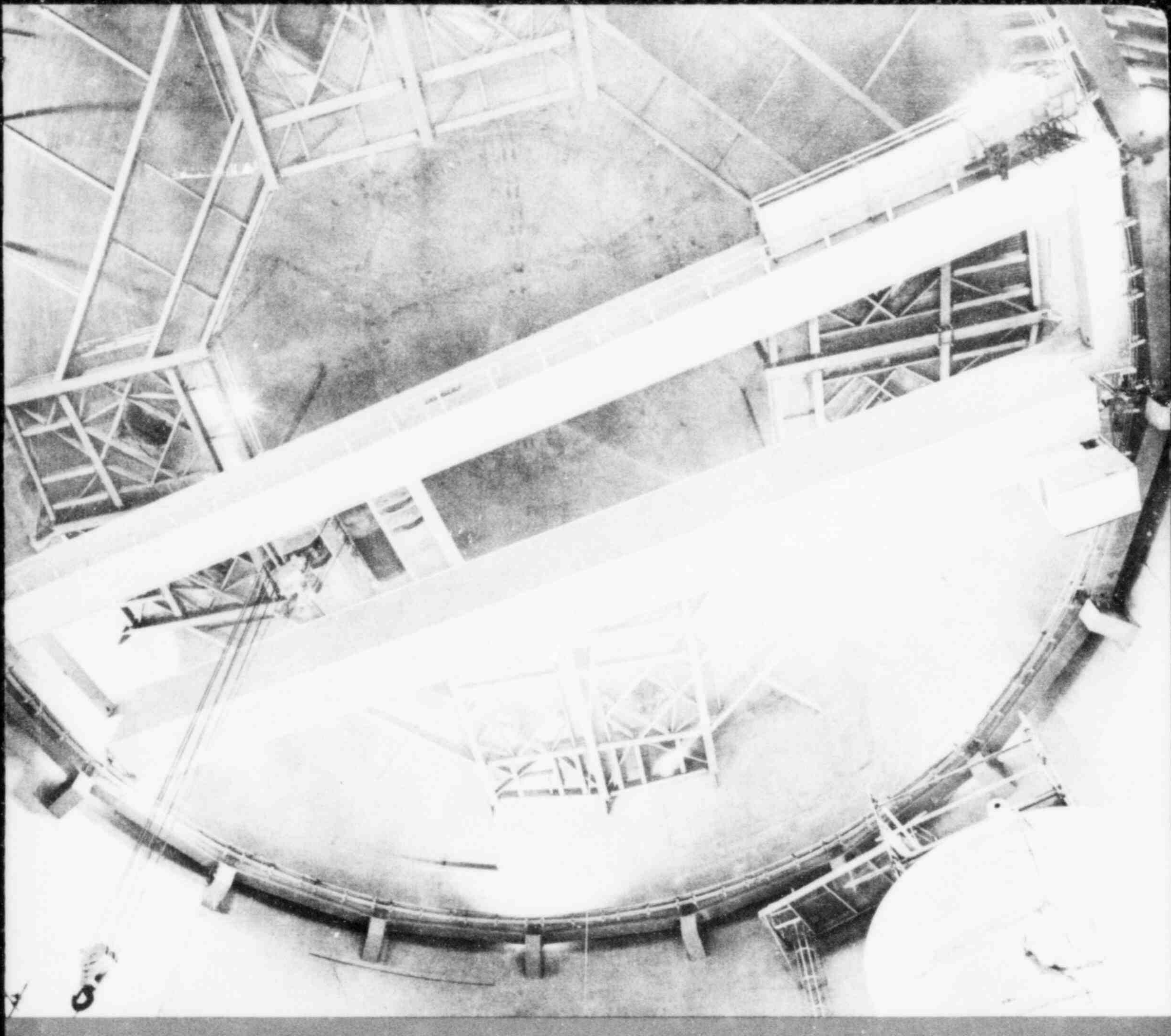

EDERER CRANES

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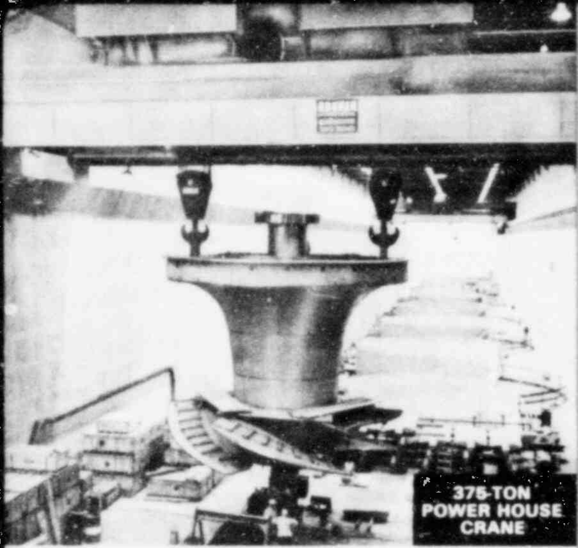
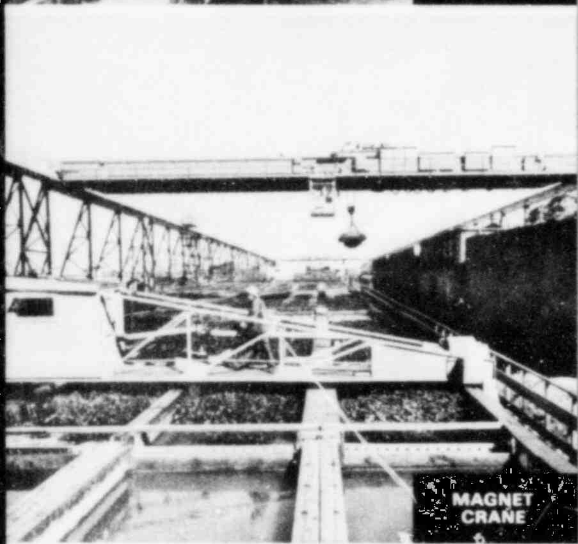
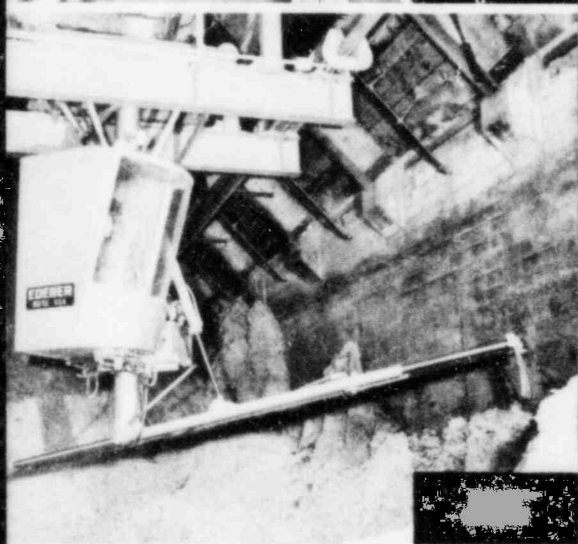
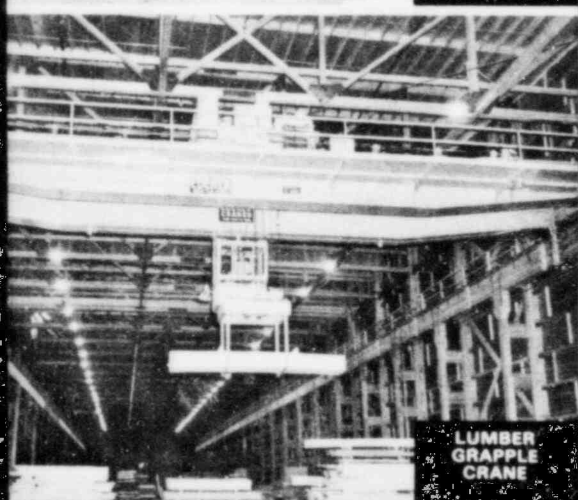


375-TON POWER HOUSE CRANE



MAGNET CRANE





LUMBER GRAPPLE CRANE

SINCE 1901

It was in 1901 that the ownership of Seattle's only milling machine set EDERER Incorporated on the course that has made the company a major factor in the manufacture of cranes, occupying a unique place through its exclusive "job-engineering" designing and manufacturing methods.

In its early days, EDERER was a supplier of cranes, hoists and specialized equipment for the forest products industries...lumber, plywood, pulp and paper. The entrance into new markets followed—and EDERER moved into the production of cranes for all types of industry.

Every year since the company's beginning, has seen more and more EDERER cranes at work in hydro and nuclear power plants, steel mills, warehouses and fabricating plants, foundries, forge shops, machine shops and other heavy industry. You'll find EDERER cranes the length and breadth of the United States and overseas.

Today, EDERER has the experience, the engineering knowledge and the plant facilities to design and build any type of crane for any industry. A glance at the photos on these pages will give you an idea of our scope and breadth.

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EDERER CRANES
WASHINGTON CRANES

GENERIC LICENSING TOPICAL REPORT

EDR-1 (NP)-A

EDERER'S

Nuclear Safety Related

eXtra-Safety And Monitoring

(X-SAM)

CRANES

NON-PROPRIETARY VERSION

Notice

This revision of EDR-1 supersedes all previous revisions.

REVISION 3 10/8/82

AMENDMENT 3

Assistance in Preparation Provided by:

HOLLORAN & ASSOCIATES
Mechanical and Nuclear Engineering Services
SUITE 102
205 108TH AVE NE
BELLEVUE, WA 98004
(206) 453-0525

COPY 08

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

AUG 2 6 1983

C. William Clark, Jr.
Director of Engineering
Ederer Incorporated
2925 First Avenue South
Box 24708
Seattle, Washington 98124

Dear Mr. Clark:

Subject: Acceptance for Referencing of Licensing Topical Report EDR-1(P), Revision 3, "Ederer Nuclear Safety-Related Extra Safety and Monitoring (X-SAM) Cranes"

We have completed our review of the subject topical report submitted by Ederer's October 8, 1982 letter. We find this report is acceptable for referencing in license applications to the extent specified and under the limitations delineated in the report and the associated NRC evaluation which is enclosed. The evaluation defines the basis for acceptance of the report.

We do not intend to repeat our review of the matters described in the report and found acceptable when the report appears as a reference in license applications except to assure that the material presented is applicable to the specific plant involved. Our acceptance applies only to the matters described in the report.

In accordance with procedures established in NUREG-0390, it is requested that Ederer publish accepted versions of this report, proprietary and non-proprietary, within three months of receipt of this letter. The accepted versions should incorporate this letter and the enclosed evaluation between the title page and the abstract. The accepted versions shall include an -A (designating accepted) following the report identification symbol.

Should our criteria or regulations change such that our conclusions as to the acceptability of the report are invalidated, Ederer and/or the applicants referencing the topical report will be expected to revise and resubmit their respective documentation, or submit justification for the continued effective applicability of the topical report without revision of their respective documentation.

Sincerely,

Cecil O. Thomas

Cecil O. Thomas, Chief
Standardization & Special
Projects Branch
Division of Licensing

Enclosure:
As stated

SAFETY EVALUATION REPORT

GENERIC LICENSING TOPICAL REPORT EDR-1, REVISION 3

EDERER'S NUCLEAR SAFETY-RELATED

EXTRA SAFETY AND MONITORING (X-SAM) CRANES

AUXILIARY SYSTEMS BRANCH

INTRODUCTION

As a result of Generic Task A-36, "Control of Heavy Loads Near Spent Fuel," NUREG-0612, "Control of Heavy Loads at Nuclear Plants" was developed. Following the issuance of NUREG-0612, a generic letter dated December 22, 1980 was sent to all operating plants, applicants for operating licenses and holders of construction permits requesting that responses be prepared to indicate the degree of compliance with the guidelines of NUREG-0612. As a result, several utilities have opted to perform modifications to existing load handling systems, or to replace existing components with more "reliable" components in accordance with the criteria of NUREG-0554 as a means of meeting the guidelines of NUREG-0612.

Ederer Incorporated, crane designers and manufacturers submitted a topical report, EDR-1(P)A, Rev. 1, which discussed the engineering concepts of load handling systems designed for "Nuclear Safety Related Extra Safety and Monitoring (X-SAM) cranes." This revision of the topical report was reviewed by EG&G Idaho and approved by the staff on January 2 and February 7, 1980 subject to the provision that a revision to the report incorporating changes identified in an October 23, 1979 Ederer letter be issued. Revision 2 of the topical report, dated February 15, 1980 was subsuquently submitted.

Revision 3 of the topical report was issued on October 8, 1982, January 24 and May 27, 1982 which discusses the application of the X-SAM principles to compact hoists. This safety evaluation report provides the staff's evaluation of Revision 3.

NRC REVIEW AND EVALUATION

The staff and its consultant, EG&G Idaho, have reviewed Ederer Inc. submittals regarding Revision 3 of Topical Report EDR-1(P)-A dated October 8, 1982; January 24 and May 27, 1983. As a result of its review, EG&G has issued a Technical Evaluation Report (TER). The staff has reviewed the TER and concurs with its conclusion that the design provisions of Revision 3 to EDR-1 (as amended) are equivalent to, or more conservative than the design provisions of Revision 2. The enclosed TER forms a part of this SER.

In addition, the staff has reviewed Ederer's July 18, 1983 response to staff concerns regarding the hoist's single-failure-proof features design from an electrical standpoint (i.e., the effects of phase reversal or loss of phasing in the hoist power supply). For the case of phase reversal, Ederer has stated that a phase reversal relay is provided to ensure the proper functioning of the hoist(s) and travel limits, including those of non-XSAM hoists that are installed with X-SAM hoists on the same bridge. For thecase of loss of phasing, either provision for shutting the hoist down and setting the holding brake(s) will be provided upon the loss of one phase, or load motion and kinetic energy will be verified in accordance with Appendices E and/or I guidelines (to EDR-1) such that acceptable motion and kinetic energy are not exceeded following a loss of one phase of hoist power.

Based on the above, we conclude that the electrical design provisiion for EDR-1 meet the criteria for single-failure-proof features.

TOPICAL REPORT EVALUATION

REPORT NUMBER AND TITLE: EDR-1: GENERIC LICENSING TOPICAL REPORT, REV. 3 AMENDMENTS 1 AND 2. ORIGINATING ORGANIZATION: EDERER INC., CRANE DESIGNERS AND MANUFACTURERS

A. Introduction

Generic Licensing Topical Report, EDR-1 (P)A, Rev. 2, dated February 15, 1980, describes the design and testing of the "single-failure-proof" features that are added to or working in connection with standard hoisting equipment which is intended for handling of spent fuel casks and other loads that are considered critical to preserving the safety of the plant operation. Such cranes are labeled "eXtra-Safety And Monitoring" (X-SAM). The report includes calculations showing the safe margin on wire rope strength for cases where the protective devices are called upon to prevent failure of the hoisting system to safely hold the critical load in case of malfunction or failure in the hoisting system. In addition, the report shows the method of compliance with the individual regulatory positions in proposed Revision 1 (Draft 3) of Regulatory Guide 1.104 (guide now withdrawn but republished as NUREG-0554).

The topical report, including Revisions 1 and 2, was approved by NRC in 1980. Ederer has now developed a compact X-SAM hoist which has essentially the same design features as the cranes described in EDR-1. Revision 3 has been developed to document necessary changes in that report.

In order to make the compact X-SAM Hoist practical, it was necessary to change some of the design details described in EDR-1, Revision 2. Changes were made in all sections with the exception of Appendices G and H, which were entirely new.

Appendix G presents a detailed description of the totally mechanical drive train continuity detector and emergency drum brake actuator.

Appendix H is a detailed description of the continuously engaged emergency drum brake system.

Since then, two amendments to Revision 3 have been submitted. Amendment 1 describes certain design options that have been identified to simplify the application of X-SAM to underhung hoists. Amendment 2 is principally Appendix I. This amendment extends the wire rope failure analysis included in Appendix E to account for the differences in the operation of the designs that are described by Revision 3.

Appendix I analyzes load motion and cable loading following a wire rope failure in an X-SAM type crane which is equipped with a totally mechanical drive train continuity detector and emergency drum brake actuator or continuously engaged emergency drum brake system.

B. Evaluation

The topical report evaluation of EDR-1, Revisions 1 and 2, analyzed and approved the X-SAM principle, and associated engineering concepts, in 1980. In Revision 3, the applicability of EDR-1 has been extended to compact hoists, such as underhung monorail hoists, by including the following special features that make a compact single-failure-proof hoist practical:

1. A totally mechanical Emergency Drum Brake Actator and its companion Drive Train Continuity Detector. (Appendix G)

2. A continuously engaged Emergency Drum Brake and its integral Drive Train Continuity Detector. (Appendix H)

3. Use of a single holding brake on the high speed shaft.

4. Line speeds above 50 fpm at the Hoist Drum.

5. Alternate Hydraulic Load Equalizer Design.

The general descriptive material has been revised to reflect the following characteristics of the new types of Emergency Drum Brakes and their associated Drive Train Continuity Detectors:

1. The Emergency Drum Brake does not set when power is removed.

2. The Emergency Drum Brake always sets if the load lowers, if there is a discontinuity in the drive train, or there is an error signal.

3. The Emergency Drum Brake is capable of lowering the load without power continuously throughout the full hook travel, but not necessarily at the design rated speed.

Amendment 1, to Revision 3, describes certain design options that have been identified to simplify the application of X-SAM to underhung hoists.

In Amendment 2, Appendix I has been prepared to extend the wire rope failure analysis included in Appendix E to account for the differences in the operation of the designs that are described by Revision 3, i.e., the Totally Mechanical Drive Train Continuity Detector and Emergency Drum Brake Actuator; the Continuously Engaged Emergency Drum Brake System; and the Alternate Hydraulic Equalization System. Specifically the previous wire rope failure analysis has been extended to:

1. Account for the small amount of drum rotation that may occur during a rope failure.

2. Evaluate a wire rope failure while lowering the design rated load at the design rated speed, since a wire rope failure may become the controlling incident with respect to the facility actions needed to accommodate load motion and load kinetic energy following a postulated single failure in the overhead crane handling system.

3. Account for the additional load motion and kinetic energy associated with the equalizer motion permitted by the Alternate Hydraulic Load Equalizer Design following a wire rope failure.

The general descriptive material has been revised to:

1. Reflect the performance of the operation of the Totally Mechanical Drive Train Continuity Detector and Emergency Drum Brake Actuator and the Continuously Engaged Emergency Drum Brake System following a single wire rope failure.

2. Identify that the analyses methods described in Appendix I are used to evaluate the maximum load motion and load kinetic energy associated with a single wire rope failure when the Totally Mechanical Drive Train Continuity Detector and Emergency Drum Brake Actuator; the Continuously Engaged Emergency Drum Brake System; or the Alternate Hydraulic Equalization System are used.

The staff finds that Revision 3, with amendments, provides the same level of protection as Revision 2. We find that the equations of motion of the load and drum that result from the application of the principles of mechanics are acceptable and provide reasonable estimates of the wire rope loads. As a result, we conclude that in a worst case condition a minimum safety margin of about 1.5 can be expected. The margin is acceptable.

C. Conformance with NUREG 0554

Additional information regarding conformance with, and exceptions to, certain guidelines is provided below. This evaluation report addresses only those guidelines, where conformance with those guidelines has been changed by Revision 3 of EDR-1. Appendices B and C identify the additional plant specific information that is needed to verify a specific retrofit crane's conformance with the NUREG guidelines.

- In addition to determining the maximum extent of load motion following a drive train failure, Ederer now determines the maximum kinetic energy of the load following a drive train failure.

- If necessary, provisions can be made for automatically actuating the Emergency Drum Brake prior to carrying the load over areas of the facility that the applicant determines cannot accommodate the amount of load motion that can follow a drive train failure.

Section 4.1 and 4.4

Figure III.C.3.e now illustrates the two types of Balanced Dual Reeving Systems used with Nuclear Safety Related X-SAM hoists.

Appendices E and I describe the analysis of cable loading following the failure of a cable in the other reeving.

The maximum line speed of the wire rope is kept below 50 fpm for hoists with capacities greater than 30 tons. The maximum line speed for compact hoists and auxiliary hoists is consistent with CMAA No. 70's suggested slow operating speed.

Section 6.3

The Energy Absorbing Torque Limiter (EATL) and the wire rope absorb the kinetic energy of the rotating machinery in the event of a control system malfunction. The Hydraulic Load Equalization System actuates the Failure Detection System, which deenergizes the motor and sets the high speed holding brake in the event of a wire rope failure. The primary motion of the lower block, following a single wire rope failure, is the vertical displacement associated with the transfer of the shared load to the intact reeving. The alternate design Hydraulic Equalizer System may allow the load to lower until the equalizer contacts the trolley structure. Appendices E and I describe the analysis of the maximum load motion and the kinetic energy associated with it. In any case, the results of the calculation of the maximum kinetic energy and the total vertical displacement of the load are provided to the applicant for use in verifying that the facility design will accommodate this limited controlled load motion.

Section 4.5

The analysis described in Section 6.A of Appendix F is used to verify that the lead line loading, if a high speed two-blocking occurs while making a critical lift, will not exceed Ederer's wire rope criteria described in C.3.e of Revision 3.

Section 4.9

The Emergency Drum Brake is capable of continuously lowering the rated load from the hooks maximum height without exceeding the temperature limits of the brakes.

Section 6.1, 6.5, 6.6

The provisions of these regulatory positions are met by Nuclear Safety Related X-SAM Cranes and retrofit equipment supplied by Ederer in accordance with Generic Licensing Topical Report. Separate overspeed sensors, which actuate the trolley and bridge drive brakes, are not provided when AC motors that inherently cannot overspeed, are used, i.e., when their maximum speed is limited by the 60 HZ line frequency.

Section 10

Ederer's X-SAM Cranes incorporate components produced at various locations by one or more divisions of Ederer and by various suppliers to Ederer.

Based on the above, we conclude that the design provisions of Revision 3 to EDR-1 (as amended) are equivalent to, or more conservative than, the design provisions of Revision 2.

D. Conclusions

We find that the equations of motion of the load and drum provide reasonable estimates of the wire rope loads. These loads show that an acceptable minimum safety margin of 1.5 can be expected.

Based on our review, we conclude that the design provisions of Revision 3 to EDR-1 (as amended) are equivalent to, or more conservative than, the design provisions of Revision 2.

E. Appendices

Appendix G presents a detailed description of the totally mechanical drive train continuity detector and emergency drum brake actuator.

Appendix H is a detailed description of the continuously engaged emergency drum brake system.

Appendix I analyzed load motion and cable loading following a wire rope failure in an X-SAM type crane which is equipped with a totally mechanical drive train continuity detector and emergency drum brake actuator or a continuously engaged emergency drum brake system.

The staff finds that the equations of motion of the load and drum that result from the application of the principles of mechanics are acceptable and provide reasonable estimates of the wire rope loads. As a result, the staff concludes that in a worst case condition a minimum safety margin of about 1.5 can be expected. The margin is acceptable to the staff.

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

January 2, 1980

Mr. C. William Clark, Jr.
Manager of Engineering
Ederer Incorporated
P. O. Box 24708
Seattle, Washington 98124

Dear Mr. Clark:

SUBJECT: REVIEW AND ACCEPTANCE OF TOPICAL REPORT EDR-1, EDERER"S NUCLEAR SAFETY RELATED eXtra-Safety And Monitoring (X-SAM) CRANES, REVISION 1

The Nuclear Regulatory Commission staff has completed its review of the Generic Licensing Topical Report EDR-1, "Ederer's Nuclear Safety Related eXtra-Safety And Monitoring (X-SAM) Cranes, Revision 1. The topical report describes the design and testing of the "single-failure proof" features which are included in Ederer's X-SAM cranes intended for handling spent fuel casks and other safety-related loads in a nuclear plant. A summary of our evaluation of the topical report is enclosed.

As a result of our review, we have concluded that the design features described in the topical report are acceptable for assuring that a single failure will not result in the loss of capability to safely retain a critical load. These features are limited to the hoisting system and brake system for trolley and bridge. We also conclude that the features are acceptable because they conform to the guidelines of Regulatory Guide 1.104, "Overhead Crane Handling Systems for Nuclear Power Plants;" and NUREG-0554, "Single-Failure-Proof Cranes for Nuclear Power Plants." Therefore, the Topical Report EDR-1, "Ederer's Nuclear Safety-Related (X-SAM) Cranes, Revision 1, may be referenced as accepted for use in crane systems for nuclear power plants. Both the proprietary and non-proprietary versions of the topical report must be referenced in future license applications.

The topical report and our evaluation describe the degree of conformance of the Ederer X-SAM crane system with each of the regulatory guide positions given in Regulatory Guide 1.104, "Overhead Crane Handling Systems for Nuclear Power Plants." Our safety evaluation notes that the applicant should include the information identified in Appendices B and C of the topical report in the Safety Analysis Report. Furthermore, in the alteration or conversion of an existing crane to provide features found acceptable in the topical report, the acceptability of unreplaced structures and components must be demonstrated.

We do not intend to repeat our review of the safety features described in the topical report and found acceptable in Enclosure 1. Our acceptance applies only to the use of features described in the topical report and does not constitute acceptance of the total overhead crane handling system or the requirements (e.g., limits on loads or load movement) which may be necessary to assure the safe application of the crane system within the nuclear power plant.

In accordance with established procedure, it is requested that Ederer issue revised versions of these reports within three months of receipt of this letter to include the NRC acceptance letter and the enclosed evaluation. The changes described in your letter dated October 23, 1979 should also be made.

Should Nuclear Regulatory Commission criteria or regulations change, such that our conclusions concerning these reports are invalidated, you will be notified and given an opportunity to revise and resubmit your topical reports, should you so desire.

If you have any questions about our review of this Ederer topical report, please contact us.

Sincerely,

Robert L. Baer

Robert L. Baer, Chief
Light Water Reactors Branch No. 2
Division of Project Management

Enclosure:
Topical Report Evaluation

TOPICAL REPORT EVALUATION

REPORT NUMBER AND TITLE: EDR-1; GENERIC LICENSING TOPICAL REPORT, REV. 1

ORIGINATING ORGANIZATION: EDERER INC., CRANE DESIGNERS AND MANUFACTURERS

A. Summary of Topical Report

The topical report describes the design and testing of the "single-failure-proof" features that are added to or working in connection with standard hoisting equipment which is intended for handling of spent fuel casks and other loads that are considered critical to preserving the safety of the plant operation. Such cranes are labeled "eXtra-Safety And Monitoring" (X-SAM). The report includes calculations showing the safe margin on wire rope strength for cases where the protective devices are called upon to prevent failure of the hoisting system to safely hold the critical load in case of malfunction or failure in the hoisting system. In addition, the report shows the method of compliance with the individual regulatory positions in proposed Revision 1 (Draft 3) of Regulatory Guide 1.104 (guide now withdrawn but republished as NUREG-0554).

B. Staff Evaluation

1. General

EDERER has developed a single-failure-proof crane with features that differ from the approach that has been indicated or used by the crane industry in general. The basic difference lies in the manner in which the hoisting system brakes are applied both conventionally and also directly to the hoisting drum(s) and the subsequent elimination of a dual drive gear train in favor of a single drive gear train. It is customary on overhead cranes to place the hoisting brake(s) close to the driver, and the ability of the brakes to stop and hold the drum(s) is, therefore, dependent upon the continued integrity of any gears and shafts that are interposed between the brake and drum locations in the hoisting system. For designs such as those, it is generally necessary to provide two sets of gear trains to make a hoisting system single-failure-proof. The X-SAM system does not require this redundancy.

Another unique feature is the Energy Absorbing Torque Limiter which protects the wire ropes from bein strained excessively in case of an overload in the hoisting system. Such overloading could be caused by a "two blocking" or "load hangup" incident. These have occurred with conventional cranes and have resulted in failure of the wire rope and injury to personnel.

The X-SAM crane features are basically confined to the equipment located on the trolley. Where an existing crane is altered to include single-failure-proof features it involves changing the hoisting equipment on the trolley if the latter is large enough to accommodate it; however, in most cases it becomes necessary to replace the trolley with a new trolley which is designed to accommodate the larger hoisting system. Whether the crane girder structure has sufficient strength to support the additional weight of the single-failure-proof equipment without a reduction of the rated capacity can only be determined by review of the seismic stress analysis for the girder structure

The X-SAM concept includes a dual reeving system which consists of two independent sets of reeving and a hydraulic load equalization system that ensures equal loading of the two reeving systems for normal operation and cushions any sudden motion caused by an incident such as a damaged or broken wire rope.

2. Individual Safety Systems on the X-SAM Crane

   a. Improvements in the X-SAM Crane System over Conventional Hoist Safety Systems

As a minimum, overhead cranes are constructed and operated in accordance with the Standard ANSI B30.2.0-1976. Essentially, this means that only one travel limit device such as a hoist upper travel limit switch, or a single hoist holding brake is required. The ERERER report indicates that the conventional hoist safety systems for their X-SAM crane includes two separate upper limit travel switches for the hoisting system, and also a lower travel limit switch to prevent the wire rope from being unwrapped from the drum(s). The lower limit switch is not a mandatory requirement but is helpful to operators of cranes categorized for standby service or for infrequent use where complete familiarity with the crane may not be readily attained by the operator.

The X-SAM crane system provides two high speed holding brakes at the hoist motor location, although basically only one is required as part of the conventional hoist safety system by ANSI B30.2.0. The second high speed holding brake is provided in compliance with the regulatory guide guidelines for two holding brakes. The gear train between the hoist motor and drum is single and, therefore, not single-failure-proof; however, additional and separate emergency brakes are provided and applied directly to the drum thus eliminating the need for a dual gear train. These emergency drum brakes will not be used as holding brakes during normal operation, and therefore, are inoperative except for emergencies.

On the X-SAM crane system, a load cell installed in the hoist reeving system senses overloads during hoisting, deenergizes the motor drive and sets the conventional holding brakes. A load cell or sensing device is not an ANSI B30.2.0 requirement, but is included in the R. G. 1.104 guidelines.

The staff finds the selection and arrangement of additional control components and safety systems provided on the X-SAM cranes as described above acceptable because the number of safety devices are in excess of the minimum required by the ANSI B30.2.0 Standard, and are also in excess of the guidelines in R.G. 1.104 and NUREG-0554.

b. Additional Hoist Safety Systems and Features of the X-SAM Crane System

(1) An energy absorbing torque limiter (EATL) is incorporated in the hoist gear case. The EATL unit is a wet type (oil) multi-disc spring loaded clutch which can be adjusted or calibrated to slip at a prescribed torque. The wet type clutch is preferable to a dry type friction clutch because of the repeatability of its performance without any concernable change in the coefficient of friction. The dry type clutch would be susceptible to contamination of the friction surfaces and would have difficulty dissipating the heat energy if required to operate for more than a short time; the torque setting of the dry clutch thus would be affected and would introduce uncertainty about the margin of safety for the hoisting system components.

The EATL unit has been used and tested on the LOFT Containment Building Polar Crane. The tests simulated a "two blocking" accident and were conducted at several hoisting speeds, including 169% motor speed. All the tests showed that the EATL could effectively prevent damaging overloading of the wire ropes and other affected components in the hoisting systems.

The staff finds the application and performance of an oil-wetted torque clutch an acceptable method of preventing failures in the reeving system components due to overloading because this type of clutch has been proven to be a reliable type as evidenced in the automotive and industrial applications and also in the tests performed on the LOFT crane (ref. Safety System Tests, para. D.1).

(2) The Emergency Drum Brake System typically consists of either disc or band type brakes that are applied directly to the wire rope drum(s). These

brakes will not be used as regular holding brakes but will be applied automatically if failure occurs in the hoisting system or when the manual emergency stop button for the crane is activated. The brakes are applied by spring pressure and are released by an external force thus having the same fail-safe features as the regular holding brakes. The staff finds the application of separate emergency brakes in connection with a single gear train and regular high speed holding brakes an acceptable method of providing single-failure-proof features for the hoisting system because it reduces the number of components involved in holding of the critical load and satisfies the guidelines in R.G. 1.104 (position C.3.h) and NUREG-0554 (par. 6.3).

(3) Drum Safety Structure

The hoist drum safety support structure consists of a special and separate hub and stub assembly that is applied to both ends of the drum shell and a restraint structure to prevent the drum gear and emergency brakes from disengaging. An alternate design permits the drum to drop a small distance to be cradled on a safety support; however, this method can be used only if there is no net uplifting force exerted by the drum gear.

The staff finds the drum safety support structures acceptable methods as stated, to assure that the drum will remain in place and hold the load safely in case of shaft or bearing failure because the concepts satisfy the guidelines in R.G. 1.104 (position C.3.k) and NUREG-0554 (par. 4.2).

(4) Failure Detection Systems

The basic function of the failure detection system is to effect a shutdown of the crane hoist machinery and setting of the emergency brakes on the drum(s) if one or more detectors sense improper operation of the hoisting system. The detection system will remove the power when an error signal is received from the following sources:

Main drum overspeed sensor,

Mechanical discontinuity and actuation of the EATL,

Load equalization assembly,

Wire rope spooling monitor, and

Backup upper limit hoist travel switch.

Provisions can also be made for automatically applying the emergency drum brake prior to carrying a load over areas that could tolerate little or no vertical load motion while the transfer is occurring. The electronic failure detection system is fabricated and tested in accordance with IEEE Standard 279-1971 as it relates to the quality of the unit; redundancy requirements are considered satisfied by the mechanical diversity of safety features of the crane.

The staff finds the combination of sensor applications and the solid state electronic failure detection system for the hoisting system acceptable, as stated, because it implements the guidelines in R.G. 1.104 (positions C.3.h and C.3.i) and NUREG-0554 (par. 6.2-6.3).

The failure detection system for drive train continuity can include a mechanical continuity detector that will function in a manner similar to the electronic equipment. The system operates through a set of reducing gear units to sense excess angular velocity of drive motor or drum. Redundant drum overspeed detectors operating off the drum give additional assurance in case of failure in the other detector.

The staff finds the mechanical angular velocity detector in combination with the redundant overspeed detectors an acceptable method of assuring application of the holding brakes in case of failure in the drive train because it implements the guidelines in R.G. 1.104 (positions C.3.h and C.3.i) and NUREG-0554 (par. 6.2-6.3).

(5) Hydraulic Load Equalization System

Equalization of loads between the two reeving systems is maintained by a beam with limited movement. The beam is connected to the piston in a hydraulic cylinder which will cushion any sudden motion of the beam resulting from failure of one of the reeving systems. In addition, the momentary increase in hydraulic pressure due to a failure of a reeving system will actuate the failure detection system which will remove power to the hoist machinery and set the emergency drum brakes.

The staff finds the arrangement and function of the hydraulic load equalization system and the failure detection method acceptable because it implements the guidelines in R.G. 1.104 (position C.3.f) and NUREG-0554 (par. 4.1).

(6) Wire Rope Spooling Monitor

Improper wire rope spooling can take place under conditions such as excessive side pull or off-center lifts, and the wire ropes can be nicked or damaged by crossing over the groove barriers of the drum. Improper spooling is sensed by a beam device and the hoisting action is stopped.

The staff finds the method used to sense improper wire rope spooling and subsequent activation of the failure detection system an acceptable solution to protecting the wire rope from damage due to improper spooling because it implements the guidelines in NUREG-0554 (par. 4.7).

C. COMPLIANCE WITH REGULATORY GUIDE 1.104

1. General

The report states that all the regulatory positions of Regulatory Guide 1.104 proposed Rev. 1 (Draft 3) have been addressed in the design of Nuclear Safety Related X-SAM cranes, and goes on to clarify the compliance with, and exceptions to certain regulatory positions. However, the completeness of the report must be considered in light of potential applications such as when a crane is supplied new and complete or when an existing crane is altered in order to make it single-failure-proof. In addition, a few guide positions relate to the physical arrangement of areas over which the crane can travel, control system arrangement, exclusion areas, quality assurance program, etc.. Appendix B of the topical report identifies the crane specific information supplied to the applicant by Ederer which relates to the application of the crane. Appendix C identifies the regulatory positions which are outside the scope of the topical report and for which the applicant is responsible. When referencing the topical report the applicant should include in the Safety Analysis Report all of the information identified in Appendices B and C.

2. Alternate Solutions for Compliance With Guidelines in Regulatory Guide 1.104

a. New Cranes:

Regulatory position C.3.a

A single load attaching point is provided on the load block in lieu of two attaching points. The reason given for such a deviation is that building height often restricts the net lifting height of the crane and it becomes necessary to use components that will utilize space more economically than possible with a dual point attachment. To compensate for omission of one attachment point the safety factor of the single point attachment (hook) is increased from 5 to 10. A safety factor of 10 has been accepted on past plant applications for single point attachment for hooks.

The staff finds the use of a single attachment point acceptable for cases where building height restricts the net lifting height of the crane provided the safety factor for the attachment point (hook) is 10 as a minimum. This acceptance is based on the approach that in cases where single-failure-proof features cannot be attained, the design factor should be increased to a point where this component is not the weakest link in the train of component part in the hoisting system.

Regulatory position C.3.e.

EDERER departs from the commonly used approach of relating wire rope strength to the breaking strength of wire rope and relates instead to the yield strength to provide a more conservative approach on wire rope safety by keeping the stress within the elastic range of the stress-strain curve.

The staff considers the use of yield strength limits a conservative and acceptable method of assuring wire rope integrity during abnormal operation because it results in additional margin of safety on wire rope strength than obtainable from adhering to Standard B30.2.0.

Regulatory position C.3.k.

The drum safety support scheme of the X-SAM crane, consisting of a separate hub and stub assembly together with the restraint structure, is an acceptable method of complying with this recommendation.

Regulatory position C.3.n.

In paragraph 2.d the application of "emergency holding brakes" directly to the drum(s) was mentioned in connection with a single gear train to achieve single-failure-proof features for that portion of the hoisting system. This feature is considered an acceptable alternative to the conventional method of supplying holding brakes only at the high speed driver location combined with a dual drive gear train to the drum(s) to make it single-failure-proof.

Regulatory positions C.3.s and C.4.c.

The X-SAM cranes are designed to MCL rating without margin for degradation. In other words, the crane could be degraded to 0.85 of MCL rating before being restored to full capacity by the maintenance program. This approach is claimed equivalent to the recommendation in Regulatory Guide 1.104 which suggests design to 115% of MCL to account for degradation between maintenance periods. The approach is justified first by the use of the wire rope yield strength instead of the ultimate or breaking strength, and secondly by controlling the overload through the EATL unit. The EATL unit does not alone control the load on the wire rope during a seismic event if the emergency drum brakes are applied; in this case the emergency brake and the EATL will slip together at 2.6 times the design rated load and thus preserve the integrity of the wire rope by limiting the stress in the rope. EDERER also sizes the wire rope to limit stresses in it during a seismic event to not exceed 90% of the yield strength of the wire rope with a 15% margin for degradation, which results in a margin of 1.5 for overload conditions (see page 13) and a minimum of 1.1 for peak seismic overload. The staff finds the use of MCL minus degradation allowance an acceptable approach for X-SAM cranes when equipped with the HIPS systems because the margin on safety is consistently higher than that obtainable with a conventional non-slip overload sensing system.

b. Existing Cranes:

In the case of alteration or conversion of an existing crane to a crane having single-failure-proof features, it is an objective to evaluate the acceptability of the components and structures that are not replaced. Because an enumeration of changes or limitations to conformance with the regulatory guide cannot be determined until the existing crane has been surveilled and evaluated, the EDERER report must of necessity refer to the applicant for compliance for those structures and component that are not replaced. The staff concurs with the conclusion that the structures and components not replaced by a conversion effort should be evaluated separately for conformance to the regulatory guide positions. In addition, information identified in Appendix C (pages C.4 and C.5) related to regulatory positions C.1.c, C.1.d, C.1.e, C.1.f, C.5.a and C.5.b should be addressed in the Safety Analysis Report by the applicant or owner of the crane.

D. Appendices

1. Safety System Tests

Tests were performed on both the main hoist and the auxiliary hoist for the LOFT Containment Building Polar Crane to demonstrate that the EATL would limit the stress in the wire rope during an actual two blocking incident. The lessons learned from these tests are reported in Appendix D of the topical report. These tests were conducted at various hoisting speeds in order to observe the difference in wire rope loading as affected by the kinetic energy of the moving machinery.

The test results show the load cell output (cable load) during the two blocking tests as a function of the static cable load. For the main hoist. the peak load on the load cell was approximately 1 1/3 times the static cable load. For the auxiliary hoist the peak load was approximately 1 2/3 times the the static cable load. The higher peak load fraction on the auxiliary hoist is a result of the higher hook speed for the smaller hoist. Since the static cable load, when converted to stress, is approximately 40 percent of the yield strength of the wire rope, the tests show an ample reserve strength for the wire rope to endure abnormal incidents such as overloading or two blocking. A further margin is available when comparing the test results against wire rope loading limits based on ultimate strength as given in standards such as ANSI B30.2.0. For this comparison we estimate that the wire rope yield strength is 80 percent of the ultimate strength.

The staff finds the results of tests on the EATL torque limiting device acceptable as indication of its ability to provide adequate margin on wire rope strength during conditions of overloading or two blocking.

2. Analytical and Numerical Techniques.

Appendices E and F describe general analytical and numerical techniques for evaluating accident conditions such as a drive train failure, a wire rope failure, and two-blocking in a single drive train hoist protected by an energy absorbing torque limiter. Specifically, these conditions are mathematically simulated and the resulting responses are calculated. These results provide the bases for evaluating the consequences of these accident conditions on the integrity of the wire rope. Although these loadings can be transmitted to crane internals and supporting structures, the analyses of most importance address wire rope loading resulting from the three conditions.

The staff finds that the equations of motion of the load and drum that result from the application of the law on rigid body mechanics are acceptable and provide reasonable estimates of the wire rope loads for the three conditions identified above. Additional assurance that the rope load resulting from two-blocking simulates actual load is provided by the good agreement with results from the LOFT hoist test. It should be noted that some parameter adjustments had to be made in the equations to achieve good agreement; however, the staff concludes that the adjustments are justified.

Although specific safety margins cannot be predicted until the wire ropes have been sized, the staff concludes that a minimum safety margin of approximately 1.5 can be expected when one of the wire ropes fails which is the worst case loading condition. This margin is acceptable to the staff.

Revision 2 2/15/83

NOTICE

This report was prepared by Ederer Incorporated (Ederer), with assistance from Holloran & Associates, for the use of Ederer. Its use by others is permitted only on the understanding that there are no representations or warranties, express or implied, as to the validity of the information or conclusions contained herein.

ABSTRACT

Ederer's Nuclear Safety Related eXtra-Safety And Monitoring (X-SAM) Cranes and Compact Hoists are designed for a wide range of "single-failure-proof" overhead handling equipment applications in nuclear power plants. This report provides generic descriptions of the safety systems and components of X-SAM Cranes and Compact Hoists that are utilized to meet the guidance of Regulatory Guide 1.104, "Single-Failure-Proof Overhead Crane Handling Systems for Nuclear Power Plants."

A single-failure-analysis of the reference design Nuclear Safety Related X-SAM trolley for installation on an existing crane bridge is included. Typical design data is provided for cranes and hoists of the reference design that range in capacity from 10 Tons to 250 Tons. Compliance with the applicable Regulatory Guides and the provisions for operational testing of the hoist safety systems are also described.

Design of the girder structure is highly dependent upon site and plant specific seismic parameters. Therefore, girder design is dealt with in licensing documents for specific plants.

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NON-PROPRIETARY VERSION

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TABLE OF CONTENTS AND REVISION STATUS, Continued

NOTE

Not all of the reference design hoists depicted in these figures are of the same capacity. Therefore, some of the design details and arrangements shown will not always be consistent between figures.

TABLE OF CONTENTS AND REVISION STATUS, Continued

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ABSTRACT

Ederer's Nuclear Safety Related eXtra-Safety And Monitoring (X-SAM) Cranes and Compact Hoists are designed for a wide range of "single-failure-proof" overhead handling equipment applications in nuclear power plants. This report provides generic descriptions of the safety systems and components of X-SAM Cranes and Compact Hoists that are utilized to meet the guidance of Regulatory Guide 1.104, "Single-Failure-Proof Overhead Crane Handling Systems for Nuclear Power Plants."

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I. INTRODUCTION

References A and B allow applicants 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 critical loads are carried. Regulatory Guide 1.104 and its successor, NUREG-0554, describe an acceptable approach to making an overhead crane handling system "single-failure-proof." This document is the Generic Licensing Topical Report for Ederer's Nuclear Safety Related eXtra-Safety And Monitoring (X-SAM) Hoisting System, which is Ederer's way of complying with Regulatory Guide 1.104 and NUREG-0554.

Ederer's "Job Engineered" X-SAM Cranes represented a substantial advancement in the state of the art of design and manufacture of "single-failure-proof" hoists. This breakthrough in hoist safety and monitoring systems allowed a single drive train hoist to be "single-failure-proof", for the first time.

The Hoist's Integrated Protective System (HIPS)* lies at the heart of all X-SAM Cranes. HIPS gives X-SAM Hoists the capability of reporting abuse, in addition to their inherent protection against damage. The monitoring features of HIPS allow the X-SAM Cranes to be conservatively designed, without massive duplication or oversizing of hardware. Thus, Ederer's X-SAM Cranes can accommodate more abuse, without damage, than comparable capacity conventional cranes and hoists. Certain of the HIPS monitoring systems report abuse resulting from operator errors and component failures, to allow management the prerogative of corrective action. Thereby, recurrence of incidents, which would have resulted in failure or degradation of critical components in conventional cranes and hoists, are minimized.

Most of the important safety features of X-SAM Cranes can be retrofitted on existing cranes, either by a complete replacement of the trolley or by replacing selected hoisting machinery components. The substantive safety features of HIPS are particularly important in retrofit applications, since they protect existing structural components, whose quality and margin of safety may not be fully documented, from overloads throughout their life. The inherent safety available with HIPS also gives Ederer greater flexibility in meeting Regulatory Guide 1.104's "single-failure-proof" criteria, within previously established facility space and weight restrictions.

Subsequent to NRC acceptance of Revision 2 of this topical report, the design of the HIPS has evolved to the point where compact hoists with the features of X-SAM Cranes are now practical. Previously, low capacity (10 to 20 Ton) X-SAM hoists were simply smaller versions of the high capacity (50 to 250 Ton) X-SAM hoists. The size and arrangement of these low capacity hoists restricted their application to auxiliary hoists on overhead crane trolleys. However, most nuclear power facilities have compact low capacity (1 to 20 Ton) hoists in areas that are not served by overhead cranes, e.g., underhung monorail hoists. Evaluations performed in accordance with Reference A have revealed situations where such hoists must carry critical loads. However, most compact hoists are produced as off-the-shelf hardware in large quantities, without the quality and design features required by the Regulatory Guide 1.104. So, single-failure-proof low capacity compact hoists have not been commercially available. Therefore, Ederer has developed Compact X-SAM Hoists that have essentially the same design features as the hoists in X-SAM Cranes. The physical arrangement of the Compact X-SAM Hoists' components has been varied to provide the compact package needed for this application. Throughout this report references to X-SAM Cranes and Hoists also apply to Compact X-SAM Hoists, unless otherwise indicated.

A. Purpose

This report has two purposes:

1. Generic licensing of Nuclear Safety Related X-SAM Hoisting Systems for use in existing facilities.

2. Extention of this generic licensing to complete Nuclear Safety Related X-SAM Cranes for new facilities.

B. Scope

1. This report describes the reference design's:

   o Special hoist safety systems and components;

   o Compliance with the applicable regulatory positions;

   o Operational test provisions;

   o Single-failure-analysis; and

   o Envelope of design characteristics, including those of complete cranes for new facilities.

2. The generic issues involved in licensing a "single-failure-proof" hoisting system in accordance with Regulatory Guide 1.104 are addressed. The only actions required to retrofit a Nuclear Safety Related X-SAM Hoisting System in an existing facility involve:

   o Sizing and arranging the hoist components;

   o Ascertaining compliance with the report's generic design bases;

   o Evaluating the acceptability of the components and structures that are not replaced; and

   o Verifying that the plant design will safely accommodate the limited, controlled load motion following a single cable failure or a drive train component failure during hoisting and lowering operations.

3. Appendices B and C summarize the plant specific information that is needed to complete licensing of a retrofit Nuclear Safety Related Hoisting System.

4. The generic information regarding the Nuclear Safety Related X-SAM Hoisting System is equally applicable to complete new cranes and hoists. The only additional actions necessary to incorporate a complete Nuclear Safety Related X-SAM Crane or Compact X-SAM Hoist in a new facility design are:

   - o Developing the detailed girder or monorail design to support the trolley or hoist; and

   - o Performing the requisite structural and seismic analyses of the girder or monorail design.

C. Applicability

This report, being generic in nature, is intended to apply to all types of nuclear facilities requiring "single-failure-proof" overhead handling equipment, as defined by Regulatory Guide 1.104.

D. History and Background

Ederer is a pioneer supplier of dual load path hoists. It all started, over ten years ago, with one of the dual load path hoists ever built for a nuclear power plant—the reactor crane for TVA's Browns Ferry Station. In the ensuing years Ederer refined the design of the Browns Ferry crane into its second generation of dual load path hoists. In 1976 Northern States Power selected Ederer to design and build the replacement trolley for Monticello's Cask Handling Crane, which was one of the first cranes licensed under Revision 0 of Regulatory Guide 1.104. Reference C, as revised by Reference D, describes the Monticello Crane. The NRC approved use of this crane for making nuclear safety related lifts, with certain restrictions, in Reference E.

Based upon the lessons learned from the design, manufacture, and licensing of Monticello's dual load path trolley, Ederer established the ambitious research and development program that has already lead to HIPS and X-SAM Cranes and Compact Hoists.

Ederer's first two "Nuclear Safety Related" Hoists with the new HIPS are installed in the new trolley for the Loss of Fluid Test (LOFT) Containment Building Polar Crane. Both the 50 Ton Main Hoist and the 10 Ton Auxiliary Hoist incorporated HIPS. The new LOFT trolley fits within the same space and operating envelopes as the original 25-year-old trolley, which was of a conventional design. Appendix D summarizes the "lessons learned" from this retrofitting.

The Nuclear Safety Related X-SAM hoisting system has a wide variety of applications in both existing nuclear power plants and new facilities, including cask handling cranes, containment building polar cranes, and auxiliary and compact hoists for use when the critical loads are smaller than casks and reactor vessel heads.

II. REFERENCES

A. NUREG-0612, "Control of Heavy Loads at Nuclear Power Plants"

B. Regulatory Guide 1.13, "Spent Fuel Storage Facility Design Basis"

C. "Redundant Design Feature Modifications and Safety Evaluation for the Reactor Building Crane System at the Monticello Nuclear Generating Plant," Licensing Report NSC-LS&R-NOR-0151-17, dated November 11, 1976, Docket No. 50-263

D. Northern States Power letter to Mr. Dennis L. Ziemann, Chief Operating Reactors Branch #2, Division of Operating Reactors, U.S. N.R.C., dated February 28, 1977, which submitted revisions to NSC-LS&R-NOR-0151-17, Docket No. 50-263

E. NRC letter to Northern States Power, dated May 19, 1977, Docket No. 50-263

F. Crane Manufacturers Association of America (CMAA), Specification #70, "Specification for Electric Overhead Traveling Cranes"

G. ANSI N42.7/IEEE Standard 279, "Criteria for Protection Systems for Nuclear Power Generating Stations"

H. IEEE Standard 323, "Standard for Qualifying Class I Equipment for Nuclear Power Generating Stations"

III. BODY OF REPORT

A. DESCRIPTION OF HOW THE SAFETY SYSTEMS OPERATE AS AN INTEGRATED SYSTEM

Nuclear Safety Related X-SAM Hoists utilize three types of safety systems for protection against equipment malfunctions and operator errors:

- o Conventional hoist safety systems;
- o The new Hoist's Integrated Protective System (HIPS); and
- o The Balanced Dual Reeving System.

The conventional hoist safety systems in Ederer's X-SAM Hoists include the usual upper and lower travel limits; overload sensing devices; hoist control protective features; and a holding brake on the high speed shafting. By preventing the incidents that cause overloads from occurring, these systems provide X-SAM Hoists their first line of defense against overloads. The conventional holding brake on the high speed portion of drive train holds the load during normal operations. Hoisting and load control is provided by hoist duty electric motors and controls.

Such standard protective devices cannot provide protection from the forces generated if a malfunction allows a two blocking, load hangup, etc., to occur. So conventional hoists, protected only by limit switches, load cells, etc., must absorb the forces of two blocking, load hangup, etc., in deflection or yielding of their load bearing components and structural supports. The typically large design margins in overhead crane structures and machinery allow them to forgive many abuses. However, once these margins are exhausted, either by an accumulation of minor abuses or a single serious incident, a conventional crane can fail catastrophically without warning.

Normally, it is impossible to verify, throughout the life of a crane, that unreported two blockings, overloads, or other abuses have not previously occurred. Therefore, unless the consequences of such incidents are controlled, the factor of safety of certain components will almost always be suspect.

HIPS provides X-SAM Hoists a second line of defense. HIPS prevents overload of hoist components even if incidents occur that would have caused overloads in conventional hoists. HIPS also protects against other types of incidents, such as improper wire rope spooling, to which conventional hoists are vulnerable. In addition, HIPS provides an independent, emergency path for stopping and holding the load in the event of any single, credible failure in the hoist drive train.

As shown in Figure III.A, HIPS includes a special Emergency Drum Brake System that acts on the wire rope drum, a Failure Detection System, and an Energy Absorbing Torque Limiter (EATL) in the drive train. The

Failure Detection System actuates the Emergency Drum Brake System--stopping the wire rope drum--if a drive train discontinuity or component failure occurs.

The EATL allows the hoist to safely withstand two blocking*, overloading, or load hangup**, and still retain the load, even if the drive motor is not de-engergized. Not only are the loads controlled following a two blocking, load hangup, etc., but the hoist's components are also protected, throughout their life, from being overstressed by these incidents. To provide this protection, the EATL directly converts the hoists' high speed kinetic energy to heat during an overloading incident.

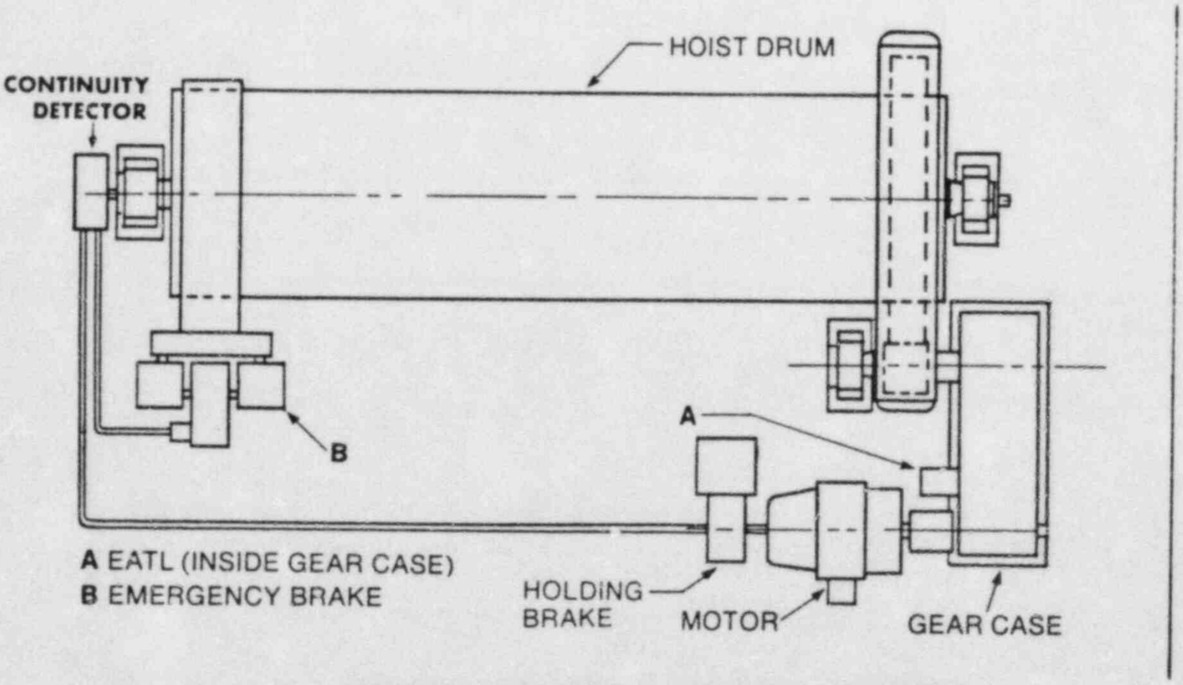
The Balanced Dual Reeving System protects against loss of the load and load sway in the event of a single cable failure. In achieving this capability, the system is balanced in a unique, yet simple, way that protects the wire rope from being cut or crushed if the upper limit switches fail--allowing the lower block to contact the trolley structure. This feature permits Nuclear Safety Related X-SAM Hoists to also utilize the wire rope's inherent energy absorbing capability in withstanding two blockings. The Hydraulic Load Equalization System limits load motion following a cable failure. The Failure Detection System is also actuated in the event of a cable failure.

Another safety feature of all X-SAM Hoists is the emergency lowering capability afforded by the Emergency Drum Brake System. It is not necessary to frequently stop the lowering of the load to allow the brakes to cool, as is required if only conventional high speed holding brakes are used. The Emergency Drum Brake System allows lowering of the design rated load continuously from the maximum hook height without exceeding the temperature limits of the brakes. The emergency load lowering capability provided by the Drum Brake System is in addition to the conventional emergency method, which relies upon the hoist's high speed holding brakes.

*<u>Two blocking</u>--Continued hoisting in which the load block and head block assemblies are brought into physical contact, thereby preventing further movement of the load block.

**<u>Load hangup</u>--Abrupt stopping of the load or load block during hoisting by entanglement with fixed objects.

FIGURE III.A



TYPICAL X-SAM CRANE HOIST ARRANGEMENT

B. CRANE SAFETY SYSTEM DESCRIPTIONS

This section describes the various safety features of Ederer's reference design Nuclear Safety Related X-SAM Hoists.

1. Hoists' Integrated Protective System (HIPS)

HIPS is a series of special hoist safety systems, and subsystems, which have been integrated to:

- o Monitor abuse of the crane or compact hoist;
- o Limit the amount of abuse to which the crane or compact hoist can be subjected;
- o Protect the crane or compact hoist against the consequences of an abnormally large amount of abuse; and
- o Report abuse of the crane or compact hoist so that management can take action to prevent its recurrence.

The systems that make up HIPS include:

a. Energy Absorbing Torque Limiter (EATL)--The EATL is incorporated in the hoist gear case and acts both as an energy absorber and a torque limiter. Under normal loading conditions, the EATL functions as a standard gear in transmitting the drive motor's power. During load hangup, two blocking, or overload, the EATL limits the maximum load imposed on the reeving system, while dissipating the rotational kinetic energy of the high speed components. Even while it is absorbing the rotational kinetic energy, the EATL continues to transmit sufficient torque to hold the load. The EATL automatically resets mechanically and needs no special maintenance other than periodic checks of the torque limit setting. Since the line pull during load hangup, two blocking or overload has been limited, the crane or compact hoist can be promptly returned to service, as soon as the cause of the incident has been identified and corrected. Replacement of components following a two blocking, etc., is not required, since the stress levels have not exceeded known, acceptable values. Further information regarding the EATL is contained in Section III.D.2.

b. Emergency Drum Brake System--The Emergency Drum Brake System is activated by the Failure Detection System. This system provides an independent means for reliably and safely stopping and holding the load following a failure in the hoist machinery. The brake is released by an externally supplied force and needs no externally supplied force for actuation, to provide fail safe operation.

The Emergency Drum Brake System normally will not set during the normal duty cycle.

A manual control station is located on the trolley deck. It allows safe lowering of the load without electrical power in an emergency. The Emergency Drum Brake is described in Section III.D.1.

c. Failure Detection System--The primary function of the Failure Detection System is to detect a loss of mechanical continuity in the hoist machinery and, when necessary, detect actuation of the EATL. Secondarily, its detectors sense improper rope spooling, reeving continuity, and drum overspeed.

An error in any of the above parameters results in shutdown of the crane hoist machinery and setting of the Emergency Drum Brake System after the load lowers a small amount. The key to a locked control panel or key operated switch is required to reset the Failure Detection Sysrem. Both the crane control relays and the Emergency Drum Brake System require electrical power to remain in their normal operating mode. The Failure Detection System removes the electrical power when an error is sensed. Therefore, loss of electrical power results in the same action as an error signal, although a key is not required to start the crane after power is restored.

Provisions for detecting main hoist drum overspeed are included, since drum overspeed can occur only if there has been a control malfunction or a mechanical failure in the drive train. Mechanical continuity is also sensed by monitoring the differential in motor and drum shaft rotation after compensating for the gear train ratio. This method also detects actuation of the EATL. Section III.D.3 describes the Drive Train Continuity Detector.

The Wire Rope Spooling Monitor is an electro-mechanical assembly that senses improper spooling caused by misuse of the crane, such as excessive side pull or off center lifts. Improper spooling is sensed prior to cable damage. However, the possible catastrophic consequences of damaged cables dictate that the Failure Detection System be actuated, if improper spooling occurs.

d. Drum Safety Structure--Retention of the drum on the trolley, in case of drum shaft or support bearing failure, is provided by the Drum Safety Structure. The Drum Safety Structure design ensures that a shaft or bearing failure will not allow the drum to disengage from its drive gear or Emergency Drum Brake System. Section III.D.4 describes the Drum Safety Structure Design.

e. Wire Rope Protection--The hoist is designed to withstand two blocking without mechanically damaging the wire rope. The hoist drum has sufficient grooving to accommodate the additional wire rope spooled in raising the lower block to the trolley load girt, without ropes crossing or chafing. The upper and lower block sheaves are arranged so that the wire rope does not contact the support structure, nor is it subjected to excessive fleet angles if a two blocking occurs. Further, the lower block is designed to mate with the load girt in such a manner that the lower block sheaves will not contact the load girt so they will remain free to rotate.

f. Emergency Stop Button--An emergency stop button at each control station removes power from the crane and sets the Emergency Drum Brake System as soon as the load starts to lower.

2. Conventional Hoist Safety Systems

X-SAM hoists also have the hoist safety systems that are commonly installed on conventional overhead cranes and compact hoists. HIPS protects against the consequences of maloperation of these conventional safety systems, as well as operator abuses and component failures.

a. Dual Upper Limit Switches--Two separate and independent limit switches sequentially actuate as the load block reaches its upper limit of travel. The primary, rotary limit switch on the drum shaft senses both the upper and lower positions of load block travel. The primary upper limit switch de-energizes the hoist controls.

If the hoisting motion is not stopped by the rotary limit switch, a secondary, lever operated, limit switch is tripped by the lower block. The secondary switch actuates the Failure Detection System, since it can be tripped only if there has been a primary limit switch or control system failure. The Failure Detection System sets the Emergency Drum Brake, which removes all power from the hoist. A phase reversal relay is provided when necessary to ensure the proper functioning of the hoist and travel limits, including those of non-XSAM hoists that are installed with X-SAM hoists on the same bridge.

b. Overload Sensing and Indication--A load cell is installed in the hoist reeving. Exceeding the load limit setting shuts down the hoist, but does not actuate the Failure Detection System. The load cell senses overloads that result from two blocking or load hangup--de-energizing the hoist controls, and setting the conventional holding brakes on the high speed shafting.

c. Load Control System--Conventional crane control systems are provided to suit the needs of the applicant. The HIPS protects against the consequences of control system malfunctions, so most aspects of Nuclear Safety Related X-SAM Cranes' control systems do not have to be "single-failure-proof."

d. High Speed Holding Braking--Conventional high speed holding braking is provided on the high speed shafting to hold the load during normal operations. Redundancy in the high speed holding braking is not required since the Emergency Drum Brake provides single failure proof braking.

3. Balanced Dual Reeving System

HIPS provides substantial protection of the reeving by preventing overloads and mechanical damage of the cables. The Balanced Dual Reeving System provides further protection against loss of the load in the event of a cable failure. It includes:

a. Dual Reeving--A standard reeving scheme has been modified to provide a balanced load path using two independent sets of reeving. Figure III.C.3.e shows the reeving arrangement of Nuclear Safety Related X-SAM Cranes. The number of parts of reeving per wire rope and the number of wire ropes per set of reeving are adjusted, along with the wire rope diameter and the number of drums, to suit the hoist's design rated capacity.

b. Hydraulic Load Equalization System--The dead ends of the two independent sets of reeving are attached to the Hydraulic Load Equalization System. This system allows equalization of the two sets of reeving during normal operations, but retards any sudden motion caused by a broken rope. The Hydraulic Load Equalization System is described in Section III.D.5.

c. Wire Rope--Each system is designed to withstand the peak static and dynamic loads imposed by a single wire rope failure, without exceeding 90% of the yield strength of the cable, with the allowance for cable wear and fatigue described in Section III.C. (C.3.e) of this report.

C. SUMMARY OF COMPLIANCE WITH REGULATORY POSITIONS OF REGULATORY GUIDE 1.104

The regulatory positions of Revision 1 (Draft 3) of Regulatory Guide 1.104 have been addressed in the design of Nuclear Safety Related X-SAM Cranes. Additional information regarding compliance with, and exceptions to, certain of the regulatory positions is provided below. Appendices B and C identify the additional plant specific information that is needed to verify a specific retrofit crane's compliance with the Regulatory Positions.

Regulatory Position	Additional Information
C.1.a	Nuclear Safety Related X-SAM Cranes are designed to handle the rated load and may be used for construction loads up to this capacity. At no time should the cranes handle more than the design rated load. The applicant is responsible for establishing a conservative estimate of the projected construction total load spectrum and specifing crane duty classification compatible with the total of anticipated construction and operational usage. As a minimum all Nuclear Safety Related X-SAM Cranes and Hoists have a crane duty classification of A-1 in accordance with Reference F.
C.1.b (1)	Closed box sections of crane structures located outside of containment may not be vented.
C.1.b (2)	Nil Ductility Transition Testing is performed in accordance with this regulatory position for load bearing structural members fabricated from rolled materials as indicated on the sample Critical Items List (Appendix A). The minimum operating temperature specified by the applicant is used to establish the acceptance criteria in accordance with this regulatory position.
C.1.b (3) C.1.b (4)	These regulatory positions are not applicable to complete new Nuclear Safety Related X-SAM Cranes since the testing recommended by C.1.b (2) is performed and low-alloy steel, such as ASTM A514, is not used in Nuclear Safety Related X-SAM Cranes. The applicant is responsible for any required testing of existing crane structures and components when Nuclear Safety Related X-SAM hoisting systems are retrofitted.
C.1.c	Maximum stress levels under SSE seismic conditions in load bearing structures and machinery provided by Ederer are limited to 90% of the yield strength of the material, based upon the gross section of the member, excepting the wire rope. The maximum tension in the wire rope is limited to 77% of the published yield strength of the wire rope to provide an extra 15% margin for wire rope degradation.

C.1.d Figures III.C.1.d.1 and III.C.1.d.2 identify the type of trolley and girder structural welds whose failure might result in the loss of a critical load. The sample Critical Items List (Appendix A) identifies the nondestructive examinations to be performed on welds and base material at weld joints.

C.1.e Dynamic stress levels of critical structural and mechanical components, during projected usage, are kept below the endurance limit of the materials. Stress concentration factors are used in determining dynamic stresses.

C.1.f Post weld heat treatment normally is provided only for welded gear cases. Additional post weld heat treatment of small weldments is also provided, e.g., hook trunnion, etc., when the materials joined are more than 1 1/2 inches thick and the fillet, partial penetration or material repair welds used are more than 3/4 inches thick. Normally, it is possible to select material and weld thickness of the large weldments, e.g., girders, trolleys, etc., such that this criteria, which is consistent with Section III, Subarticle NF-4620, of the ASME Code, does not require their post weld heat treatment.

C.2.a Nuclear Safety Related X-SAM Crane's automatic controls, limiting devices, and HIPS are designed so that, when disorders due to inadvertent operator action, component malfunction, or disarrangement of subsystem control functions occur singularly 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. An emergency stop button is included at all control stations. This button removes power from the crane and sets the Emergency Drum Brake if the load starts to lower.

Provisions for shutting the hoist down and setting the holding brake(s) are provided if needed so that the holding brake(s) will set upon loss of one phase of hoist power. Alternatively, analyses in accordance with Appendices E and/or I are performed to verify that load motion and kinetic energy will not exceed acceptable amounts following a loss of one phase of hoist power.

The EATL, in combination with the Failure Detection System, protects the hoist and thus the load from a failure of the hoist motor control system to deenergize motor when required. Furthermore, the Failure Detection System will actuate the Emergency Drum Brake upon a failure of the hoist motor control system to hold the load. Therefore, neither a single failure analysis or a Failure Modes and Effects Analysis of the hoist motor control system is necessary to ensure that any single failure in the hoist motor control system will not result in loss of a critical load.

C.2.b The Failure Detection System and the Emergency Drum Brake System stop and hold the load in an immobile safe position in case of a subsystem or component failure. The analysis described by Appendix E is used to determine the maximum extent of load motion, following a drive train failure. The maximum kinetic energy of the load following a drive train failure is also determined. This information is provided to the applicant for use in verifying that the facility design will accommodate this limited controlled load motion. If necessary, provisions can be made for automatically actuating the Emergency Drum Brake prior to carrying the load over areas of the facility that the applicant determines cannot accommodate the amount of load motion that can follow a drive train failure.

C.2.c The Emergency Drum Brake allows most repairs to the hoist to be made without lowering the load. The applicant is responsible for establishing safe load lay down areas for use in the event repairs to the crane are required that cannot be made with the load suspended. Provisions are made in the crane design for moving the crane to the designated lay down areas. The Emergency Drum Brake allows the load to be lowered to the lay down area without power.

C.2.d Depending upon the location and application of the crane, it may not be possible to place the crane handling system back into service after component failure(s) with the reactor operating, e.g., the crane may be located in an "exclusion area" during reactor operations. The applicant is responsible for verifying that replacement crane components can be brought into the building/containment without an unacceptable release of radioactivity. The applicant is also responsible for verifying that an area is available where repair work can be accomplished on the crane without affecting the safe shut down capability of the reactor, i.e., a load drop associated with the crane repairs in this area will not damage equipment required to maintain the reactor in a safe shut down condition, or continued operation of the reactor if the applicant intends to operate the reactor during such repairs.

C.3.a A single load path attaching point and lower block trunnion/sideplates are provided in the reference design in lieu of the two load attaching points specified by the regulatory position. Nuclear Safety Related X-SAM Cranes provide an equivalent margin of safety to that specified by providing the single load path parts with a capacity equal to or greater than the combined capacity specified for two attaching points. HIPS prevents overloads of the components. Figure III.C.3.a illustrates the areas of the lower block that have a single load path.

Two load attaching points of at least the specified capacity are provided when the applicant's rigging is not compatible with an oversized single attaching point. Figure III.C.3.a also illustrates the type of dual load attaching point lower block used when facility constraints dictate that one be used.

C.3.b The applicant is responsible for the lifting devices attached to the load block.

C.3.c When higher speed hoisting is required for non-critical loads, key operated cutout switches are provided to restrict the hoisting speed, while handling critical loads, to that specified in this regulatory position.

C.3.d The Balanced Dual Redundant Reeving System meets this regulatory position.

C.3.e Figure III.C.3.e illustrates the two types of Balanced Dual Reeving Systems used with Nuclear Safety Related X-SAM hoists. The special safety features of HIPS preclude damage to the crane cables from two blocking, load hangup, or overloads. Thus, the most severe condition imposed on the cable occurs when the shared load is transferred to the intact reeving, following failure of a cable in the other reeving. Appendices E and I describe the analysis of cable loading following such a failure. Therefore, the wire rope is selected such that the lead lines are capable of safely withstanding the peak static and dynamic loads imposed by this incident, without exceeding 90% of the yield strength of the wire rope. The wire rope manufacturer's published yield strength is multiplied by the wire rope's published "reserve strength" to provide a more conservative margin for wear and fatigue than is provided in the Balanced Dual Reeving Systems supplied with non-nuclear safety related X-SAM Cranes. These criteria can be restated in terms of the following equation for calculating the minimum required wire rope breaking strength:

$$S = \frac{(.5)(L+B)(f)(d)}{(.9y)(r)}$$

Where:

S = Minimum required wire rope breaking strength in pounds.

L = Design rated load in pounds.

B = Lower block weight in pounds.

f = Lead line factor of one side of reeving.

$$y = \frac{\text{Published Yield Strength of Wire Rope}}{\text{Published Breaking Strength of Wire Rope}}$$

r = Published 'Reserve Strength' of Wire Rope

d = Dynamic factor from Appendix E or I = about 3 (worst case).

The margin of safety implied in these criteria appears in the '.9' term, which limits the tension to 90% of the yield strength of the wire rope, and in the 'r' term, which assumes that none of the outer wires of the rope are present. It should be noted that ANSI B30.2.0 requires the wire rope to be replaced when the wear of the outer wire exceeds one-third the original diameter of the outside individual wires. This amount of wear represents a loss of only 10% to 16% of the total metallic area of typical 6 x 37 Class IWRC wire rope. Replacing the wire rope, when required by ANSI B30.2.0, also assures that degradation of the wire rope by fatigue will be limited to approximately 6%. By using the reserve strength to account for wear and fatigue, the above equation assumes that the wire rope metallic area has been reduced by 35% to 55%.

The above criteria is used instead of the one in the regulatory position, which appears to assume that the crane will not be able to safely absorb the high speed kinetic energy in the event of a two blocking.

The maximum line speed of the wire rope is kept below 50 fpm for hoists with capacities greater than 30 Tons. The maximum line speed for compact hoists and auxiliary hoists is consistent with CMAA No. 70's suggested slow operating speed.

C.3.f The fleet angle restrictions of this regulatory position are met in order that the wire rope will not be cut or crushed in the event a two blocking occurs.

C.3.g The portions of the vertical hoisting system components, which include the head block, rope reeving system, load block, and load-attaching device are designed to support a minimum static load of 200% the load imposed on them by the maximum critical load. The sample Critical Items List (Appendix A) identifies the nondestructive examinations and load tests to be performed on load attaching points.

C.3.h The EATL and the wire rope absorb the kinetic energy of the rotating machinery in the event of a control system malfunction. The Hydraulic Load Equalization System actuates the Failure Detection System, which denergizes the motor and sets the high speed holding brake in the event of a wire rope failure. The primary motion of the lower block, following a single wire rope failure, is the vertical displacement associated with the transfer of the shared load to the intact reeving. The alternate design Hydraulic Equalizer System may allow the load to lower until the equalizer contacts the trolley structure. Appendices E and I describe the analysis of the maximum load motion and the kinetic energy associated with it. In any case, the results of the calculation of the maximum kinetic energy and the total vertical displacement of the load are provided to the applicant for use in verifying that the facility design will accommodate this limited controlled load motion.

C.3.i The actual control system design is specified by the applicant. Interlocks to prevent trolley and bridge movements while fuel elements are being lifted, when recommended by Regulatory Guide 1.13.

C.3.j The EATL provides the ability to absorb the kinetic energy of two blocking or load hangup. The alternative protective features allowed by this position are also incorporated. Appendix F contains an analysis of the lead line and machinery loading following two blocking of a crane protected by an EATL.

The analysis described in Section 6.A of Appendix F is used to verify that the lead line loading, if a high speed two blocking occurs while making a critical lift, will not exceed Ederer's wire rope criteria described in Paragraph C.3.e above. The results described in Section 5 of Appendix F indicate that even if the EATL does not actuate during such a high speed two blocking, there is still a substantial margin of safety in the cables, since they are not cut or crushed by the two blocking.

In some applications a non-single-failure-proof hoist, either main or auxiliary, is provided in conjunction with a Nuclear Safety Related X-SAM Hoist. In such cases the non-single failure proof hoist will have

at least two independent travel limit switches to minimize the likelihood of an empty block two blocking over a critical area.

C.3.k The Drum Safety Supports are provided to meet this regulatory position. See Section III.D.4 for further information on the Drum Safety Supports.

C.3.l The EATL protects the individual components of the hoisting system from application of excessive drive motor torque.

C.3.m Only the Emergency Drum Brake System is operable following a drive train failure. However, alone, this system has more emergency lowering capability than two conventional high speed holding brakes have together. Indication of drum lowering speed, which does not require power to the crane, is provided. The Emergency Drum Brake System is capable of continuously lowering the rated load from the maximum hook height without exceeding the temperature limits of the brakes.

C.3.n The conventional redundant holding brake system located on the high speed shafting is fail safe since the failure of any component between the holding brakes and the hoisting drum would be detected by the Failure Detection System, which would then set the Emergency Drum Brake.

C.3.o The control system design includes features to prevent abrupt change in motion if jogging or plugging is allowed. The drift point for bridge and trolley movement is at the low end of the controller movement.

C.3.p
C.3.q
C.3.r

The provisions of these regulatory positions are met by Nuclear Safety Related X-SAM Cranes and retrofit equipment supplied by Ederer in accordance with Generic Licensing Topical Report. Separate overspeed sensors, which actuate the trolley and bridge drive brakes, are not provided when AC motors that inherently cannot overspeed, are used, i.e., when their maximum speed is limited by the 60 HZ line frequency.

C.3.s

Ederer establishes Nuclear Safety Related X-SAM Cranes' Maximum Critical Load Rating equal to the Design Rated Load. An extra margin for wire rope wear and fatigue is provided in Ederer's design criteria for the wire rope, which is described in Section C.3.e above. Ederer's X-SAM Crane design also provides margin in the form of additional substantive safety features. These features protect the crane from the unidentified overloadings and operator abuse, which are responsible for much of the expected degradation of cranes during operation.

C.3.t

The applicant is responsible for inspection and certifications of permanent plant cranes, used for construction, prior to handling critical loads.

C.3.u

Ederer Field Service Personnel oversee the erection and installation of Nuclear Safety Related X-SAM Cranes. Operating instructions provided to the applicant include information on the special safety systems, as well as operating and maintenance instructions for the conventional equipment.

C.4.a

Ederer Field Service Personnel, in conjunction with the applicant, make a complete mechanical check of all crane systems to verify proper installation. Required information concerning proof testing of crane components and subsystems performed by or for Ederer are included in the Quality Records Package that is shipped with the crane.

C.4.b

The specified testing can be performed by the applicant on X-SAM Cranes, including the demonstration of the manual lowering capability afforded by the Emergency Drum Brake. X-SAM Cranes can also be two blocked during the hoisting test to provide assurance of the integrity of the design, equipment, controls, and overload protection devices. Section III.G of this report describes Ederer's recommended two blocking/overload tests.

C.4.c

If the applicant performs the preventive maintenance specified by Ederer, including replacement of the wire rope when required by ANSI B30.2, the Maximum Critical Load Rating can be maintained equal to the Design Rated Load. The substantive safety features of X-SAM Cranes provide the desired margin of safety needed to account for degradation of wear susceptible component parts.

C.4.d A cold proof test of X-SAM Cranes is not required, since the required material testing of Regulatory Positions C.1.b(2) is provided. The applicant is responsible for inspection, testing and certification of existing crane structures when X-SAM's safety features are backfitted into existing facilities.

C.5.a The applicant is responsible for the quality assurance program for site assembly, installation, and testing of the crane. Ederer's Quality Assurance Manual implements the pertinent provisions of Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," to 10 CFR Part 50 for design and manufacture of Nuclear Safety Related X-SAM Cranes. Ederer's X-SAM Cranes incorporate components produced at various locations by one or more divisions of Ederer and by various suppliers to Ederer. From time to time during the manufacturing process it may be necessary, in order to meet demand for particular types of cranes and equipment, or to meet federally mandated safety standards, or Nuclear Regulatory Commission requirements, or for other reasons, to produce Ederer products with different components or differently sourced components than the typical components described or illustrated in this Report. All components are approved for use in Ederer's Nuclear Safety Related X-SAM Cranes by the Ederer Engineering and Quality Assurance Departments, and provide equivalent quality and performance described by this Generic Licensing Topical Report.

Subcontractors are normally involved in the following operations on Ederer fabricated equipment: fabrication, rolling, welding, and nondestructive examination of welded drum shells and oversized structural components; forging and machining of large gear blanks and hooks; painting of major components; and fabrication of some electrical control packages. Most nondestructive examination at Ederer is performed by an independent test lab. Consultants provide Ederer specialized technical support in seismic analysis, licensing, and quality assurance. When required, consultants also supplement Ederer's engineering capability in design and detailing of cranes.

C.5.b Project Quality Assurance Plans for Nuclear Safety Related X-SAM Cranes invoke the Ederer Quality Assurance Manual. The Project Quality Assurance Plans address the recommendations of Regulatory Guide 1.104 in the Critical Items List.

The Critical Items List for a specific crane is based upon Appendix A. Adjustments to the list are made to accommodate the detailed design and the actual components provided. The nondestructive examinations, quality documentation, and special inspections provided are equivalent to those indicated by Appendix A.

Only those items and services identified on the Critical Items List are subject to the controls of Ederer's Quality Assurance Manual. Other equipment is provided in accordance with the manufacturers' customary procedures and design practices.

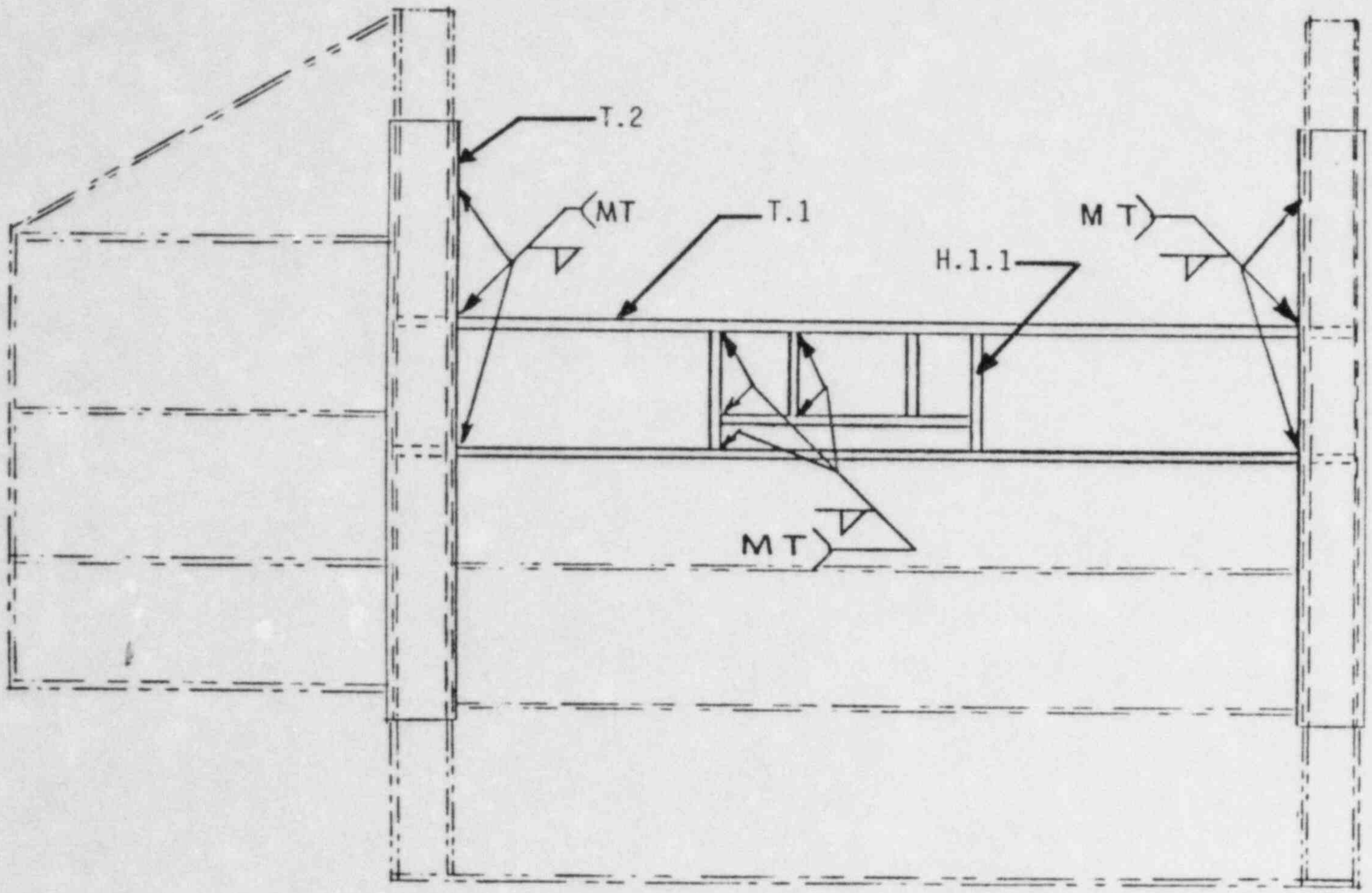
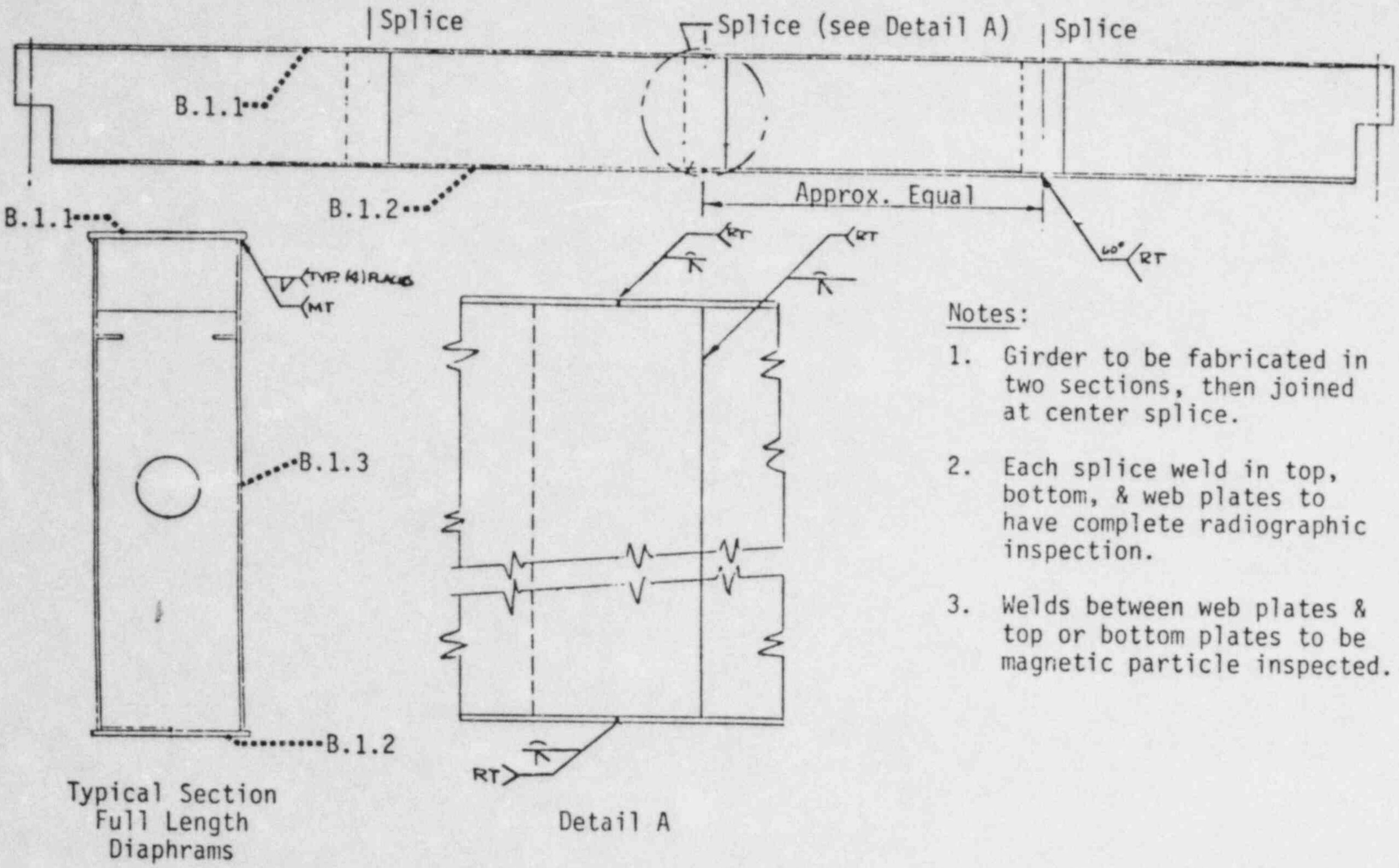


Figure III.C.1.d.1

Typical Trolley Structural Welds



Notes:

1. Girder to be fabricated in two sections, then joined at center splice.

2. Each splice weld in top, bottom, & web plates to have complete radiographic inspection.

3. Welds between web plates & top or bottom plates to be magnetic particle inspected.

Figure III.C.1.d.2

Girder Structural Welds

PROPRIETARY
FIGURE
DELETED

Figure III.C.3.a
Typical Load Attaching Points

PROPRIETARY
FIGURE
DELETED

Figure III.C.3.e
Typical Balanced Reeving Diagrams

D. KEY SAFETY SYSTEM COMPONENT DESCRIPTIONS

1. Emergency Drum Brake

Figure III.D.1 depicts two typical pneumatically released, spring set Emergency Drum Brakes. In some instances, tandem brakes may be utilized to provide the required braking. The reference design is also compatible with hydraulically released, spring set Emergency Drum Brakes. Both disk and band brakes are compatible methods of engaging the drum. Brakes, which have been proven in other industrial applications, some of which involve extended energy dissipation, are selected.

The pneumatically released Emergency Drum Brakes are designed such that their friction surfaces remain in contact even when the brake is not engaged. The brake's retarding torque is directly proportional to the force applied to the actuator, which in turn is directly proportional to the distance the actuator moves. Motion of the actuator would normally be expected to follow an exponential decay as the pressure, which holds the brake open, is bled off. However, for simplicity in analysis, Ederer assumes that the brake engagement is linear with time once it has been actuated by the Failure Detection System and that the time to complete actuation is the same as for the real brake. Therefore, at any given time during the engagement period, the actual brake, with the same timing characteristics as those assumed in the analysis, will provide more braking. Thus, the analysis is conservative. Section III.G.3 describes the testing performed to establish the time required for the brake to fully engage following actuation by the Failure Detection System, as well as the fully engaged retarding torque developed by the Emergency Drum Brake.

When necessitated by space restrictions or other facility-dependent design parameters for large capacity cranes, the Emergency Drum Brake may be located on a higher speed shaft of an independent increasing speed gear train. In these cases, the added rotational inertia of the system is considered and accommodated during two blocking. The brakes are sized so that their thermal capacity will still be sufficient to continuously lower the maximum critical load from the maximum work height. When this arrangement is used, the Drive Train Continuity Detector will detect continuity from the drum brake shaft to the motor shaft in order to assure that a failure in the gear train to the brake would be detected.

Appendix H describes a continuously engaged Emergency Drum Brake.

2. Energy Absorbing Torque Limiter

Figure III.D.2 depicts two typical EATL designs and the location of the EATL within the gear case. The number of friction surfaces is varied to suit the torque requirements. The torque at which these typical EATLs actuate is adjusted using the adjustment nut(s).

3. Drive Train Continuity Detectors

Figure III.D.3 is a generic block diagram of a Drive Train Continuity Detector. It detects a loss of drive train continuity by monitoring the hoist drum shaft speed and the differential rotation between the high speed motor and the hoist drum shafts. Depending upon the location of the discontinuity, it is indicated by either a drum overspeed condition or by excess differential rotation between the two shafts. In monitoring the differential rotation of the high speed motor and hoist drum shafts, the Drive Train Continuity Detector automatically accounts for the gear ratio between the two shafts.

The functions of the Drive Train Continuity Detector can be performed either in a digital or analog manner. As described below, the components shown in Figure III.D.3 can be electronic, electrical, mechanical, or a combination of these types of equipment. Regardless of the type of components used, the Drive Train Continuity Detector is designed such that any single failure in it will either actuate the Failure Detection System or will not prevent detection of a drive train discontinuity.

Figure III.D.3.a is a schematic diagram of a typical electronic Drive Train Continuity Detector. It is made up of industrial grade electrical and electronics equipment. Digital transducers driven by the hoist drum and high speed motor shafts provide the information input to the comparison circuits. The comparison circuits are comprised of a number of catalog integrated circuits. Analog electronic components can be used in a similar manner. In either case, the single failure criteria of Reference G are invoked on the design of the electronic Drive Train Continuity Detectors. Reference H is the basis used for qualifying and testing electronic Drive Train Continuity Detectors. Since a failure of both the drive train and the Drive Train Continuity Detector would be required for a loss of the load, the redundancy provisions of References G and H are not applicable.

Figure III.D.3.b is a schematic diagram of a typical mechanical Drive Train Continuity Detector that functions in an analagous manner to the electronic detector shown in Figure III.D.3.b. This detector mechanically compares the differential rotation of the high speed motor and the hoist drum shafts and actuates the Failure Detection System when the prescribed amount of differential rotation is exceeded. A torque limiter coupling protects the differential motion detector from excessive inertial forces that might result from a drum gear failure. Sufficient drag is introduced on either side of the differential to allow detection of a detector shaft or torque limiter failure.

To avoid spurious trips caused by gear backlash, the differential indicator does not actuate the Failure Detection System until a preset amount of differential rotation of the two shafts has occurred. The differential indicator is periodically reset to avoid spurious trips caused by the accumulation of system noise or minute slippage of the EATL over a large number of operating cyles. The reset periods are selected to assure that any undetectable, uncontrolled load motion is within the plant specified limits. Some or all of the components in this arrangement can be replaced with electrical servos and counters.

The type of detectors shown in Figures III.D.3.a and III.D.3.b directly detect excess differential rotation between the high speed motor and hoist drum shafts. Figure III.D.3.c illustrates a mechanical continuity detector that performs the same function by monitoring the rate of differential rotation between the two shafts. With this type of design, a separate reset function is not required to avoid spurious trip. Also with this approach it is not necessary to exactly match the total reduction of the detector to the drive train's reduction. The minimum detectable differential velocity is selected to assure that any undetectable, uncontrolled load motion is within the plant specified limits. During normal operation of this type detector, the high speed motor drives the worm through the differential. The drag on the differential is set at a level that drives the worm at the rate allowed by the rate the drum rotates the worm wheel. The rate of rotation of the differential is determined by the difference in the total reduction of the detector and the drive train. With this design alternative, a drive train discontinuity is detected by:

a. The drum overspeed detector, as in the other alternatives, if the drive train failure occurs near the hoist drum.

b. A longitudinal force exerted by the worm wheel on the worm when the drum attempts to drive the worm wheel faster than the rate of rotation of the worm will allow.

c. An excessive rate of differential rotation resulting from EATL slippage during a two blocking.

In this design, sufficent drag is introduced on the differential and the worm wheel to allow detection of a shaft failure. A torque limiter is provided in the shaft to the worm wheel to protect the detector from excessive torques once the discontinuity has been detected.

The types of Drive Train Continuity Detectors shown in Figures III.D.3.a, b, and c actuate solinoids that vent the pneumatic pressure that holds the Emergency Drum Brake pads away from the braking surface. A mechanical Drive Train Continuity Detector that is capable of developing sufficient force to restrain a mechanical Drum Brake Actuator developed initially for use in X-SAM Cranes provided to the space program and hot metal industry. This capability was an essential element in the development of a Compact X-SAM Hoist. Appendix G describes the operation of both this type of Drive Train Continuity Detector and the Drum Brake Actuator that it operates.

Appendix H describes the type of Drive Train Continuity Detector used for the continuously engaged Emergency Drum Brake. The continuously engaged Emergency Drum Brake is another method for making X-SAM practical for Compact Hoists.

4. Drum Safety Structure

Figure III.D.4 depicts a typical Drum Safety Structure, which serves to limit the motion of the drum following failure of the drum shaft, drum hub, or bearings. This structure, located on both ends of the drum, keeps the drum gear and Emergency Drum Brake from disengaging sufficiently to prevent them from supporting the load. Figure III.D.4 also shows an alternate design Drum Support Structure built into the trolley structure that is compatible with the reference design when there is no net upward force exerted by the drum pinion. With this alternate design, which is provided at both ends of the drum, the drum drops a small distance onto the safety support, where it is safely cradled.

5. Hydraulic Load Equalization System

Figure III.D.5 is a schematic diagram of a typical Hydraulic Equalization System. The pressure relief protects the hydraulic system and the intact reeving from excessive stress. The relief setting is at a pressure corresponding to 150% of the equilibrium tension in the intact wire rope. A hydraulic fluid velocity fuse and/or an orifice are used to retard the motion of the ends of the reeving in the event of a single wire rope failure.

Alternatively, Figure III.D.5.b illustrates a more compact Hydraulic Equalization System that was developed initially for the Compact X-SAM Hoist. This system includes a shock absorber that limits the impact forces applied to the equalizer and crane structure as the equalizer rotates into contact with the structure following a wire rope failure. In the process a small additional amount of load motion occurs, as is calculated in accordance with Appendix I.

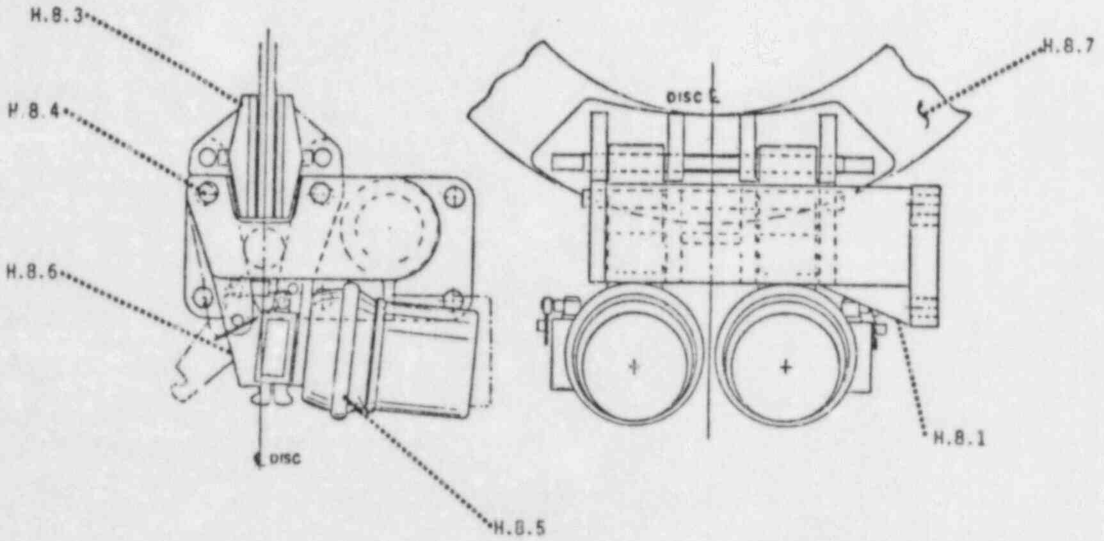
6. Lower Block and Hook

Figure III.C.3.a and III.D.6 depict typical lower blocks and hooks. The number of sheaves is adjusted to suit the hoist capacity.

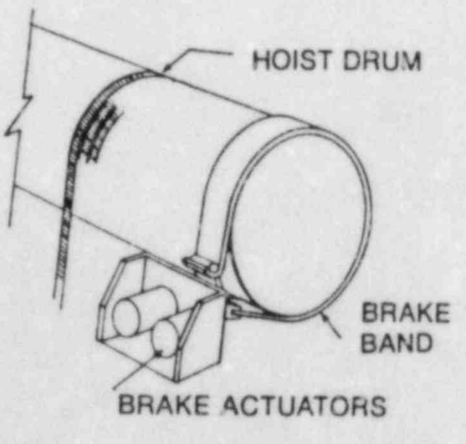
7. Wire Rope Spooling Monitor

Figure III.A identifies the location of the wire rope spooling monitor. The wire rope spooling monitor consists of a rod positioned across the entire grooved area of the drum so that it is tripped by the wire rope if the wire rope crosses a groove in the drum or if the wire rope wraps over itself. During normal spooling the cylinder does not contact the wire rope or any moving parts of the drum. The electrical proximity switches are actuated by the motion of the rod that results from improper wire rope spooling.

FIGURE III.D.1
TYPICAL EMERGENCY DRUM BRAKE DESIGNS



DISC BRAKE



BAND BRAKE

FIGURE III.D.2
TYPICAL ENERGY ABSORBING TORQUE LIMITER DESIGNS

PROPRIETARY MATERIAL DELETED

ORIGINAL DESIGN

PROPRIETARY MATERIAL DELETED

ALTERNATE DESIGN

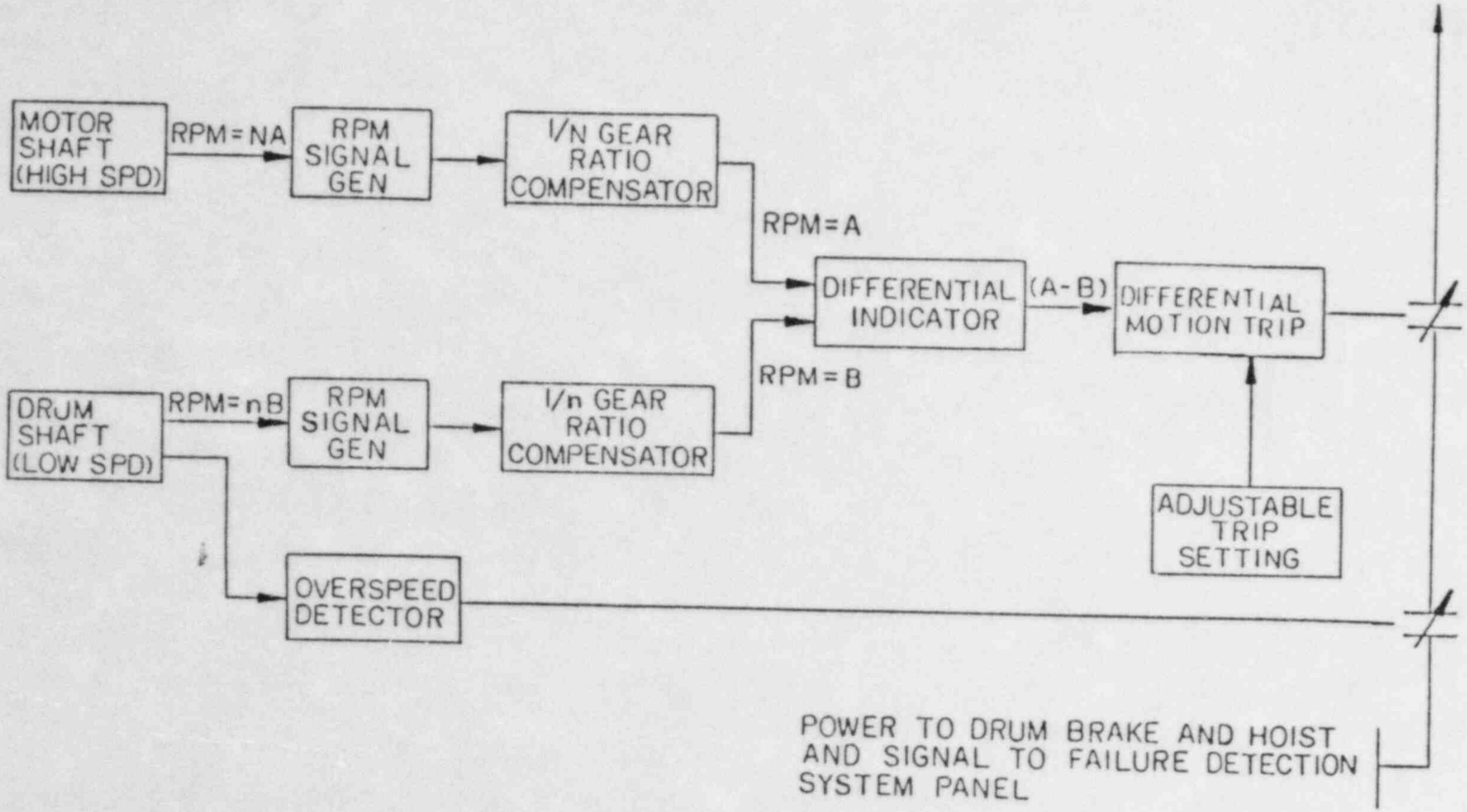


Figure III.D.3

Generic Drive Train Continuity Detector

PROPRIETARY MATERIAL DELETED

Figure III.D.3.a
Electronic Drive Train Continuity Detector

PROPRIETARY MATERIAL DELETED

Figure III.D.3.b
Mechanical Drive Train Continuity Detector

PROPRIETARY MATERIAL DELETED

Figure III.D.3.c
Alternate Concept Mechanical Drive
Train Continuity Detector

FIGURE III.D.4
TYPICAL DRUM SAFETY SUPPORT DESIGNS

PROPRIETARY MATERIAL DELETED

FIGURE III.D.5

PROPRIETARY MATERIAL DELETED

Schematic Diagram of the Original Design
Hydraulic Load Equalization System

PROPRIETARY MATERIAL DELETED

Schematic Diagram of the Alternate Design
Hydraulic Load Equalization System

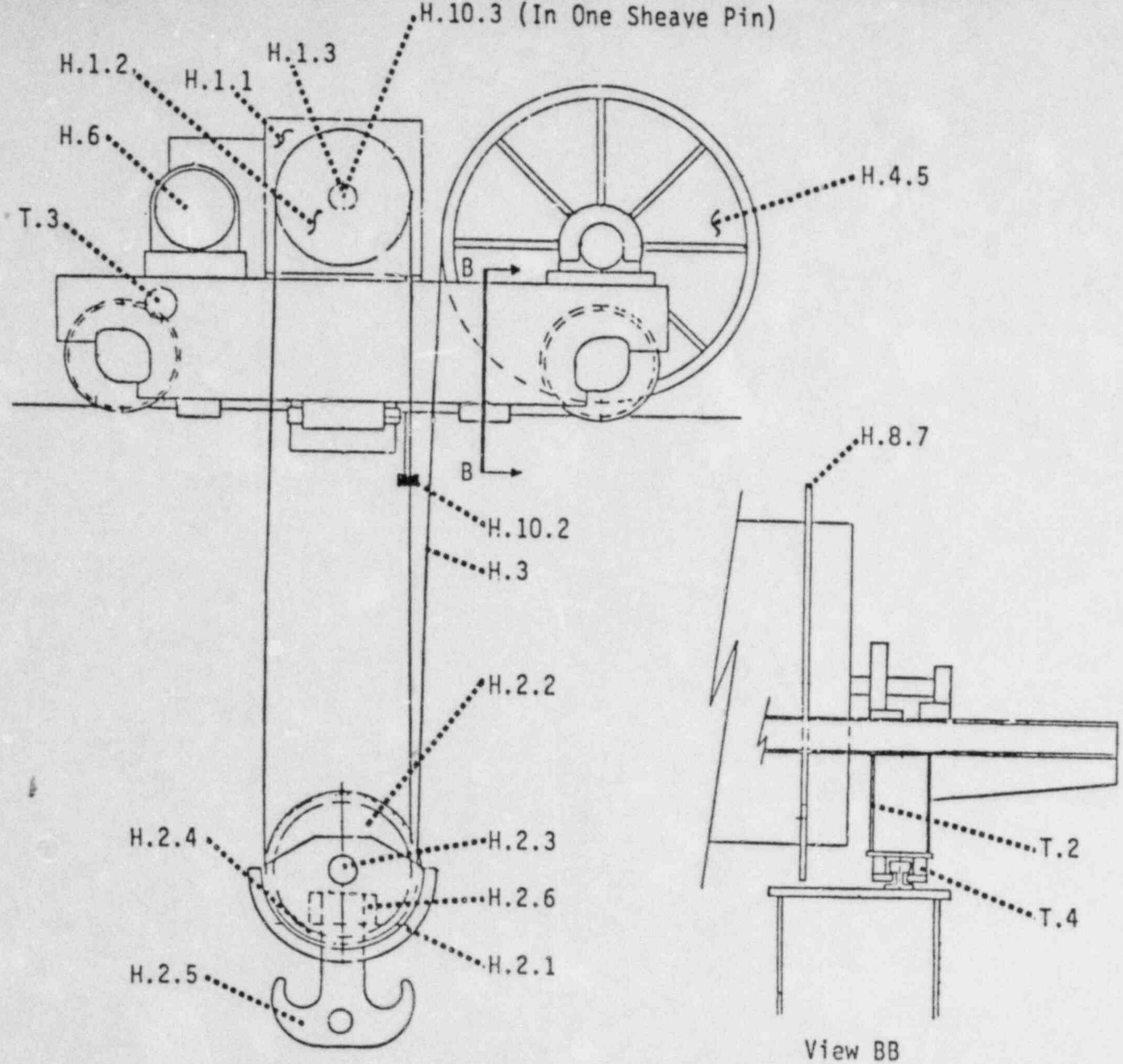


Figure III.D.6

Typical Design of Dual Load Path
Lower Block and Attaching Points

E. Single-Failure-Analysis of Hoist

Defense in depth is provided by the Hoist's Integrated Protective System (HIPS) of Ederer's X-SAM Cranes. These systems are designed to allow the X-SAM cranes to safely withstand incidents and operator errors that would cause catastrophic failures in most conventional cranes. However, to assure that operators do not routinely rely on the safety features of the HIPS, the Failure Detection System cannot be reset following serious incidents without access to a locked panel or the key to a key operated switch. This feature allows management the prerogative, through control of the key to the panel or switch, to prevent continued operation of the crane following a serious failure or operator abuse.

If the crane is properly serviced and operated, the Failure Detection System will never be actuated during normal crane operations. The following paragraphs describe the performance of Nuclear Safety Related X-SAM Cranes during a variety of serious incidents.

1. Overload--On overload, the X-SAM Cranes' standard electronic load sensing and automatic cutout system interrupts power to the hoist motor and sets the holding brakes. Shutdown by the electronic load sensor does not actuate the Failure Detection System of the HIPS.

   Minor overloads, which the operator attempts to pick up gradually, will not actuate the Energy Absorbing Torque Limiter (EATL) or the Failure Detection System of the HIPS. Thus, the crane can be restarted without access to the locked panel under these conditions.

   If the operator attempts to "snatch" a large or immovable load, or if the electronic system fails to perform its function during an overload, the EATL will limit the load imposed upon the crane. When the EATL limits the load it actuates the Failure Detection System, which means that access to the locked panel will be required to restart the crane following this type of incident.

2. Load Hangup--In the event of a hangup of the load, the kinetic energy of the high speed rotating machinery will be absorbed by the EATL, protecting the hoist machinery, reeving, and crane structure. However, unless the EATL torque setting has been reduced to be consistent with the weight of the load, the crane's design hoisting force may be imposed on the load and its rigging, during an instantaneous, rigid load hangup.

   Some protection of the load and its rigging is afforded by the adjustment option that is available in addition to the standard electronic load sensing system. With this option, the load sensing system can be set for any pre-determined hoisting force, providing it is less than the design rated load of the hoist. If the load exceeds this setting, power to the hoist motor is interrupted and the high speed holding brakes are set. Depending upon how quickly the load hangup occurs, the high speed holding brakes may have time to engage and absorb part of the high speed kinetic energy before the design rated hoisting force can be imposed on the load or its rigging. The electronic load sensing system does not actuate the Failure Detection System, and the Emergency Drum Brake System is not set. Therefore, the crane can be restarted by changing the setting if only the electronic load sensing system actuates.

3. Two Blocking--Two blockings during operations are normally prevented by a primary upper rotary travel limit switch on the hoist drum and a backup upper limit switch on the upper block. Actuation of either limit switch de-energizes the hoisting motor, which sets the high speed holding brakes. The crane can be reactivated by reversing the hoist control and backing out of the first limit switch. Actuation of the backup limit switch also actuates the Failure Detection System, since it will not actuate unless there has been a primary limit switch or control system failure. The Failure Detection System sets the Emergency Drum Brake, which removes all power to the hoist. Of course, failure of both limit switches to actuate, or their inability to de-energize the motor, results in a mechanical two blocking.

   Mechanical two blocking a hoist protected by HIPS simply causes the EATL to actuate, which is detected by the Failure Detection System, setting the Emergency Drum Brake System. The load is retained in a safe condition, even if an electrical short circuit prevents removal of power from the hoist motor, since the EATL is capable of dissipating the entire energy input to the motor while still transmitting sufficient torque to hold the load.

   Even if the EATL fails to actuate at the specified torque setting during a two blocking or load hangup, Appendix F indicates that the wire rope has substantial ability to continue to hold the load if it is not cut or crushed.

4. Hoist Drive Train Failure--When a significant discontinuity between the motor shaft and the wire rope drum, e.g., failure of a key, shaft, coupling or gear, or actuation of the EATL, is detected, the Failure Detection System sets the Emergency Drum Brake System--interrupting the power to the hoist motor. Appendix E describes the analysis that Ederer uses to determine the amount of load motion that can result from a drive train component failure. The maximum calculated load motion and load kinetic energy is provided to the applicant for use in verifying that the facility design can safely accommodate this amount of controlled load motion. When required, the Emergency Drum Brake can be automatically engaged prior to traversing with the load. In this condition, no load motion will follow a single drive train failure while the load is traversing over critical areas.

5. Drum Support Failure--Following a drum support failure, the drum will be safely held by the Drum Safety Structure. The failure would

be sensed when the EATL slipped and/or a discontinuity is created in the drive train. The Failure Detection System would also be actuated, setting the Emergency Drum Brake System when the EATL actuates. The Emergency Drum Brake System is still capable of holding the drum when it is supported by the Drum Safety Structure.

6. Overspeed--Overspeed can occur only if there has been a major mechanical or control system failure. Overspeed following a control system failure is sensed by the motor overspeed detector. A control system failure may prevent the high speed holding brakes from engaging. Therefore, drum overspeed actuates the Failure Detection System, which sets the Emergency Drum Brake System.

   The drum overspeed detector is part of the Drive Train Continuity Detectors, so it also actuates the Failure Detection System if a mechanical failure results in an overspeed condition.

7. Total Loss of Power While Hoisting a Critical Load--A total loss of electrical power sets the conventional high speed holding brake and, if the load starts to lower, the Emergency Drum Brake as well, thereby stopping the load.

   Substantial capability for lowering a load to a safe resting place, following a total loss of electrical power, is provided by HIPS. Its Emergency Drum Brake System provides a large margin of safety under these conditions because of the brake's substantial thermal capacity. The rated load can be safely lowered continuously from maximum hook height to the floor without exceeding the temperature limits of the brakes. It is not necessary to stop the load frequently, as is required when only conventional holding brakes are used.

8. Hoist Control System Failure--HIPS protects against the consequences of a hoist control system failure, which results either in an overspeed condition or inability to remove hoisting power. The EATL is capable of dissipating the full energy output of the drive motor until the Emergency Drum Brake System sets, if the motor cannot be de-energized and a two blocking results. The Emergency Drum Brake also provides the operator an independent means of manually stopping a load in the event a control system failure prevents the conventional holding brake from setting while the control system's regenerative braking is operating. Thus, the Emergency Drum Brake restores most of the protection provided by mechanical load brakes, which was lost when electrical load controls were adopted to obtain improved speed control.

9. Off Center Lifts--In the event an excessive off center lift is made, the Wire Rope Spooling Monitor senses the improper spooling of the wire rope before damage can occur. Because of the potentially catastrophic consequences of damage to the wire rope, the monitor

actuates the Failure Detection System, requiring management concurrence to restart the crane.

10. Failure of High Speed Motor Holding Brake--The Emergency Drum Brake System provides a backup to the conventional holding brake during normal operations, since it automatically actuates either on overspeed or as soon as the load starts to lower. With the Emergency Stop Button, the operator is able to manually engage the Emergency Drum Brake System.

11. Cable Failure--The entire load is transferred to the remaining rope system under controlled acceleration and forces. The relationship between the load and the supporting structure is not changed, so load sway is kept to an acceptable level. The failure is automatically detected by the Failure Detection System, which sets the high speed holding brake and actuates the Emergency Drum Brake System. Depending upon the type of Emergency Drum Brake Actuator that is used, the Emergency Drum Brake may also be set by the Failure Detection System. In any event the Emergency Drum Brake will automatically set if necessary to stop the load from lowering. In this manner the load is retained in a safe, stable position. In all cases the management concurrence is required to restart the crane since the Failure Detection System was actuated.

    The actual amount of vertical displacement of the load depends upon the length of cable unspooled and the weight of the load. Appendices E and I describe the analysis that Ederer uses to determine the maximum amount of transient load motion and kinetic energy that can result from a cable failure. A small additional amount of load motion may result when the alternate Hydraulic Equalization System allows the equalizer beam to move into contact with the trolley structure. This additional load motion is calculated, as described in Appendix I, and is provided to the applicant for use in verifying that the facility design can safely accommodate this amount of controlled load motion.

F. Envelope of Design Characteristics and the Design Criteria Utilized to Extend the Reference Design to Complete Cranes for New Facilities

1. Typical Design Characteristics -- The reference design utilizes the same basic approaches to meeting the requirements of Regulatory Guide 1.104, independent of the capacity of the hoist. Table III.F.1 summarizes the design characteristics of reference design Nuclear Safety Related X-SAM hoists with capacities typical of four different applications in nuclear power plants. For particular facility applications some of the characteristics listed in Figure III.F.1 are adjusted to suit the specific capacity and specified configuration of the trolley, e.g., with or without auxiliary hoist and the facility space envelope. Appendix B identifies the design characteristics Ederer provides for licensing of specific Nuclear Safety Related Hoists.

2. Complete Cranes for New Facilities -- The reference design hoisting system is equally applicable to complete cranes for new facilities. The detailed girder design is developed and analyzed in accordance with Reference F, Regulatory Guide 1.104, and the site-specific seismic requirements.

TABLE III.F.1
TYPICAL CHARACTERISTICS OF FOUR DIFFERENT CAPACITY NUCLEAR SAFETY RELATED X-SAM HOISTS OF THE REFERENCE DESIGNS

Application	Compact Hoist	Medium Capacity Main Hoist	Fuel Cask Handling Crane	Containment Building Polar Crane
Crane Classification	A-1[1]	A-1[1]	A-1[1]	A-1[1]
Design Rated Load	10 Tons[2]	50 Tons[2]	130 Tons[2]	250 Tons[2]
Maximum Critical Load Rating	10 Tons	50 Tons	130 Tons	250 Tons
TROLLEY:				
Trolley Runway Rail Size	(I-Beam)	80 lbs.	171 lbs.	171 lbs.
Trolley Weight (net)	5,000 lbs.	50,000 lbs.[3]	114,000 lbs.[3]	200,000 lbs.[3]
Trolley Weight (w/load)	25,000 lbs.	150,000 lbs.[3]	374,000 lbs.[3]	550,000 lbs.[3]
No. Wheels - Size	8 - 6"	4 - 15"	4 - 24"	8 - 24"
Design Speed	30 fpm	30 fpm	30 fpm	30 fpm
Drive Motor	½ hp	1½ hp	5 hp	10 hp
HOIST:				
Hook Type	Single[4]	Single[4]	Single[4]	Dual[4]
Hook Lift	60 feet[5]	61 feet[5]	77 feet[5]	120 feet[5]
Number of Drums	1	1	1	1 or 2
Drum Size (Pitch Diameter)	18"	38"	70"	70" or 50"
Full Load Hook Speed, Max.	15fpm[6]	4 fpm	4.5 fpm	4 fpm
No Full Load Hook Speed, Max.	15fpm	4 fpm	4.5 fpm	4 fpm
Drive Motor	7.5 hp (A.C.)[7]	15 hp (D.C.)[7]	60 hp (A.C.)[7]	90 hp (A.C.)[7]
Controller	5 Speed-Magnetic[7]	Maxspeed 100[7]	5 Speed-Regulated[7]	5 Speed-Magnetic[7]
Control Braking	Regulated Eddy Current[7]	Regenerative[7]	Eddy Current[7]	Regulated Eddy Current[7]
Hook Design Load	10 Tons	50 Tons	130 Tons	250 Tons
Hook Test Load	20 Tons	100 Tons	260 Tons	500 Tons

1 Minimum per CMAA 70, actual classification established by applicant's determination of duty cycle.

2 Greater if used for construction or non-critical lifts in excess of required Maximum Critical Load Rating.

3 Approximate dead weight of trolley. Actual weight depends upon whether an auxiliary hoist selected and number of drums selected.

TABLE III.F.1, Continued

Application	Compact Hoist	Medium Capacity Main Hoist	Fuel Cask Handling Crane	Containment Building Polar Crane
HOIST REEVING SYSTEM:				
Rope Class	6 x 37 IWRC	6 x 37 IWRC	6 x 37 IWRC	6 x 37 IWRC
No. Parts Rope	2 x 4	2 x 4	2 x 8	2 x 8 or 4 x 4
Rope Diameter	1/2"	1 1/8"	1 1/4"	1 3/8"
Max. Rope Speed	60 fpm	16 fpm	36 fpm	16 fpm - 32 fpm
Exterior Fleet Angle	3.5 Degrees	3.5 Degrees	3.5 Degrees	3.5 Degrees
No. Reverse Bends	1	1	1	1
HOIST SAFETY FEATURES:				
No. Ropes	2	2	2	2 or 4
Hook Safety Factor (Minimum)	10[4]	10[4]	10[4]	10[4]
No. Load Cell Devices	1	1	1	1
Load Equalizer Type	Hydraulic	Hydraulic	Hydraulic	Hydraulic
Holding Brake Type	Spring Set	Spring Set	Spring Set	Spring Set
No. Holding Brakes	1	1	1	1
Holding Brake Capacity	150%	150%	150%	150%
No. Upper Travel Limit Switches	2	2	2	2
No. Lower Travel Limit Switches	1	1	1	1
Energy Absorbing Torque Limiter	1	1	1	1
Failure Detection System	1	1	1	1
Emergency Drum Brake	1	1 tandem brake	1 tandem brake	1 or 2 tandem drum brakes or brake on separate gear train off the drum
Emergency Drum Brake Capacity, total	130%	130%	130%	130%

4 Dual load path hook utilized with minimum 5 to 1 factor of safety on each attaching point when facility constraints do not permit use of single load path hook design.

5 Hook lift is established by applicant's facility design requirements.

6 Key operated switch reduces hoisting speed to less than 5 fpm for critical lifts.

7 Selection of specific type of Controller and Control Braking is made by the applicant. The reference design is compatible with regulated or nonregulated eddy current brake/AC wound rotor multi-speed hoist drives; D.C. Variable Voltage regenerative hoist drives.

G. Safety System Test Provisions

Standard pre-operational and periodic checks, tests, and maintenance as specified by ANSI B.30.2, OSHA, and Regulatory Guide 1.104 are performed. These tests include the following:

1. Test of Conventional Hoist Safety Systems

a. Tests of Upper Limit Switches--During pre-operational testing, the upper limit switches are tested as follows: The backup limit switch is disconnected and the block is raised at full speed to verify that the primary limit switch functions correctly. Then the primary limit switch is disconnected, the backup limit switch is reconnected and the test is repeated to verify proper operation of the backup limit switch.

During periodic inspections of the crane as required by OSHA and ANSI B30.2, the upper limit switches are tested as follows: The block is raised at low speed until the primary limit switch is actuated to verify proper operation of the limit switch. Then the primary limit switch is disconnected and the backup limit switch is tested in the same manner.

b. Test of Lower Limit Switch--During pre-operational testing, the lower limit switch is tested as follows: The block is lowered at full speed until the lower limit switch is actuated, thereby verifying proper operation. During periodic testing, this test is conducted at low speed.

c. Test of Overload Sensing System--During pre-operational and periodic inspection testing, the overload sensing system is tested as follows: The upper limit switches are disconnected and the block is very slowly raised until it is touching the bottom of the load girt. At this point, the high speed holding brakes are set and the crane power is shut off. Then a torque wrench is used to bring the cable tension up to the level at which the overload sensing system is set to trip. Power to the hoist motor is restored and if the overload sensing system is operating correctly, it will actuate. If the electronic overload sensing system does not actuate, it is adjusted and the test is repeated until proper operation is verified.

2. Testing of Balanced Dual Reeving System

a. Load Testing in Accordance With OSHA Requirements--Periodic load tests are performed as required by OSHA, ANSI B30.2, and Regulatory Guide 1.104.

b. Test of Hydraulic Load Equalization System--The Hydraulic Load Equalization System is tested and sealed by the manufacturer.

During pre-operational testing and periodic inspections of the crane, the hydraulic fluid level is checked by the operator by monitoring the oil pressure gauge.

3. Testing of HIPS

a. Test of EATL--During pre-operational and periodic testing, the EATL is checked as follows. The upper limit switches are bypassed and the block is slowly brought into contact with the load girt. The drum brake is set, the holding brakes are released and a torque wrench is used to manually actuate the EATL to verify that it is properly set and operates correctly.

During pre-operational testing, a slow speed two-blocking test is performed to verify that the EATL protects the hoist during such an incident. During the slow speed two blocking test the upper limit switches are bypassed and the crane is two blocked. The slow speed two blocking test represents the worst case slow speed load hangup. Therefore, a separate load hangup test is not required for X-SAM Cranes.

b. Test of Emergency Drum Brake System--The time required for the Emergency Drum Brake to engage, following action by the Failure Detection System, is measured with an oscillograph. The fully engaged Emergency Drum Brake dynamic torque is measured by adjusting the EATL to a known torque value at the desired minimum value of Emergency Drum Brake dynamic torque. The hoist is then started and then the Emergency Drum Brake actuated without removing power to the motor. If the actual dynamic brake torque is greater than the minimum the drive train torque will increase to the EATL set point after which EATL actuation will occur.

During pre-operational and periodic testing, the Emergency Drum Brake is tested when the low speed two blocking test is performed. If the safety systems are operating properly, the brake will set when the EATL actuates.

During pre-operational testing, the manual lowering capability of the Emergency Drum Brake System is verified by manually lowering the maximum load as required by Regulatory Guide 1.104. The ability of the Emergency Drum Brake to retain the load without the high speed shaft holding brakes is also verified.

During pre-operational and periodic testing, the drum brake is manually actuated to verify that all power to the crane is interrupted when it engages.

c. Tests of Failure Detection System--Qualification testing and burning in of electronic Failure Detection Systems is accomplished in accordance with the applicable sections of Reference H.

During pre-operational and periodic testing, operation of the portion of the Drive Train Continuity Detector that monitors the relative rotation of the high speed motor and drum shafts is verified in conjunction with the low speed two blocking test.

During pre-operational and periodic testing, the drum overspeed portion of the Drive Train Continuity Detector is tested by uncoupling the detector shaft and manually rotating it to verify that the detector actuates the Failure Detection System.

The Wire Rope Spooling Monitor is tested during pre-operational and periodic testing by manually actuating it to verify that it actuates the Failure Detection System.

APPENDIX A

SAMPLE CRITICAL ITEMS LIST
FOR EDERER'S NUCLEAR SAFETY RELATED X-SAM CRANES

Critical Item Number	Figure Number	Description (1)	Material Test Reports (2)	Non Destructive Examinations (3)	Miscellaneous Inspections, Tests, and Certifications (4)
TROLLEY					
T.1	III.C.1.d.1	Load Girts	MS NDTT (5)	MT (6)	NSR (7)
T.2	III.C.1.d.1 III.D.6	Truck Structure (Inside Plates)	MS NDTT (5)	NA	SR (8) NSR (7)

KEY:

(1)

H=Hoist
B=Bridge
T=Trolley
O=Other
C=Consulting

(2)

MS=Material Specification Test Report. Includes CP, HP, and/or PP, as appropriate. Where:
- CP=Material Chemical Properties
- PP=Material Physical Properties
- HP=Material Hardness Properties

NDTT=Material Nil Ductility Transition Temperature
UT=Ultrasonic Test of Material
MP=Magnetic Particle Inspection of Material
LP=Dye Penetrant Inspection of Material
NA=Not Applicable

(3)

VW=Visual Weld Inspection
MT=Magnetic Particle Inspection of Critical Welds
PT=Dye Penetrant Inspection of Critical Welds
UW=Ultrasonic Inspection of Critical Welds
RT=Radiographic Inspection of Critical Welds
NA=Not Applicable

NOTES (5) AND ABOVE ARE AT THE END OF THE LIST

(4)

I (M)=Mechanical Inspection for Conformance to Detail Drawings
I (S)=Structural Inspection for Conformance to Detail Drawings
CC=Certificate of Conformance or Certified Data Sheet
SPF=Sample Pulled to Failure
LT=Load Test
SF=Shop Functional Test
SR=Stress Relief
RMTR=Routine Motor Test Reports
NSR=Nuclear Safety Related (10CFR21)
NCP=Nuclear Certified Paint
NA=Not Applicable

NOTE: Whenever practical, listed nondestructive examinations of raw material will be procured from the supplying mill to an appropriate national standard, prior to material delivery to Ederer.

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Critical Item Number	Figure Number	Description (1)	Material Test Reports (2)	Non Destructive Examinations (3)	Miscellaneous Inspections, Tests, and Certifications (4)
T.3	III.D.6	Motors	NA	NA	RMTR
T.4	III.D.6	Seismic Restraints	MS	MT (6)	NSR (7)
T.5	III.D.4	Drum Safety Support	MS NDTT (5)	MT (6)	NSR (7)
T.6	Not Shown	Drum Brake Mounting Base	MS NDTT (5)	MT (6)	NSR (7)
T.7	Not Shown	Trolley Overspeed Detector	NA	NA	CC SF
T.8	III.D.6	Wheels	MS HP (18)	NA	NA
<u>HOIST With HIPS</u>					
H.1	III.D.6	<u>Upper Block Assembly</u>	--	--	--
H.1.1	III.C.1.d.1 III.D.6	Structure (Side Plates)	MS NDTT (5)	MT (6)	NSR (7)
H.1.2	III.D.6	Sheaves	MS MP (10)	NA	NA

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Critical Item Number	Figure Number	Description (1)	Material Test Reports (2)	Non Destructive Examinations (3)	Miscellaneous Inspections, Tests, and Certifications (4)
H.1.3	III.D.6	Sheave Pins	MS UT (9)	NA	NSR (7)
H.1.4	III.C.3.e	Equalizer Assembly	MS NDTT (5) UT (17)	NA	NSR (7)
H.1.5	III.C.3.e III.D.5	Hydraulic Load Equalization System	NA	NA	CC NSR (7, 15)
H.1.5.1	III.C.3.e III.D.5	Hydraulic Load Equalization System Supports	MS NDTT (5)	MT (6)	NSR (7, 15)
H.2	III.C.3.a III.D.6	<u>Lower Block Assembly</u>	—	—	—
H.2.1	III.C.3.a III.D.6	Structure (Side Plates)	MS NDTT (5)	MT (6)	SR (8) NSR (7)
H.2.2	III.C.3.a III.D.6	Sheaves	MS MP (10)	NA	NA
H.2.3	III.C.3.a III.D.6	Sheave Pins	MS UT (9)	NA	NSR (7)
H.2.4	III.C.3.a III.D.6	Trunnion	MS UT (9) MP (10)	NA	SR (8) NSR (7)

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Critical Item Number	Figure Number	Description (1)	Material Test Reports (2)	Non Destructive Examinations (3)	Miscellaneous Inspections, Tests, and Certifications (4)
H.2.5	III.C.3.a III.D.6	Hook	MS UT (11) MP (10) or LP (19)	NA	LT 200% NSR (7, 15) MP (10, 12) or LP (19)
H.2.6	III.C.3.a	Hook Nut	MS UT (9) MP (10) or LP (19)	NA	NSR (7, 15) MP (10, 12) or LP (19)
H.3	III.C.3.a III.D.6	Wire Rope	NA	NA	CC SPF NSR (7)
H.4	III.A	<u>Drum Assembly</u>	--	—	—
H.4.1	III.D.4	Drum Shell	MS NDTT (5)	RT (13) (Drum Shell butt welds only)	NSR (7)
H.4.2	III.D.4	Drum Shaft	MS UT (9) MP (10)	NA	NSR (7)
H.4.3	III.A	Drum Gear	MS	NA	NSR (7)
H.4.4	III.A	Drum Pinion	MS	NA	NSR (7)

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Critical Item Number	Figure Number	Description (1)	Material Test Reports (2)	Non Destructive Examinations (3)	Miscellaneous Inspections, Tests, and Certifications (4)
H.4.5	III.D.4 III.D.6	Drum Hubs	MS NDTT (5)	MT (6)	SR (8) NSR (7)
H.5	III.A	<u>Hoist Reduction Gear Assembly</u>	--	--	--
H.5.1	III.D.2	Gear Case Structural Shell	MS	NA	SR (8) NSR (7)
H.5.2	III.D.2	Hoist Case Gears	MS	NA	NSR (7)
H.5.3	III.D.2	Hoist Case Shafts	MS	NA	NSR (7)
H.6	III.A III.D.6	Hoist Motor	NA	NA	RMTR
H.7	III.A III.D.2	<u>Energy Absorbing Torque-Limiter</u>	--	--	SF
H.7.1	III.D.2	Spring	MS	NA	NSR (7)
H.7.2	III.D.2	Pinion (With or without Spline)	MS	NA	NSR (7)
H.7.3	III.D.2	Through Shaft	MS	NA	NSR (7)

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Critical Item Number	Figure Number	Description (1)	Material Test Reports (2)	Non Destructive Examinations (3)	Miscellaneous Inspections, Tests, and Certifications (4)
H.7.4	III.D.2	Gear or Splined Ring	MS	NA	NSR (7)
H.7.5	III.D.2	Pressure Plate	MS	NA	NSR (7)
H.7.6	III.D.2	Separator Plates (When Applicable)	NA	NA	CC NSR (7)
H.7.7	III.D.2	Splined Carrier	MS	NA	NSR (7)
H.7.8	III.D.2	Friction Discs	NA	NA	CC NSR (7)
H.7.9	III.D.2	Pressure Hubs (When Applicable)	MS	NA	NSR (7)
H.7.10	III.D.2	Screw Studs (When Applicable)	MS	NA	NSR (7)

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Critical Item Number	Figure Number	Description (1)	Material Test Reports (2)	Non Destructive Examinations (3)	Miscellaneous Inspections, Tests, and Certifications (4)
H.8	III.A	Emergency Drum Brake System	--	--	--
H.8.1	III.D.1	Brake Frame	MS	NA	NSR (7)
H.8.2	III.A	Emergency Actuation Components (When applicable)	NA	NA	CC SF NSR (7)
H.8.3	III.D.1	Actuator Hardware (When applicable)	MS	NA	NSR (7)
H.8.4	III.D.1	Brake Band (When applicable)	MS NDTT (5)	NA	NSR (7)
H.8.5	III.D.1	Brake Anchors (When applicable)	MS NDTT (5)	NA	NSR (7)
H.8.6	III.D.1	Linings (When applicable)	NA	NA	CC NSR (7)
H.8.7	III.D.1 III.D.6	Drum Brake Disk (When Applicable)	MS NDTT (5)	MT (6)	NSR (7)

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Critical Item Number	Figure Number	Description (1)	Material Test Reports (2)	Non Destructive Examinations (3)	Miscellaneous Inspections, Tests, and Certifications (4)
H.9	III.A	Failure Detection System	--	--	--
H.9.1	III.D.3	Drive Train Continuity Detector Components	MS	NA	CC SF NSR (7, 15)
H.9.2	III.D.3	Drum Overspeed Detector (When Applicable)	NA	NA	CC SF NSR (7, 15)
H.9.3	III.A	Wire Rope Spooling Monitor	NA	NA	CC SF NSR (7)
H.9.4		Failure Actuation & Monitoring Assembly (When Applicable)	NA	NA	SF NSR (7) CC

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Critical Item Number	Figure Number	Description (1)	Material Test Reports (2)	Non Destructive Examinations (3)	Miscellaneous Inspections, Tests, and Certifications (4)
H.10	--	<u>Miscellaneous Hoist Assemblies</u>	--	--	--
H.10.1	III.A	Rotary Limit Switch	NA	NA	CC SF NSR (7)
H.10.2	III.D.6	Backup Upper Limit Switch	NA	NA	CC SF NSR (7)
H.10.3	III.D.6	Load Sensing System and Overload Protection	NA	NA	CC SF NSR (7)
<u>OTHER</u>					
O.1	Not Shown	Weld Material	MS	NA	CC NSR (7)
O.2	Not Shown	Threaded Fasteners for Critical Items Designated as NSR	NA	NA	CC NSR (7)
O.3	Not Shown	Paint	NA	NA	NCP

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Critical Item Number	Figure Number	Description (1)	Material Test Reports (2)	Non Destructive Examinations (3)	Miscellaneous Inspections, Tests, and Certifications (4)
CONSULTING					
C.1	NA	Seismic Analyses of Nuclear Safety Related Items	NA	NA	NSR (7, 15)
C.2	NA	Drafting and Detailing Services for Nuclear Safety Related Items	NA	NA	NSR (7, 15)
C.3	NA	NDE Services for Nuclear Safety Related Items	NA	NA	NSR (7, 15)
C.4	NA	Accident Analyses of Nuclear Safety Related Items	NA	NA	NSR (7, 15)

APPENDIX A

SAMPLE CRITICAL ITEMS LIST FOR EDERER'S NUCLEAR SAFETY RELATED X-SAM CRANES

Critical Item Number	Figure Number	Description (1)	Material Test Reports (2)	Non Destructive Examinations (3)	Miscellaneous Inspections, Tests, and Certifications (4)
BRIDGE		(Complete Cranes Only)			
B.1	III.C.1.d.2	Girder Structure	--	--	--
B.1.1	III.C.1.d.2	Top Plate	MS NDTT (5) UT (17,14)	RT (13)	NSR (7)
B.1.2	III.C.1.d.2	Bottom Plate	MS NDTT (5) UT (17,14)	RT (13)	NSR (7)
B.1.3	III.C.1.d.2	Web Plates	MS NDTT (5) UT (17,14)	RT (13) MT (16)	NSR (7)
B.2	III.A	Motors	NA	NA	RMTR
B.3	Similar to T.4	Seismic Restraints	MS	MT (6)	NSR (7)
B.4		Wheels	MS HP (19)	NA	NA
B.5		Rails	MS	NA	NA
B.6		Axles	MS HP	NA	NA

APPENDIX A

SAMPLE CRITICAL ITEMS LIST
FOR EDERER'S NUCLEAR SAFETY RELATED X-SAM CRANES

Critical Item Number	Figure Number	Description (1)	Material Test Reports (2)	Non Destructive Examinations (3)	Miscellaneous Inspections, Tests, and Certifications (4)
B.7	Not Shown	Bridge Overspeed Detector	NA	NA	CC SF

Appendix A

SAMPLE CRITICAL ITEMS LIST
FOR EDERER'S NUCLEAR SAFETY RELATED X-SAM CRANES

ADDITIONAL NOTES

(5) Nil Ductility Transition Testing of rolled structural materials shall be performed in accordance with Draft 3 of Revision 1 of Regulatory Guide 1.104. Actual testing of materials for listed item is performed only if material thickness is such that testing is required by the Regulatory Guide.

(6) MT inspect the welds, in the listed structure, whose failure could result in loss of the load. Acceptance Criteria: AWS D1.1, Section 9.25.

(7) Special Ederer evaluation of deviations and nonconformances in these items or services is required, since they may involve defects or noncompliances related to a substantial safety hazard in delivered nuclear safety related equipment, thus requiring prompt reporting to the NRC.

(8) Post weld heat treatment per AWS D1.1 is normally provided for welded gear cases. Depending upon the detailed design parameters, i.e., material thickness and weld sizes, some additional post weld heat treatment of listed weldments is also provided.

(9) UT inspect material after rough machining per ASTM A-388. The acceptance standard, using straight beam, is as follows: One or more reflectors which produce complete loss of back reflection, not attributable to geometric configuration, are unacceptable. Complete loss of back reflection is assumed when back reflection falls below 5 percent of full calibration.

(10) MP inspect per ASTM E-709. Acceptance Standard: Cracks, forging laps, or linear indications open to the surface are not allowed. Linear subsurface indications more than 1/2 inch long are not acceptable.

(11) UT inspect hooks per ASTM A-388. Acceptance Standard for UT of hooks: MIL-I-8950B, Class B.

A. For custom fabricated hooks, perform the UT examination prior to flame cutting.

B. Because standard catalogue hooks must be inspected in a semi-finished condition, only about 90% of their surfaces are suitable for UT examination.

(12) Following load test.

(13) RT inspect all full penetration butt welds present, if any, in listed item. Acceptance Criteria: AWS D1.1, Section 9.25.

Appendix A

SAMPLE CRITICAL ITEMS LIST
FOR EDERER'S NUCLEAR SAFETY RELATED X-SAM CRANES

ADDITIONAL NOTES, Continued

(14) UT inspect:

A. The area within five inches of both longitudinal edges for the entire length of the plates.

B. The area within 12 inches of both transverse edges for the entire width of the plates.

(15) When these items or services are not procured as, or normally available with, standard catalogue items or services, the procurement documents for them shall state that the provisions of 10CFR21 apply.

(16) MT inspect the lateral welds between the flange and web plates on the girders. Acceptance Criteria: AWS D1.1, Section 9.25.

(17) UT inspect the plates per ASTM A-578. Acceptance Standard: Level 2.

(18) Minimum BHN 321 in tread area.

(19) LP inspect per ASTM E-165. Acceptance Standard: No cracks at points of high stress or at stress risers, with ASTM E-443 as a guideline.

SUMMARY OF PLANT SPECIFIC CRANE DATA SUPPLIED BY EDERER

Regulatory Position	Topical Report Section		Information to be Provided		Specific Crane Data
C.1.a	III.C (C.1.a)	1.	The actual crane duty classification of the crane specified by the applicant.	1.	
C.1.b	III.C (C.1.b)	1.	The minimum operating temperature of the crane specified by the applicant.	1.	
C.2.b	III.C (C.2.b) III.E.4	1.	The maximum extent of load motion and the peak kinetic energy of the load following a drive train failure.	1.	
		2.	Provisions for actuating the Emergency Drum Brake prior to traversing with the load, when required to accommodate the load motion following a drive train failure.	2.	

SUMMARY OF PLANT SPECIFIC CRANE DATA SUPPLIED BY EDERER

Regulatory Position	Topical Report Section	Information to be Provided	Specific Crane Data
C.3.e	III.C (C.3.e)	1. The maximum cable loading following a wire rope failure in terms of the acceptance criteria established in Section III.C (C.3.e.)	1.
C.3.f	—	1. Maximum fleet angle	1.
		2. Number of reverse bends	2.
		3. Sheave diameter	3.
C.3.h	III.C (C.3.h) III.E.11	1. The maximum extent of motion and peak kinetic energy of the load following a single wire rope failure.	1.

SUMMARY OF PLANT SPECIFIC CRANE DATA SUPPLIED BY EDERER

Regulatory Position	Topical Report Section	Information to be Provided	Specific Crane Data
C.3.i	III.C (C.3.i)	1. The type of load control system specified by the applicant.	1.
		2. Whether interlocks are recommended by Regulatory Guide 1.13 to prevent trolley and bridge movements while fuel elements are being lifted and whether they are provided for this application.	2.
C.3.j	III.C (C.3.j)	1. The maximum cable and machinery loading that would result in the event of a high speed two blocking, assuming a control system malfunction that would allow the full breakdown torque of the motor to be applied to the drive motor shaft.	1.
		2. Means of preventing two blocking of auxiliary hoist, if provided.	2.

SUMMARY OF PLANT SPECIFIC CRANE DATA SUPPLIED BY EDERER

Regulatory Position	Topical Report Section	Information to be Provided	Specific Crane Data
C.3.k	III.C(C.3.k)	1. Type of drum safety support provided.	1.
C.3.o	—	1. Type of hoist drive to provide incremental motion.	1.
C.3.p	—	1. Maximum trolley speed.	1.
		2. Maximum bridge speed.	2.
		3. Type of overspeed protection for the trolley and bridge drives.	3.
C.3.q	—	1. Control station location.	1.

SUMMARY OF PLANT SPECIFIC CRANE DATA SUPPLIED BY EDERER

Regulatory Position	Topical Report Section	Information to be Provided	Specific Crane Data
--	III.D.1	1. The type of Emergency Drum Brake used, including type of release mechanism.	1.
		2. The relative location of the Emergency Drum Brake.	2.
		3. Emergency Drum Brake Capacity.	3.
--	III.D.2	1. Number of friction surfaces in EATL.	1.
		2. EATL Torque Setting.	2.
--	III.D.3	1. Type of Failure Detection System.	1.

SUMMARY OF PLANT SPECIFIC CRANE DATA SUPPLIED BY EDERER

Regulatory Position	Topical Report Section		Information to be Provided		Specific Crane Data
--	III.D.5	1.	Type of Hydraulic Load Equalization System.	1.	
--	III.D.6	1.	Type of hook.	1.	
		2.	Hook design load.	2.	
		3.	Hook test load.	3.	
--	III.F.1	1.	Design rated load.	1.	
		2.	Maximum critical load rating.	2.	
		3.	Trolley weight (net).	3.	
		4.	Trolley weight (with load).	4.	
		5.	Hook lift.	5.	

SUMMARY OF PLANT SPECIFIC CRANE DATA SUPPLIED BY EDERER

Regulatory Position	Topical Report Section	Information to be Provided	Specific Crane Data
--	III.F.1	6. Number of wire rope drums.	6.
		7. Number of parts of wire rope.	7.
		8. Drum size (pitch diameter).	8.
		9. Wire rope diameter.	9.
		10. Wire rope type.	10.
		11. Wire rope material.	11.
		12. Wire rope breaking strength.	12.
		13. Wire rope yield strength.	13.
		14. Wire rope reserve strength.	14.
		15. Number of wire ropes.	15.

SUMMARY OF REGULATORY POSITIONS TO BE
ADDRESSED BY THE APPLICANT
(FOR RETROFITTED NUCLEAR SAFETY RELATED X-SAM CRANES)

Regulatory Position	Topical Report Section	Information to be Provided	Specific Crane Data
--	C.1.b(1)	1. The extent of venting of closed box sections.	1.
C.1.b(3) C.1.b(4) C.4.d	III.C (C.1.b(3)) III.C (C.1.b(4)) III.C (C.4.d)	1. The nondestructive and cold proof testing to be performed on existing structural members for which satisfactory impact test data is not available.	1.
C.1.c	III.C (C.1.c)	1. The extent the crane's structures, which are not being replaced, are capable of meeting the seismic requirements of Regulatory Guide 1.29.	1.

SUMMARY OF REGULATORY POSITIONS TO BE
ADDRESSED BY THE APPLICANT
(FOR RETROFITTED NUCLEAR SAFETY RELATED X-SAM CRANES)

Regulatory Position	Topical Report Section	Information to be Provided	Specific Crane Data
C.I.d	III.C (C.I.d)	1. The extent welds joints in the crane's structures, which are not being replaced, were nondestructively examined, and	1.
		2. The extent the base material, at joints susceptible to lamellar tearing, was nondestructively examined.	2.
C.I.e	III.C (C.I.e)	1. The extent the crane's structures, which are not being replaced, are capable of withstanding the fatigue effects of cyclic loading from previous and projected usage, including any construction usage.	1.
C.I.f	III.C (C.I.f)	1. The extent the crane's structures, which are not being replaced, were post-weld heat-treated in accordance with Subarticle 3.9 of AWS DI.I, "Structural Welding Code."	1.

SUMMARY OF REGULATORY POSITIONS TO BE
ADDRESSED BY THE APPLICANT
(FOR RETROFITTED NUCLEAR SAFETY RELATED X-SAM CRANES)

Regulatory Position	Topical Report Section	Information to be Provided	Specific Crane Data
C.2.b	III.C (C.2.b) III.E.4	1. Provisions for accommodating the load motion and kinetic energy following a drive train failure when the load is being traversed and when it is being raised or lowered.	1.
C.2.c	III.C (C.2.c)	1. Location of safe laydown areas for use in the event repairs to the crane are required that cannot be made with the load suspended.	1.
C.2.d	III.C (C.2.d)	1. Size of replacement components that can be brought into the building for repair of the crane without having to break its integrity,	1.
		2. Location of area where repair work can be accomplished on the crane without affecting the safe shut-down capability of the reactor, and	2.

SUMMARY OF REGULATORY POSITIONS TO BE ADDRESSED BY THE APPLICANT (FOR RETROFITTED NUCLEAR SAFETY RELATED X-SAM CRANES)

Regulatory Position	Topical Report Section	Information to be Provided	Specific Crane Data
		3. Any limitations on reactor operations that would result from crane repairs.	3.
C.3.b	III.C (C.3.b)	1. The design margin and type of lifting devices that are attached to the hook to carry critical loads.	1.
C.3.t	III.C (C.3.t)	1. The extent construction requirements for the crane's structures, which will not be replaced, are more severe than those for permanent plant service.	1.
		2. The modifications, and inspections to be accomplished on the crane following construction use, which was more severe than those for permanent plant service.	2.

SUMMARY OF REGULATORY POSITIONS TO BE
ADDRESSED BY THE APPLICANT
(FOR RETROFITTED NUCLEAR SAFETY RELATED X-SAM CRANES)

Regulatory Position	Topical Report Section	Information to be Provided	Specific Crane Data
C.3.u	—	1. The extent of installation and operating instructions.	1.
C.4.a C.4.b C.4.c C.4.d	—	1. The extent of assembly check-out, test procedures, load testing and rated load marking of the crane.	1.
C.5.d	III.C (C.5.a)	1. The extent the procurement documents for the crane's structures, which will not be replaced, required the crane manufacturer to provide a quality assurance program consistent with the pertinent provisions of Regulatory Guide 1.28.	1.

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WASHINGTON CRANES

Appendix D

SUMMARY OF LESSONS LEARNED IN RETROFITTING THE NEW TROLLEY ON THE LOFT CONTAINMENT BUILDING POLAR CRANE

NON-PROPRIETARY VERSION

REVISION 2

2/15/80

Assistance in
Preparation
Provided by:

HOLLORAN & ASSOCIATES
Mechanical and Nuclear Engineering Services
SUITE 102
205 108TH AVE NE
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(206) 453-0525

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EDERER INCORPORATED

TABLE OF CONTENTS AND REVISION STATUS
FOR APPENDIX D

(Non-Proprietary Version)

Summary of Lessons Learned in Retrofitting the New Trolley on the LOFT Containment Building Polar Crane

1. Introduction

1.1 The document summarizes the lessons learned from the shop and field testing of the LOFT Trolley. The shop testing sequence, with charts of cable loading during two blocking tests are also included.

2. Shop Tests

2.1 The two blocking tests of the LOFT Crane were conducted in the Ederer shop from April 22 to April 27, 1978. A shop test sequence was used. Several two-blocking tests were conducted on each hoist.

2.2 The conditions unique to the shop testing environment included:

.1 The trolley was positioned on blocks in the Ederer Production Shop such that sufficient clearance was available for approximately 4 feet vertical movement of the lower block.

.2 DC electrical power to the hoist was provided by a motor generator set.

PROPRIETARY MATERIAL DELETED

2.3 The test sequence was the same for both the main and auxiliary hoists. Two blocking tests were conducted using several different motor torques and speeds to obtain variations in the wire rope load.

PROPRIETARY MATERIAL DELETED

2.4 The attached figures represent typical results of the two blocking tests. After comparing many sets of test data, inferences have been drawn as to what phenomenon caused a certain curve shape on the test data. These phenomenon are marked by dotted lines on Figures 1 through 6. Each individual figure contains the pertinent descriptive information of the test results:

PROPRIETARY MATERIAL DELETED

3. Lessons Learned

3.1 The lessons learned during the shop testing and field installation involved correction of mechanical and electronic malfunctions. These malfunctions did not affect the ability of the hoist to withstand a two-blocking or load hang-up.

3.2 Lessons Learned During Shop Testing

PROPRIETARY MATERIAL DELETED

3.3 Lessons Learned During Field Installation

PROPRIETARY MATERIAL DELETED

Figure 1
Revision 0 1/15/79

D.3

MAIN HOIST
MOTOR SPEED - 78%

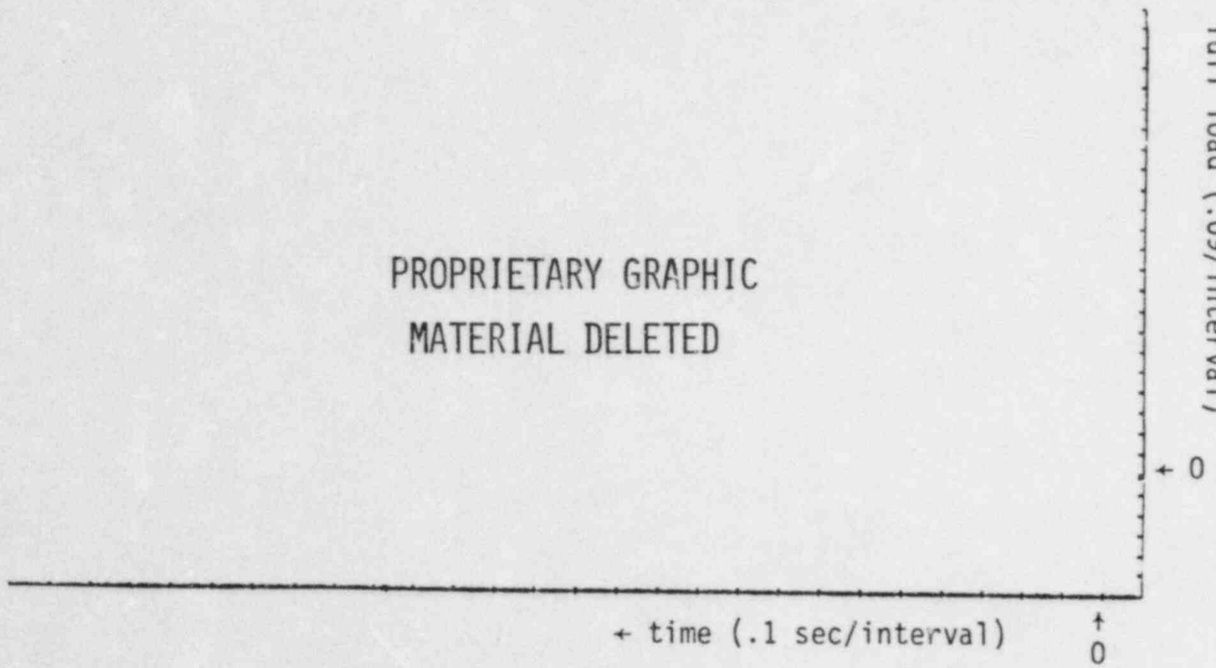


Figure 2
Revision 0 1/15/79

MAIN HOIST

MOTOR SPEED - 120%

D.4

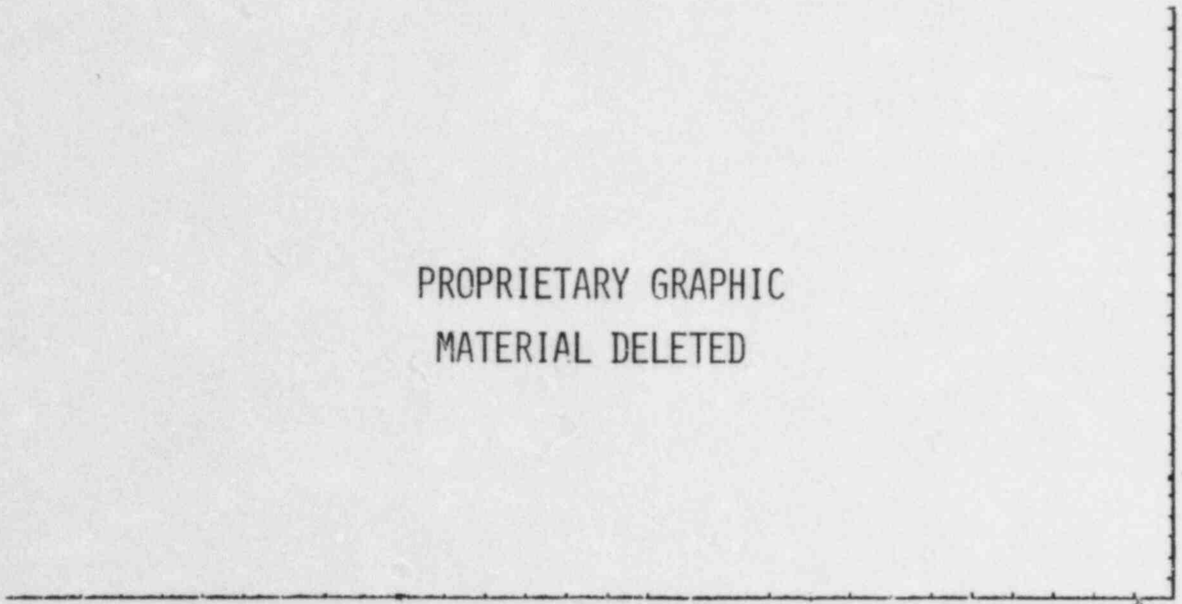
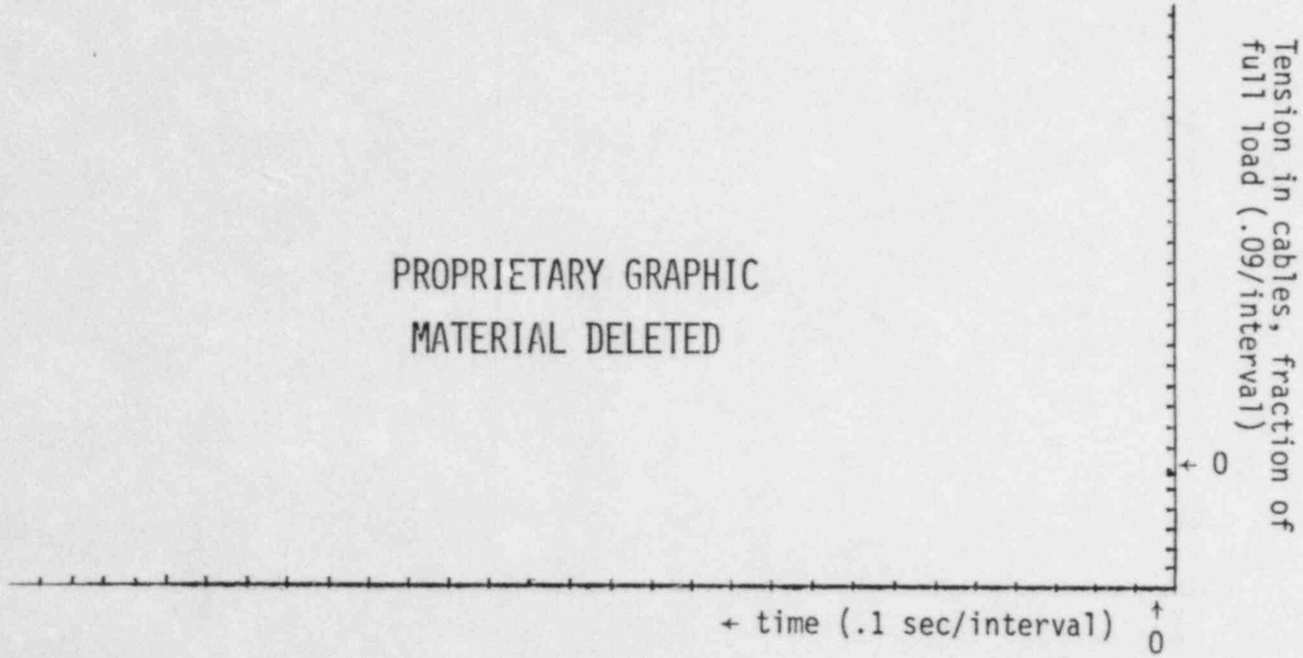


Figure 3
Revision 0 1/15/79

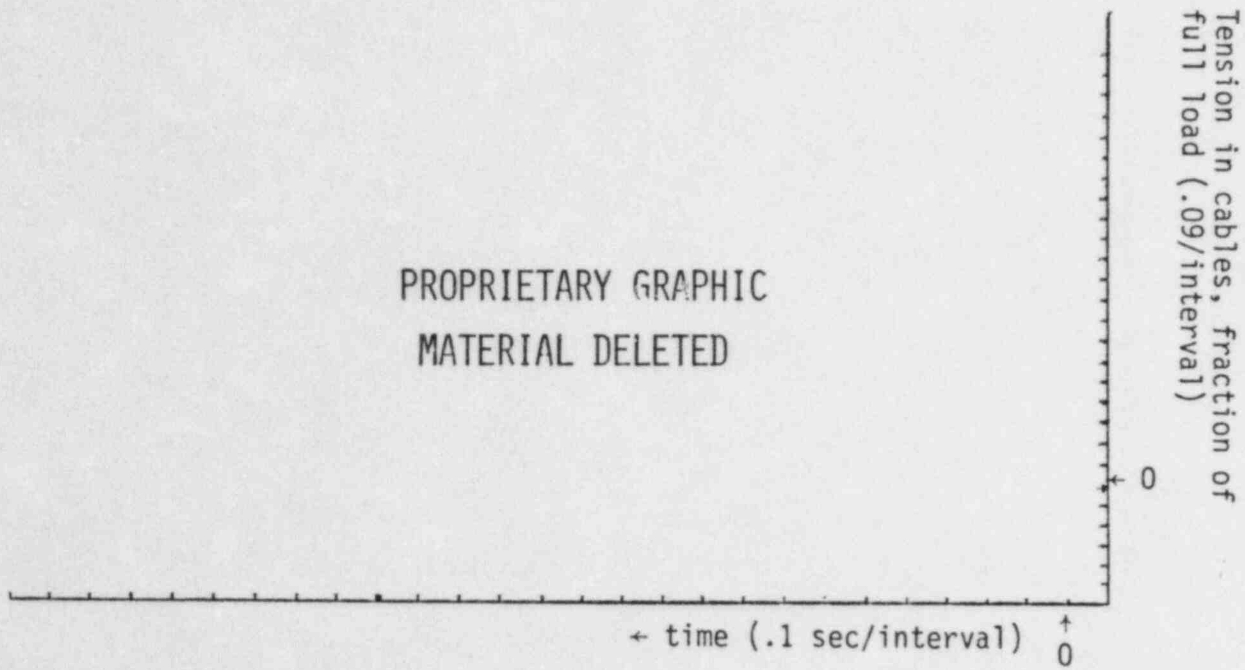
AUXILIARY HOIST

MOTOR SPEED - 43%



AUXILIARY HOIST

MOTOR SPEED - 78%



PROPRIETARY GRAPHIC
MATERIAL DELETED

AUXILIARY HOIST

MOTOR SPEED - 100%

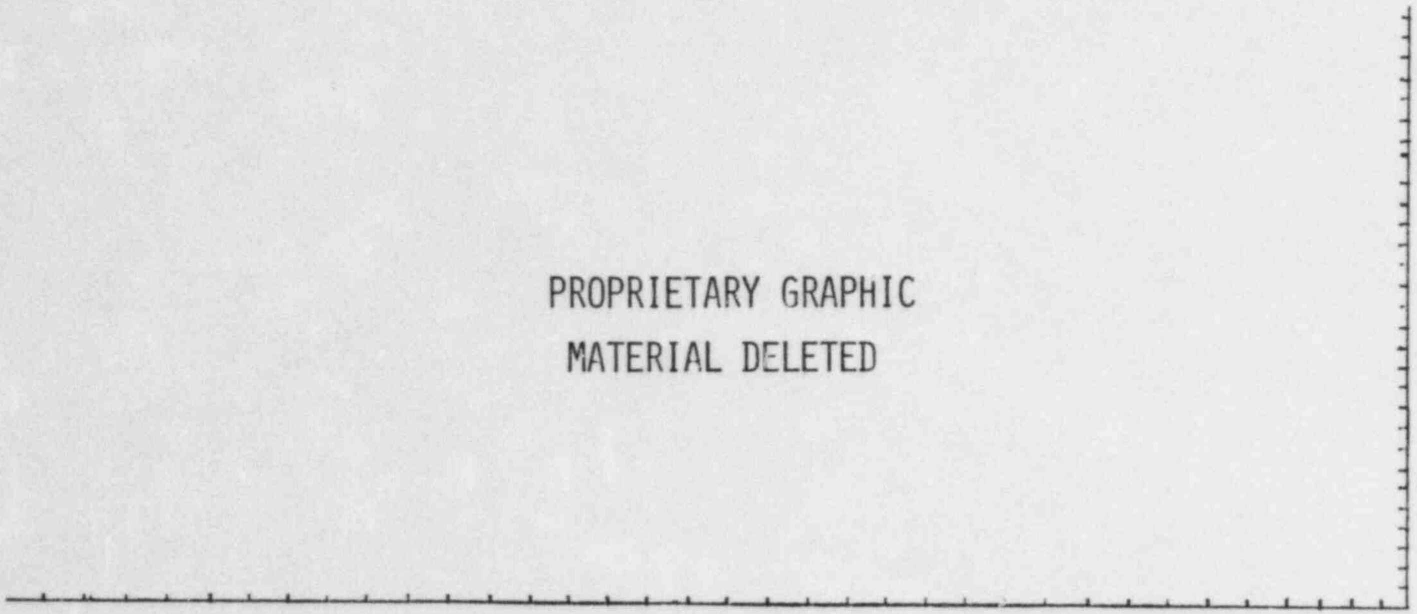
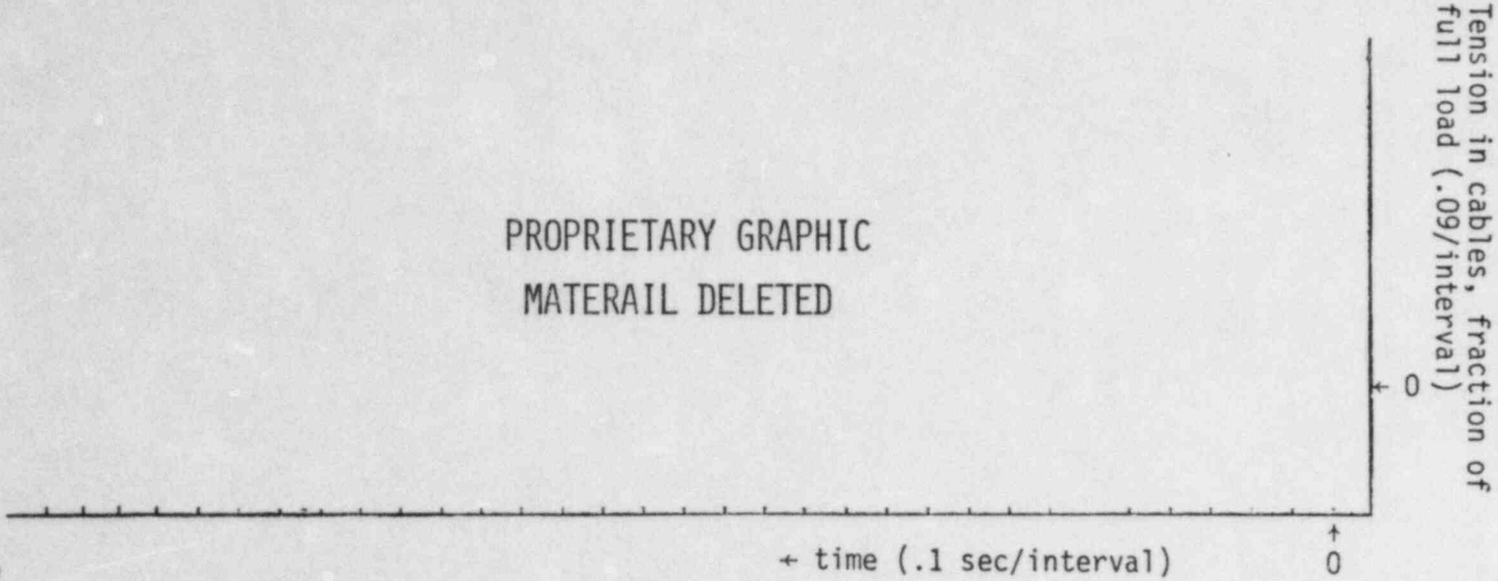


Figure 6A & 6B
Revision 0 1/15/79

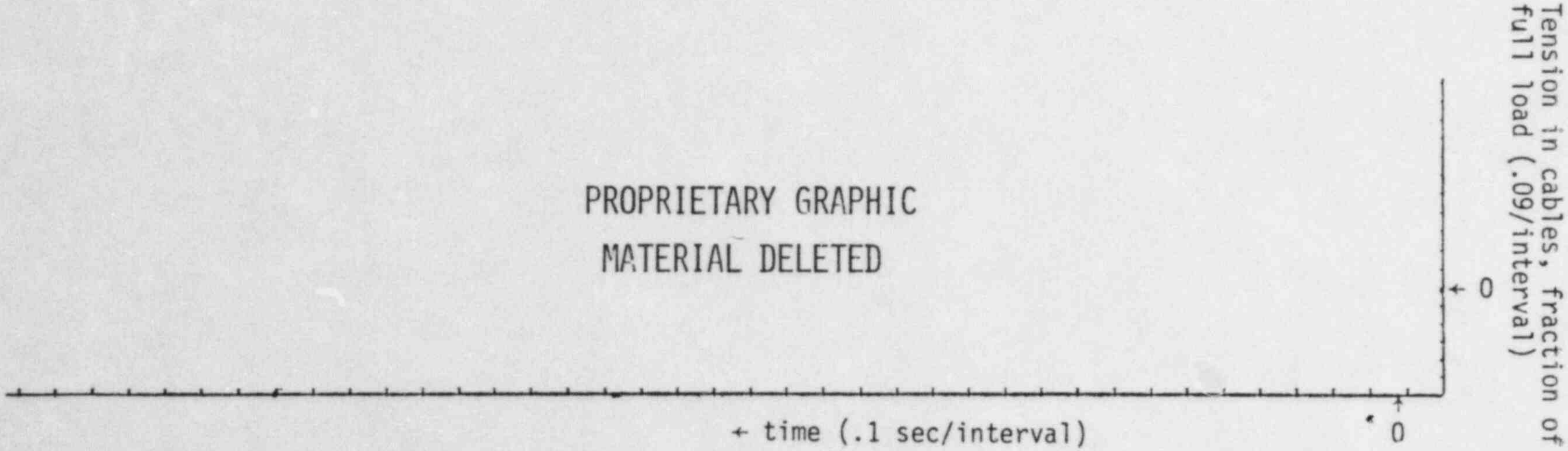
MAIN HOIST
MOTOR SPEED - 169%

"A"



MAIN HOIST
MOTOR SPEED - 109%

"B"



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Appendix E

ANALYSIS OF LOAD MOTION AND CABLE LOADING FOLLOWING A SINGLE DRIVE TRAIN FAILURE OR WIRE ROPE FAILURE IN AN X-SAM TYPE CRANE

NON-PROPRIETARY VERSION

R. W. Holloran

M. N. McDermott

R. E. Morton

C. A. Rusch

Revision 2

February 1980

Revision 2 2/15/80

TABLE OF CONTENTS AND REVISION STATUS
FOR APPENDIX E

(Non-Proprietary Version)

APPENDIX E TABLE OF CONTENTS AND REVISION STATUS, Continued

1. Introduction

The purpose of this report is to describe the analytical and numerical techniques developed for evaluating the consequences of a drive train failure in a single drive train hoist that is equipped with an emergency drum brake, which is actuated by a drum overspeed detector or drive train continuity detector. These techniques also can be used to evaluate the consequences of failure of a single wire rope in a dual reeved crane that is protected by an energy absorbing torque limiter in the drive train. Section 2 describes the analytical approach to the wire rope failure problem.

Since the complete solution for an actual drive train or wire rope failure cannot be expressed in a simple form, a FORTRAN program solving these problems was developed. Sample numerical results from the program are provided in Section 3 for a reference design hoist, with three different sets of assumptions regarding emergency drum brake performance. Section 4 provides two different sets of numerical results for a wire rope failure in the reference design hoist.

Section 5 explains the mathematical model used. Expressions for the displacement and kinetic energy of the load, as a function of time following the failure, are developed in Sections 6 and 7. These expressions provide a basis for evaluating the consequences of the failures on the equipment and structures under the load. Expressions for the tension in the wire ropes are also developed in Sections 6 and 7 in order to determine whether the ropes would be overloaded by the incidents. Section 8 summarizes the basis for using the tackle system efficiency to account for sheave friction and inertia in the analysis.

2. Approach

The analysis starts with the equations of motion for the following two general cases: (1) the wire rope drum is rotating, and (2) the wire rope drum is being held stationary by a friction brake or energy absorbing torque limiter. See Figure 10 for a diagram of the hoist model used in deriving the equations.

The solutions given for these general cases are valid only if certain physical conditions are met. Specifically, the solution to the case where the drum is rotating is valid only if the time derivative of the braking torque remains constant, and the drum continues to move in the lowering direction. The solution for the stationary drum case is valid only as long as the torque applied on the drum by the tension in the wire ropes is less than the torque required for the emergency drum brake to start slipping. These conditions are not always valid in the situations of interest. The complete solutions for specific cases at all times of interest are obtained by dividing the problem into a series of time regions in which the appropriate physical conditions are properly modeled. The relevant general solution is applied to each of these time regions in turn.

The two solutions of the general cases are sufficiently complicated to make the complete expressions for load displacement, velocity, etc., intractable if the formal expressions for these quantities at the end of each region are used for the initial conditions of the next region. To get around this difficulty, the solutions are evaluated numerically one region at a time. Appropriate tests are used in the numerical solutions to determine the time when one region ends and another starts. The numerical results calculated for the end of a region provide the initial conditions for the numerical solution in the following region.

Analysis of a drive train failure typically involves the following regions:

a. The interval between the drive train failure and the start of braking. This region is characterized by a constant retarding torque, which is usually assummed to be zero, but not necessarily. The end of this region occurs when the specified braking reaction time has elapsed following occurrence of a drum overspeed trip or detection of a drive train discontinuity.

b. The interval between the start of braking and the full engagement of the drum brake. This region is characterized by a linearly increasing retarding torque, starting from the constant retarding torque present in the first region. This region ends when the drum brake is fully engaged, i.e., the design value of the dynamic retarding torque of the drum brake is reached, or when the drum stops rotating.

c. The interval between the full engagement of the emergency drum brake and the time when the drum stops rotating.

d. The interval between the stopping of the drum and the resumption of emergency drum brake slipping. This region ends when the tension in the wire ropes increases sufficiently to apply a torque on the drum that is greater than the emergency drum brake can hold, at which time the conditions of paragraph c. above, are again appropriate. The solution alternates between these two final regions until sufficient energy has been removed from the system to prevent the tension in the wire rope from exceeding the level at which the drum brake will slip. Once this condition is met, the stationary drum region of this paragraph is appropriate for all subsequent times.

The analysis of a single wire rope failure starts with the drum being held by the static retarding torque of the EATL. This region is very similar to region d. above, with the exception of the initial conditions. This region ends when the tension in the wire rope exceeds that which is required for the EATL to actuate or when the emergency drum brake starts to engage.

The next region will be comparable to a. or b. above, depending upon which condition ended the initial region. The applicable static or dynamic retarding torque of the EATL is used, in addition to the retarding torque automatically applied by the emergency drum brake, during the remainder of the analysis.

3. Summary of the Drive Train Failure Results

The equations of Sections 6 and 7 were programmed in FORTRAN on a CDC 6400/CYBER 73 computer system. Results of three sample drive train failure analyses are presented in the CALCOMP plots that follow. The figures provide plots of the load motion, kinetic energy, and cable tension (not including lead line efficiency) for a base case drive train failure (reference design with nominal configuration and damping) superimposed on: (1) the base case without damping and (2) a similar case where the times associated with braking are increased by 50 percent. It should be noted that, because the kinetic energy of the load becomes so large during the incident relative to the kinetic energy of the load moving at rated speed, it is difficult to see that the initial energy is nonzero and does, in fact, account for initial load velocity.

Input constants, which were the same for all cases of a particular design, are listed in Table 1. Input parameters that vary are listed in Table 2 for the base case and Table 3 for the case of slower braking. Figures 1 through 3 show the base case superimposed on the same case without damping. Figures 4 through 6 show the base case superimposed on the same case with 50 percent longer braking times.

TABLE 1

Reference Design Case Independent Constants

Drum Radius	2.88 feet
Drum Moment of Inertia	4106 slug-ft^2
Weight of Load	260000 lb
Rated Load	260000 lb
Number of Parts of Cable	8
Rope Modulus of Elasticity	1.2×10^7 PSI
Rope Metal Area	.79 in^2
Rope Length When Two Blocked	80 feet

TABLE 2
REFERENCE DESIGN BASE CASE CONSTANTS

TABULAR PROPRIETARY
MATERIAL DELETED

TABLE 3
REFERENCE DESIGN WITH 50% LONGER BRAKING TIMES

TABULAR PROPRIETARY
MATERIAL DELETED

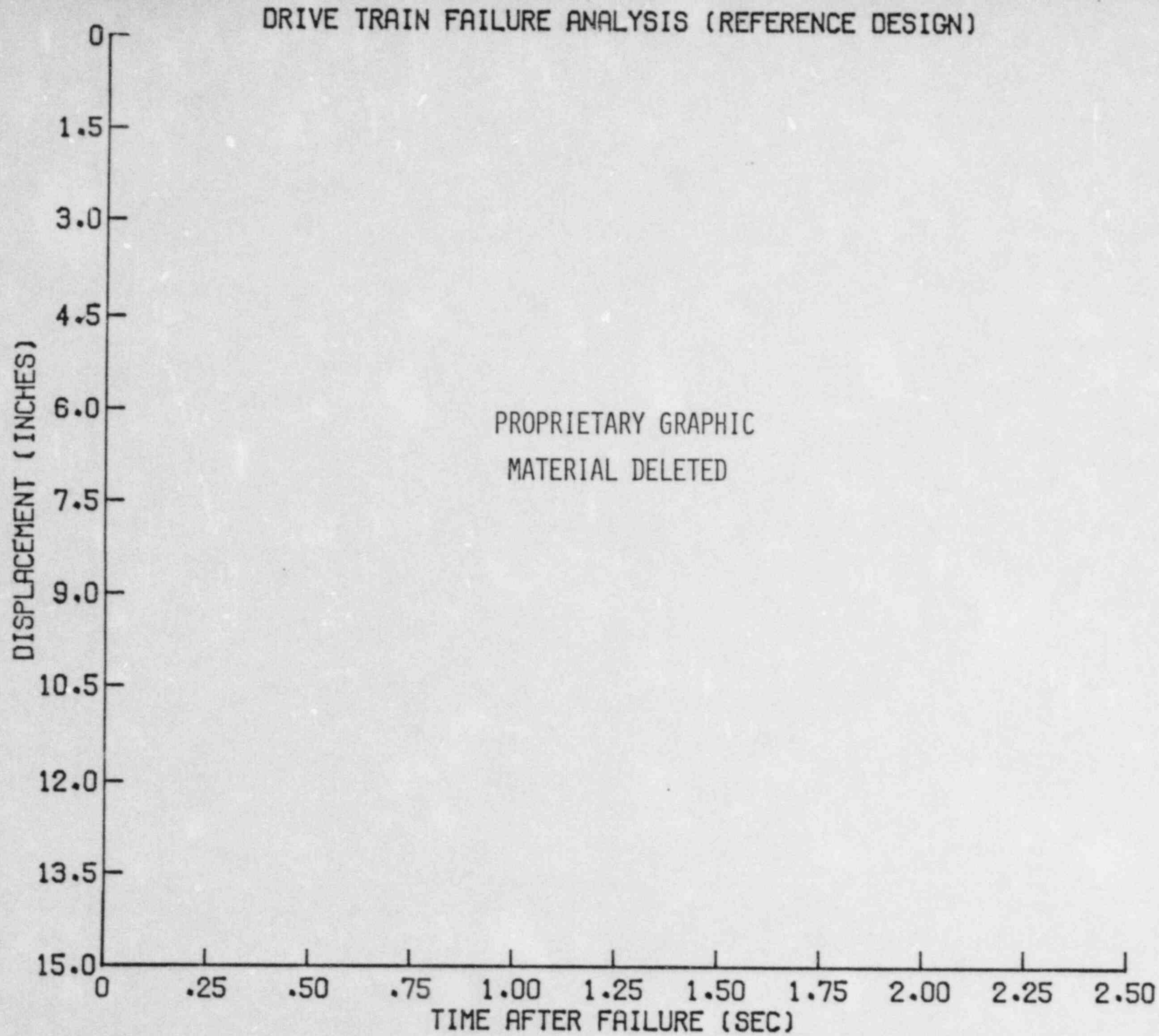

Figure 1
Displacement of Base Case and
Base Case Without Damping

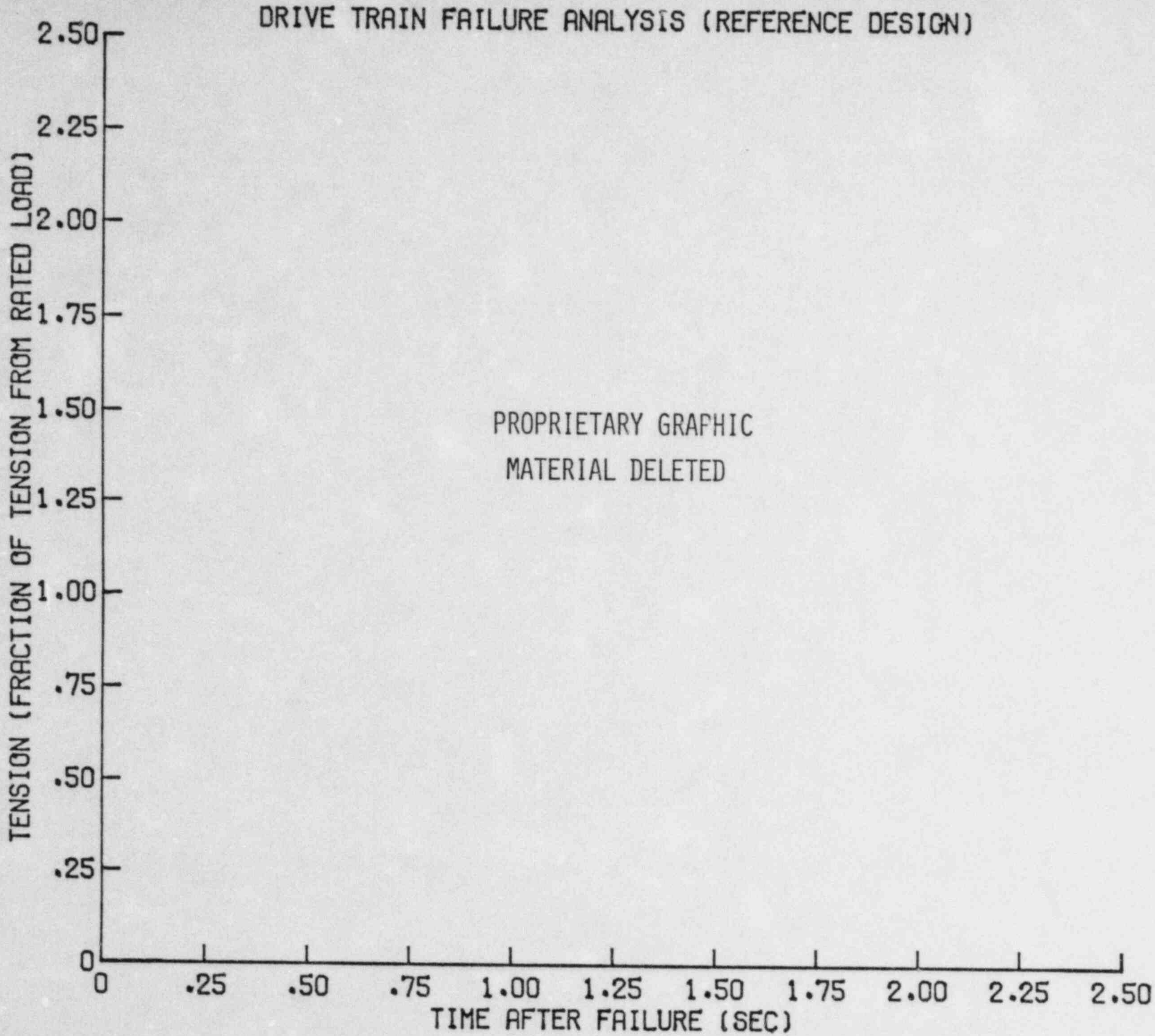

FIGURE 2
TENSION OF BASE CASE AND
BASE CASE WITHOUT DAMPING

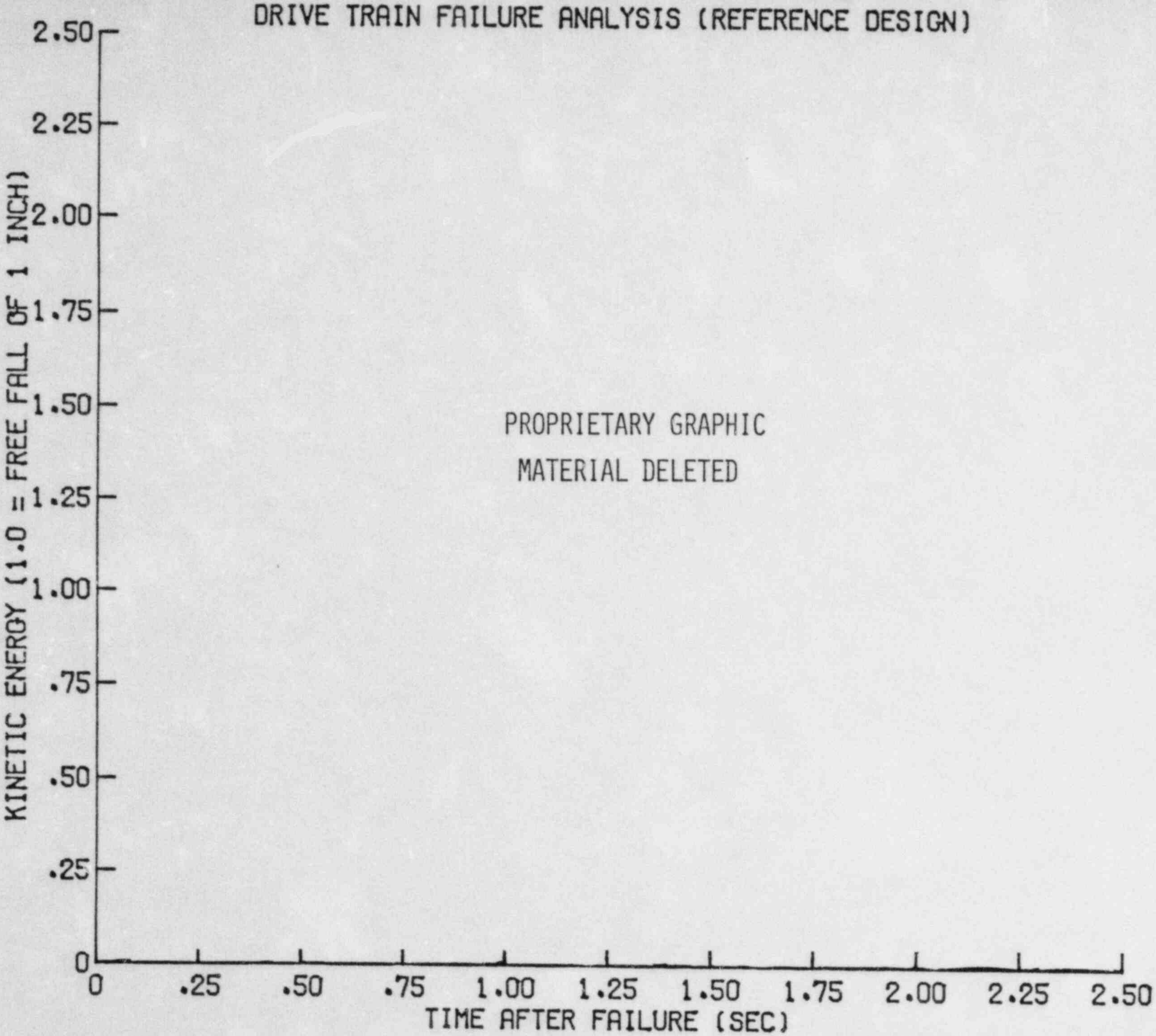

Figure 3
Kinetic Energy of Base Case
And Base Case Without Damping

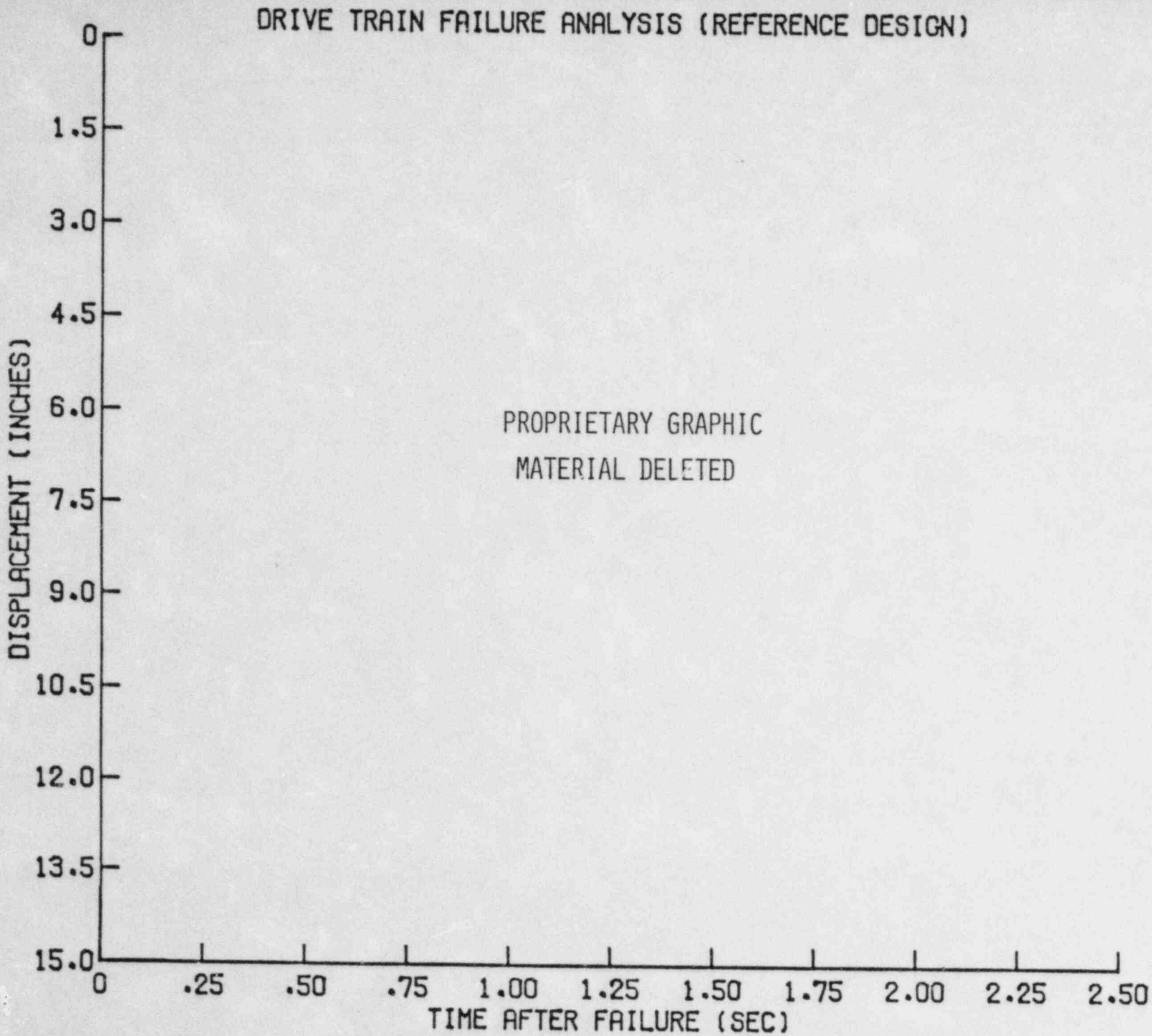

FIGURE 4
DISPLACEMENT OF BASE CASE AND BASE CASE
WITH 50% LONGER BRAKING TIMES

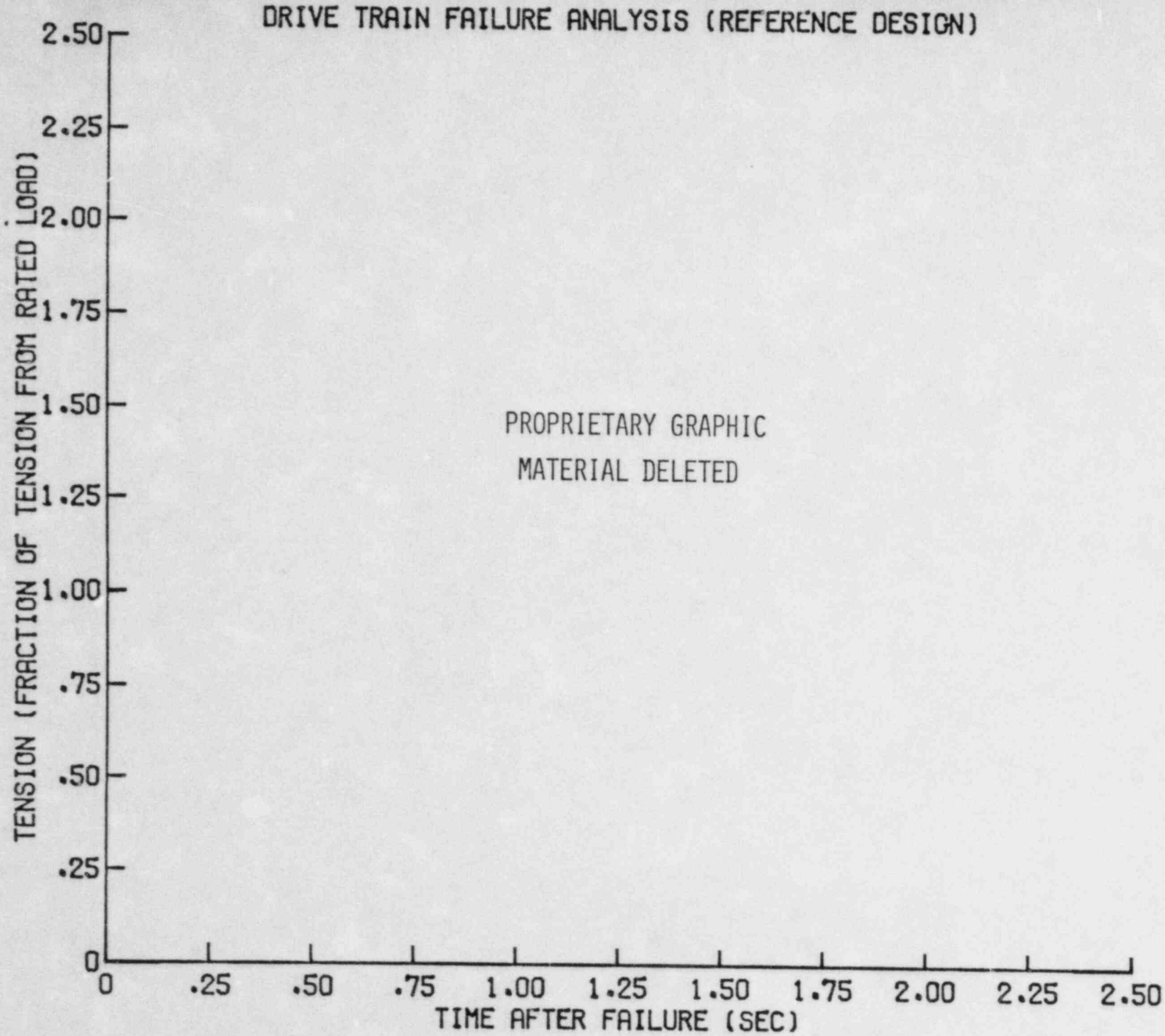

FIGURE 5
TENSION OF BASE CASE AND BASE CASE
WITH 50% LONGER BRAKING TIMES

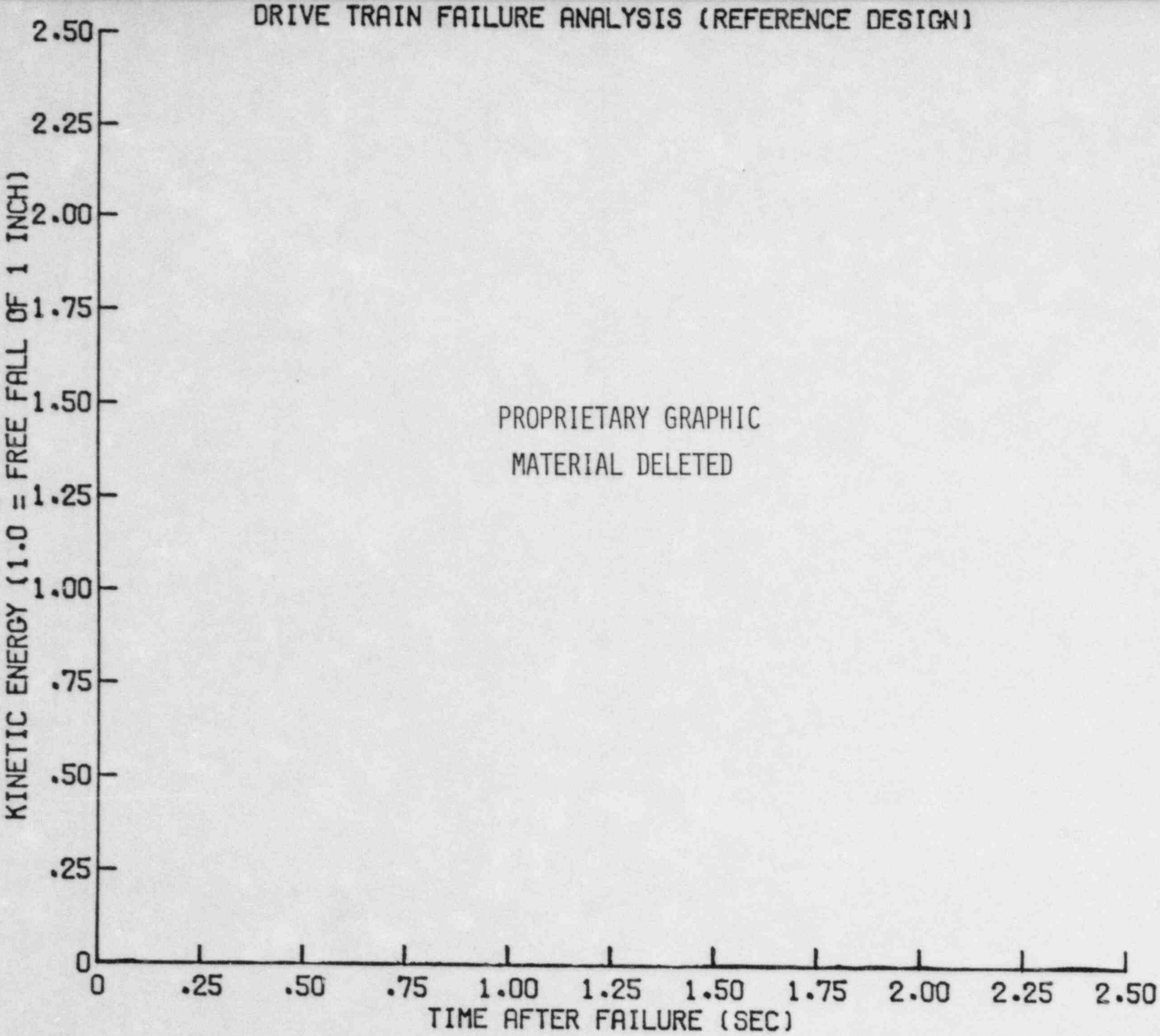

Figure 6
Kinetic Energy of Base Case and Base Case With 50% Longer Braking Times

4. Summary of the Single Wire Rope Failure Results

The equations of Section 7 were programmed in FORTRAN on a CDC 6400/ CYBER 73 computer system.

Proprietary Material Deleted

Figures 7, 8, and 9 provide sample CALCOMP plots of the load motion, kinetic energy, and cable tension (not including the tackle system efficiency) following a single wire rope failure of the reference design crane (both with and without the damping assumed in the drive train failure analysis). The appropriate crane design parameters of Table 1, and the variable input data of Table 4, were used to generate these figures.

Table 4

Rope Break Analysis

Reference Design Base Case Constants

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MATERIAL DELETED

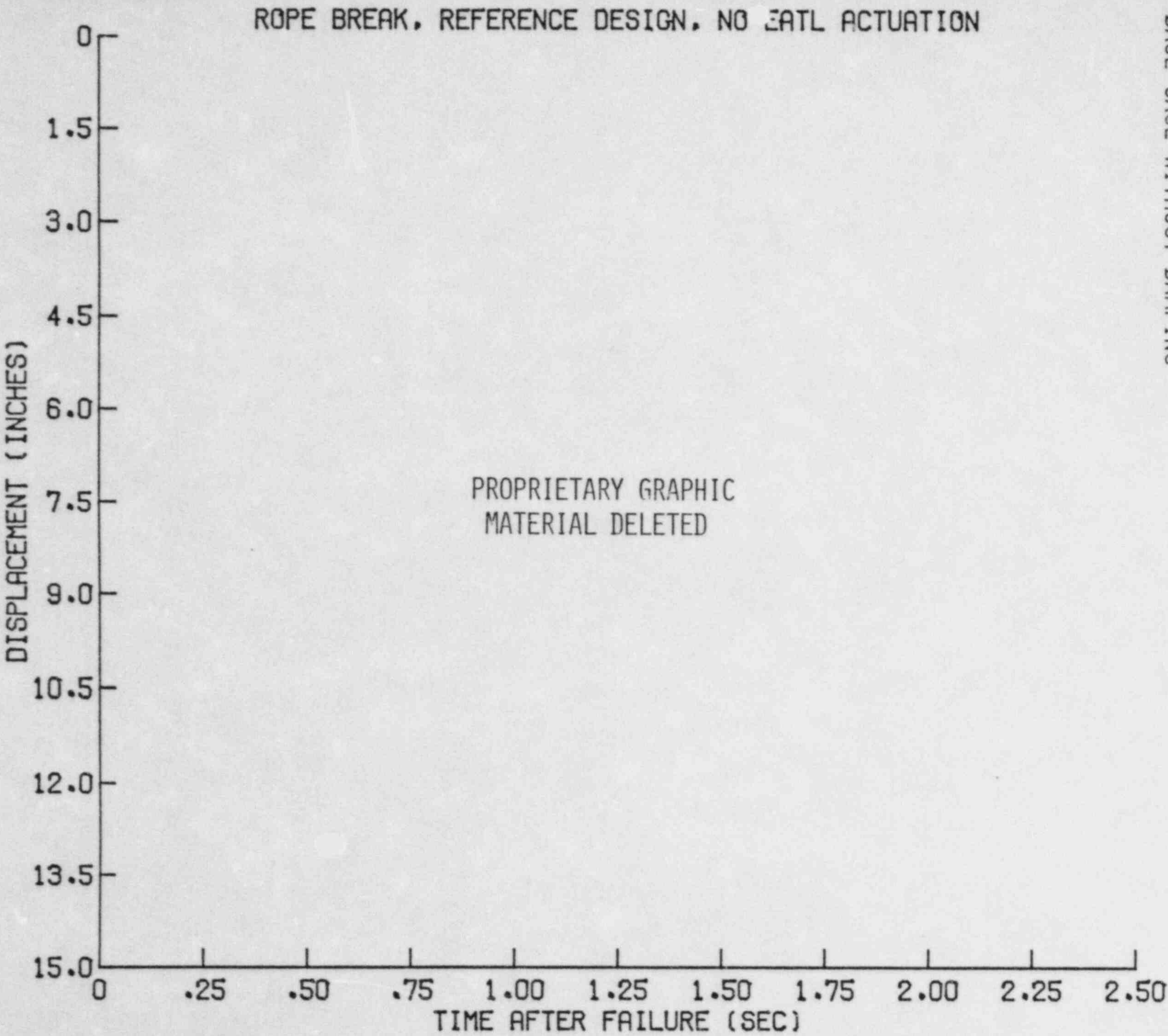


FIGURE 7
DISPLACEMENT OF BASE CASE AND
BASE CASE WITHOUT DAMPING

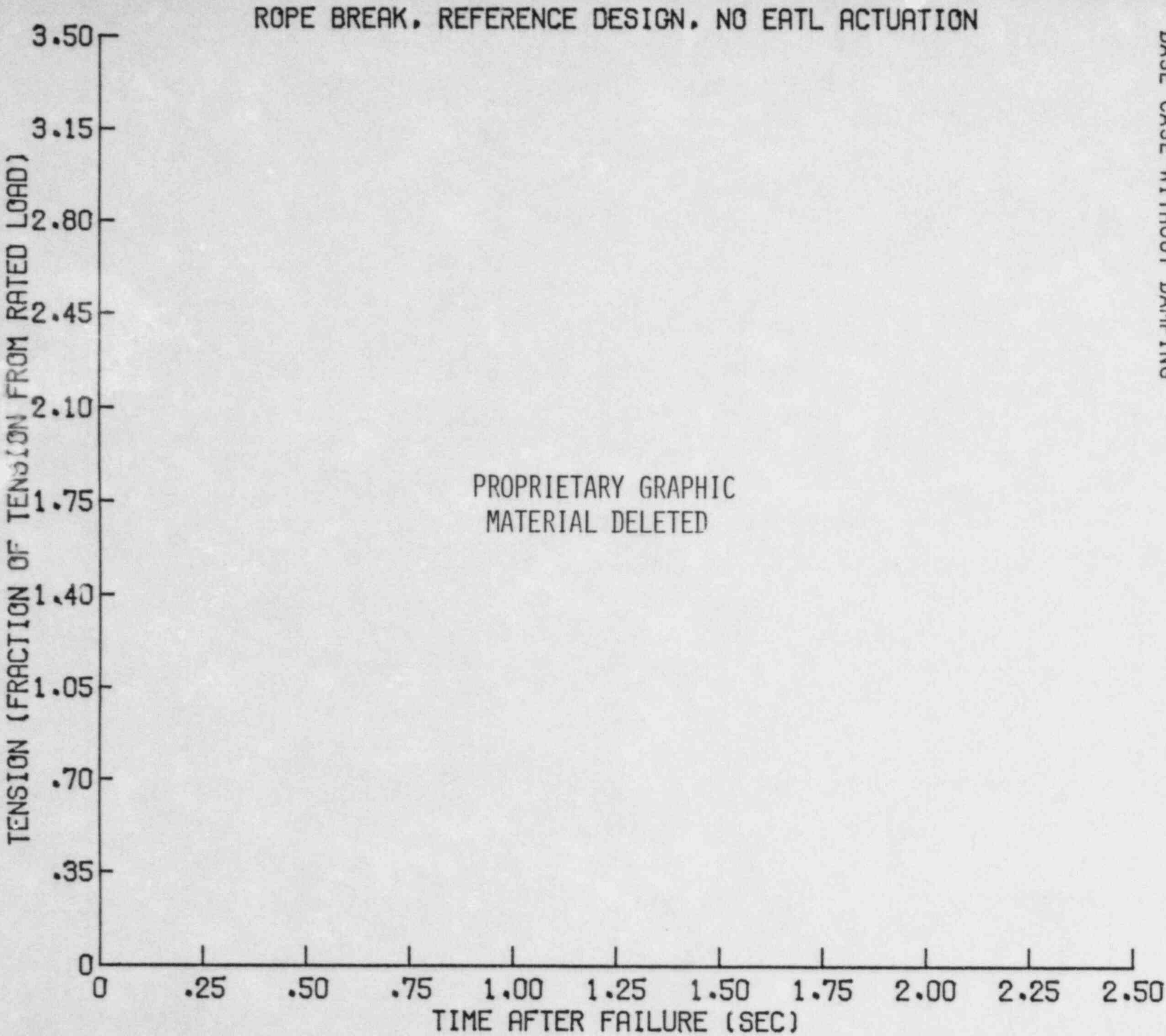


Figure 8
Tension of Base Case and
Base Case Without Damping

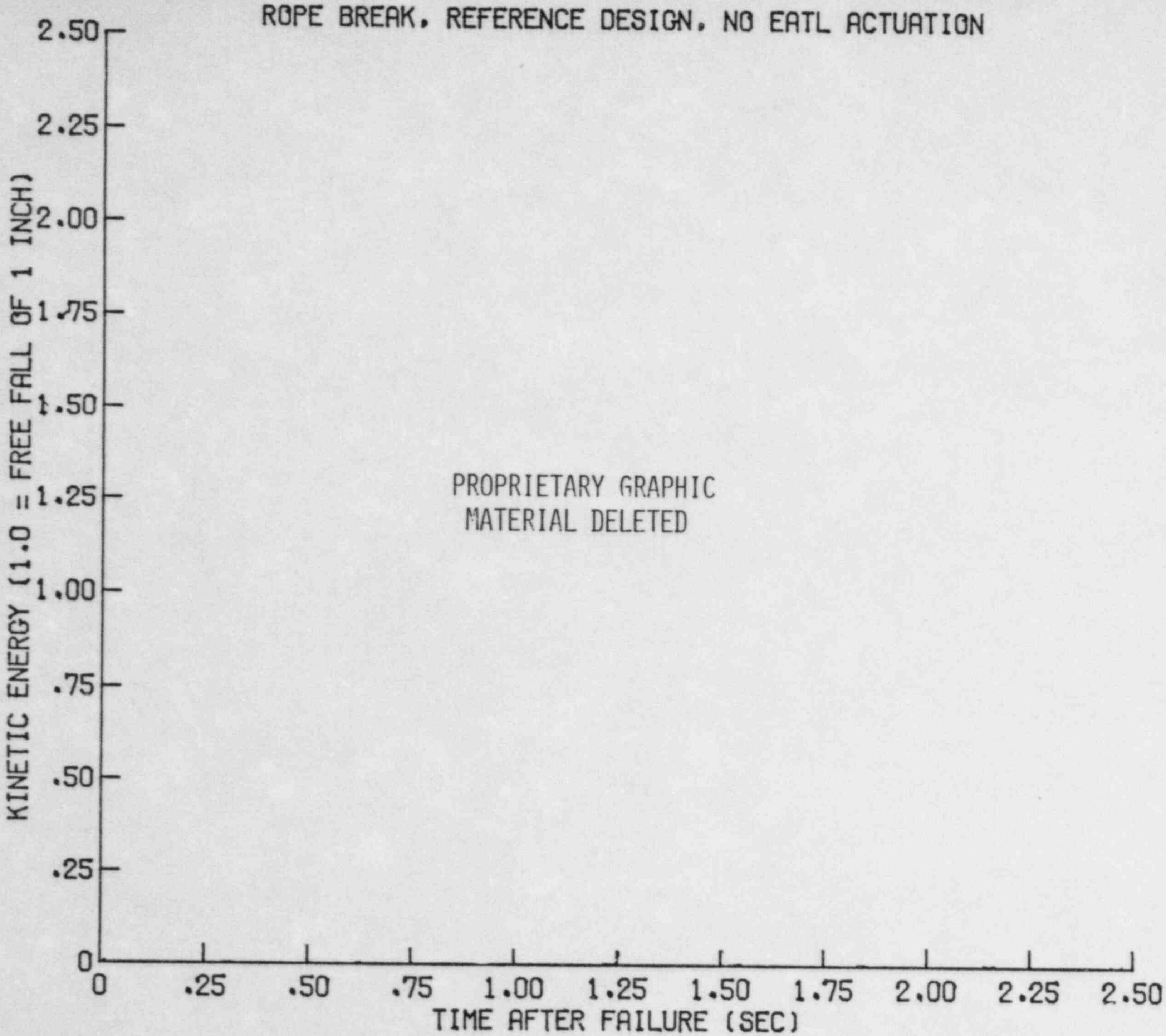


FIGURE 9
KINETIC ENERGY OF BASE CASE
AND BASE CASE WITHOUT DAMPING

5. Description of Mathematical Model

This section describes the mathematical model of the hoist that is used to derive the general solutions and to link them to obtain the specific solutions for individual cases.

a. Model of Crane

Figure 10 shows a typical reeving arrangement, the pertinent physical parameters, and the sign conventions used. The following assumptions are made:

Proprietary Material Deleted

b. Model of Drive Train Failure Detection System

A drive train failure can be detected either directly, by a drive train continuity detector, or indirectly, by a drum overspeed detector. A drum overspeed detector also detects a holding brake failure, which a drive train continuity detector alone would not detect.

Proprietary Material Deleted

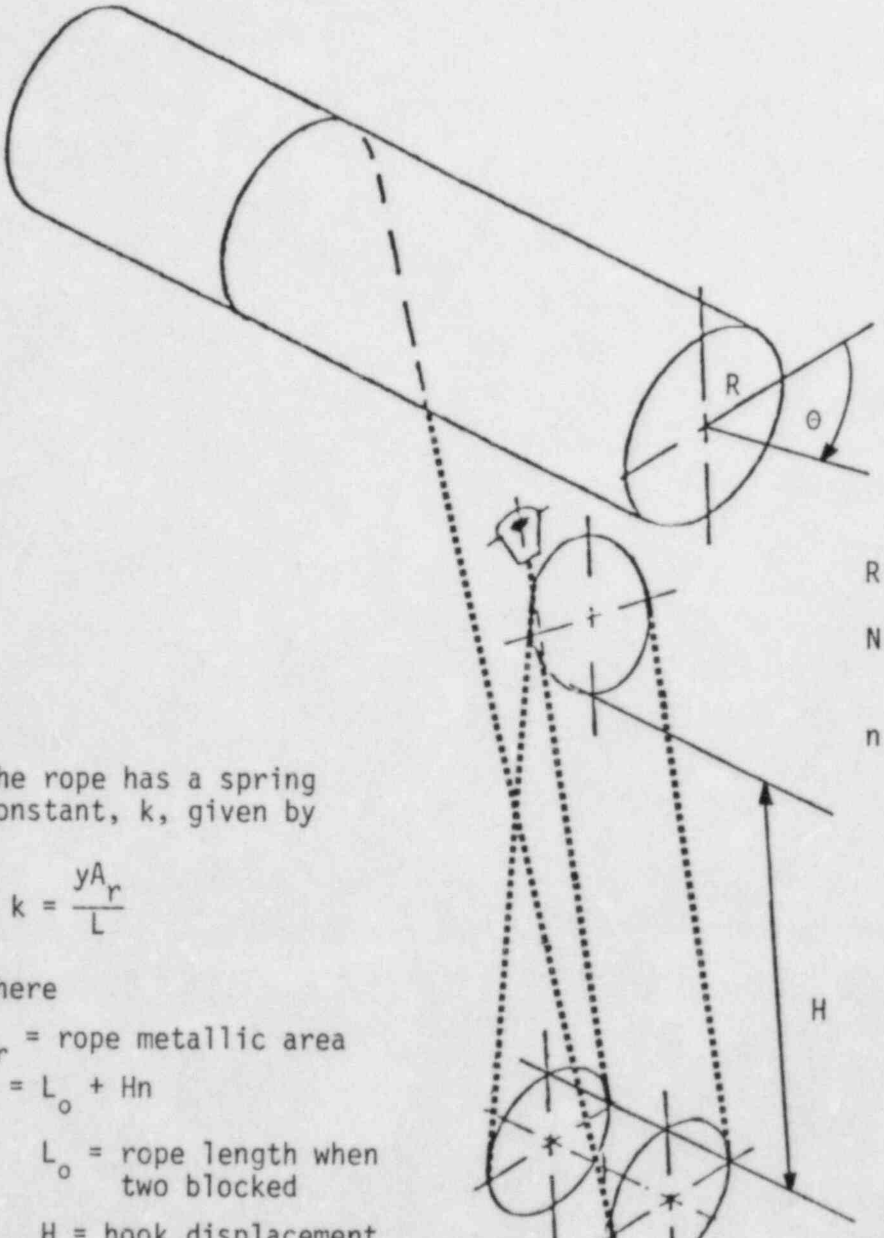
c. Model of Emergency Drum Brake

Proprietary Material Deleted

d. Model of Hydraulic Equalization System

The Hydraulic Load Equalization System is assumed to function such that the bitter end of the two wire ropes remains stationary following a wire rope failure.

Figure 10



R = drum radius

N = number of ropes attached to Drum and Equalizer

n = number of parts of line in one rope

The rope has a spring constant, k, given by

$$k = \frac{yA_r}{L}$$

where

A_r = rope metallic area

$L = L_o + Hn$

L_o = rope length when two blocked

H = hook displacement

y = rope modulus of elasticity

e. Model of Failure

The failure is assumed to happen instantaneously. In the case of a drive train failure, the failure is assumed to be a complete severing of the drive train at a given point. After the failure, the drum is restrained only by the moment of inertia of the intact portions of the drive train connected to the drum and whatever constant retarding braking is assumed. Therefore, the drum accelerates in response to the difference between the force applied by the ropes and the restraining forces. In a wire rope break, the failure is assumed to be a complete severing of one wire rope, with the attendent increase in static and dynamic tension in the remaining rope and additional dynamic forces on the drum resulting from the load motion.

6. General Solution of the Equations of Motion that is Valid When the Drum is Rotating

PROPRIETARY MATERIAL DELETED

7. General Solution of the Equations of Motion That is Valid When the Drum is Stationary

PROPRIETARY MATERIAL DELETED

8. Assessment of the Effects of Sheave Inertia and Bearing Friction

PROPRIETARY MATERIAL DELETED

The simplified analysis described above indicates that including sheave effects through use of the tackle system efficiency produces conservative estimates of the maximum tension in the wire rope. Furthermore, the actual load motion will be smaller and slower than that predicted without sheave effects.

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Appendix F

ANALYSIS OF CABLE AND MACHINERY LOADINGS FOLLOWING TWO BLOCKINGS OF X-SAM TYPE CRANES

NON-PROPRIETARY VERSION

R. W. Holloran

C. A. Rusch

R. E. Morton

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Revision 2

February 1980

TABLE OF CONTENTS AND REVISION STATUS FOR APPENDIX F

NON-PROPRIETARY VERSION

APPENDIX F TABLE OF CONTENTS AND REVISION STATUS, Continued

1. Introduction

The purpose of this analysis is to develop analytical and numerical techniques for evaluating the consequences of a two blocking in a single drive train hoist protected by an energy absorbing torque limiter (EATL). Specifically, expressions for drum hoist displacement and cable tension, as a function of time following the two blocking, are developed. These expressions provide a basis for evaluating the consequences of a two blocking on the cables and machinery.

2. Approach

The analysis starts with the equations of motion following the two blocking of a crane without an EATL. From this basic case, the expressions are extended to include a crane with an EATL. Finally, damping, motor shutdown, and variable spring constants are included in the analysis to provide a model that can closely approximate the results generated from actual two blocking tests.

3. Description of the Mathematical Model

a. Model Description

A crane two blocking creates a situation in which the lower (moving) block stops, by coming in contact with the trolley, while the torque applied by the drive motor increases the cable tension rather than lifting the load. The cable tension will increase until the stall torque of the motor is reached, if an EATL is not installed.

PROPRIETARY MATERIAL DELETED

b. Model Assumptions and Definitions

This section describes the mathematical model of the hoist that is used to derive the general solutions for cable and machinery loading. Figure 1 shows a typical reeving arrangement, the pertinent physical parameters, and the sign conventions used. The following assumptions are made:

(1) The hoist and trolley structures are rigid;

(2) The hoist motor turns at a constant speed unless it reaches its stall torque, at which time a constant torque is applied.

(3) The use of an effective moment of inertia, calculated with respect to the hoist drum axis, accounts for the inertia effects of the hoist motor, hoist drum, gears, and gear shafts, and the gear ratio of these pieces relative to the drum. It is given by:

$$I_{eff} = \sum_{\text{shafts}} (I_{shaft}) \text{ (Shaft Reduction)}^2 \qquad (2)$$

$$I_{shaft} = \sum_{\text{components}} \frac{\pi \rho L}{2} (R_o^{\,4} - R_i^{\,4}) \qquad (3)$$

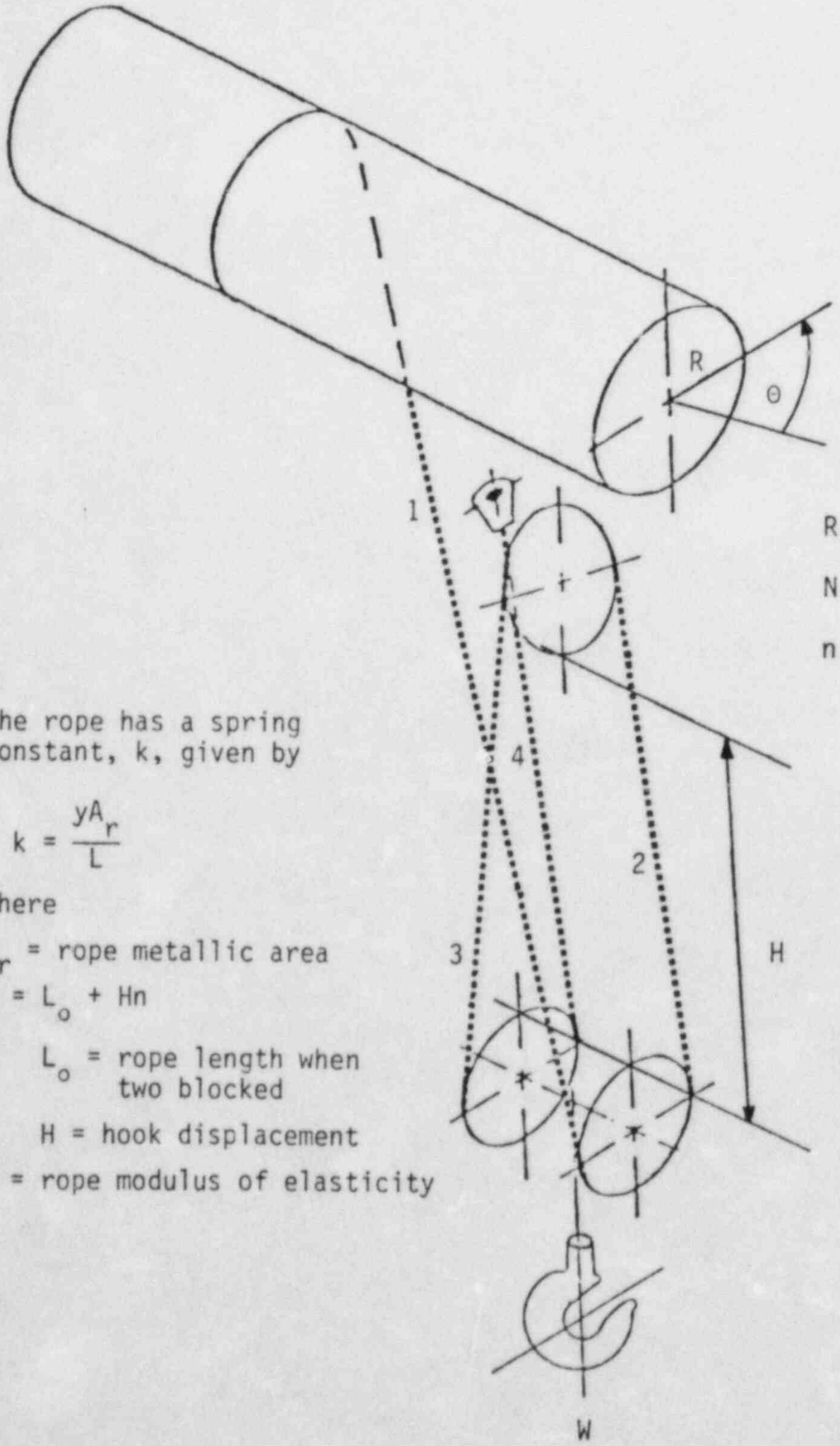
where L = Length of the Component (e.g. gear)
R_o = Outside Radius of Component
R_i = Inside Radius of Component
ρ = Density of the Component Material

(4) The load is shared equally between nN parts of line.

(5) The hoist cable reacts as an elastic spring.

(6) Sheave inertia can be neglected.

(7) Use of an effective length corrects for the effects of the sheaves on the spring constant. The effective length is obtained from the expression:



R = drum radius

N = number of ropes

n = number of parts of line in one rope

The rope has a spring constant, k, given by

$$k = \frac{yA_r}{L}$$

where

A_r = rope metallic area

$L = L_o + Hn$

L_o = rope length when two blocked

H = hook displacement

y = rope modulus of elasticity

Typical Reeving System

$$L = \sum_{i=1}^{n} \frac{l_i}{K^{i-1}} = \frac{l_1}{K^o} + \frac{l_2}{K^1} + \frac{l_3}{K^2} + \frac{l_4}{K^3} + \ldots + \frac{l_n}{K^{n-1}} \qquad (1)$$

where l_i is the length of rope between the (i+1)th and (i)th sheave, K is the ratio of tension in the rope unwinding from a sheave to the tension in the rope winding onto the sheave, and n is the number of parts of line in a single rope.

(8) The lead line tension while hoisting, P, is related to the average tension, T_s, by the tackle system efficiency, E, as follows:

$$P = \frac{T_s}{E} \qquad (4)$$

Table F.2 contains the derivation of the expression for the tackle system efficiency.

4. Solutions for Cable and Machinery Loading for a Crane Without an EATL Following a Two Blocking

A drum of radius R carrying N ropes, turns to lift the load (Figure 1). An effective moment of inertia I is used for the system, which is calculated with respect to the hoist drum axis of rotation. Figure 2 represents a typical hoist drive system without EATL. The wire rope is assumed to be fully elastic and is characterized by a spring constant k. The spring constant is obtained from the expression

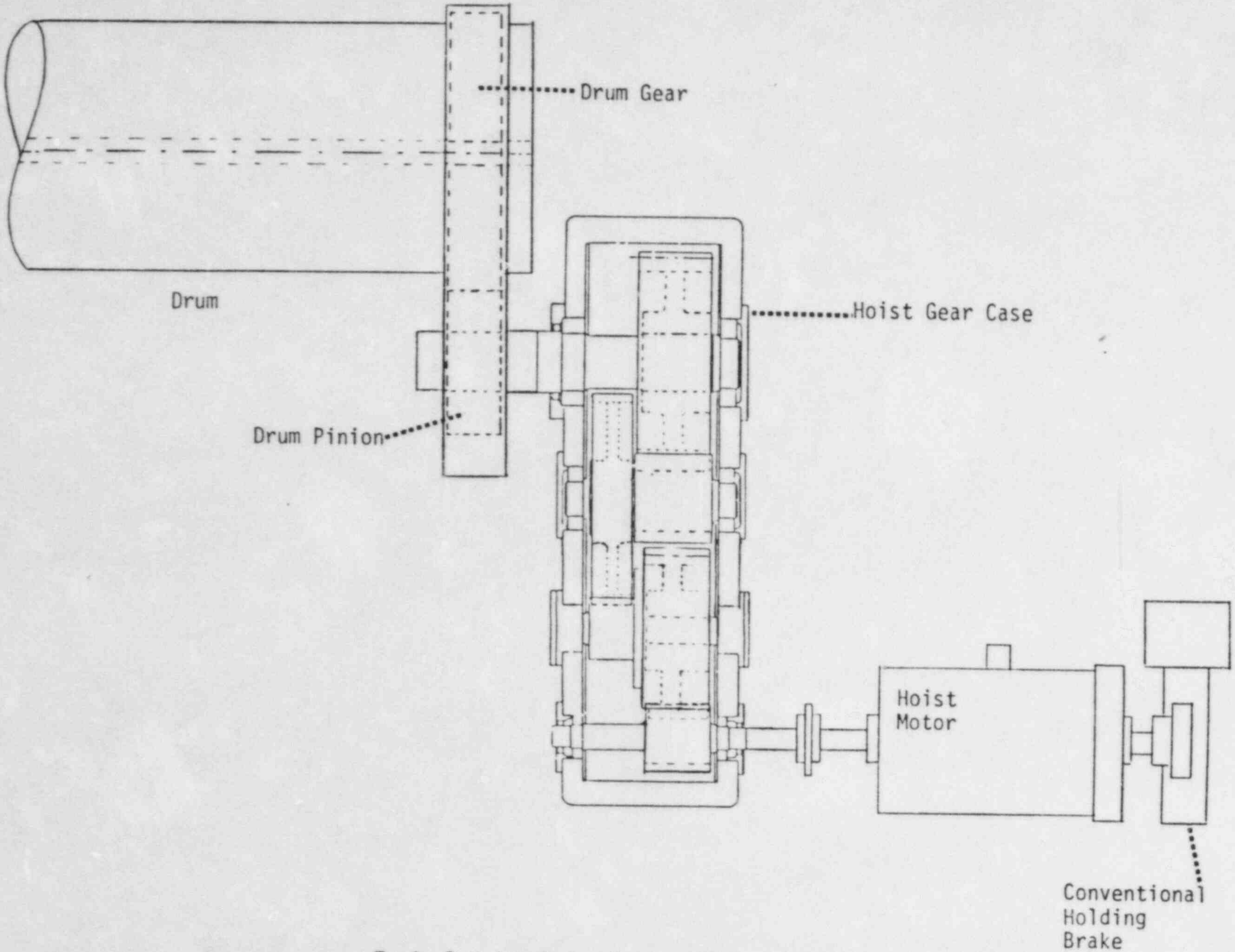
$$k = \frac{yA_r}{L} \tag{5}$$

where y is the elastic modulus of the wire rope, A_r is the metallic cross sectional area of the rope, and L is the effective length of one of the wire ropes. The effective length accounts for the sheave friction effects on the spring constant. The inertial effects of the sheaves are neglected and the system is assumed to be undamped.

For N identical ropes on the drum and a time varying torque J(t) applied by the motor to the drum, the dynamical equation that gives the angle θ through which the drum rotates following two blocking, with $\theta = 0$ at $t = 0$, is

$$I \frac{d^2\theta}{dt^2} = J(t) - kNR^2\theta - NRP \tag{6}$$

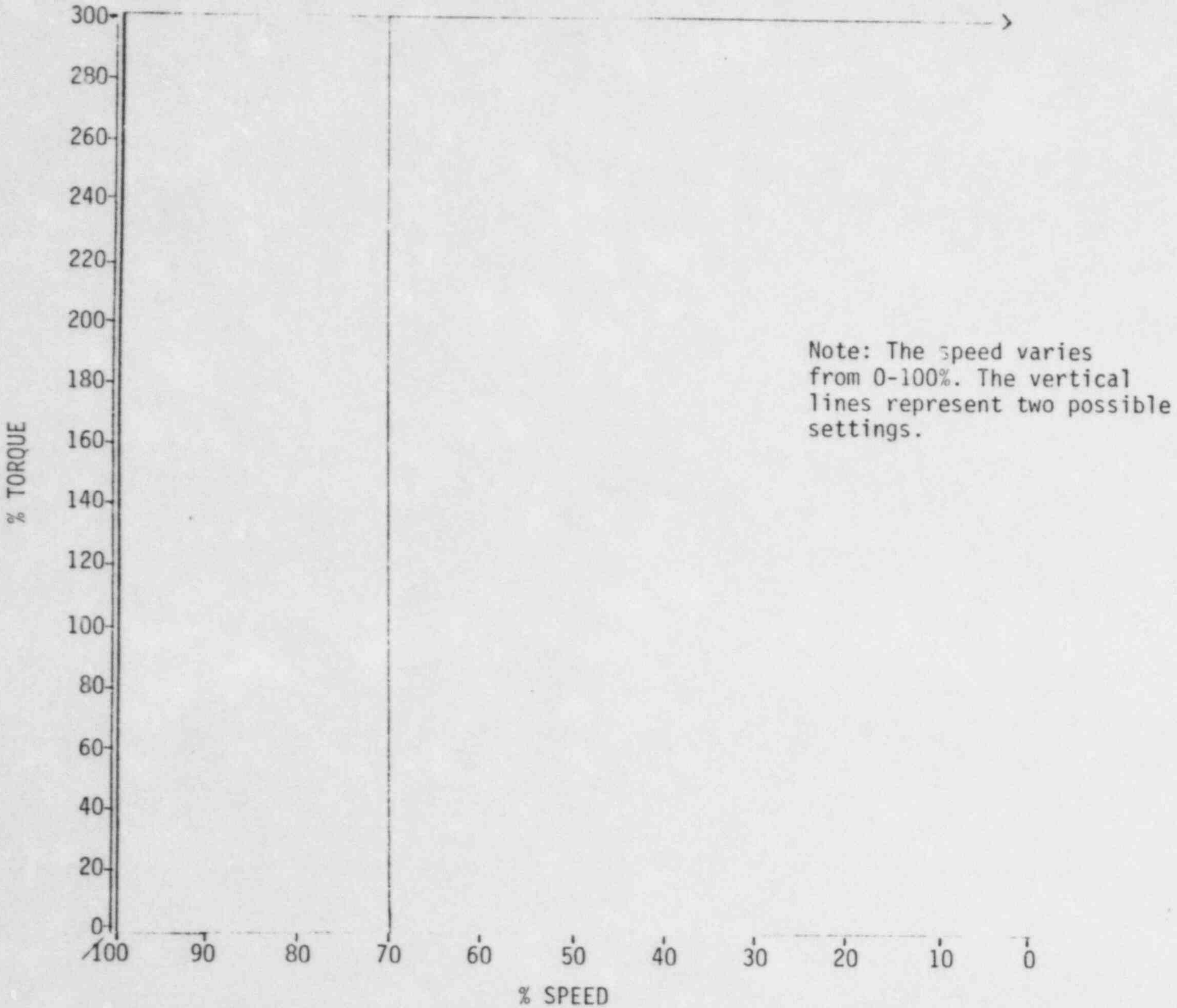
where the tackle system efficiency is used in calculating P, the initial tension in one lead line prior to two blocking. The case considered is one in which the angular velocity of the drum remains constant until a limiting torque is reached, whereupon the torque remains constant at its limiting value. This case is closely approximated by crane systems that are designed to hoist at virtually a constant speed, i.e., DC systems. Figure 3 illustrates the assumed torque-speed curve for a typical DC motor. The vertical lines represent the speed regulation of a DC motor controller in which the speed is maintained for any torque below the stall torque. Figure 4 represents two speed points of an AC motor torque-speed curve, in which the



Typical Hoist Drive System Without EATL

Figure 2

Figure 3



DC Motor Torque Speed Curve

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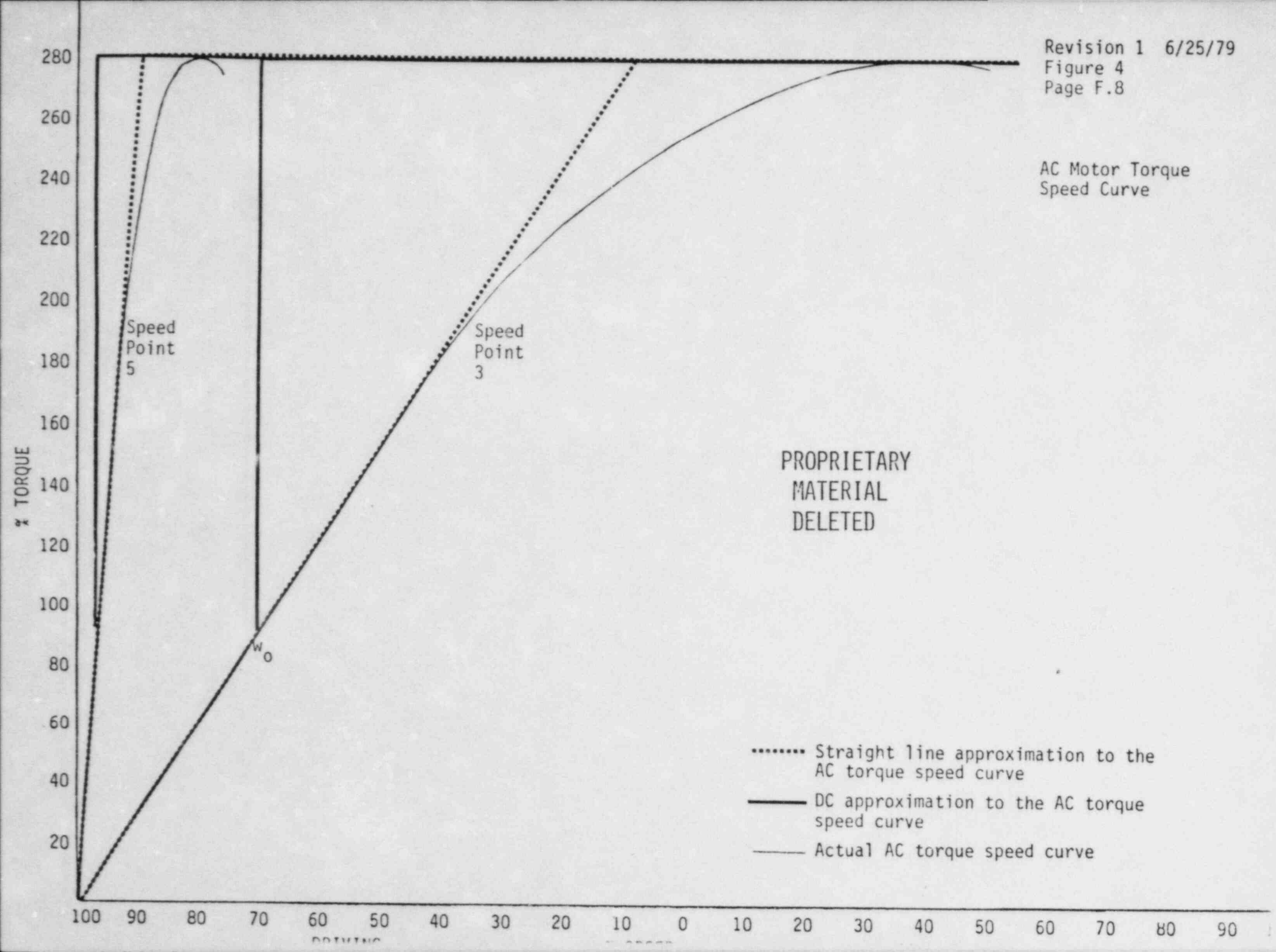
Figure 4
Page F.8



speed decreases with increasing torque and fewer resistors remain in the circuit as the Speed Point increases. When Speed Point 5 is selected, all resistors are out of the circuit and the torque speed curve approaches a vertical relationship similar to that of a DC motor. The AC motor can conservatively be assumed to have the speed control torque characteristics of a DC motor. A more accurate solution, which accounts for ramp torque speed relationships, is presented in Table F.3 for use when a less conservative solution is desired. This solution approaches the constant angular velocity solution as resistors are cut out of the AC motor control circuit.

The solution to equation (6) divides naturally into two regions. The first region applies to the time prior to reaching the torque limit.

Region 1--Constant angular velocity (DC Motor) Model

$$\frac{d^2\theta}{dt^2} = 0 \text{ and } \frac{d\theta}{dt} = w_o$$

Equation (6) reduces to

$$J(t) = kNR^2\theta + NRP \tag{7}$$

or, in terms of T = Tension in one cable

$$T = kR\theta + P \tag{8}$$

Since the angular velocity is constant

$$\theta = w_o t \tag{9}$$

and

$$T = kRw_o t + P \tag{10}$$

If J_r is the motor torque required to lift the design rated load, and "h" is the ratio of the limiting torque to the torque required to lift the design rated load, equation (7) yields the drum angle θ_1 at which the torque becomes constant.

$$\theta_1 = \frac{hJ_r - NRP}{kNR^2} \tag{11}$$

From equation (9) the drum angle reaches θ_1 at a time t_1

$$t_1 = \frac{\theta_1}{w_o} = \frac{hJ_r - NRP}{kNR^2 w_o} \tag{12}$$

Table F.3 describes the Region 1 solution for a ramp torque speed relationship, i.e., typical of AC motors.

Region 2

Once the torque limit is reached the form of the remaining solutions is the same, regardless of which of the two torque speed relationships was assumed in Region 1. For angles θ greater than or equal to θ_1 and times t greater than or equal to t_1, equation (6) becomes

$$\frac{d^2\theta}{dt^2} + \frac{kNR^2}{I}\,\theta = \frac{hJ_r}{I} - \frac{NRP}{I} \tag{13}$$

which can be written in terms of a natural frequency C

$$\frac{d^2\theta}{dt^2} + C^2\theta = \frac{hJ_r}{I} - \frac{NRP}{I} \tag{14}$$

where

$$C = \left(\frac{kNR^2}{I}\right)^{1/2} \tag{15}$$

The solution obtained for the conditions $\theta = \theta_1$, and $\frac{d\theta}{dt} = w_o$ at $t^* = 0$ where $t^* = t - t_1$ is

$$\theta = \frac{w_o}{C}\sin(Ct^*) + \frac{hJ_r - NRP}{kNR^2} \tag{16}$$

The lead line tension for times after $t = t_1$ is therefore,

$$T = kR\theta + P \tag{17}$$

where the expression for θ in equation (16) is substituted into equation (17).

Summary

The tension in the lead lines is

$$T = kRw_o t + P \qquad 0 \leq t \leq t_1 \tag{18}$$

$$= \frac{kRw_o}{C} \sin(Ct^*) + \frac{hJ_r}{NR} \qquad t \geq t_1, \text{ i.e., } t^* \geq 0 \tag{19}$$

where

$$C = \left(\frac{kNR^2}{I}\right)^{1/2} \tag{20}$$

and

$$t_1 = \frac{\theta_1}{w_o} = \frac{hJ_r - NRP}{kNR^2 w_o} \tag{21}$$

This analysis can be extended to represent the tension in the lead line and the stresses in the hoist machinery/girder structure following a load hangup, by accounting for the additional cable extended. The analysis can also be extended to dual drive train cranes by the appropriate adjustment of the effective moment of inertia. Cranes with multiple hoist drums can be analyzed with the same approach used herein.

5. Cable and Machinery Loading Following a High Speed Two Blocking
Figure 5 illustrates the lead line tension in a dual reeved, single drive train, 130 Ton capacity hoist, which is not protected by an EATL, following a two blocking at rated speed. The equations, derived in Section 4, were evaluted using a FORTRAN IV program and the figure was generated by a CALCOMP Plotter. The scale for cable loading is on the right hand side of these figures. This scale has been normalized to 90% of the wire rope yield strength. The scale for machinery loading is on the left hand side of these figures. It has been normalized such that the machinery loading is 1.0 when a design rated load is being hoisted.

For this calculation it has been assumed that the maximum torque that can be applied by the DC drive motor is 2.75 times the torque required to hoist the design rated load. This value represents an internal limit based on design constraints for voltage and current as determined by the manufacturer.

The following data were used in generating these figures:

$$k = \frac{.79 \times 12 \times 10^6}{80} = 118500 \text{ lb/ft}$$

$$A_r = .79 \text{ in}^2$$

$$y = 12 \times 10^6 \text{ lb/in}^2$$

$$R = 2.88 \text{ ft}$$

w_o = .2189 radian/sec (rated motor speed, 1200 RPM)

h = 2.75 (no EATL)

$$P = \frac{260000}{(2)(8)} \frac{(1.04^7)(8)(1.04-1)}{(1.04^8-1)} = 18570 \text{ lb}$$

J_r = 128000 ft-lb

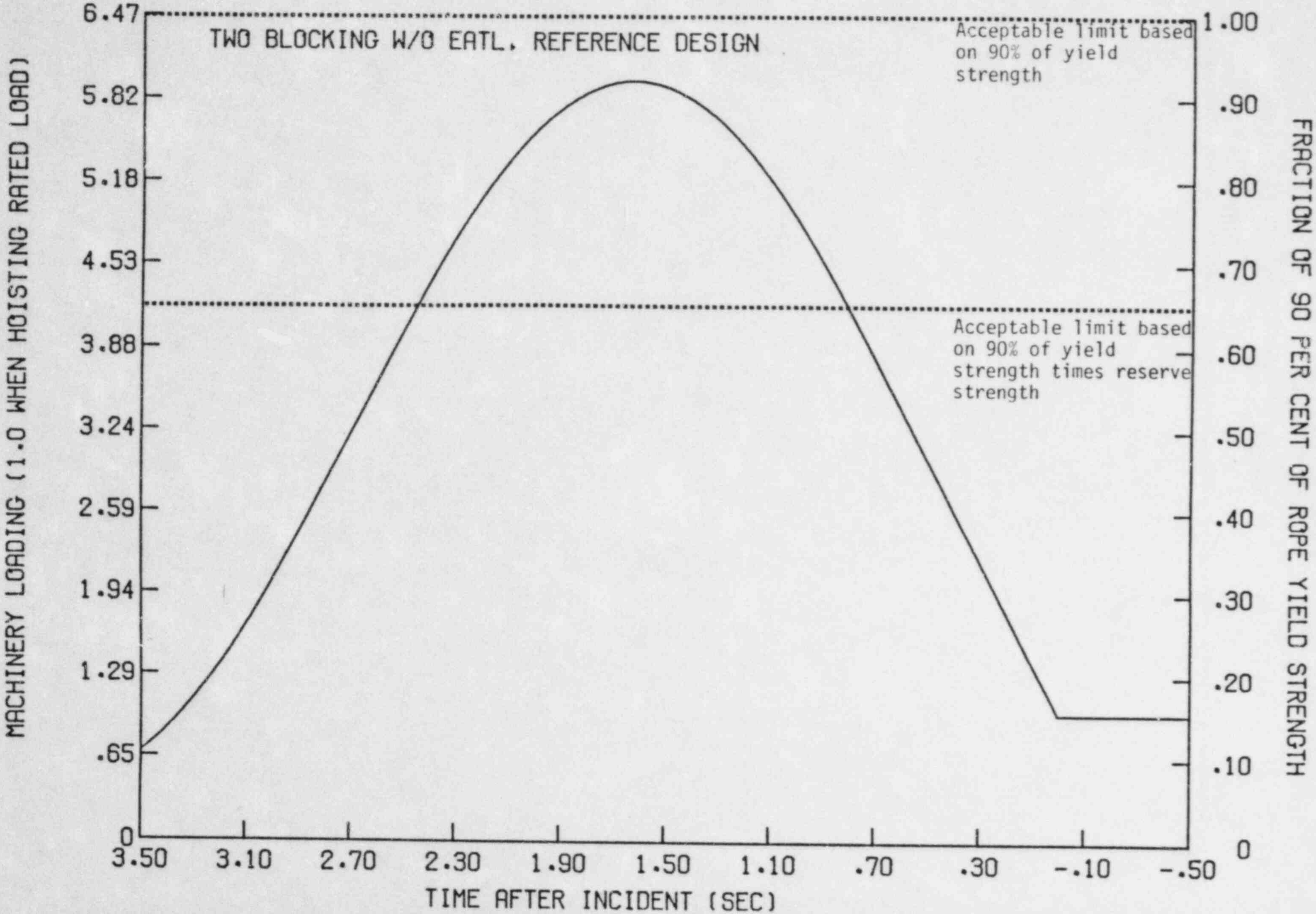
L = 80 ft

N = 2

n = 8

K = 1.04

I = 911000 slug - ft^2


TWO BLOCKING W/O EATL. REFERENCE DESIGN
Acceptable limit based on 90% of yield strength
Acceptable limit based on 90% of yield strength times reserve strength
MACHINERY LOADING (1.0 WHEN HOISTING RATED LOAD)
6.47
5.82
5.18
4.53
3.88
3.24
2.59
1.94
1.29
.65
0
FRACTION OF 90 PER CENT OF ROPE YIELD STRENGTH
1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10
0
3.50
3.10
2.70
2.30
1.90
1.50
1.10
.70
.30
-.10
-.50
TIME AFTER INCIDENT (SEC)

6. Description of the Analysis of Cable and Machinery Loading Following Two Blocking of a Crane With an EATL

a. Introduction and Analysis

Section 4 provided an analysis of two blockings of conventional cranes without an EATL. This section extends that analysis by including an EATL in the drive train. As in Section 4, the analysis will be separated into two sections.

Region 1

PROPRIETARY MATERIAL DELETED

Region 2

PROPRIETARY MATERIAL DELETED

b. Inclusion of Damping in the Analyisis

PROPRIETARY MATERIAL DELETED

c. Region 3--Inclusion of Motor Shutdown in the Analysis

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d. Inclusion of a Varying Spring Constant in the Analysis

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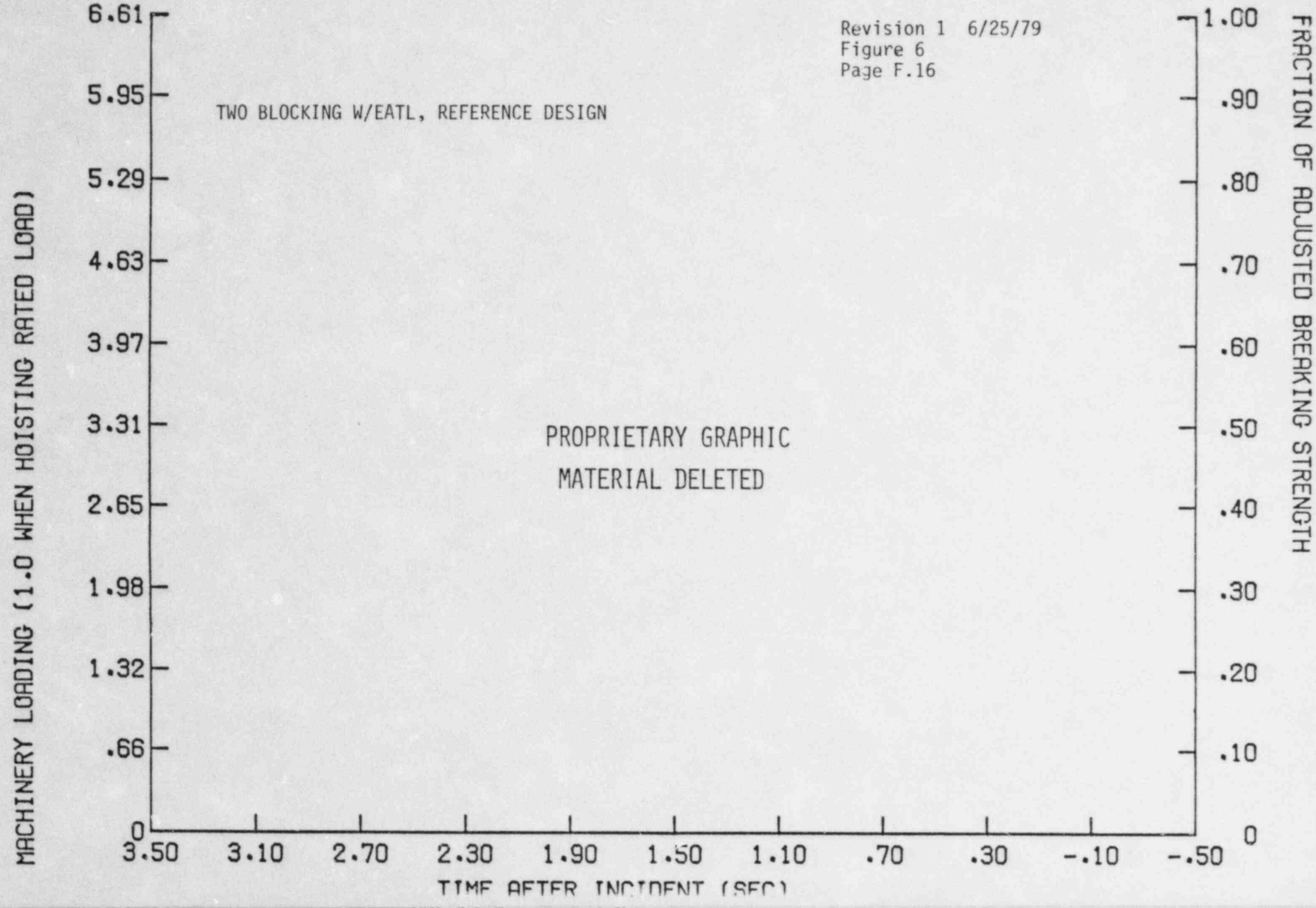

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Figure 6
Page F.16
TWO BLOCKING W/EATL, REFERENCE DESIGN
PROPRIETARY GRAPHIC
MATERIAL DELETED
MACHINERY LOADING (1.0 WHEN HOISTING RATED LOAD)
6.61
5.95
5.29
4.63
3.97
3.31
2.65
1.98
1.32
.66
0
FRACTION OF ADJUSTED BREAKING STRENGTH
1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10
0
3.50
3.10
2.70
2.30
1.90
1.50
1.10
.70
.30
-.10
-.50
TIME AFTER INCIDENT (SEC)

PROPRIETARY
FIGURE
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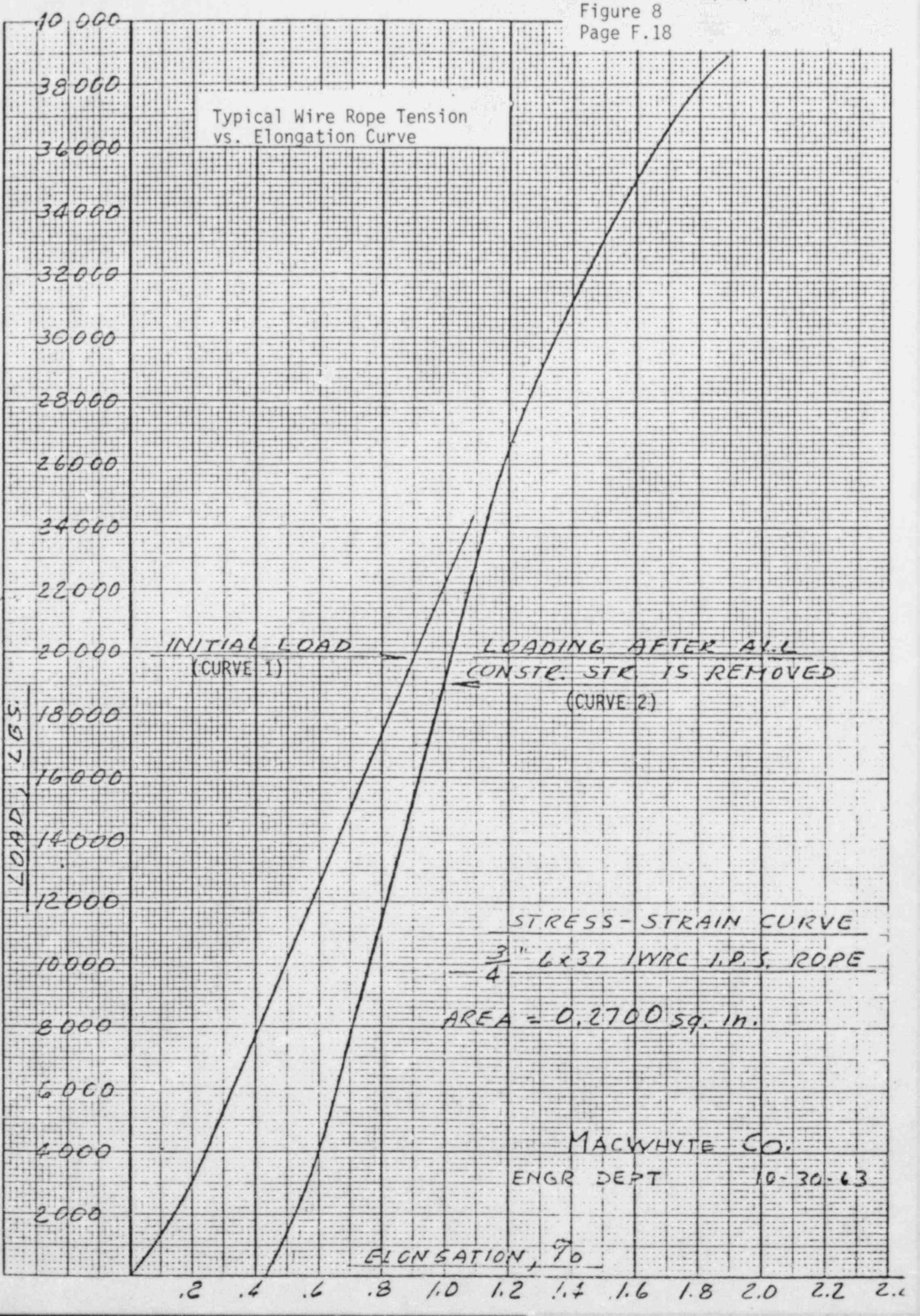
Typical Hoist Drive System With EATL


Typical Wire Rope Tension vs. Elongation Curve
40,000
38000
36000
34000
32000
30000
28000
26000
24000
22000
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
LOAD, LBS.
INITIAL LOAD
(CURVE 1)
LOADING AFTER ALL CONSTR. STR. IS REMOVED
(CURVE 2)
STRESS-STRAIN CURVE
3/4" 6x37 IWRC I.P.S. ROPE
AREA = 0.2700 sq. in.
MACWHYTE CO.
ENGR DEPT
10-30-63
ELONGATION, %
.2
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2

7. Comparison of Actual Test Data Versus Analytical "Best Fit" for Cable Loading Following Two Blocking With an (EATL)

The curve designated "Actual Test Curve" in Figure 9 represents the results of a shop two blocking test conducted as part of the LOFT hoist test program prior to delivery. The report "Summary of Lessons Learned in Retrofitting the New Trolley on the LOFT Containment Building Polar Crane" contains the outline used in conducting the shop two blocking tests.

The curve designated "Analytical Best Fit Curve" was generated by a CALCOMP plotter utilizing information from a FORTRAN IV computer program. This curve was generated selecting spring constants, damping coefficients, hysteresis effects and constructional stress effects with the express purpose of fitting the analytical solutions to the actual test data. Table F.1 lists the constants used for the analytical best fit curve. The "Original Value" column of Table F.1 indicates the expected values based on data gathered from the shop two blocking tests and manufacturer's product information. The "Original Values Changed to Achieve Best Fit Curve" column lists those values that were changed in order to "best-fit" the analytical, computer generated curve to the shop test curve.

Two Blocking Comparison, Actual Shop Test Data
vs. Analytical Best Fit Curve

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Figure 9
Page F.20

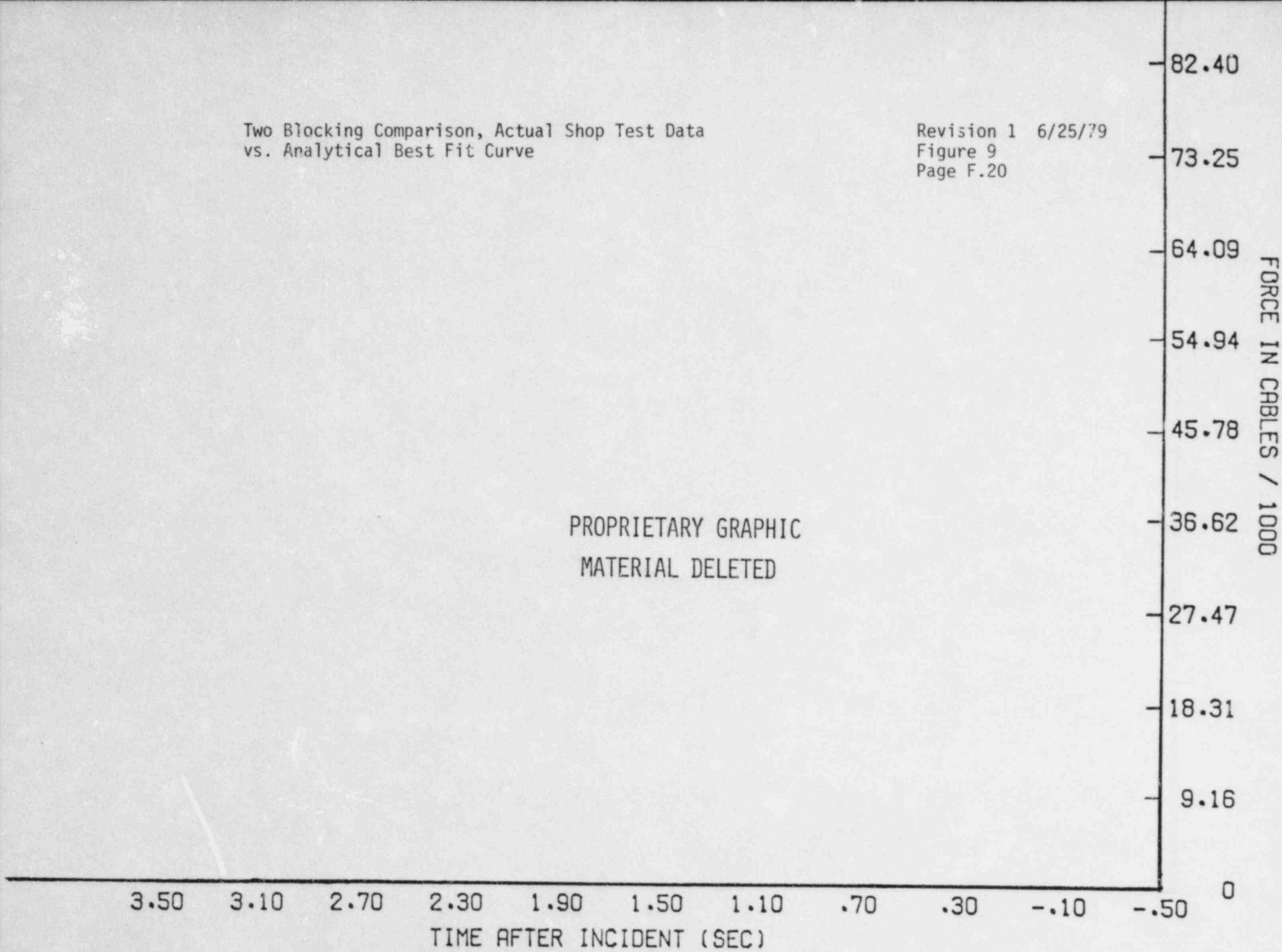

Table F.1

BEST FIT CURVE (FIGURE 9) CONSTANTS

	Original Design Value Unless Otherwise Annotated	Values Changed to Achieve Best Fit Curve

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MATERIAL
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Revision 1 6/25/79
Figure 10

Tension vs. Elongation Curve Illustrating Actual Spring Constants Used for Best Fit Curve

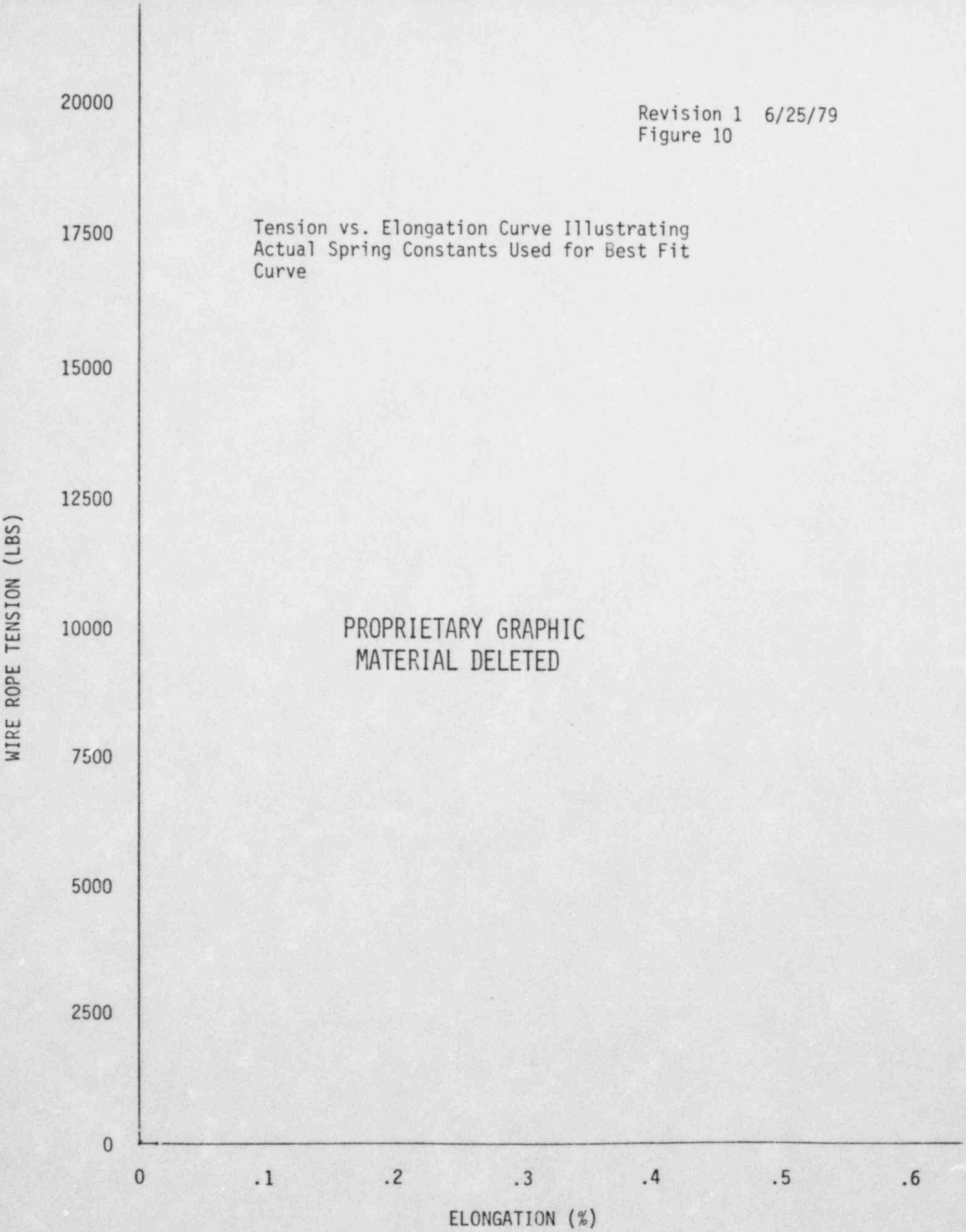

TABLE F.2

TACKLE SYSTEM EFFICIENCY DERIVATION

When the load W is staticly supported by multiple-part wire ropes, the load on each wire rope part is given by

$$T_s = \frac{W}{nN} \tag{33}$$

where T_s is the static tension in one part, W is the load, n is the number of parts of line in one rope, and N is the number of ropes. When hoisting, the effects of sheave friction and of bending a wire rope around a sheave cause the tension in each part of the rope to successively increase from the part attached to the dead end (part #4, Figure 1) to the lead line (part #1, Figure 1). The lead line tension while hoisting, P, is greater than the static tension in one part, T_s. P and T_s are related by an efficiency factor

$$E = \frac{T_s}{P} \tag{34}$$

where E is the tackle system efficiency.

E can be derived by starting with the expression for the tension in all of the wire rope parts

$$\frac{W}{N} = P + \frac{P}{K} + \frac{P}{K^2} + \frac{P}{K^3} + \frac{P}{K^4} + \ldots + \frac{P}{K^s} \tag{35}$$

where W/N is the static tension in one rope, P is the tension in the lead line, all other terms represent the tension in the parts of rope moving away from the hoist drum, s is the number of rotating sheaves, and K is defined in Paragraph 3a(5).

TABLE F.2, Continued

Substituting the expressions for T_s, equation (33), and P, equation (35) into equation (34) yields

$$E = \frac{\frac{W}{nN}}{\frac{W}{N(1 + \frac{1}{K} + \frac{1}{K^2} + \frac{1}{K^3} + \frac{1}{K^4} + \ldots + \frac{1}{K^s})}} \qquad (36)$$

Now by cancellation, multiplying both numerator and denominator by $K^s(K-1)$, and noting that $n=s+1$, the result is

$$E = \frac{K^n-1}{K^s n(K-1)} \qquad (37)$$

The expression for E, equation (37), is the same equation found in the "Catalog of Tables, Data and Helpful Information, G-17," MacWhyte Wire Rope Co., pg. 150. Other wire rope companies also use the same expression for E.

Substituting this expression for E into equation (34) and solving for P, yields the desired relation for initial lead line tension

$$P = \frac{(W)\ K^s n(K-1)}{(nN)\ (K^n-1)} = \frac{T_s}{E} \qquad (38)$$

TABLE F.3

GENERIC SOLUTION FOR HOIST MOTORS WITH RAMP TYPE TORQUE SPEED CHARACTERISTICS

If a ramp type torque speed relationship is assumed, an equation for the time varying torque must be established. Given the torque speed relationship shown by Figure 4 for an AC motor, where J_f is the torque limit of the motor or EATL which ever is lower, w_o is the initial speed, and w_f is the speed corresponding to the torque limit, the equation that defines the torque, J, for any speed between w_f and w_o is:

$$J = \left(\frac{J_f}{w_f - w_o}\right)\left(w_o - \frac{d\theta}{dt}\right) \tag{39}$$

Substituting this value for J into equation (6) yields

$$\frac{d^2\theta}{dt^2} + 2Z\frac{d\theta}{dt} + C^2\theta = \frac{J_f w_o}{(w_f - w_o)I} - \frac{NRP}{I} \tag{40}$$

where $2Z = \frac{J_f}{(w_f - w_o)I}$ and $C^2 = \frac{kNR^2}{I}$

For the initial conditions $\theta = 0$ and $\frac{d\theta}{dt} = w_o$, there are two solutions to equation (40) depending on the relationship of Z to C. The solution is comprised of exponentials when $Z^2 \geq C^2$ and is given by

$$\theta = \left(w_o + (Z + (Z^2 - C^2)^{\frac{1}{2}})\left(\frac{(w_f - w_o)NRP - J_f w_o}{(w_f - w_o)kNR^2}\right)\right)\left(\frac{\exp(-Z + (Z^2 - C^2)^{\frac{1}{2}})t}{2(Z^2 - C^2)^{\frac{1}{2}}}\right)$$

$$- \left(w_o + (Z - (Z^2 - C^2)^{\frac{1}{2}})\left(\frac{(w_f - w_o)NRP - J_f w_o}{(w_f - w_o)kNR^2}\right)\right)\left(\frac{\exp(-Z - (Z^2 - C^2)^{\frac{1}{2}})t}{2(Z^2 - C^2)^{\frac{1}{2}}}\right)$$

$$+ \left(\frac{J_f w_o - (w_f - w_o)NRP}{(w_f - w_o)kNR^2}\right) \tag{41}$$

TABLE F.3, Continued

The solution is comprised of trignometric terms when $Z^2 < C^2$ and is given by

$$\theta = \exp^{-Zt}\left(\frac{w_o + Z\left(\frac{(w_f - w_o)NRP - J_f w_o}{(w_f - w_o)kNR^2}\right)}{(C^2 - Z^2)^{\frac{1}{2}}}\right)\sin(C^2 - Z^2)^{\frac{1}{2}}t$$

$$+ \exp^{-Zt}\left(\frac{(w_f - w_o)NRP - J_f w_o}{(w_f - w_o)kNR^2}\right)\cos(C^2 - Z^2)^{\frac{1}{2}}\,t$$

$$+ \left(\frac{J_f w_o - (w_f - w_o)NRP}{(w_f - w_o)kNR^2}\right) \quad (42)$$

This relationship can be used to determine the cable tension and torque. When the torque applied equals the limiting torque, the equations of Region 2 of Section 4 or Section 6 are applied as applicable.

Finally, when $(w_f - w_o) = 0$, the solution to equation (40) becomes

$$\theta = w_o t \quad (43)$$

Equation (43) is the same solution for angular displacement as was assumed for a constant speed motor.

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Appendix G

DESCRIPTION

OF

TOTALLY MECHANICAL

DRIVE TRAIN CONTINUITY DETECTOR

AND

EMERGENCY DRUM BRAKE ACTUATOR

NON-PROPRIETARY VERSION

REVISION 3

10/8/82

AMENDMENT 3

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TABLE OF CONTENTS AND REVISION STATUS FOR APPENDIX G

(Non-Proprietary Version)

TABLE OF CONTENTS AND REVISION STATUS
FOR APPENDIX G, Continued

(Non-Proprietary Version)

1. Introduction

1.1 The purpose of this Appendix is to describe the operation of the totally mechanical Emergency Drum Brake Actuator and its companion Drive Train Continuity Detector. The response to each of the failures described in Section III.E of the body of EDR-1 is described for a Hoist's Integrated Protective System (HIPS), which contains these two components. In addition the provisions for testing the totally mechanical Emergency Drum Brake Actuator and its companion Drive Train Continuity Detector are also defined.

1.2 Figure 1 is a schematic overview of a Typical Nuclear Safety Related X-SAM Hoist System that is equipped with a totally mechanical Emergency Drum Brake Actuator and Drive Train Continuity Detector. The actual apparatus may be arranged differently in some respects, but the function, operation and operating environments are as shown. For the convenience of the reader the following overview of the remainder of the system is provided prior to the subsequent description of the Emergency Drum Brake Actuator, Drive Train Continuity Detector, and Failure Actuation and Monitoring Assembly.

1.3 A seismically qualified trolley or hoist frame supports a conventional crane duty motor and electrical load control (2), which are coupled to a gear case (3). The gearing may take a variety of forms, e.g., spur, helical, or planetary, depending upon the hoist arrangement. A single conventional crane duty high speed holding brake (4) is mounted on the high speed shafting. An Energy Absorbing Torque Limiter (EATL) assembly (5) is intergal with the gearing. The wire rope drum may be either journaled in the gear case, as shown in Figure 1, or may be driven through a bull gear by a pinion on the output shaft of the gear case. Motion of the wire rope drum following failure of the drum shaft, hub, or bearings is limited by the the Drum Safety Support Structure (9) and the gear case, when the drum is journaled into the gear case. The Emergency Drum Brake Assembly (10) is located on the wire rope drum so that it can stop and hold the load in the event of a drive train failure. The various detectors in the Failure Detection System that actuate the Failure Actuation and Monitoring Assembly are descibed later in Section 4 of this Appendix.

FIGURE I

PROPRIETARY MATERIAL DELETED

FIGURE 2

LIST OF COMPONENTS

PROPRIETARY MATERIAL DELETED

FIGURE 2 Continued

LIST OF COMPONENTS

PROPRIETARY MATERIAL DELETED

2. Emergency Drum Brake Actuator

2.1 A band brake is normally used with the totally mechanical Emergency Drum Brake Actuator, as shown in Figure 3. However, the totally mechancial Emergency Drum Brake Actuator is also compatible with a disk brake. The totally mechanical Emergency Drum Brake Actuator has the following basic functions:

1. Use energy from an external non-safety related source to release the Emergency Drum Brake

2. Store internally the energy needed set the Emergency Drum Brake in the event of a failure.

3. Release the energy from the storage device to set the Emergency Drum Brake in the event of a "failure." In this context, the term "failure" includes lack of continuity of the drive train, a failure in the continuity detector, or an error signal from the drum over-speed detector, the wire rope spooling monitor, or the backup upper travel limit switch, and continued lowering of the load following a wire rope failure.

4. Not release the energy from the storage device and thus not set the Emergency Drum Brake when power to the crane is shut off, unless there is a failure, as defined above.

5. Manually lowering the load if required in the event of an emergency.

2.2 In the reference design these functions are accomplished by:

1. High pressure air compressing a spring in a spring chamber used to release the Emergency Drum Brake.

2. A "pelican hook" holding the compressed spring after the air pressure in the spring chamber is vented, allowing the drum to rotate, unless the Drive Train Continuity Detector detects a discontinuity between its input shafts, as is described in Section 3 of this Appendix. Alternatively, the Drive Train Continuity Detector described in Section 3 of this Appendix is capable of directly holding the compressed spring in low capacity hoists--generally 10 Tons or less.

3. The Failure Actuation and Monitoring Assembly opening the mechanical link between the two input shafts to the Drive Train Contuity Detector, as is described in detail in Section 5 of this Appendix.

4. A manually controlled air valve pressurizing the spring chamber, thereby releasing some of the tension in the brake band--allowing the load to lower.

2.3

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2.4

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FIGURE 3

PROPRIETARY MATERIAL DELETED

EMERGENCY DRUM BRAKE ACTUATOR
PLAN VIEW

FIGURE 4

PROPRIETARY MATERIAL DELETED

EMERGENCY DRUM BRAKE ACTUATOR
SIDE VIEW

FIGURE 4a

PROPRIETARY MATERIAL DELETED

EMERGENCY DRUM BRAKE ACTUATOR
OPERATED DIRECTLY BY CONTINUITY DETECTOR
SIDE VIEW

3. **Drive Train Continuity Detector**

3.1 As is the case with the other types of Drive Train Continuity Detectors discussed in the main body of EDR-1, the totally mechanical Drive Train Continuity Detector is driven by both the lowest and highest speed shafts in the hoist so that any failure between the motor and wire rope drum will be detected. The totally mechanical Drive Train Continuity Detector has three basic functions:

1. Monitoring the ratio between the angular displacement of the motor and drum shafts and sense changes in this ratio that indicate there is a disconinuity in either the drive train or the inputs to the detector.

2. Mechanically nulling the accumulation of very small angular displacements between the motor and drum shaft that may result from a slight slippage of the EATL when the hoist stops.

3. Providing an output torque of sufficient magnitude to operate a release mechanism for the pelican hook in the totally mechanical Drum Brake Actuator.

3.2 In the reference design these functions are accomplished by:

1. A differential that is driven by the drum and the motor.

2. A mechanism in one of the inputs to the differential that provides an output from the differential that is always in the same direction during normal operation and the opposite direction in the event of a discontinuity between the inputs of the detector's differential.

3. A one way Sprag clutch that allows the differential's output shaft to turn freely under normal conditions, allowing the release mechansim to hold the totally mechanical Drum Brake Actuator. When the differential's output shaft rotates in the opposite direction, it drives the release mechanism out of engagement, releasing the the totally mechanical Drum Brake Actuator.

3.3 As shown in Figure 5, the totally mechanical Drive Train Continuity Detector is essentially a rugged minature crane duty gear box housed in a steel enclosure (63). In the reference design this enclosure is supported and torque mounted on an extension (80) of the drum shaft (41). The enclosure protects all of the components from the environment. The moving components of the detector operate in an oil bath. The components required to set the brake in the event of a drive train failure will either shutdown the hoist in the event of their failure during normal operation, or they are designed with a minimum 10:1 factor of safety during normal operation and a 5:1 factor of safety when the inertial forces of the worst case drive train hoist failure are considered. The components in the reference design that will not shutdown the hoist in the event of their failure during normal operations are identified with an "*" on Figure 2.

3.4 The following notation is used in all of the figures of this Appendix to identify the relative rotation of hoist and Drive Train Continuity Detector components:

1. ——— indicates the direction of rotation while hoisting and

2. ——o indicates the direction of rotation while lowering.

3.5

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3.11

PROPRIETARY MATERIAL DELETED

FIGURE 5

PROPRIETARY MATERIAL DELETED

DRIVE TRAIN CONTINUITY DETECTOR

4. **Failure Actuation and Monitoring Assembly**

4.1 The purpose of the Failure Actuation and Monitoring Assembly (FAM) is to monitor the signals from the other detectors in the Failure Detection System and actuate the Emergency Drum Brake by creating a discontinuity in the high speed input to the Drive Train Continuity Detector.

4.2 In the reference design, an electric clutch (14) serves as the Failure Actuation and Monitoring Assembly. One side of the Failure Actuation and Monitoring Assembly is driven by a high speed shaft, shown in the reference design as the motor shaft (2). The other side of the Failure Actuation and Montoring Assembly drives the flexible cable or line shaft (13) previously described in Section 3 of this Appendix, which provides the high speed input to the Drive Train Continuity Detector. The electric clutch is engaged when the hoist is energized. Each of the detectors in the Failure Detection System trips a limit switch that opens the electric circuit that engages the clutch. For convenience these detectors, the functions of which has been described in the main body of EDR-1, are also shown on Figure 6 and listed here:

1. Wire rope spooling monitor (11).
2. Drum overspeed detector (16).
3. Rope break detector (21).
4. Backup upper travel limit (not shown).
5. Brake Actuation Detector (28).

4.3 De-energizing the electric clutch creates a discontinuity in the high speed input to the Drive Train Continuity Detector. This discontinuity will be detected by the Drive Train Continuity Detector after the load starts to lower a small amount.

FIGURE 6

PROPRIETARY MATERIAL DELETED

FAILURE ACTUATION AND MONITORING ASSEMBLY

5. **Single Failure Analysis of Totally Mechanical Emergency Drum Brake and Drive Train Continuity Detector**

Section III.E of the body of EDR-1 describes the overall response of a crane or hoist equipped with a Hoist's Integrated Protective System (HIPS) to eleven different incidents. The purpose of this section is to identify how the commitments of Section III.E are implemented by a HIPS that includes a totally mechancial Emergency Drum Brake Actuator and Drive Train Continuity Detector. Unless otherwise indicated, all part numbers are shown on Figure 5.

5.1 Overload--Similar to all X-SAM cranes, the EATL (item 5 of Figure 1) starts slipping when its pre-set torque capability is exceeded during an overload.

PROPRIETARY MATERIAL DELETED

5.2 Load Hangup--A HIPS', which includes a totally mechancial Emergency Drum Brake Actuator and Drive Train Continuity Detector, response to a load hangup is the same as its response to an overload.

5.3 Two Blocking--A HIPS', which includes a totally mechancial Emergency Drum Brake Actuator and Drive Train Continuity Detector, response to a two blocking is the same as its response to an overload.

5.4 Hoist Drive Train Failure--

PROPRIETARY MATERIAL DELETED

Power is removed from the hoist when the Emergency Drum Brake actuates by opening a limit switch (item 28 of Figure 4). In previous designs of HIPS the Drum Overspeed Detector detected and actuated the Emergency Drum Brake substantially before the Drive Train Continuity Detector could detect a change in the ratio of the high and low speed shafts. However, in the event of a drive train failure, the totally mechanical Emergency Drum Brake Actuator and Drive Train Continuity Detector will detect and actuate the Emergency Drum Brake faster than the Drum Overspeed Detector. Furthermore, totally mechanical Emergency Drum Brake Actuator and Drive Train Continuity Detector, generally provide overall faster response times to drive train failures than previous systems, as measured by the maximum load displacement and kinetic energy of the load.

5.5 Drum Support Failure--Following a drum support failure, the drum will be safely held by the Drum Safety Structure, which is functionally identical to the ones shown in Section III.D.4 of the main body of

EDR-1. In the reference design shown in Figure 1, the hoist gear case (8) also functions as a Drum Safety Support of the alternate design described in Section III.D.4 of the main body of EDR-1.

5.6 Overspeed--Overspeed following a control system failure is sensed by the motor overspeed detector (not shown). A control system failure may prevent the high speed holding brakes from engaging. Therefore, a separate drum overspeed detector removes power to Failure Actuation and Monitoring Assembly (FAM), which causes the Emergency Drum Brake to set. Since the function of the Overspeed Detector is less critical when a totally mechanical Emergency Drum Brake Actuator and Drive Train Continuity Detector is used, only one Overspeed Detector is required.

5.7 Total Loss of Power While Hoisting a Critical Load--As in all X-SAM Cranes, a total loss of electrical power sets the conventional high speed holding brake, thereby stopping the load. However, unless the high speed holding brake fails to hold the load the Emergency Drum Brake will not set. Since a total loss of electric power disconnects the Failure Actuation and Monitoring Assembly, the Drive Train Continuity Detector will actuate the Emergency Drum Brake as soon as the load starts lowering for any reason.

Emergency lowering without power is accomplished by manually locking holding brake (item 4 of Figure 1) open, which will automatically set the Emergency Drum Brake (10) since the Failure Actuation and Monitoring Assembly is deenergized. As shown in Figure 4, to start lowering the load the air valve (27), which admits pressurized air to the spring chamber (25), is cracked open--pressurizing the spring chamber (25), thereby releasing some of the tension in the brake band (24). A mechanical tachometer can be used on one of the high speed shafts to monitor the lowering speed. The lowering speed is modulated with the air valve by adjusting the air pressure in the spring chamber. At any time during the manual lowering of the load, the operator can release the valve handle, which vents the air pressure in the spring chamber, setting the Emergency Drum Brake. The Actuator cannot return to the battery position during a manual lowering operation because the Failure Actuation and Monitoring Assembly is still de-energized so that the Drive Train Continuity Detector will actuate the release mechanism as soon as it starts to reset.

5.8 Hoist Control System Failure--A HIPS, which includes a totally mechanical Emergency Drum Brake Actuator and Drive Train Continuity Detector, responds to a hoist control system failure in the same manner as is described in Section III.E.8 of the main body of EDR-1.

5.9 Off Center Lifts--In the event an excessive off center lift is made, the Wire Rope Spooling Monitor senses the improper spooling of the wire rope before damage can occur. The monitor (item 11 of Figure 6) removes power from the Failure Actuation and Monitoring Assembly, and the hoist motor controls through a relay. A key is required to reset the relay, so the hoist cannot be restarted until the problem is remedied and management concurrence obtained.

5.10 Failure of High Speed Motor Holding Brakes--The Emergency Drum Brake System provides a backup to the conventional holding brake during normal operations, since it automatically actuates on overspeed. The Emergency Stop Button removes power from the Failure Actuation and Monitoring Assembly, permitting the operator to manually engage the Emergency Drum Brake.

5.11. Cable Failure--As shown in Figure 6, failure of either wire rope opens a travel limit or hydraulic pressure switch (21) in response to the resultant movement of the Equalizer Arm (20). The monitor removes power from the Failure Actuation and Monitoring Assembly, and the hoist motor controls through a relay. A key is required to reset the relay, so the hoist cannot be restarted until the problem is remedied and management concurrence obtained.

6. Special Test Provisions for the Totally Mechanical Emergency Drum Brake Actuator and Its Companion Drive Train Continuity Detector

6.1 The testing identified by Section III.G.3.b and c is modified in the following ways to account for the special characteristics of the totally mechanical Emergency Drum Brake.

1. Test of the Actuator--The time required for the Emergency Drum Brake to engage, following action by the Failure Detection System, is measured with an oscillograph. During pre-operational and periodic testing, the drum brake is manually actuated to verify that all power to the crane is interrupted when it engages.

2. Test of the Drive Train Continuity Detector--Proper operation of the Drive Train Continuity Detector is verified by the brake setting when the EATL actuates during the slow speed two-blocking test.

3. Test of the Failure Actuation and Monitoring Assembly--During pre-operational and periodic testing, the Failure Actuation and Monitoring Assembly is manually denergized. Then the hoist is lowered to verify that the brake will set as soon as the load starts lowering when the Failure Actuation and Monitoring Assembly is actuated.

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Appendix H

DESCRIPTION

OF

CONTINUOUSLY ENGAGED

EMERGENCY DRUM BRAKE SYSTEM

NON-PROPRIETARY VERSION

REVISION 3

10/8/82

AMENDMENT 3

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Revision 3 10/8/82

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TABLE OF CONTENTS AND REVISION STATUS FOR APPENDIX H

(Non-Proprietary Version)

TABLE OF CONTENTS AND REVISION STATUS
FOR APPENDIX H, Continued

(Non-Proprietary Version)

I. Introduction

1.1 The purpose of this Appendix is to describe the operation of the continuously engaged Emergency Drum Brake and its intergal Drive Train Continuity Detector. This system provides the inherent safety of a worm drive, with the efficiency of a non-worm gear drive. The response to each of the failures described in Section III.E of the body of EDR-1 is described for a Hoist's Integrated Protective System (HIPS), which contains these two components.

1.2 Figure 1 illustrates the reference design of the continuously engaged Emergency Drum Brake System. The actual apparatus may be arranged differently in some respects, but the function, operation and operating environments are as shown. For the convenience of the reader the following overview of the remainder of the system is provided prior to the subsequent description of the continuously engaged Emergency Drum Brake System with its intergal Drive Train Continuity Detector, and the Failure Actuation and Monitoring Assembly.

1.3 A seismically qualified trolley or hoist frame (1) supports a conventional crane duty motor and electrical load control (2), which are coupled to a gear case (3). The gearing may take a variety of forms, e.g., spur, helical, or planetary, depending upon the hoist arrangement. A single conventional crane duty high speed holding brake (4) is mounted on one of the high speed shafts. An Energy Absorbing Torque Limiter (EATL) assembly (5) is intergal within the gear case (3). The wire rope drum (6) may be either journaled in the gear case, as shown in Figure 1, or may be driven through a bull gear by a pinion on the output shaft of the gear case. Motion of the wire rope drum following failure of the drum shaft, hub, or bearings is limited by the worm housing/ Drum Safety Support Structure (9) and the gear case register (8) when the drum is journaled into the gear case. The Emergency Drum Brake Assembly engages the end of the wire rope drum opposite from the end of the hoist drum that is driven by the hoist drive train. This configuration has been selected so that the Emergency Drum Brake will stop and hold the load in the event of a drive train failure. The various detectors in the Failure Detection System that actuate the Failure Actuation and Monitoring Assembly are descibed later in Section 4 of this Appendix.

FIGURE 1

PROPRIETARY MATERIAL DELETED

FIGURE 1a

PROPRIETARY MATERIAL DELETED

FIGURE 2

LIST OF COMPONENTS

PROPRIETARY MATERIAL DELETED

2. Continuously Engaged Emergency Drum Brake System

2.1 The continuously engaged Emergency Drum Brake System utilizes a worm wheel integral with the drum. It also includes a worm driven by a motor, or last safety related high speed shaft. Alternatively, the worm can be driven by a separate electric motor. The worm has a non-reversing gear ratio. Therefore, the worm wheel, and thus the drum, cannot rotate at a different rate or in a direction opposite to that in which the worm is being driven, as would occur during a drive train failure. In order to effectively function as an Emergency Drum Brake:

1. The worm must also stop the hoist drum in response to error signals from the drum overspeed detector, the wire rope spooling monitor, and the backup upper travel limit switch, and if load continues to lower following a single wire rope failure;

2. The loads imposed on the worm and worm wheel by the kinetic energy of the drive train and the load must be limited to a safe level when the worm stops rotating in response to an error signal while hoisting or lowering at the rated speed; and

3. There must be provisions for manually lowering the load.

2.2 In the reference design these functions are accomplished by:

1. The Failure Actuation and Monitoring Assembly opening the mechanical link between the motor and the worm in response to an error signal, as is described in detail in Section 4 of this Appendix. Alternatively, the Failure Actuaction and Monitoring Assembly removes power from the worm drive motor in response to an error signal.

2. The EATL dissipating the high speed kinetic energy of the high speed components of the hoist drive train.

3. The worm and worm wheel being designed to safely absorb the kinetic energy of the load, the drum, and the drive train components between the drum and the EATL, as is described in Section 3 of this Appendix.

4. The worm and worm wheel assembly being designed to withstand forces imposed by the overhauling of the rated load overhaul and the maximum torque that the EATL allows the motor to impose.

5. A drive provided on the worm shaft to allow lowering the load in the event of a total loss of power.

2.3 As will be shown in Section 5 of this Appendix, the worm wheel, the worm and their supporting structure are the only safety related portions of the continuously engaged Emergency Drum Brake System. The emergency load path is always engaged and the ancillary apparatus only allows the hoist system to operate. Reaction time is also not a factor, since the emergency load path is always in position to stop the load after a small amount of load motion. Failure of any parts other than the load supporting elements results in a safe shutdown.

2.4

PROPRIETARY MATERIAL DELETED

3. **Drive Train Continuity Detector**

3.1 Ideally the rotation rates of the worm and worm wheel would be set exactly at the rates required for them to stay in mesh, without contact during normal operations. However, gear backlash and EATL creep could accumulate to the point that either the worm could lock on the worm wheel—stopping the hoist, or the worm could start driving the drum instead of the drive train, reducing the hoist's efficiency. High tooth tangential friction may also result when the worm wheel rotates against the stationary worm following reversal of the direction of drum, since the worm will not be driven until all of the backlash has been taken out of the drive train and the drive train coninuity detector. To avoid these unacceptable conditions, the integral Drive Train Continuity Detector is designed to serve four basic functions:

1. Limiting the motor torque transmitted to the worm;
2. Nulling out the effects of gear backlash and accumulated EATL creep;
3. Limiting the tangential tooth friction between the worm and worm wheel during normal operations; and
4. Driving the worm out of engagement with the worm wheel after the direction of drum rotation is reversed.

3.2 In the reference design these functions are accomplished by:

PROPRIETARY MATERIAL DELETED

3.3

PROPRIETARY MATERIAL DELETED

3.4

PROPRIETARY MATERIAL DELETED

3.4

PROPRIETARY MATERIAL DELETED

FIGURE 3

PROPRIETARY MATERIAL DELETED

DRIVE TRAIN CONTINUITY DETECTOR

PROPRIETARY MATERIAL DELETED

4. Failure Actuation and Monitoring Assembly

4.1 The purpose of the Failure Actuation and Monitoring Assembly (FAM) is to monitor the signals from the other detectors in the Failure Detection System. When the Failure Actuation and Monitoring Assembly receives an error signal it creates a discontinuity in the high speed input to the Drive Train Continuity Detector. This discontinuity will be detected by the Drive Train Continuity Detector as soon as the load starts to lower or raise.

4.2 In the reference design, an electric clutch (14) serves as the Failure Actuation and Monitoring Assembly. One side of the Failure Actuation and Monitoring Assembly is driven by a high speed shaft, shown in the reference design as the motor shaft (2). The other side of the Failure Actuation and Montoring Assembly drives the torque limiting device (80) previously described in Section 2 of this Appendix. This device provides the high speed input to the Drive Train Continuity Detector. The electric clutch is engaged when the hoist is energized. Each of the detectors in the Failure Detection System trips a limit switch that opens the electric circuit that engages the clutch. De-energizing the electric clutch creates a discontinuity in the high speed input to the Drive Train Continuity Detector. For convenience these detectors, the functions of which has been described in the main body of EDR-1, are also shown on Figure 4 and listed here:

1. Wire rope spooling monitor (11).
2. Motor overspeed detector (98).
3. Rope break detector (21).
4. Backup upper travel limit (not shown).
5. Drum Brake Actuator Switch (97).

Alternatively, the function of the Failure Actuation and Monitoring Assembly can be fulfilled by a relay in the control circuit for the worm drive motor. Each of the detectors in the Failure Detection System trips a limit switch that opens the relay. De-energizing this motor stops the high speed input shaft to the Drive Train Continuity Detector.

Revision 3 10/8/82
Amendment 3

FIGURE 4

PROPRIETARY MATERIAL DELETED

FAILURE ACTUATION AND MONITORING SYSTEM

5. Single Failure Analysis of Continuously Engaged Emergency Drum Brake System

Section III.E of the body of EDR-1 describes the overall response of a crane or hoist equipped with a Hoist's Integrated Protective System (HIPS) to eleven different incidents. The purpose of this section is to identify how the commitments of Section III.E are implemented by a HIPS that includes a continuously engaged Emergency Drum Brake. Unless otherwise indicated, all part numbers are shown on Figure 1.

5.1 Overload--Similar to all X-SAM cranes, the EATL (5) starts slipping when its pre-set torque capability is exceeded during an overload. However, when a continuously engaged Emergency Drum Brake is used, the Drive Train Continuity Detector is insensitive to discontinuities in which both the drum and the motor are rotating in the hoisting direction and the motor's relative rate of rotation is faster than that of the drum. In order to detect such discontinuities would require a additional Drive Train Continuity Detector of the type described in Appendix G. The only function of this detector would be to detect EATL slippage when the drum is rotating in the hoisting direction. The load is protected by the worm, even if the EATL fails to hold the load following an overloading incident. Therefore, the additional complication of another Drive Train Continuity Detector is not warranted.

5.2 Load Hangup--A HIPS equipped with a continuously engaged Emergency Drum Brake has the same response to a load hangup as to an overload.

5.3 Two Blocking--A HIPS equipped with a continuously engaged Emergency Drum Brake has the same response to a two blocking as to an overload. The backup upper limit switch will detect the two blocking. The backup upper limit switch will remove power from the Failure Actuation and Monitoring Assembly (14), and the hoist motor controls through a relay. A key is required to reset the relay, so the hoist cannot be restarted until the problem is remedied and management concurrence obtained.

5.4 Hoist Drive Train Failure--The drum accelerates in the lowering direction and is immediately stopped by the worm (83) when it contacts the worm wheel (82). The Emergency Drum Brake System is sized to absorb the kinetic energy of all elements below the EATL. Torque limiting device (80) protects the worm drive system from overtorque. In addition any failure in the input to the Drive Train Continuity Detector also stops the load. Translation of the carrier assembly in either direction actuates switch (97), removing power from the Failure Actuation and Monitoring Assembly (14), and the hoist motor controls through a relay. A key is required to reset the relay, so the hoist cannot be restarted until the problem is remedied and management concurrence obtained.

5.5 Drum Support Failure--Following a drum support failure, the drum will be safely held by the Drum Safety Structure. As shown in Figure 1, the hoist gear case (8) and the housing (9) function are functionally identical to the alternative shown in Section III.D.4 of the main body of EDR-1. Alternatively, a Drum Safety Support of the other design described in Section III.D.4 of the main body of EDR-1 can be used.

5.6 Overspeed--Overspeed, following a control system failure, is sensed by the motor overspeed detector (98). A control system failure may prevent the high speed holding brake from engaging. Therefore, the drum overspeed detector removes power to Failure Actuation and Monitoring Assembly, which stops the drum in the manner described above. Because the Emergency Drum Brake is continuously engaged a Drum Overspeed Detector is not required.

Alternatively, inherent overspeed protection is provided by a separately driven Drive Train Continuity Detector, since the worm wheel and hence the drum's rate of rotation is limited by the rate at which the worm is driven. Since overhauling loads cannot be imposed on the worm, its speed is controlled by the constant speed drive motor.

5.7 Total Loss of Power While Hoisting a Critical Load--As in all X-SAM Cranes, a total loss of electrical power sets the conventional high speed holding brake, thereby stopping the load. However, unless the high speed holding brake fails to hold the load the Emergency Drum Brake will not set. A total loss of electric power disconnects the Failure Actuation and Monitoring Assembly, or alternatively denergizes the separate motor that drives the worm. Therefore, if for any reason the load starts lowering, the Emergency Drum Brake will stop the drum after only a small amount of drum rotation has occured. Emergency lowering without power is accomplished by releasing the conventional high speed holding brake (4) and rotating the worm (83) using an air motor or other auxiliary device on the external hex drive (98).

5.8 Hoist Control System Failure--A HIPS, which includes a continuously engaged Emergency Drum Brake responds to a hoist control system failure in the same manner as is described in Section III.E.8 of the main body of EDR-1.

5.9 Off Center Lifts--In the event an excessive off center lift is made, the Wire Rope Spooling Monitor senses the improper spooling of the wire rope before damage can occur. The monitor (11) removes power from the Failure Actuation and Monitoring Assembly, and the hoist motor controls through a relay. A key is required to reset the relay, so the hoist cannot be restarted until the problem is remedied and management concurrence obtained.

5.10 Failure of High Speed Motor Holding Brakes--The continuously engaged Emergency Drum Brake System provides a backup to the conventional holding brake during normal operations, since it is always in a position to stop the load. The Emergency Stop Button removes power from the Failure Actuation and Monitoring Assembly, permitting the operator to manually set the Emergency Drum Brake.

5.11. Cable Failure--As shown in Figure 4, failure of either wire rope opens a switch (21) in response to the resultant movement of the Equalizer Arm (20). The monitor removes power from the Failure Actuation and Monitoring Assembly, and the hoist motor controls through a relay. A key is required to reset the relay, so the hoist cannot be restarted until the problem is remedied and management concurrence obtained.

6. Special Test Provisions for the Continuously Engaged Emergency Drum Brake System

6.1 The testing identified by Section III.G.3.b and c is modified in the following ways to account for the special characteristics of the Continuously Engaged Emergency Drum Brake System:

1. Test of the Drive Train Continuity Detector--During pre-operational and periodic testing, the Failure Actuation and Monitoring Assembly is manually denergized. Then the hoist is lowered to verify that the brake will set as soon as the load starts lowering when the Failure Actuation and Monitoring Assembly is actuated. This test verifies proper operation of the Drive Train Continuity Detector.

2. Test of the Actuator--During pre-operational and periodic testing, proper operation of the Emergency Drum Brake Actuator is also verified during the test of the Drive Train Continuity Detector that is described above.

3. Test of the Failure Actuation and Monitoring Assembly--During pre-operational and periodic testing, proper operation of the Failure Actuation and Monitoring Assembly is also verified during the test of the Drive Train Coninuity Detector that is described above.

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Appendix I

ANALYSIS OF LOAD MOTION AND CABLE LOADING FOLLOWING A WIRE ROPE FAILURE IN AN X-SAM TYPE CRANE EQUIPPED WITH A TOTALLY MECHANICAL DRIVE TRAIN CONTINUITY DETECTOR AND EMERGENCY DRUM BRAKE ACTUATOR OR A CONTINUOUSLY ENGAGED EMERGENCY DRUM BRAKE SYSTEM

NON-PROPRIETARY VERSION

R. W. Holloran

Revision 3
10/8/82
Amendment 3

Revision 3 10/8/82
Amendment 2

NOTICE

This report was prepared by Halloran & Associates, for the use of Ederer Incorporated. Its use by others is permitted only on the understanding that there are no representations or warranties, express or implied, as to the validity of the information or conclusions contained herein.

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Revision 3 10/8/82
Amendment 3

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FOR APPENDIX I

(Non-Proprietary Version)

0. References

(a) Holloran and Associates Report, "Analysis of Load Motion and Cable Loading Following a Single Drive Train Failure or Wire Rope Failure in an X-SAM Type Crane," Revision 2, February 1980

(b) Holloran & Associates Report, "Analysis of Cable and Machinery Loadings Following Two Blockings of X-SAM Type Cranes," Revision 2, February 1980

1. Introduction

The purpose of this report is to extend the analytical and numerical techniques for evaluating the consequences of a single wire rope failure that were previously developed in reference (a). The wire rope failure analysis described in reference (a) was restricted to one in which the wire rope drum and equalizer was held stationary throughout the load transfer from the failed to the intact reeving. This limitation was consistent with the type of emergency drum brakes and failure detection systems developed up to that time and the fact that a single wire rope failure was not the limiting failure in terms of load motion or kinetic energy.

With previous designs, the failure detection system quickly set the emergency drum brake before the torque limit of the energy absorbing torque limiter could be exceeded during a postulated wire rope failure--preventing drum rotation. With the recently developed designs, i.e., the totally mechanical drive train continuity detector and emergency drum brake actuator and the continuously engaged emergency drum brake system, a small amount of drum rotation is required to set the emergency drum brake. Therefore, the previous wire rope failure analysis must be extended to account for the additional load motion and kinetic energy associated with this drum rotation.

Furthermore, the response time of the new designs to a drive train failure is typically faster than the previous systems' response times. Therefore, the load excursion and load kinetic energy associated with a single wire rope failure may be the limiting failure with regards to the provisions that must be taken at the facility to accommodate the maximum load motion and kinetic energy from a postulated single failure in the crane handling system. Specifically, with previous designs, the load motion and kinetic energy associated with a design basis drive train failure exceeded that associated with a single wire rope failure. Therefore, a wire rope failure while lowering the design rated load at the design rated speed was not analyzed. Since the single wire rope failure may represent the worst case load motion and kinetic energy, it is considered prudent to evaluate the load motion and kinetic energy following a wire rope failure while lowering the load at the design rated speed rather than with a stationary drum, when a totally mechanical drive train continuity detector and emergency drum brake actuator, or a continuously engaged emergency drum brake system, is used.

Previously, the hydraulic equalization system prevented motion of the equalizer by creating a hydraulic lock following a wire rope failure. However, in some applications, a shock absorber is used in the hydraulic equalization system that allows the equalizer to slowly rotate into contact with a structural member. Therefore, the analysis of the load motion and load kinetic energy following a wire rope failure also accounts for constant angular velocity equalizer motion.

As was the case with the previous analyses described in reference (a), the complete solution for a wire rope failure cannot be expressed in a simple form. Therefore, a computer program has again been used to obtain numerical results.

Section 3 explains the mathematical model used. This model is essentially the same as described in reference (a). Expressions for the displacement and kinetic energy of the load, as a function of time following the failure, are developed in Sections 4 and 5. These expressions, which are very similar to those developed in reference (a), provide a basis for evaluating the consequences of a wire rope failure on the equipment and structures under the load.

2. Approach

The analysis starts with the equations of motion for the following two general cases: (1) the wire rope drum and equalizer are rotating at constant rates (a stationary drum and equalizer represents a special case of this general solution, since their speed is still constant, albeit zero), and (2) the wire rope drum is being retarded by a friction brake or an energy absorbing torque limiter and the equalizer is rotating at a constant rate. See Figure 1 for a diagram of the hoist model used in deriving the equations.

The solutions given for these general cases are valid only for specific periods. To obtain complete solutions for all times of interest, the problems are divided into a series of time regions in which the appropriate physical conditions are properly modeled by one of the general solutions. The relevant general solution is applied to each of these time regions in turn.

The solutions of the general cases are sufficiently complicated to make the complete expressions for load displacement, velocity, etc., intractable if the formal expressions for these quantities at the end of each region are used for the initial conditions of the next region. To get around this difficulty, the solutions are evaluated numerically one region at a time. Appropriate tests are used, when necessary, in the numerical solutions to determine the time when one region ends and another starts. The numerical results calculated for the end of a region provide the initial conditions for the numerical solution in the following region.

Just before the wire rope failure, it is assumed that the motor is rotating the drum at a constant angular velocity, which is moving the load at a constant speed. With either type of the new designs, the sequence of events that follow a wire rope failure typically include:

(1) Drum rotation at a constant angular velocity until the motor is denergized. The shock absorber in the hydraulic equalization system permits the equalizer to start rotating at a constant angular velocity, with an attendant lowering of the load.

(2) The motor is denergized. It is assumed that there will be no retarding torque until the motor holding brake starts to engage.

(3) The third region starts when the motor holding brake starts to engage. (As explained in section 3.c, the motor holding brake is assumed to increase linearly with time up to a maximum level.)

(4) The maximum motor holding brake retarding torque is reached. (The kinetic energy of the motor and drum is absorbed by this constant retarding torque.)

(5) The drum stops rotating. (The tension in the intact reeving builds up as the load's gravitational potential energy is converted to kinetic energy and then mechanical energy in the stretched wire ropes.)

(6) The energy absorbing torque limiter starts slipping because the torque imposed on the drum by the tension in the lead line of the reeving exceeds the static torque setting of the energy absorbing torque limiter. (It is assumed that the torque limiter imposes a constant retarding torque on the drum.)

(7) The drum stops rotating because either the tension in the wire rope has decreased below the dynamic slipping torque of the energy absorbing torque limiter or there has been sufficient drum rotation, since the failure actuation and monitoring assembly was disengaged, for the emergency drum

brake to be engaged. (The load will continue to oscillate in response to the Hooke's Law forces imposed by the elastic wire ropes until viscous forces damp out the oscillations. The analysis of Section 7 of reference (a) can be used if these viscous forces are to be included in the analysis.)

(8) The equalizer rotates into contact with a structural member, which stops further rotation. (Depending upon the shock absorber design, the equalizer may come into contact with a structural member during regions (1) to (7). If it did, the region in which the equalizer stopped rotating is subdivided into two regions, one in which the equalizer is rotating, and one in which it has stopped.)

The exact sequence and duration of these events may vary depending upon the type of motor holding brake and controls that are specified by the Applicant for the crane. However, these differences are readily accounted for, since the same general equations remain valid--only the sequence of their use and the initial conditions need to be changed to account for the variations.

3. Description of Mathematical Model

This section describes the mathematical model of the hoist that is used to derive the general solutions and to link them to obtain the specific solutions for individual cases.

a. Model of Crane

Figure 1 shows a typical reeving arrangement, the pertinent physical parameters, and the sign conventions used. The following assumptions made in reference (a) remain valid:

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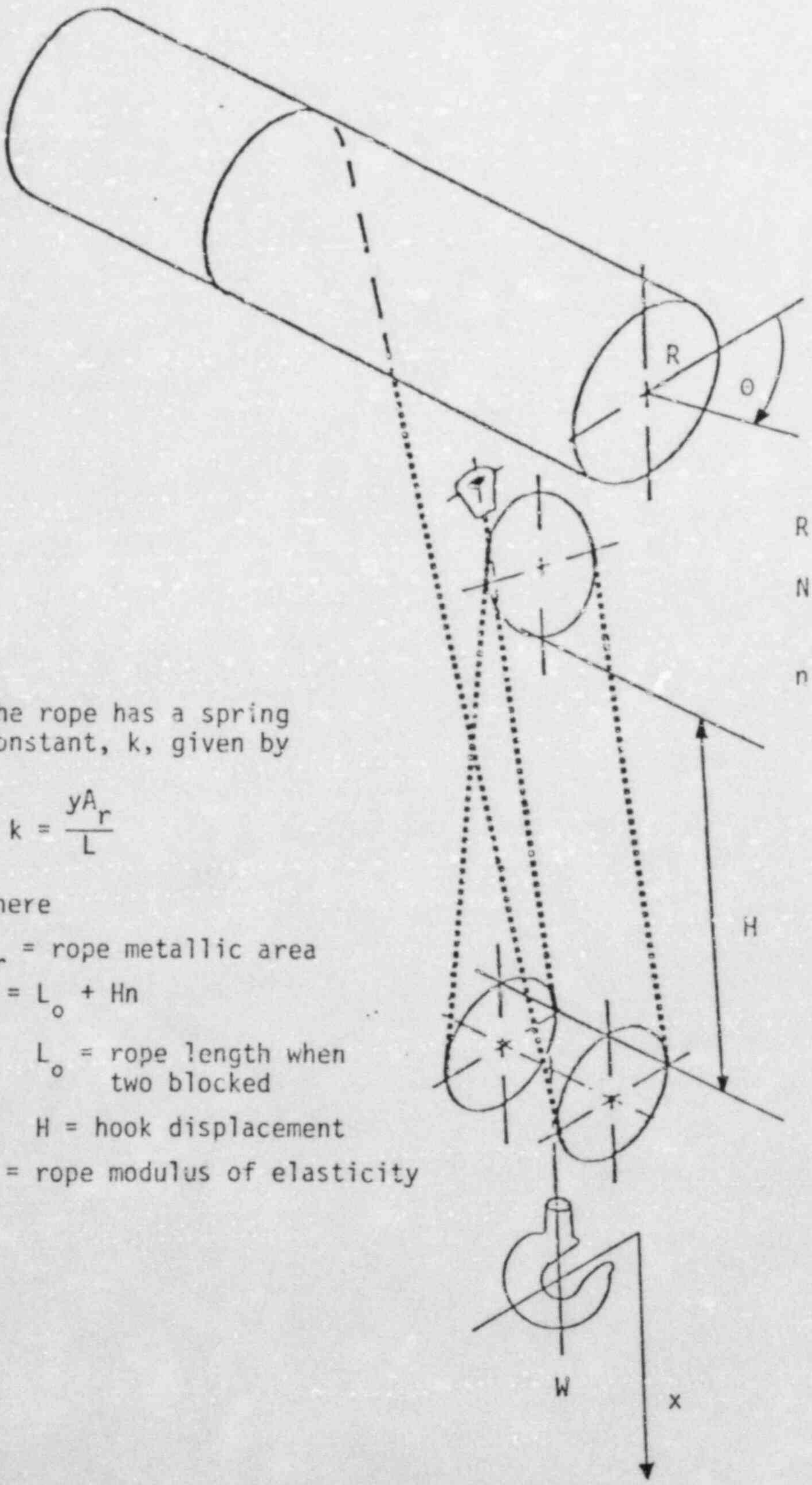
FIGURE 1



R = drum radius

N = number of ropes attached to Drum and Equalizer

n = number of parts of line in one rope

The rope has a spring constant, k, given by

$$k = \frac{yA_r}{L}$$

where

A_r = rope metallic area

$L = L_o + Hn$

L_o = rope length when two blocked

H = hook displacement

y = rope modulus of elasticity

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b. Model of Rope Break Detection System

It is assumed that after a known time delay the rope break detector will denergize the hoist motor and after an additional time delay after the hoist motor is denergized, the hoist motor brake will start engaging. In addition, after a known time delay, the rope break detector will denergize the failure actuation and monitoring assembly in the input to the drive train continuity detector. After a known time delay, it is then assumed that the failure actuation and monitoring assembly will create a discontinuity in the input to the drive train continuity detector, which will then be detected by the drive train continuity detector, which is set to actuate when the drum and motor become out of phase by a given drum angle. Once this out-of-phase condition exists, it is assumed that the emergency drum brake will start actuating after a constant time interval. (Normally, it is expected that there will be insufficient drum rotation for the drum brake to engage following a rope break, unless for some reason the hoist motor brake does not engage.)

c. Model of Emergency Drum Brake and High Speed Holding Brake

Ederer Incorporated provided Holloran & Associates with the following information and assumptions regarding the performance of the emergency drum brake and the high speed holding brake:

(1) The brakes apply a constant retarding torque (which may be zero) prior to actuation.

(2) Upon its actuation, each brake applies a linearly

increasing braking torque until the maximum braking is achieved.

(3) After reaching the maximum, the braking torque remains constant until the drum stops.

(4) The dynamic braking torque is independent of drum speed and can be replaced by the static braking torque once the drum stops.

(5) The brakes' torque can be characterized as a multiple of the torque imposed on the drum by the design rated load.

d. Model of Hydraulic Equalization System

The reference design hydraulic load equalization system is assumed to function such that the bitter end of the two wire ropes remains stationary following a wire rope failure. If equalizer motion following a wire rope failure is permitted by the design of the hydraulic equalization system, Ederer Incorporated has determined that the angular velocity of the equalizer will be approximately constant until it stops when it contacts a structural member. To be conservative, the maximum angular velocity, which is determined by the peak wire rope loading and the shock absorber design, is used in this analysis for the constant angular velocity. The total angle through which the equalizer may rotate is determined from the equalizer configuration. Therefore, the effective time period during which the equalizer rotates is determined by dividing this angle by the assumed average angular velocity.

e. Model of Failure

The failure is assumed to be a complete severing of one wire rope, with the attendant increase in static and dynamic tension in the remaining ropes and additional dynamic forces on the drum resulting from the load motion.

4. General Solution of the Equations of Motion That is Valid When the Drum and Equalizer are Rotating at Constant Rates

This solution is a more general solution than was developed in Section 7 of reference (a) for the stationary drum case, which is a special case of the more general case in which the drum is rotating at a constant rate. For the stationary drum case, reference (a) included viscous damping of the mechanical system. However, such damping is omitted from this more general case, in which the drum and equalizer may be in motion, for the same reasons that it was omitted in the rotating drum case of reference (a), i.e., because the weak damping appropriate to the crane system has only a small effect over the period of the very few oscillations encountered prior to the stopping of the drum and equalizer. Omission of damping is conservative and its inclusion would have unnecessarily complicated the solution of this more general case. The solution developed in Section 7 of reference (a) can be used when the drum and equalizer finally stop rotating to account for viscous damping for the remainder of the analysis.

The equation of motion of the load becomes:

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5. General Solution of the Equations of Motion that is Valid When the Drum is Being Retarded and the Equalizer is Rotating at a Constant Rate

This solution is a more general solution than was developed in Section 6 of reference (a) for the rotating drum case in which no ropes had failed and the equalizer is stationary. That solution is a special case of the more general case provided herein in which ropes have failed and the equalizer may be rotating at a constant rate.

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Nuclear Safety Related

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(X-SAM)

CRANES

NON-PROPRIETARY VERSION

Notice

This revision of EDR-1 supersedes all previous revisions.

REVISION 3 10/8/82

AMENDMENT 3

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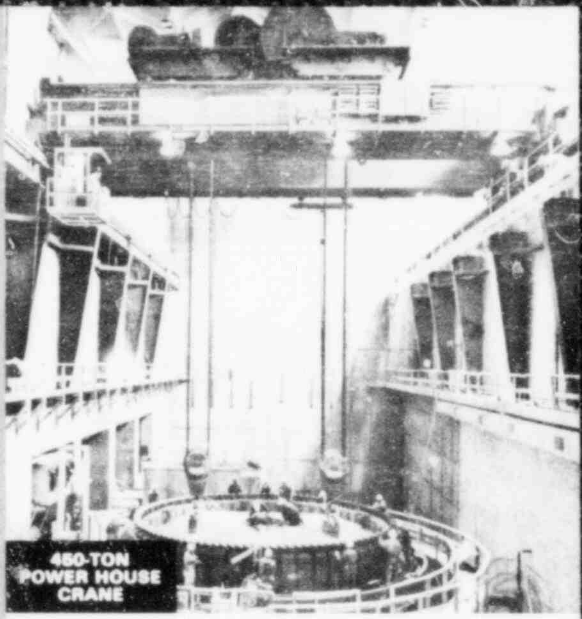
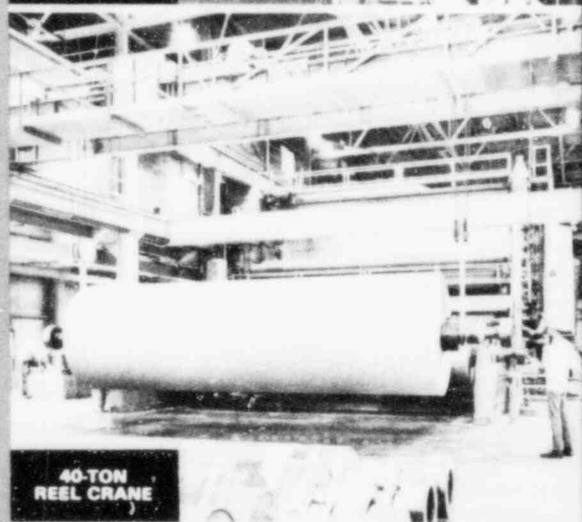


450-TON POWER HOUSE CRANE

BARGE UNLOADER



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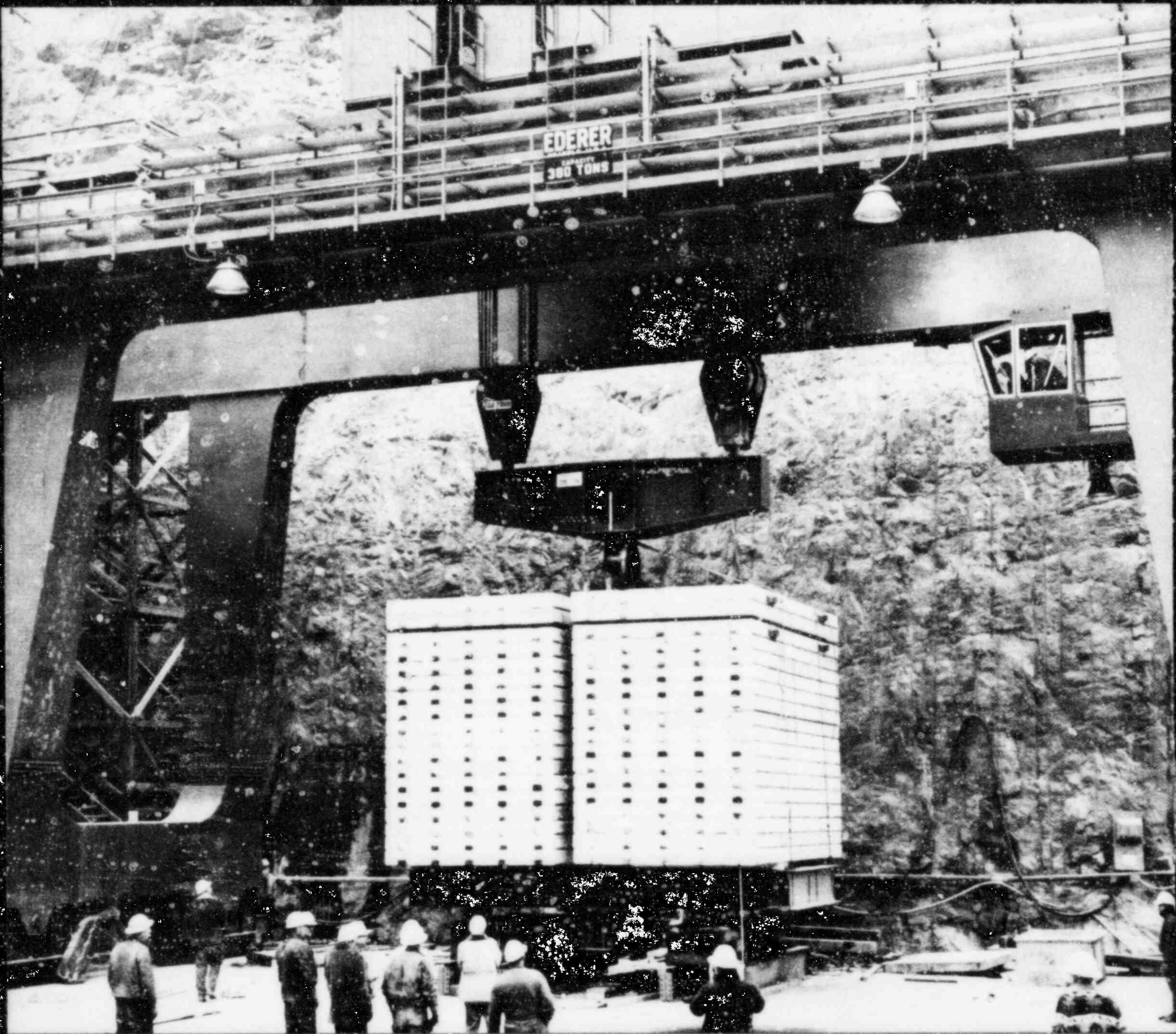
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