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EVALUATION OF THE ACCEPTABILITY OF THE REACTOR VESSEL HEAD LIFT RIG, REACTOR VESSEL INTERNALS LIFT RIG, LOAD CELL, AND LOAD CELL LINKAGE TO THE REQUIREMENTS OF NUREG 0612
for
TEXAS UTILITIES GENERATING COMPANY
COMANCHE PEAK UNITS NO. 1 AND NO. 2

FEBRUARY, 1983

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ABSTRACT

An evaluation of the Comanche Peak reactor vessel head and internal lift rigs, load cell and load cell linkage was performed to determine the acceptability of these devices to meet the requirements of NUREG 0612. The evaluation consists of: (1) a comparison report of the ANSI N14.6 requirements and the requirements used in the design and manufacture of these devices; (2) a stress report in accordance with the design criteria of ANSI N14.6; and (3) a list of recommendations to enable these devices to demonstrate compliance with the intent of NUREG 0612 and ANSI N14.6.

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A. Comparison of ANSI N14.6-1978 Requirements for Special Lifting Devices and the Requirements for the Reactor Vessel Head Lift Rig, Reactor Vessel Internals Lift Rig, Load Cell and Load Cell Linkage for Texas Utilities Generating Company, Comanche Peak Units No. 1 and No. 2.

B. Stress Report - Reactor Vessel Head Lift Rig, Reactor Vessel Internals Lift Rig, Load Cell and Load Cell Linkage for Texas Utilities Generating Company, Comanche Peak Units No. 1 and 2.

REFERENCES

1. George, H., Control of Heavy Loads at Nuclear Power Plants Resolution of Generic Technical Activity A-36, NUREG-0612, July, 1980.

2. ANSI N14.6-1978 Special Lifting Devices for Shipping Containers Weighing 10,000 Pounds or More for Nuclear Material

3. Westinghouse Drawing 1212E27 - 4 Loop Lifting Rig - Head, General Assembly

4. Westinghouse Drawing 1216E68 - 4 Loop Reactor Plant Internals Lifting Rig General Assembly

5. Manual of Steel Construction, Seventh Edition, American Institute of Steel Construction.

SECTION 1

INTRODUCTION

The Nuclear Regulatory Commission (NRC) issued NUREG 0612 "Control of Heavy Load at Nuclear Power Plants"[1] in 1980 to address the control of heavy loads to prevent and mitigate the consequences of postulated accidental load drops. NUREG 0612 imposes various training, design, inspection and procedural requirements for assuring safe and reliable operation for the handling of heavy loads. In the containment building, NUREG 0612 Section 5.1.1(4) requires special lifting devices to meet the requirements of ANSI N14.6-1978-"American National Standard for Special Lifting Devices for Shipping Containers Weighing 10,000 Pounds or More for Nuclear Materials"[2]. In general, ANSI N14.6 contains detailed requirements for the design, fabrication, testing, maintenance, and quality assurance of special lifting devices. The Comanche Peak lifting devices which can be categorized as special lifting devices and which are contained in the scope of this report are:

1. Reactor vessel head lift rig

2. Reactor vessel internals lift rig

3. Load cell and load cell linkage

This report contains the evaluation performed on these lifting devices to determine the acceptability of these devices to meet the above requirements.

1.1 BACKGROUND

The reactor vessel head lift rig, the reactor vessel internals lift rig, load cell and load cell linkage were designed and built for the Comanche Peak circa 1975-76. These devices were designed to the requirement that the resulting stress in the load carrying members when subjected to the total combined lifting weight should not exceed the allowable stresses specified in the AISC[5] code. Also, a 125 percent load test was required on both devices followed by appropriate non-destructive testing. These items were not classified as nuclear safety components and requirements for formal documentation of design requirements and stress reports were not applicable. Thus, stress reports and design specifications were not formally documented. Westinghouse defined the design, fabrication and quality assurance requirements on detailed manufacturing drawings and purchase order documents. Westinghouse also issued field assembly and operating instructions, where applicable.

SECTION 2
COMPONENT DESCRIPTION

2.1 REACTOR VESSEL HEAD LIFT RIG

The reactor vessel head lift rig[3] (Figure 2-1) is a three legged carbon steel structure, approximately 48 feet high and 16 feet in diameter, weighing approximately 16,000 pounds. It is used to handle the assembled reactor vessel head.

The three vertical legs and Control Rod Drive Mechanism (CRDM) platform assembly are permanently attached to the reactor vessel head lifting lugs. The legs, clevis, and pins which are a part of the support for the seismic platform meet the requirements of the ASME Boiler and Pressure Vessel Code, Section III, Subsection NF Class I Supports. The tripod assembly is attached to the three vertical legs and is used when installing and removing the reactor vessel head. During plant operation, the sling assembly is removed and the three vertical legs and platform assembly remain attached to the reactor vessel head.

2.2 REACTOR VESSEL INTERNALS LIFT RIG

The internals lifting rig[4] (Figure 2-2) is a three-legged carbon and stainless steel structure, approximately 30 feet high and 14 feet in diameter weighing approximately 21,000 pounds. It is used to handle the upper and lower reactor vessel internals packages. It is attached to the main crane hook for all lifting, lowering and traversing operations. A load cell linkage is connected between the main crane hook and the rig to monitor loads during all operations. When not in use, the rig is stored on the upper internals storage stand.

The reactor vessel internals lift rig attaches to the internals package by means of three rotolock studs which engage three rotolock inserts located in the internals flange. These rotolock studs are manually operated from the internals lift rig platform using a handling tool which is an integral part of the rig. The studs are normally spring retracted upward and are depressed to engage the inserts. Rotating the mechanism locks it in both positions.

2.3 LOAD CELL AND LOAD CELL LINKAGE

The load cell is used to monitor the load during lifting and lowering the reactor vessel head or internals to ensure no excessive loadings are occurring. The unit is a load sensing clevis type, rated at 500,000 pounds.

This load cell is a part of the load cell linkage which is an assembly of pins, plates, and bolts that connect the polar crane main hook to the lifting blocks of both the reactor vessel head and the internal lift rigs.

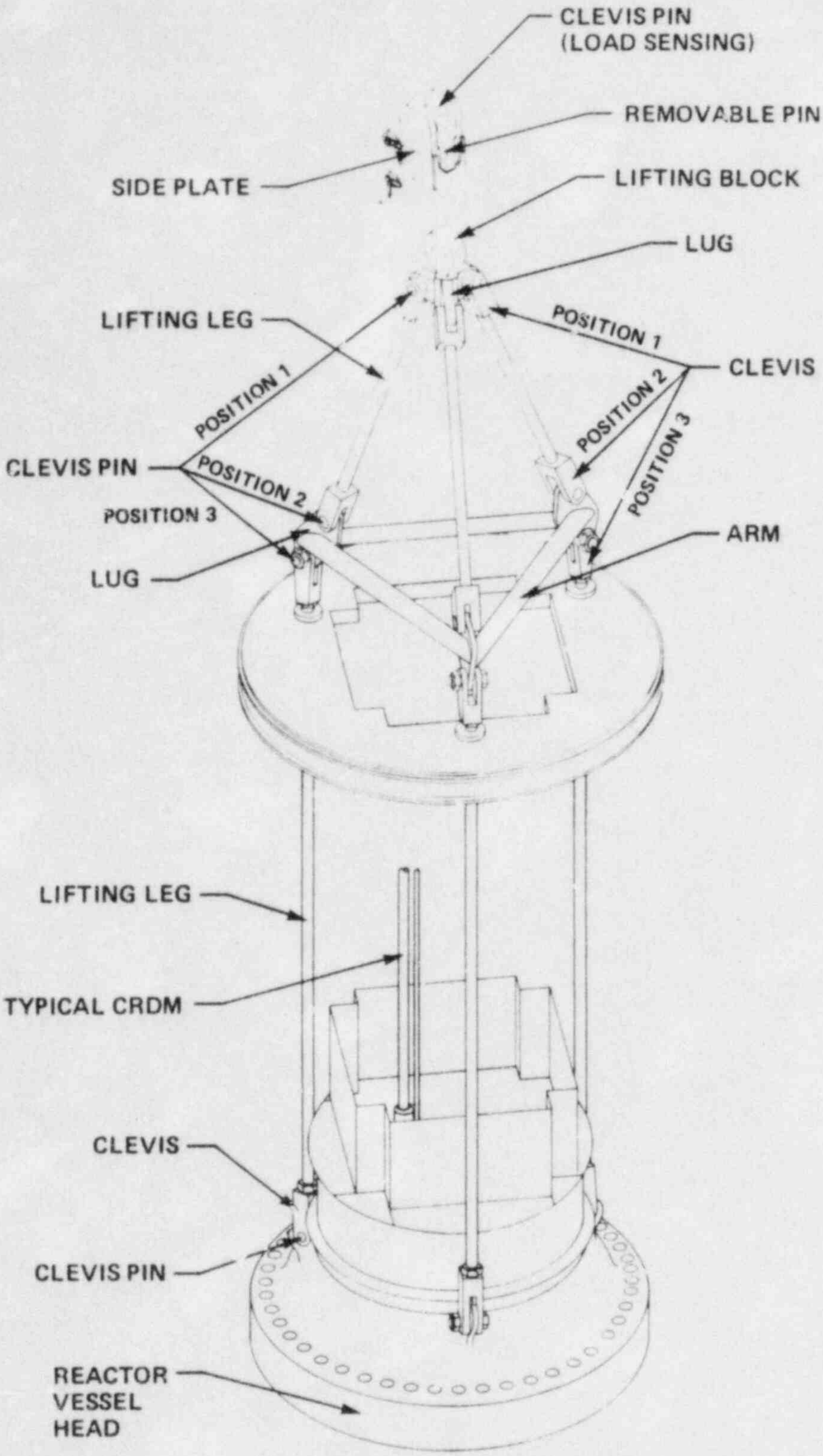

Figure 2-1. Reactor Vessel Head Lift Rig

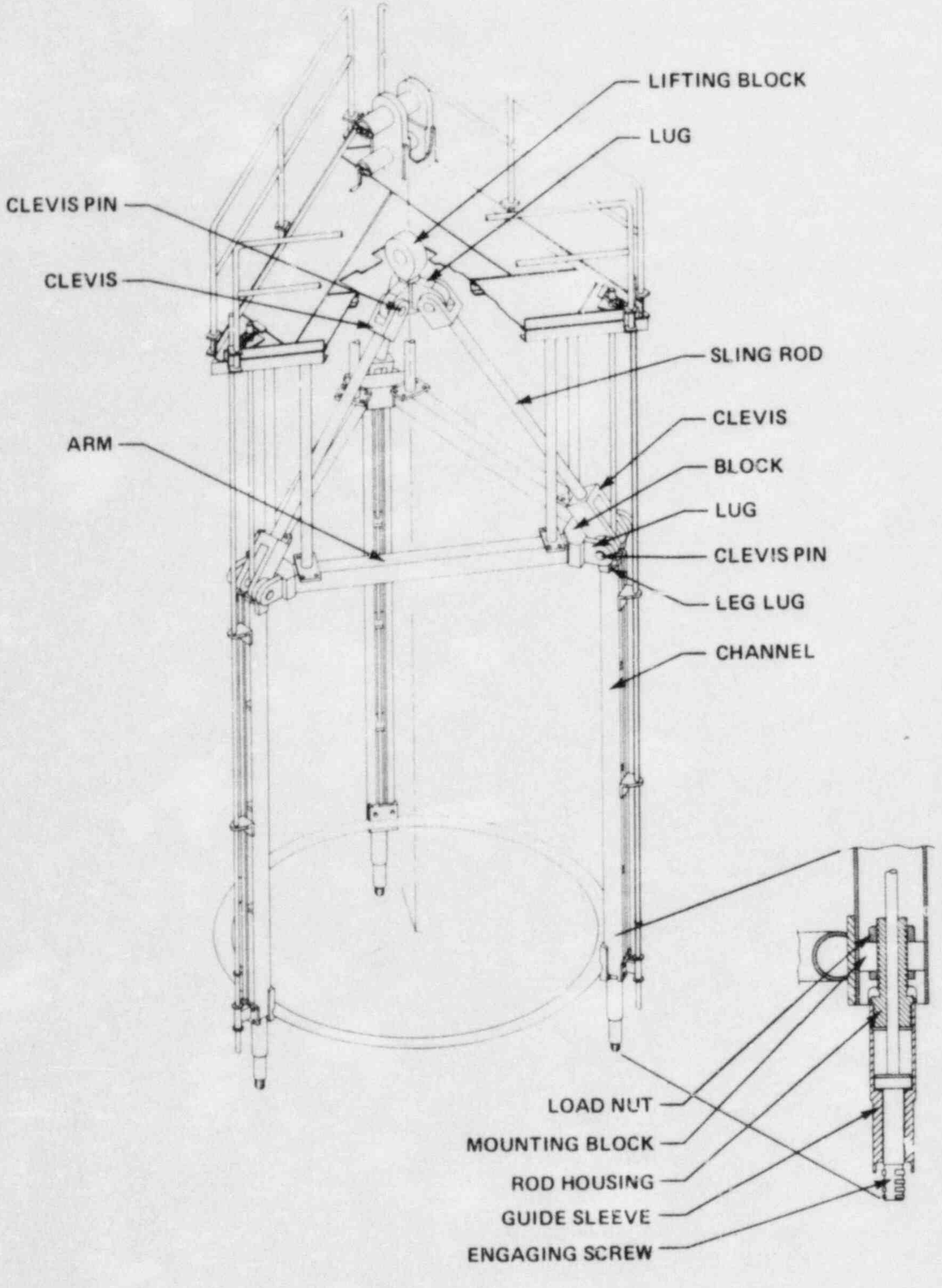

Figure 2-2. Reactor Vessel Internals Lift Rig

SECTION 3
SCOPE OF EVALUATION

The evaluation of these lifting devices consists mainly of three parts:

1. A detailed review of the ANSI N14.6 requirements

2. Preparation of a stress report

3. Recommendations to demonstrate compliance with NUREG 0612, Section 5.1.1(4).

Discussion of these items follows.

3.1 REVIEW OF ANSI N14.6-1978

A detailed comparison was made of the information contained in ANSI N14.6 with the information that was used to design, manufacture, inspect and test these special lifting devices. The detailed comparison is provided in three parts:

1. Overall item by item comparison of requirements

2. Preparation of a critical item list per ANSI N14.6 Section 3.1.2, and

3. Preparation of a list of nonconforming items.

This detailed analysis is contained in Attachment A to this report.

3.2 PREPARATION OF A STRESS REPORT

Section 3.1.3 of ANSI N14.6 and NUREG 0612 Section 5.1.1(4) require a stress report to be prepared. Special loads and allowable stress criteria are specified for this analysis. The stress report is Attachment B to this report.

3.3 RECOMMENDED ACTIONS

An obvious result from the previous evaluations is a list of items that can be performed to demonstrate to the NRC that these special lifting devices are in compliance with the guidelines of ANSI N14.6 and NUREG 0612 Section 5.1.1(4). These recommendations are identified in Section 6.

SECTION 4
DISCUSSION OF EVALUATIONS

4.1 STUDY OF ANSI N14.6-1978

A review of ANSI N14.6 identifies certain analyses to be performed and certain identifications that are required to be made to demonstrate compliance with this document. These are a preparation of a stress report in accordance with Section 3.2 and a preparation of a critical items list in accordance with Section 3.1.2. The stress report is Attachment B to this report. The critical items list has been prepared per Section 3.1.2 and is contained in Appendix A to Attachment A. This list identifies the critical load path parts and welds, the materials of these items, and the applied non-destructive volumetric and surface inspections that were performed. (Details of these non-destructive processes and acceptance standards are available at Westinghouse should they be needed.)

A detailed item by item comparison of all the requirements of ANSI N14.6 and those used for the design, manufacture and inspection of these lifting devices is contained as Table 2-1 of Attachment A. The comparison shows that these devices meet the intent of the ANSI document for design, fabrication and quality control. However, they do not meet the requirements of ANSI N14.6 for periodic maintenance, proof and functional testing. Thus, a tabulation of those ANSI N14.6 requirements that are incompatible with these lifting devices was prepared and is Appendix B to Attachment A. Included in Appendix B to Attachment A are recommended actions that may be used to demonstrate acceptability to the NRC.

4.2 STRESS REPORT

As part of the invoking of the ANSI N14.6 document, the NRC requested utilities to demonstrate their compliance with the stress criteria with some qualifying conditions. Attachment B is the stress report for these devices performed in accordance with the criteria of ANSI N14.6. A discussion is included which responds to the NRC qualifying conditions of NUREG 0612. All of the tensile and shear stresses, meet the design criteria of Section 3.2.1.1 of ANSI N14.6, requiring application of stress design factors of three and five with the accompanying allowable stress limits of yield and ultimate strength, respectively. In addition, all of the tensile and shear stresses meet the requirements of the AISC[5] code.

4.3 RECOMMENDATIONS

The recommendations identified in Section 6 require a review of plant maintenance and operating instructions to ensure that they contain information relative to the identification, maintenance and periodic testing required by ANSI N14.6. The extent of the periodic testing is also addressed and the recommendations identify procedures which are intended to fully meet the intent of NUREG 0612 and ANSI N14.6 with the least amount of perturbation to the refueling sequence. These recommendations do not involve any equipment changes.

SECTION 5
CONCLUSIONS

The following conclusions are apparent as a result of this evaluation:

1. The ANSI N14.6 requirements for design, fabrication and quality assurance are generally in agreement with those used for these special lift devices.

2. The ANSI N14.6 criteria for stress limits associated with certain stress design factors for tensile and shear stresses are adequately satisfied.

3. These devices are not in strict compliance only with the ANSI N14.6 requirements for acceptance testing, maintenance and verification of continuing compliance. Recommendations are included to identify actions that should enable these devices to be considered in compliance with the intent of ANSI N14.6.

4. The application of the ANSI N14.6 criteria for stress design factor of 3 and 5 are only for shear and tensile loading conditions. Other loading conditions are to be analyzed to other appropriate criteria.

SECTION 6
RECOMMENDATIONS

The following recommendations address the areas of ANSI N14.6 which are incompatible with the present lifting devices and which are considered most important in demonstrating the continued reliability of these devices. They consist of suggestions and proposed responses to identify compliance to the NRC and future considerations.

6.1 Recommend that no changes be made to the reactor vessel internals lift rig should the stresses, discussed in Attachment B, be considered excessive by others because:

a. The design weight used in the stress calculations is based on the weight of the lower internals. The lower internals are only removed when a periodic inservice inspection of the vessel is required (once/10 years).

b. Prior to removal of the lower internals, all fuel is removed. Thus the concern for handling over fuel is non-existent in this particular case.

c. Normal use of the rig is for moving the upper internals which weigh less than one-half of the lower internals. The design weight is based on lifting the lower internals. Thus all the stresses could be reduced by approximately 50 percent and considered well within the ANSI N14.6 criteria for stress design factors.

6.2 Review plant operating procedures to include consideration of ANSI N14.6 Sections 5.1.3 through 5.1.8. These sections include requirements for: scheduled periodic testing; special identification and marking; maintenance, repair, testing and use. Westinghouse remarks on addressing these sections are listed in Attachment A, Appendix B, Items 5, 6, and 7.

6.3 A proposed response to the requirement of ANSI N14.6, Section 5.2.1, requiring an initial acceptance load test prior to use equal to 150 percent of the maximum load is that the 125 percent of maximum load test that was performed be accepted in lieu of the 150 percent load test.

6.4 A proposed response to ANSI N14.6 Section 5.3 which requires, annually, either a 150 percent maximum load test or dimensional, visual and non-destructive testing of major load carrying welds and critical areas follows. (Since the 150 percent load test is very impractical, the approach identified in the following recommendation is to perform a minimum of non-destructive testing.)

a. Reactor Vessel Head Lift Rig:

Prior to use and after reassembly of the spreader assembly, lifting lug, and upper lifting legs to the upper portion of the lift rig, visually check all welds. Raise the vessel head slightly above its support and hold for 10 minutes. During this time, visually inspect the sling block lugs to the lifting block welds, and spreader lug to spreader arm weld. If no problems are apparent, continue to lift, monitoring the load cell readout at all times.

b. Reactor Vessel Internals Lift Rig

Prior to use, visually inspect the rig components and welds while on the storage stand for signs of cracks or deformation. Check all bolted joints to ensure that they are tight and secure. After connection to the upper or lower internals, raise the assembly slightly off its support and hold for 10 minutes. During this time, visually inspect the sling block lugs to the lifting block welds. If no problems are apparent, continue to lift, monitoring the load cell readout at all times.

The above actions do not include a non-destructive test of these welds because:

a. Access to the welds for surface examination is difficult. These rigs are in containment and some contamination is present.

b. All tensile and shear stresses in the welds are within the allowable stress.

c. The items that are welded remain assembled and cannot be misused for any other lift other than their intended function.

d. To perform non-destructive tests would require:

(1) Removal of paint around the area to be examined which is contaminated.

(2) Performance of either magnetic particle inspection or liquid penetrant inspection and

(3) Repainting after testing is completed.

(4) Cleanup of contaminated items.

Performing non-destructive tests on these welds every refueling would increase the critical path refueling time.

Dimensional checking is not included since these structures are large (about 16 ft. dia. by 50 ft. high) and the results of dimensional checking would always be questionable. Other checks on critical load path parts such as pins, are also not included since an examination of these items would require disassembly of the special lift devices.

6.5 Recommend that a periodic non-destructive surface examination of critical welds and/or parts be performed once every ten years as part of an inservice inspection outage.

ATTACHMENT A
to WCAP-10156
Rev. 1

Comparison of ANSI N14.6-1978 Requirements for Special Lifting Devices and the Requirements for the Reactor Vessel Head Lift Rig, Reactor Vessel Internals Lift Rig, Load Cell, and the Load Cell Linkage
for
Texas Utilities Generating Company
Comanche Peak Units No. 1 and 2

FEBRUARY, 1983

H. H. Sandner, P.E.

Approved [signature] for
R. J. Leduc, P.E., Manager
Component Handling Equipment

ABSTRACT

The requirements used in the original design, fabrication, testing, maintenance and quality assurance were compared to the ANSI N14.6-1978 requirements for the Comanche Peak reactor vessel head and internals lift rig, load cell and load cell linkage. A critical items list per ANSI N14.6 section 3.1.2 has been prepared and a tabulation of ANSI N14.6 requirements that are, at present, incompatible with the Comanche Peak lifting devices has been prepared.

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REFERENCES

1. Westinghouse Drawing 1212E27 - 4 Loop Lifting Rig - Head, General Assembly.

2. Westinghouse Drawing 1216E68 - 4 Loop Reactor Plant Internals Lifting Rig General Assembly.

3. Manual of Steel Construction, Seventh Edition, American Institute of Steel Construction.

SECTION 1
PURPOSE

The purpose of this report is to compare the requirements of the special lifting rigs used to lift the reactor vessel head and reactor vessel upper and lower internals with the requirements contained in ANSI N14.6 for special lifting devices.

SECTION 2
INTRODUCTION

ANSI N14.6-1978-"American National Standard for Special Lifting Devices for Shipping Containers Weighing 10,000 Pounds or More for Nuclear Materials" contains detailed requirements for the design, fabrication, testing, maintenance and quality assurance of special lifting devices. NUREG 0612 "Control of Heavy Load at Nuclear Power Plants", paragraph 5.1.1(4), specifies that special lifting devices should satisfy the guidelines of ANSI N14.6-1978. Subsequently the Nuclear Regulatory Commission (NRC) has requested operating plants to demonstrate compliance with NUREG 0612. To demonstrate compliance with this document, a detailed comparison of the original design, fabrication, testing, maintenance and quality assurance requirements with those of ANSI N14.6 is necessary.

Thus, the ANSI N14.6 document has been reviewed in detail and compared to the requirements used to design and manufacture the reactor vessel head lift rig, the reactor vessel internals lift rig, load cell, and the load cell linkage. This comparison is listed in Table 2-1.

2.1 BACKGROUND

The reactor vessel h and internals lifting rigs were designed and built for the Comanche Peak Nuclear Power Plants, circa 1975-76. These devices were designed to the requirement that the resulting stress in the load carrying members, when subjected to the total combined lifting weight, should not exceed the allowable stresses specified in the AISC[3] code. Also, a 125 percent load test was required on both devices, followed by appropriate non-destructive testing. Westinghouse also required non-destructive tests and inspections on critical load path parts and welds both as raw material and as finished items. These requirements of design, manufacturing and quality assurance were identified on detailed manufacturing drawing and purchasing documents.

Westinghouse also issued field assembly and operating instructions, where applicable.

2.2 COMPONENT DESCRIPTION

2.2.1 Reactor Vessel Head Lift Rig

The reactor vessel head lift rig[1] is a three legged carbon steel structure, approximately 48 feet high and 16 feet in diameter, weighing approximately 15,000 pounds. It is used to handle the assembled reactor vessel head.

The three vertical legs and control rod drive mechanism (CRDM) platform assembly are permanently attached to the reactor vessel head lifting lugs. The legs, clevis, and pins which are a part of the support for the seismic platform meet the requirements of the ASME Boiler and Pressure Vessel Code, Section III, subsection NF Class I supports. The tripod sling assembly is attached to the three vertical legs and is used when installing and removing the reactor vessel head. During plant operations, the sling assembly is removed and the three vertical legs and platform assembly remain attached to the reactor vessel head.

2.2.2 Reactor Vessel Internals Lift Rig

The reactor vessel internals lift rig[2] is a three-legged carbon and stainless steel structure, approximately 30 feet high and 14 feet in diameter weighing approximately 21,000 pounds. It is used to handle the upper and lower reactor vessel internals packages. It is attached to the main crane hook for all lifting, lowering and traversing operations. A load cell linkage is connected between the main crane hook and the rig to monitor loads during all operations. When not in use, the rig is stored on the upper internals storage stand.

The reactor vessel internals lift rig attaches to the internals package by means of three rotolock studs which engage three rotolock inserts located in the internals flange. These rotolock studs are manually operated from the internals rig platform using a handling tool which is an integral part of the rig. The studs are normally spring retracted upward and are depressed to engage the inserts. Rotating the mechanism locks it in both positions.

2.2.3 Load Cell and Load Cell Linkage

The load cell is used to monitor the load during lifting and lowering the reactor vessel head or internals to ensure no excessive loadings are occurring. The unit is a load sensing device type, rated at 500,000 pounds.

This load cell is a part of the load cell linkage which is an assembly of pins, plates, and bolts that connect the polar crane main hook to the lifting blocks of both the reactor vessel head and internals lift rigs.

TABLE 2-1

COMPARISON OF THE REQUIREMENTS OF ANSI N14.6 AND

COMANCHE PEAK SPECIAL LIFT DEVICES

ANSI N14.6 Section	Description of ANSI N14.6 Requirement	Actual Special Lift Device Requirements
1 1.1 to 1.3 2	Scope and Definitions - These sections define the scope of the document and include pertinent definitions of specific items	These sections are definitive, and not requirements.
3 3.1 3.1.1 to 3.1.4	Design Designer's Responsibilities - This section contains requirements for preparing a design specification and its' contents, stress reports; repair procedures; limitations on use with respect to environmental conditions; marking and nameplate information; and critical items list.	A. No design specification was written concerning these specific requirements. However, assembly and detailed manufacturing drawings and purchasing documents contain the following requirements: (1) Material specification for all the critical load path items to ASTM, ASME specifications or special listed requirements. (2) All welding, weld procedures and welds to be in accordance with ASME Boiler and Pressure Vessel Code - Section IX. (3) Special non-destructive testing for specific critical load path items to be performed to written and approved procedures in accordance with ASTM or specified requirements

TABLE 2-1 (cont)

COMPARISON OF THE REQUIREMENT OF ANSI N14.6 AND

COMANCHE PEAK SPECIAL LIFT DEVICES

ANSI N14.6 Section	Description of ANSI N14.6 Requirement	Actual Special Lift Device Requirements
		(4) All coatings to be performed to strict compliance with specified requirements. (5) Letters of compliance for materials and specifications were required for verification with original specifications. B. A stress report was not originally required but has been prepared and is Attachment B. C. Repair procedures were not identified. D. No limitations were identified as to the use of these devices under adverse environments. E. Markings and nameplate information was not addressed. F. Critical item lists have been prepared for each device and are identified as Appendix A to this Attachment A.

TABLE 2-1 (cont)

COMPARISON OF THE REQUIREMENT OF ANSI N14.6 AND

COMANCHE PEAK SPECIAL LIFT DEVICES

ANSI N14.6 Section	Description of ANSI N14.6 Requirement	Actual Special Lift Device Requirements
3.2 3.2.1 to 3.2.6	Design Criteria Stress Design Factors - These sections contain requirements for the use of stress design factors of 3 and 5 for allowable stresses of yield and ultimate respectively for maximum shear and tensile stresses; high strength material stress design factors; special pins; wire rope and slings to meet ANSI B30.9-1971; and drop-weight tests and Charpy impact test requirements	1. These devices were originally designed to the requirement that the resulting stress in the load carrying members, when subjected to the total combined lifting weight, should not exceed the allowable stresses specified in the AISC code. A stress report (Attachment B) has been generated which addresses the capability of these rigs to meet the ANSI design stress factors. 2. High strength materials are used in some of these devices (mostly for pins, load cell). Although the fracture toughness was not determined, the material was selected based on it's excellent fracture toughness characteristics. However, the stress design factors of ANSI N14.6 Section 3.2.1 of 3 and 5 were used in the analysis and the resulting stresses are acceptable. 3. Where necessary, the weight of pins was considered for handling. 4. For the Head Lifting Rig, the material for the clevis pin (item 6), the lifting leg (item 9), and the clevis (item 10) meets the Charpy V-notch requirements per ASME Boiler and Pressure Vessel Code, Section III subsection NF 2300.

TABLE 2-1 (cont)

COMPARISON OF THE REQUIREMENT OF ANSI N14.6 AND

COMANCHE PEAK SPECIAL LIFT DEVICES

ANSI N14.6 Section	Description of ANSI N14.6 Requirement	Actual Special Lift Device Requirements
3.3 3.3.1 to 3.3.8	Design Considerations - These sections contain considerations for; materials of construction, lamellar tearing; decontamination effects; remote engagement provisions; equal load distribution; lock devices; position indication of remote actuators; retrieval of device if disengaged; and nameplates.	Decontamination was not specifically addressed. Locking plates, pins, etc. are used throughout these special lifting devices. Remote actuation is only used when engaging the internals lift rig with the internals and position indication is provided from the operating platform.
3.4 3.4.1 to 3.4.6	Design Considerations to Minimize Decontamination Efforts in Special Lifting Device Use - These sections contain fabrication, welding, finishes, joint and machining requirements to permit ease in decontamination.	Decontamination was not specifically addressed. However, the design and manufacture included many of these items, i.e. lock devices, pins, etc.
3.5 3.5.1 to 3.5.10	Coatings - These sections contain provisions for ensuring proper methods are used in coating carbon steel surfaces and for ensuring non-contamination of stainless steel items.	The requirements for coating carbon steel surfaces are contained in a Westinghouse process specification referenced on the assembly and detail drawings when applicable. These specifications require a proven procedure, proper cleaning, preparation, application and final inspection of the coating. These requirements meet the intent of 3.5.1 through 3.5.8. No provisions were included in these designs for consideration of decontamination materials or the use of noncontaminating contact materials for use in stainless steel parts.

TABLE 2-1 (cont)

COMPARISON OF THE REQUIREMENT OF ANSI N14.6 AND

COMANCHE PEAK SPECIAL LIFT DEVICES

ANSI N14.6 Section	Description of ANSI N14.6 Requirement	Actual Special Lift Device Requirements
3.6 3.6.1 to 3.6.3	<u>Lubricants</u> - These sections contain requirements for special lubricants to minimize contamination and degradation of the lubricant and contacted surfaces or water pools	On the head lifting rig, threaded connections and 63 finishes are coated with Fel/pro N-1000 as indicated on the drawings. On the internals lift device, threaded connections are coated with neolube. On the load cell linkage, silicone grease is used where applicable as indicated on the drawings.
4 4.1 4.1.1 to 4.1.12	Fabrication <u>Fabricators Responsibilities</u> -These sections contain specific requirements for proper quality assurance, document control, deviation control, procedure control, material identification and certificate of compliance.	A formal quality assurance program for the manufacturer was specifically required. All the manufacturers welding procedures and non-destructive testing procedures were reviewed by Westinghouse prior to use. All critical load carrying members require certificates of compliance for material requirements. Westinghouse performed certain checks and inspections during various steps of manufacturing. Final Westinghouse review includes visual, dimensional, procedural, cleanliness, personnel qualification, etc. and issuance of a quality release to ensure conformance with drawing requirements.

TABLE 2-1 (cont)

COMPARISON OF THE REQUIREMENT OF ANSI N14.6 AND

COMANCHE PEAK SPECIAL LIFT DEVICES

ANSI N14.6 Section	Description of ANSI N14.6 Requirement	Actual Special Lift Device Requirements
4.2 4.2.1 to 4.2.5	Inspectors Responsibilities -These sections contain requirements for a non-supplier inspector.	Westinghouse Quality Assurance personnel performed some in-process and final inspections similar to those identified in these sections, and issued a Quality Release. (Also see comments to Section 4.1 above)
4.3 4.3.1 to 4.3.3	Fabrication Considerations -These sections contain special requirements for ease in decontamination or control of corrosion.	General good manufacturing processes were followed in the manufacture of these devices. However, the information defined in these sections was not specifically addressed.
5 5.1 5.1.1 to 5.1.8	Acceptance Testing Maintenance, and Assurance of Continued Compliance Owner's Responsibilities - Sections 5.1.1 and 5.1.2 require the owner to verify that the special lifting devices meet the performance criteria of the design specification by reviewing records and witness of testing.	Both the Reactor Vessel Head and Internal Lift Rigs were proof tested upon completion with a load of approximately 1.25 times the design weight. Upon the completion of the test, all parts, particularly welds, were visually inspected for cracks or obvious deformation. Critical welds were magnetic partical inspected. In addition, the Westinghouse Quality Release verifies that the criteria for letters of compliance for materials and specifications required by the Westinghouse drawings and purchasing documents was satisfied.
	Section 5.1.3 requires periodic functional testing	Maintenance and inspection procedures should be revised to include a visual check of critical welds and parts during lifting to comply with this requirement for functional testing.

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TABLE 2-1 (cont)

COMPARISON OF REQUIREMENT OF THE ANSI N14.6 AND

COMANCHE PEAK SPECIAL LIFT DEVICES

ANSI N14.6 Section	Description of ANSI N14.6 Requirement	Actual Special Lift Device Requirements
	Section 5.1.4 requires operating procedure	Operating instructions for the reactor vessel internals lift rig were furnished to the utility and operating procedures were prepared and are used.
	Sections 5.1.5, 5.1.5.1 and 5.1.5.2 require special identification and marking to prevent misuse.	It is obvious from their designs that these rigs are special lifting devices and can only be used for their intended purpose. Specific identification of the rig can be made by marking, with stencils, the rig name and rated capacity, preferably on the spreader assembly.
	Sections 5.1.6, 5.1.7 and 5.1.8 require the owner to provide written documentation on the maintenance, repair, testing and use of these rigs.	Operating instructions and maintenance instructions should be reviewed to assure that they contain the requirements to address maintenance logs, repair and testing history, damage incidents etc.

TABLE 2-1 (cont)

COMPARISON OF THE REQUIREMENT OF ANSI N14.6 AND

COMANCHE PEAK SPECIAL LIFT DEVICES

ANSI N14.6 Section	Description of ANSI N14.6 Requirement	Actual Special Lift Device Requirements
5.2 and 5.3 5.2.1 to 5.2.3 and 5.3.1 to 5.3.8	Acceptance Testing and Testing to Verify Continuing Compliance - These paragraphs require the rigs to be initially tested at 150% maximum load followed by non-destructive testing of critical load bearing parts and welds and also annual 150% load tests or annual non-destructive tests and examinations; qualification of replacement parts.	The head and internals lift rigs were load tested as indicated in Section 5. At each refueling it is suggested that a check of critical welds and parts be included in the maintenance procedures for both lifting devices. Preferably, during the initial lift at each refueling, a visual inspection should be made. Further note that with the use of the load cell for the head and internals, lifting and lowering is monitored at all times. Replacement parts should be in accordance with the original or equivalent requirements.
5.4 5.4.1 to 5.4.2	Maintenance and Repair - This section requires any maintenance and repair to be performed in accordance with original requirements and no repairs are permitted for bolts, studs and nuts.	Maintenance and repair procedures should contain, as much as possible, requirements that were used in the original fabrication. The critical items list of Appendix A contains the original type of non-destructive testing. The procedure should also define bolts, studs and nuts as non-repairable items.

TABLE 2-1 (cont)

COMPARISON OF THE REQUIREMENT OF ANSI N14.6 AND

COMANCHE PEAK SPECIAL LIFT DEVICES

ANSI N14.6 Section	Description of ANSI N14.6 Requirement	Actual Special Lift Device Requirements
5.5 5.5.1 to 5.5.2	Non-destructive Testing Procedures, Personnel Qualifications, and Acceptance Criteria - This section requires non-destructive testing to be performed in accordance with the requirements of the ASME Boiler and Pressure Vessel Code	Liquid penetrant, magnetic particle, ultrasonic and radiograph inspections were performed on identified items. These were in accordance with ASTM specifications, ASME Code, Westinghouse process specifications or as noted on detailed drawings and provide similar results to the requirement of the ASME Code.
6 6.1 6.2 6.3	Special Lifting Devices for Critical Loads - These sections contain special requirements for items handling critical loads.	It is assumed that compliance with NUREG-0612, Section 5.1 has been demonstrated and therefore this section is not applicable to these devices.

SECTION 3
DISCUSSION

The reactor vessel head and internals lift rigs, load cell and load cell linkage generally meet the intent of the ANSI N14.6 requirements for design and manufacture. However, they are not in strict compliance with the ANSI N14.6 requirements for acceptance testing, maintenance and verification of continuing compliance.

Although no specific design specification was written, the assembly and detailed manufacturing drawings and purchase order documents contain equivalent requirements. A stress report has been prepared for these devices. These devices, for the most part, were manufactured under Westinghouse surveillance with identified hold points, procedure review and personnel qualification which adequately meet these related ANSI requirements. A 125 percent load test was performed on both the head and internals lift rigs followed by the appropriate non-destructive testing.

It is anticipated that 100 percent load test, performed on each device, at each refueling, followed by a visual check of critical welds would be sufficient to demonstrate compliance. This may require modification of Comanche Peak operating and maintenance procedures.

Upon completion of the field assembly of the internals lift rig, prior to using, the assembly procedure calls for a visual inspection of all bolted joints on the rig and a visual inspection for cracks or distortions, particularly in the area of the welds. Upon completion of the field assembly of the reactor vessel head lfiting rig, the assembly procedure calls for a 100 percent load test (lifting of the assembled head), with a visual inspection for any signs of distortion.

SECTION 4

CONCLUSIONS

The review of the ANSI N14.6 requirements and comparison with the original Westinghouse requirements has shown that these items are generally in agreement for the design, fabrication and quality assurance of the lifting devices. However, the lifting devices are not in strict compliance with the ANSI N14.6 requirements for acceptance testing, maintenance and verification of continuing compliance. These specific requirements that are incompatible with the lifting devices are discussed in Appendix B with suggested actions. Westinghouse's objective was to provide a quality product and this product was designed, fabricated, assembled and inspected in accordance with internal Westinghouse requirements. In general, Westinghouse requirements meet the intent of ANSI N14.6 but not all the specific detailed requirements.

APPENDIX A

CRITICAL ITEMS LIST PER ANSI N14.6-1978

1. GENERAL

Section 3.1.2 of ANSI N14.6-1978 specifies that the design specification shall include a critical items list, which identifies critical components and defines their critical characteristics for material, fabrication, non-destructive testing and quality assurance.

"Critical items list" is further defined in ANSI N14.6, Section 2 as:

> "critical items list. A list that specifies the items of a special lifting device and their essential characteristics for which specified quality requirements shall apply in the design, fabrication, utilization, and maintenance of the device."

Load carrying members and welds of these special lifting devices are considered to be the critical items.

Tables A-1, A-2, A-3 and A-4 are the critical items list of parts and welds for the reactor vessel head lift rig, the reactor vessel internals lift rig and the load cell and load cell linkage. These tables include the material identification, and the applicable volumetric and surface inspections that were performed in the fabrication of these special lifting devices. In some instances, non-destructive testing was not specified since the material selection and strength result in very low tensile stresses and thus, non-destructive testing was not justified.

The material selection for all critical load path items was made to ASTM, ASME or special material requirements. The material requirements were supplemented by Westinghouse imposed non-destructive testing, and/or special heat treating requirements for almost all of the critical items. Westinghouse required all welding, welders, and weld procedures to be in accordance with ASME Boiler and Pressure Vessel Code Section IX for all welds. Westinghouse required a certificate, or letter of compliance that the materials and processes used by the manufacturer were in accordance with the purchase order and drawing requirements. Westinghouse also performed final inspections on these devices and issued quality releases for the internals and head lifting rigs.

TABLE A-1

REACTOR VESSEL HEAD LIFT RIG, LOAD CELL AND LOAD CELL LINKAGE

CRITICAL ITEMS LIST OF PARTS

PER ANSI N14.6-1978

Item[(a)]	Description	Material	Non-destructive Testing	
			Material	Finished
1	Lifting Block	ASTM A350 GR. LF	Ultrasonic	Magnetic Particle
2,7	Lug	ASTM A516 Grade 70	Ultrasonic Magnetic Particle	Magnetic Particle (item 2 only)
3,6	Clevis Pin	ASTM A434 AISI 4340 Steel Class BD	Ultrasonic	Magnetic Particle
4,10	Clevis	ASTM A668 Forging and Class L AISI 4340	Ultrasonic	Magnetic Particle
5,9	Lifting Leg	ASTM A434 Class BC AISI 4340	Ultrasonic	Magnetic Particle
11	Clevis Pin (load sensing)	ASTM A564 Type XM12	Ultrasonic	Magnetic Particle
12	Side Plates	ASTM 533 Type B Class 1	Ultrasonic	--
13	Removable Pin	ASTM A564 Type 630	Ultrasonic	Liquid Penetrant

(a)See figure A-1

TABLE A-2

REACTOR VESSEL HEAD LIFT RIG, LOAD CELL, AND LOAD CELL LINKAGE

CRITICAL ITEMS LIST OF WELDS

PER ANSI N14.6-1978

Item	Description	Non-destructive Testing	
		Root Pass	Final
1,2	Lugs to Lifting Block (Full Penetration)	Magnetic Particle	Magnetic Particle Radiograph
7,8	Spreader Arm Lug to Spreader Arm (fillet)	Magnetic Particle	Magnetic Particle

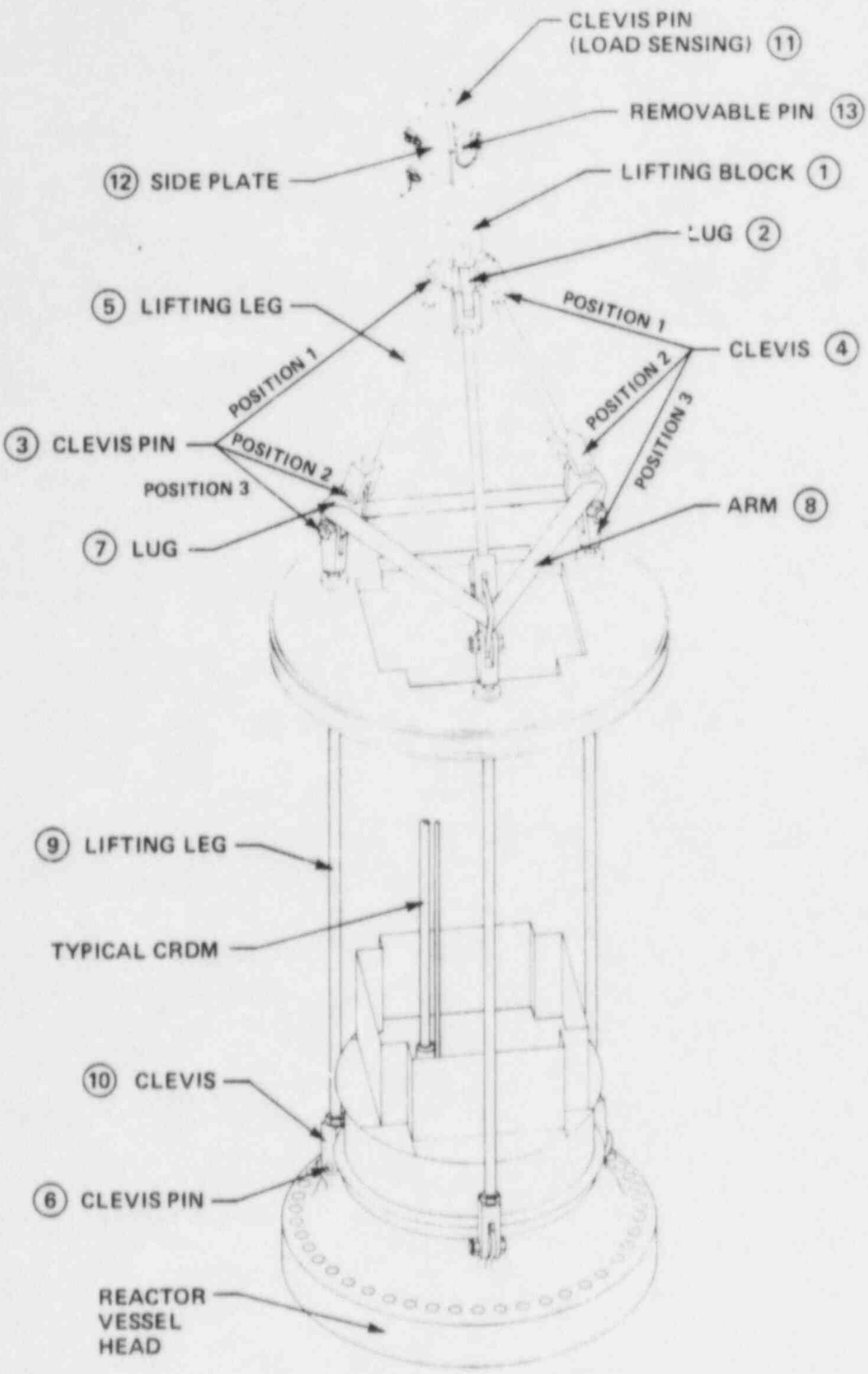

Figure A-1. Reactor Vessel Head Lift Rig

TABLE A-3

REACTOR VESSEL INTERNALS LIFT RIG

CRITICAL ITEMS LIST OF PARTS

PER ANSI N14.6-1978

Item[a]	Description	Material	Non-destructive Testing	
			Material	Finished
1	Lifting Block	ASTM A350 Grade LF 2	Ultrasonic	Magnetic Partical
2	Lifting Block Lug	ASTM A516 Grade 70	Ultrasonic Magnetic Particle	Magnetic Partical
3,7	Clevis Pin	ASTM A564, Grade 70 Precipitation Hardening SST Age treated @ 1150° F/4HRS. Air cooled RC 28-31	Ultrasonic	Liquid Penetrant
4,6	Clevis	ASTM A471 Class 3 Steel Forging	Ultrasonic	Magnetic Particle
5	Sling Rod	ASTM A434 Class BC AISI 4340 or (ASTM A588'	Ultrasonic	Magnetic Particle
8,11	Spread Lug Leg Lug	ASTM A516 GR 70 STL Plate Normalized	Ultrasonic Particle Magnetic	
13	Mounting Block	ASTM A350 LFI Forging Steel	Ultrasonic Magnetic Particle	
12	Leg Channels	ASTM A36 CS, HR	Visual	

(a)See figure A-2

TABLE A-3 (cont)

REACTOR VESSEL INTERNALS LIFT RIG

CRITICAL ITEMS LIST OF PARTS

PER ANSI N14.6-1978

Item[a]	Description	Material	Non-destructive Testing	
			Material	Finished
14,15	Load Nuts Rod Housing	ASTM A276, Type 304 SST, Hot Rolled, Condition A	Ultrasonic	
16	Guide Sleeve	ASTM A276, Type 304 SST, Hot Rolled, Annealed & Pickled, Condition A	Ultrasonic	Liquid Penetrant
17	Rotolock Stud	ASTM A564, Type 630, 17-4 pH Steel @ 1100°F for 4 hours	Ultrasonic	Liquid Penetrant

(a) See figure A-2

TABLE A-4

REACTOR VESSEL INTERNALS LIFT RIG

CRITICAL ITEMS LIST OF WELDS

PER ANSI N14.6-1978

Item	Description	Non-destructive Testing	
		Root Pass	Final
1,2	Lugs to Lifting Block (Full Penetration)	Magnetic Particle	Magnetic Particle Radiograph
8,9	Lug to Spreader Block (Full Penetration)	Magnetic Particle	Magnetic Particle
11,12	Leg Lug to Channel Leg (fillet)	Magnetic Particle	Magnetic Particle
12,13	Mounting Block to Channel Leg (fillet)	Magnetic Particle	Magnetic Particle

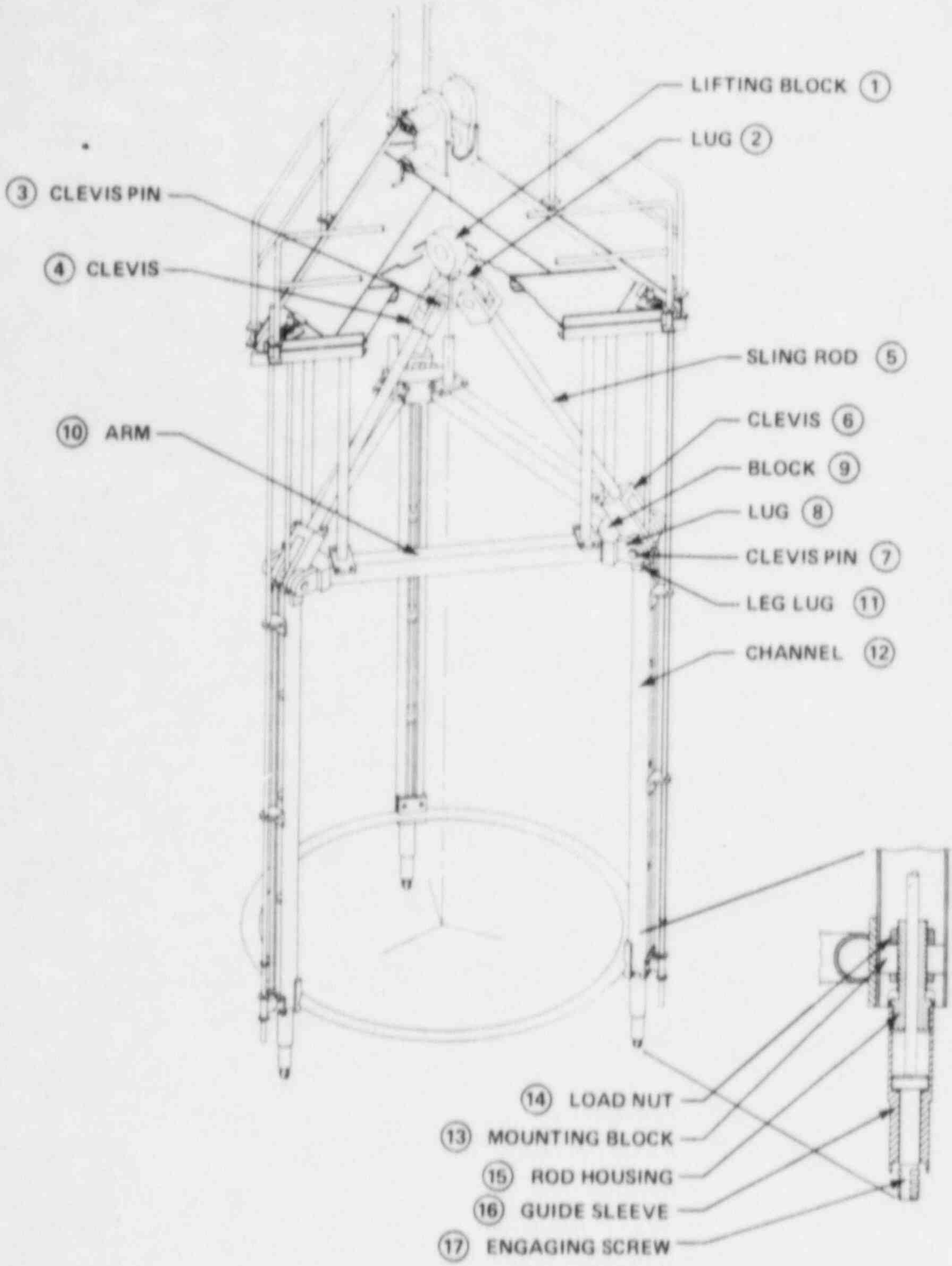

Figure A-2. Reactor Vessel Internals Lift Rig

APPENDIX B

TABULATION OF ANSI N14.6-1978 REQUIREMENTS INCOMPATIBLE WITH THE COMANCHE PEAK LIFTING DEVICES

1. GENERAL

The comparison of the various ANSI N14.6 requirements and those of these lifting devices has shown that these devices are not in strict compliance with all the ANSI N14.6 requirements. Listed below is a tabulation of those sections of ANSI N14.6 considered most important in demonstrating the continued load handling reliability of these special lifting devices. Associated Westinghouse remarks are also listed and could be used as suggested actions and/or responses to demonstrate compliance to the NRC.

1a. Requirement:
Para. 3.1.4 - requires the designer to indicate permissible repair procedures and acceptance criteria for the repair.

1b. Remarks:
Any repair to these special lifting devices is considered to be in the form of welding. Should pins, bolts or other fasteners need repair, they should be replaced, in lieu of repair, in accordance with the original or equivalent requirements for material and non-destructive testing. Weld repairs should be performed in accordance with the requirements identified in NF-4000 and NF-5000 (Fabrication and Examination) of the ASME Boiler and Pressure Vessel Code, Section III, Division 1 Subsection NF.

2a. Requirement:
Para. 3.2.1.1 - requires the design, when using materials with yield strengths above 80 percent of their ultimate strengths, to be based on the material's fracture toughness and not the listed design factors.

2b. Remarks:

High strength materials are used in these devices. Although the fracture toughness was not determined, the material was selected based on it's excellent fracture toughness characteristics. However, in lieu of a different stress design factor, the stress design factors listed in 3.2.1 of 3 and 5 were used in the analysis and the resulting stresses are considered acceptable.

3a. Requirement:

Para. 3.2.6 requires material for load-bearing members to be subjected to drop-weight or Charpy impact tests.

3b. Remarks:

Fracture toughness requirements were not identified for all the material used in these special lifting devices. However, the material selection was based on its excellent fracture toughness characteristics.

4a. Requirement:

Para. 5.1 lists Owner Responsibilities and 5.1.2 requires the owner to verify that the special lifting devices meet the performance criteria of the design specification by records and witness of testing.

4b. Remarks:

There wasn't any design specification for these rigs. A 125 percent load test followed by the appropriate non-destructive testing was performed. In addition, the Westinghouse Quality Release, may be considered an acceptable alternate to verify that the criteria for the letters of compliance for materials and specifications required by Westinghouse drawings and purchasing document were satisfied.

5a. Requirement:

Para. 5.1.3 requires periodic functional testing and a system to indicate continued reliable performance.

5b. Remarks:

Maintenance and inspection procedures should include a visual check of critical welds and parts during lifting to comply with this requirement for functional testing.

6a. Requirement:

Para. 5.1.5, 5.1.5.1 and 5.1.5.2 require special identification and marking to prevent misuse.

6b. Remarks:

It is obvious, from their designs, that these rigs are specific lifting devices and can only be used for their intended purpose and parts are not interchangeable. Specific identification of the rig can be made by marking with stencils, the rig name and rated capacity, preferably on the spreader assembly.

7a. Requirement:

Para. 5.1.6, 5.1.7 and 5.1.8 require the owner to provide written documentation on the maintenance, repair, testing and use of these rigs.

7b. Remarks:

Operating instructions and maintenance instructions should be reviewed to assure that they contain the requirements to address maintenance logs, repair and testing history, damage incidents and other items mentioned in these paragraphs.

8a. Requirement:

Para 5.2.1 requires the rigs to be initially tested at 150 percent maximum load followed by non-destructive testing of critical load bearing parts and welds.

8b. Remarks:

Both the reactor vessel head and internals lifting rigs and load cell were proof tested upon completion with a load of approximately 1.25 times the design weight. Upon completion of the test, all parts, particularly welds, were visually inspected for cracks or obvious deformation and critical welds were magnetic partical inspected. In addition the Westinghouse Quality Release verified that the criteria for letters of compliance for materials and specifications required by the Westinghouse drawings and purchasing documents were satisfied.

9a. Requirement:

Para 5.2.2 requires replacement parts to be individually qualified and tested.

9b. Remarks

Replacement parts, should they be required, should be made of identical (or equivalent) material and inspections as originally required. Only pins, bolt and nuts are considered replacement parts for the reactor vessel head and internal lift rigs.

10a. Requirement:

Para 5.3 requires testing to verify continuing compliance and annual 150 percent load tests or annual non-destructive tests and examinations to be performed.

10b. Remarks

These special lifting devices are used during plant refueling which is approximately once per year. During plant operation these special lifting devices are inaccessable since they are permanently installed and/or remain in the containment. They cannot be removed from the containment unless they are disassembled and no known purposes exist for disassembly. Load testing to 150 percent of the total weight before each use would require special fixtures and is impractical to perform. Crane capacity could also be limiting. It is suggested that a check (visual) of critical welds and parts be conducted at initial lift prior to moving to full lift and movement for these devices. Further note that with the use of the load cell for the head and internals lift rig, all lifting and lowering is monitored at all times.

2. SUMMARY

The ANSI requirements for periodic checking and functional load testing appear to be most difficult to demonstrate compliance. It is almost impractical to perform the 150 percent load test prior to each use. It is suggested that the proposal to the NRC include a 100 percent load test to be performed with a minimum of non-destructive testing, (visual-only) in the critical parts and welds.

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ATTACHMENT B to
WCAP-10156
Rev. 1

STRESS REPORT
REACTOR VESSEL HEAD LIFT RIG,
REACTOR VESSEL INTERNALS LIFT RIG
AND THE LOAD CELL LINKAGE

FOR

TEXAS UTILITIES GENERATING COMPANY

COMANCHE PEAK UNITS NO. 1 AND NO. 2

FEBRUARY, 1983

H. H. Sandner, P.E.

Approved: [signature] for
R. J. Leduc, P.E., Manager
Component Handling Equipment

ABSTRACT

A stress analysis of the Comanche Peak reactor vessel head and internal lift rigs load cell and load cell linkage was performed to determine the acceptability of these devices to meet the design requirements of ANSI N14.6.

ACKNOWLEDGMENT

Acknowledgment is hereby made to the following individuals who contributed to the structural analysis presented in this report.

J. S. Urban

F. Peduzzi

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SECTION 1

INTRODUCTION

The Nuclear Regulatory Commission (NRC) issued NUREG 0612 "Control of Heavy Load at Nuclear Power Plants"[1] in 1980 to address the control of heavy loads to prevent and mitigate the consequences of postulated accidental load drops. NUREG 0612 imposes various training, design, inspection and procedural requirements for assuring safe and reliable operation for the handling of heavy loads. In the containment building, NUREG 0612 requires special lifting devices to meet the requirements of ANSI N14.6-1978 "American National Standard for Special Lifting Devices for Shipping Containers Weighing 10,000 Pounds or More for Nuclear Materials".[2] In general, ANSI N14.6 contains detailed requirements for the design, fabrication, testing, maintenance and quality assurance of special lifting devices.

This report contains the stress analysis performed on the Comanche Peak reactor vessel head lift rig, reactor vessel internals lift rig and the load cell and load cell linkage to determine the acceptability of these devices to meet these requirements.

1.1 BACKGROUND

The reactor vessel head lift rig, the reactor vessel internals lifting rig and load cell and load cell linkage, were designed and built for the Comanche Peak Nuclear Power Plants, circa 1975-1976. These devices were designed to the requirements that the resulting stress in the load carrying members when subjected to the total combined lifting weight should not exceed the allowable stresses specified in the AISC[8] code. Also a 125 percent load test was required on both devices, followed by appropriate non-destructive testing. These items were not classified as nuclear safety components and thus requirements for formal documentation of design requirements and stress reports were not applicable. Thus, stress reports and design specifications were not formally documented. Westinghouse defined the design, fabrication and quality assurance requirements on detailed manufacturing drawings and purchase order documents. Westinghouse also issued field assembly and operating instructions, where applicable.

SECTION 2
COMPONENT DESCRIPTION

2.1 REACTOR VESSEL HEAD LIFT RIG

The reactor vessel head lift rig[3] is a three legged carbon steel structure, approximately 48 feet high and 16 feet in diameter, weighing approximately 15,000 pounds. It is used to handle the assembled reactor vessel head.

The three vertical legs and control rod drive mechanism (CRDM) platform assembly are permanently attached to the reactor vessel head lifting lugs. The leg, clevises, and pins which are a part of the support for the seismic platform, meet the requirements of the ASME Boiler and Pressure Vessel Code, Section III, Subsection NF Class I supports. The tripod sling assembly is attached to the three vertical legs and is used when installing and removing the reactor vessel head. During plant operations, the sling assembly is removed and the three vertical legs and platform assembly remain attached to the reactor vessel head.

2.2 REACTOR VESSEL INTERNALS LIFT RIG

The reactor vessel internals lift rig[4] is a three-legged carbon and stainless steel structure, approximately 30 feet high and 14 feet in diameter weighing approximately 21,000 pounds. It is used to handle the upper and lower reactor vessel internals packages. It is attached to the main crane hook for all lifting, lowering and traversing operations. A load cell linkage is connected between the main crane hook and the rig to monitor loads during all operations. When not in use, the rig is stored on the upper internals storage stand.

The reactor vessel internals lift rig attaches to the internals package by means of three rotolock studs which engage three rotolock inserts located in the internals flange. These rotolock studs are manually operated from the internals lift rig platform using a handling tool which is an integral part of the rig. The studs are normally spring retracted upward and are depressed to engage the inserts. Rotating the mechanism locks it in both positions.

2.3 LOAD CELL AND LOAD CELL LINKAGE

The load cell is used to monitor the load during lifting and lowering the reactor vessel head or internals to ensure no excessive loadings are occurring. The unit shall be a load sensing clevis type rated at 500,000 pounds. This load cell is a part of the load cell linkage which is an assembly of pins, plates, and bolts that connect the polar crane main hook to the lifting blocks of both the reactor vessel head and internals lift rig.

SECTION 3

DESIGN BASIS

3.1 DESIGN CRITERIA

NUREG 0612, paragraph 5.1.1(4) states that special lifting devices should satisfy the guidelines of ANSI N14.6. Further, NUREG 0612, 5.1.1(4) states: "In addition, the stress design factor stated in Section 3.2.1.1 of ANSI N14.6 should be based on the combined maximum static and dynamic loads that could be imparted on the handling device based on characteristics of the crane which will be used. This is in lieu of the guideline in Section 3.2.1.1 of ANSI N14.6 which bases the stress design factor on only the weight (static load) of the load and of the intervening components of the special handling device".

It can be inferred from this paragraph that the stress design factors specified in Section 3.2.1.1 of ANSI N14.6 (3 and 5) are not all inclusive. Also, it can be inferred that the specified ANSI N14.6 stress design factors should be increased by an amount based on the crane dynamic characteristics.

The dynamic characteristics of the crane would be based on the main hook and associated wire ropes holding the hook. Most main containment cranes use sixteen (16) or more wire ropes to handle the load. Should the crane hook suddenly stop during the lifting or lowering of a load, a shock load could be transmitted to the connected device. Because of the elasticity of the sixteen or more wire ropes, we consider the dynamic factor for a typical containment crane to be not much larger than 1.0.

Even if the worst conditions existed, the maximum design factor that is recommended by most design texts [5, 6, 7] is a factor of two for loads that are suddenly applied. The stress design factors required in Section 3.2.1.1 of ANSI N14.6 are:

3 x (weight) < Yield Strength

5 x (weight) < Ultimate Strength

The factor of 3 specified, based on yield strength, is certainly large enough to compensate for suddenly applied loads, where the dynamic impact factor would be as high as 2.0.

To provide flexibility on stress design factor, the analysis of the devices was performed with stress design factors of 1, 3 and 5. Thus, any stress design factor may be easily applied to satisfy any concerns.

3.2 DESIGN WEIGHTS

The following design weights were used in the analysis of the lifting devices:

3.2.1 Reactor Vessel Head Lift Rig

The design weight is 336,218 pounds which is the total weight of the assembled head and the lifting device.

3.2.2 Reactor Vessel Internals Lift Rig

The design weight for:

a. The Lower Assembly, Items 13 through 19 of calculations; is 260,000 pounds.

b. The design weight for the rest of the rig is 290,000 pounds.

SECTION 4

MATERIALS

4.1 MATERIAL DESCRIPTION

The materials and material properties for the reactor vessel head lift rig, the reactor vessel internals lift rig and load cell linkage are listed in Tables 4-1 and 4-2.

TABLE 4-1

REACTOR VESSEL HEAD LIFT RIG AND LOAD CELL LINKAGE MATERIAL AND MATERIAL PROPERTIES

Item[a]	Description	Material	Yield Strength S_y (ksi)	Ultimate Strength S_{ult} (ksi)
1	Lifting Block	ASTM A350	36	70
2,7	Lug	ASTM A516 Grade 70	38	70
3,6	Clevis Pin	ASTM A434 AISI 4340 Steel Class BD	110	140
4,10	Clevis	ASTM A668 Forging and Class L AISI 4340	85	110
5,9	Lifting Leg	ASTM A434 Class BC AISI 4340	85	110
8	Arm	ASTM A106	35	60
11	Clevis Pin (load sensing)	ASTM A564, Type XM12	105	135
12	Side Plates	ASTM A533, Type B Class 1	50	80
13	Removable Pin	ASTM A564, Type 630	105	135

(a) See figure 5-1.

TABLE 4-2

REACTOR VESSEL INTERNALS LIFT RIG MATERIAL AND MATERIAL PROPERTIES

Item[a]	Description	Material	Yield Strength S_y (ksi)	Ultimate Strength S_{ult} (ksi)
1	Lifting Block	ASTM A350, Grade LF 2	36	70
2	Lifting Block Lug	ASTM A516, Grade 70	38	70-90
3,7	Clevis Pin	ASTM A564, Grade 70 Precipitation Hardening SST, Age Treated @ 1150°F/ 4 hrs. Air Cooled RC 28-31	105	135
4,6	Clevis	ASTM A471, Class 3 Steel Forging	95	110
5	Sling Rod	ASTM A434, Class BC AISI 4340 or (ASTM A588)	85/(46)	110/(67)
8,11	Spreader Leg Lug	ASTM A516, GR 70 STL Plate Normalized	38	70-90
9,13	Spreader and Mounting Block	ASTM A350, LFI Forging Steel	30	60
10	Spreader Arm	ASTM A500, Grade B	46	58
12	Leg Channels	ASTM A36, CS, HR	36	58-80
14,15	Load Nuts Rod Housing	ASTM A276, Type 304, SST Hot Rolled, Cond. A	30	75
16	Guide Sleeve	ASTM A276, Type 304, SST, Hot Rolled, Annealed and pickled, Condition A	30	75
17	Rotolock Stud	ASTM A564, Type 630 17-4 PH Steel @ 1100°F for 4 hrs.	115	140

(a) See figure 5-2.

SECTION 5

SUMMARY OF RESULTS

Tables 5-1 and 5-2 summarize the stresses on each of the parts which make up the reactor vessel head, load cell and load cell linkage and the internals lift rig. All of the tensile and shear stresses, meet the design criteria of section 3.2.1.1 of ANSI N14.6, requiring application of stress design factors of three and five with accompanying allowable stress limits of yield and ultimate strength, respectively. In addition, all of the tensile and shear stresses meet the requirement of not exceeding the allowables of the AISC[8] code.

5.1 DISCUSSION OF RESULTS

5.1.1 Application of ANSI N14.6 Criteria

Both the reactor vessel head and internals lift rig were originally designed to the requirement that all resulting stresses in the load carrying members, when subjected to the total combined lifting weight, should not exceed the allowable stresses specified in the AISC[8] code.

The design criteria of section 3.2.1.1 of ANSI N14.6, requiring application of stress design factors of three and five with the accompanying allowable stresses, are to be used for evaluating load bearing members of a special lifting device when subjected to loading conditions resulting in shear or tensile stresses. Application of these design load factors to other loading conditions is not addressed in ANSI N14.6. However, these two stress design factors have been used to determine the stresses of the load carrying members when subject to other loading conditions, viz. bending, bearing. This is an extremely conservative approach and in several instances the resulting stresses exceed the accompanying allowable stress limit.

a) Bearing Stresses - For the internals lifting rig, several of the parts do not meet this criteria. However, since they are localized stresses, they can, if necessary, be considered under section 3.2.1.2, which states that the stress design factors of 3.2.1.1 are not intended to apply to situations where high local stresses are relieved by slight yielding. None of the bearing stresses reach the yield stress, and in fact, all of the bearing stresses meet the design criteria of the AISC[8] code.

b) Bending Stresses - The removable pin in the load cell linkage does not meet the section 3.2.1.1 criteria. However, a very conservative approach was used to calculate the bending stress in pins, as shown on page 33 of the reactor vessel head lifting rig calculations. In addition, this is a local fiber stress. Even if the fiber stresses reached anywhere near the yield stress, the rest of the pin cross-section could assume the additional load. The shear stress in the pin is extremely low and well within the section 3.2.1.1 criteria. Again, section 3.2.1.2 applies if necessary. The bending stress meets the AISC[8] code criteria.

c) Combined Stresses - The combined tensile stress from bending and tension, in the lower sling rod clevis (item 6), the spreader lug (item 8), and the leg lug (item 11) of the internals lift rig exceed the section 3.2.1.1 criteria. As indicated above, bending is not a uniform stress, but is at a maximum at the outermost fiber. Bending contributes to the major portion of the stress shown in the table, and, as a result, the tensile stress without the bending is extremely low and well within the section 3.2.1.1 criteria. The combined stresses also meet the AISC code criteria.

5.2 CONCLUSION

Application of the ANSI N14.6 criteria of (3 and 5) to these special lifting devices results in acceptable stress limits for tensile and shear stresses. Application of this criteria to all structural members subject to other types of loadings tend to result in oversimplified conservatism and with some stresses exceeding the accompanying allowable limits. However, when using the more appropriate criteria for those cases not addressed by the ANSI N14.6 criteria the stresses are within the appropriate allowable limits. In conclusion, there special lift devices meet the ANSI N14.6 criteria for tensile and shear stresses and meet other appropriate criteria for loading conditions that result in combined and bearing stresses.

TABLE 5-1

SUMMARY OF RESULTS

REACTOR VESSEL HEAD LIFT RIG AND LOAD CELL LINKAGE

Item[a] No.	Part Name And Material	Calculated Stresses (ksi) Designation	Value W[b]	3W	5W	Material Allowable (ksi) S_y[c]	S_{ult}[d]
1	Lifting Block ASTM A350 Grade LF2	Tension @ 6.515" Dia. Hole	4.1	12.3	20.5	36	70
		Bearing @ 6.515" Dia. Hole	6.4	19.2	32.0		
		Shear @ 6.515" Dia. Hole	4.1	12.3	20.5		
		Tension @ Lug Supports Cross-Section	6.7	20.1	33.5		
2	Lug ASTM A516 Grade 70	Tension @ 4.015" Dia. Hole	4.4	13.2	22.0	38	70
		Bearing @ 4.015" Dia. Hole	7.7	23.1	38.5		
		Shear @ 4.015" Dia. Hole	4.4	13.2	22.0		
		Tension @ Lug Root	2.9	8.7	14.5		
		Shear @ Lug Root	2.2	6.6	11.0		

(a) See figure 5-1 for location of item number and section

(b) W is the total static weight of the component and the lifting device

(c) S_y is the yield strength of the material (ksi)

(d) S_{ult} is the ultimate strength of the material (ksi)

TABLE 5-1 (cont)

SUMMARY OF RESULTS

REACTOR VESSEL HEAD LIFT RIG AND LOAD CELL LINKAGE

Item No.[a]	Part Name And Material	Designation	Calculated Stresses (ksi) Value			Material Allowable (ksi)	
			W[b]	3W	5W	S_y[c]	S_{ult}[d]
3	Clevis Pin	Position 1				110	140
	ASTM A434	Shear	4.9	14.7	24.5		
	AISI 4340	Bearing	7.7	23.1	38.5		
	Steel Class BD	Bending	24.1	72.3	120.5		
		Position 2					
		Shear	4.9	14.7	24.5		
		Bearing	8.0	24.0	40.0		
		Bending	24.7	74.1	123.5		

(a) See figure 5-1 for location of item number and section

(b) W is the total static weight of the component and the lifting device

(c) S_y is the yield strength of the material (ksi)

(d) S_{ult} is the ultimate strength of the material (ksi)

TABLE 5-1 (cont)

SUMMARY OF RESULTS

REACTOR VESSEL HEAD LIFT RIG AND LOAD CELL LINKAGE

Item[a] No.	Part Name And Material	Calculated Stresses (ksi)				Material Allowable (ksi)	
		Designation	Value				
			W[b]	3W	5W	S_y[c]	S_{ult}[d]
		Position 3					
		Shear	4.5	13.5	22.5		
		Bearing	7.2	21.6	36.0		
		Bending	22.4	67.2	112.0		
4	Clevis	Position 1					
	ASTM A668	Tension @ 4.005" Dia. Hole	5.0	15.0	25.0	85	110
	Forging &	Bearing @ 4.005" Dia. Hole	6.4	19.2	32.0		
	Class L	Tension @ Thread Relief	1.9	5.7	9.5		
	AISI 4340	Shear @ 4.005" Dia. Hole	5.0	15.0	25.0		
	Steel	Thread Shear	2.3	6.9	11.5		

(a) See figure 5-1 for location of item number and section

(b) W is the total static weight of the component and the lifting device

(c) S_y is the yield strength of the material (ksi)

(d) S_{ult} is the ultimate strength of the material (ksi)

TABLE 5-1 (cont)

SUMMARY OF RESULTS

REACTOR VESSEL HEAD LIFT RIG AND LOAD CELL LINKAGE

Item[a] No.	Part Name And Material	Calculated Stresses (ksi)				Material Allowable (ksi)	
		Designation	Value				
			W[b]	3W	5W	S_y[c]	S_{ult}[d]
		Position 2					
		Tension @ 4.005" Dia. Hole	5.1	15.3	25.5	85	110
		Bearing @ 4.005" Dia. Hole	6.6	19.8	33.0		
		Tension @ Thread Relief	1.9	5.7	9.5		
		Shear @ 4.005" Dia. Hole	5.1	15.3	25.5		
		Thread Shear	2.3	6.9	11.5		

(a) See figure 5-1 for location of item number and section

(b) W is the total static weight of the component and the lifting device

(c) S_y is the yield strength of the material (ksi)

(d) S_{ult} is the ultimate strength of the material (ksi)

TABLE 5-1 (cont)

SUMMARY OF RESULTS

REACTOR VESSEL HEAD LIFT RIG AND LOAD CELL LINKAGE

Item[(a)] No.	Part Name And Material	Designation	Calculated Stresses (ksi) Value $W^{(b)}$	3W	5W	Material Allowable (ksi) S_y[(c)]	S_{ult}[(d)]
		Position 3					
		Tension @ 4.005" Dia. Hole	18.4	55.2	92.0	85	110
		Bearing @ 4.005" Dia. Hole	11.6	34.8	58.0		
		Tension @ Thread Relief	1.7	5.1	8.5		
		Shear @ 4.005" Dia. Hole	9.2	27.6	46.0		
		Thread Shear	2.1	6.3	10.5		
5	Lifting Leg ASTM A434 Class BC AISI 4340 Steel	Tension @ Threads	7.0	21.0	35.0	85	110
		Thread Shear	2.3	6.9	11.5		

(a) See figure 5-1 for location of item number and section

(b) W is the total static weight of the component and the lifting device

(c) S_y is the yield strength of the material (ksi)

(d) S_{ult} is the ultimate strength of the material (ksi)

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TABLE 5-1 (cont)

SUMMARY OF RESULTS

REACTOR VESSEL HEAD LIFT RIG AND LOAD CELL LINKAGE

Item[a] No.	Part Name And Material	Designation	Calculated Stresses (ksi) Value $W^{(b)}$	3W	5W	Material Allowable (ksi) S_y [c]	S_{ult} [d]
6	Clevis Pin	Shear	4.6	13.8	23.0	110	140
	ASTM A434	Bearing	7.1	21.3	35.5		
	AISI 4340	Bending	22.4	67.2	112.0		
	Steel						
	Class BD						
7	Lug	Tension @ Upper Hole	4.6	13.8	23.0	38	70
	ASTM A516	Shear @ Upper Hole	4.6	13.8	23.0		
	Grade 70	Tension @ Lower Hole	2.8	8.4	14.0		
		Shear @ Lower Hole	4.1	12.3	20.5		
		Shear @ Weld	2.2	6.6	11.0		

(a) See figure 5-1 for location of item number and section

(b) W is the total static weight of the component and the lifting device

(c) S_y is the yield strength of the material (ksi)

(d) S_{ult} is the ultimate strength of the material (ksi)

TABLE 5-1 (cont)

SUMMARY OF RESULTS

REACTOR VESSEL HEAD LIFT RIG AND LOAD CELL LINKAGE

Item[a] No.	Part Name And Material	Designation	Calculated Stresses (ksi)			Material Allowable (ksi)	
			Value				
			W[b]	3W	5W	S_y [c]	S_{ult} [d]
8	Arm ASTM A106 Grade B Seamless	Compressive Stress Shear @ Weld	1.8 2.2	5.4 6.6	9.0 11.0	35 18[e]	60
9	Lifting Leg ASTM A434 Class BC AISI 4340 Turned, Ground & Polished	Thread Shear Tension @ Thread	2.1 6.3	6.3 18.9	10.5 31.5	85	110

(a) See figure 5-1 for location of item number and section

(b) W is the total static weight of the component and the lifting device

(c) S_y is the yield strength of the material (ksi)

(d) S_{ult} is the ultimate strength of the material (ksi)

(e) Stress limit for fillet weld from ASME Boiler and Pressur Vessel Code, Section III, Division 1 - Subsection NF 1980 Edition, Table NF-3292 1-1, page 43.

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TABLE 5-1 (cont)

SUMMARY OF RESULTS

REACTOR VESSEL HEAD LIFT RIG AND LOAD CELL LINKAGE

Item[(a)] No.	Part Name And Material	Calculated Stresses (ksi) Designation	Value W[(b)]	3W	5W	Material Allowable (ksi) S_y[(c)]	S_{ult}[(d)]
10	Clevis	Tension @ 3.947" Dia. Hole	4.5	13.5	22.5	85	110
	ASTM A668	Bearing @ 3.947" Dia. Hole	5.9	17.7	29.5		
	Forging	Shear @ 3.947" Dia. Hole	4.5	13.5	22.5		
	Grade L	Tension @ Thread Relief	1.7	5.1	8.5		
	AISI 4340	Thread Shear	2.1	6.3	10.5		
	Steel						
11	Clevis Pin	Bearing @ Midspan Section	7.2	21.6	36.0	105	135
	(Load Sensing)	Bearing @ End Sections	7.2	21.6	36.0		
	ASTM A564	Shear	4.4	13.2	22.0		
	Type XM12	Bending	24.8	74.4	124.0		

(a) See figure 5-1 for location of item number and section

(b) W is the total static weight of the component and the lifting device

(c) S_y is the yield strength of the material (ksi)

(d) S_{ult} is the ultimate strength of the material (ksi)

TABLE 5-1 (cont)

SUMMARY OF RESULTS

REACTOR VESSEL HEAD LIFT RIG AND LOAD CELL LINKAGE

Item[a] No.	Part Name And Material	Designation	Calculated Stresses (ksi) Value			Material Allowable (ksi)	
			W[b]	3W	5W	S_y [c]	S_{ult} [d]
12	Side Plates	Tension @ 7.50 Dia. Hole	4.7	14.1	23.5	50	80
	ASTM A533	Bearing @ 7.50 Dia. Hole	7.2	21.6	36.0		
	Type B, Class 1	Bearing @ 6.520 Dia. Hole	6.7	20.1	33.5		
		Shear Tear-out @ 6.52 Dia. Hole	4.1	12.3	20.5		
		Shear Tear-out @ 7.50 Dia. Hole	4.7	14.1	23.5		
13	Removable Pin	Shear	5.2	15.6	26.0	105	135
	ASTM A564	Bearing @ Midspan	6.4	19.2	32.0		
	Type 630	Bearing Ends	6.7	20.1	33.5		
		Bending	26.4	79.2	132.0		

(a) See figure 5-1 for location of item number and section

(b) W is the total static weight of the component and the lifting device

(c) S_y is the yield strength of the material (ksi)

(d) S_{ult} is the ultimate strength of the material (ksi)

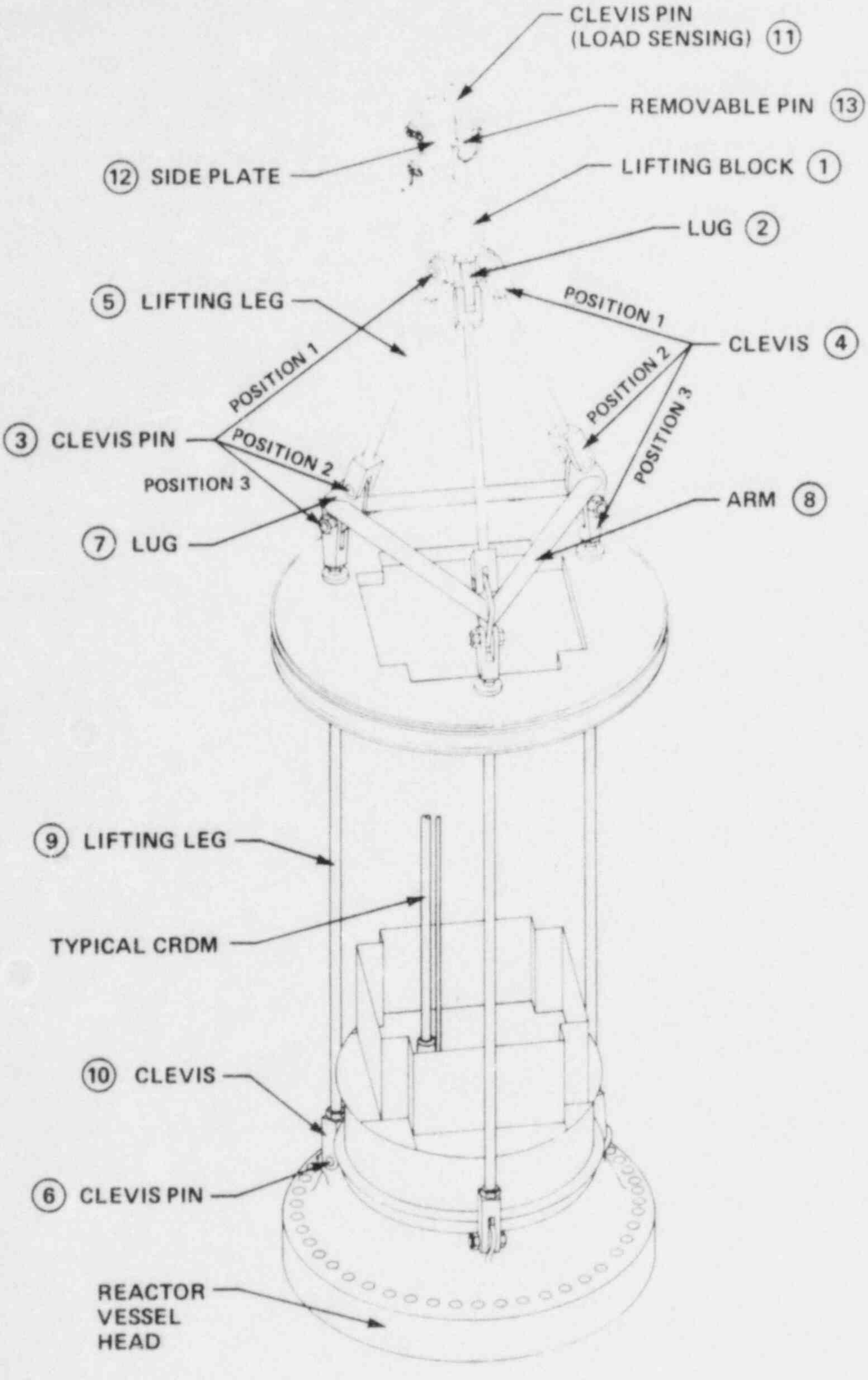

Figure 5-1. Reactor Vessel Head Lift Rig

TABLE 5-2

SUMMARY OF RESULTS

REACTOR VESSEL INTERNALS LIFT RIG

Item[a] No.	Part Name And Material	Calculated Stresses (ksi)				Material Allowable (ksi)	
		Designation	Value				
			W[b]	3W	5W	S_y [c]	S_{ult} [d]
1	Lifting Block ASTM A350 Grade LF2	Tensile Stress @ 6.515 Dia. Hole	3.7	11.1	18.5	36	70
		Bearing Stress @ 6.515 Dia. Hole	5.5	16.5	27.5		
		Shear Tear-out @ 6.515 Dia. Hole	3.7	11.1	18.5		
		Tensile Stress @ Central Cylinder	5.8	17.4	29.0		

(a) See figure 5-2 for location of item number and section

(b) W is the total static weight of the component and the lifting device

(c) S_y is the yield strength of the material (ksi)

(d) S_{ult} is the ultimate strength of the material (ksi)

TABLE 5-2 (cont)

SUMMARY OF RESULTS

REACTOR VESSEL INTERNALS LIFT RIG

Item[a] No.	Part Name And Material	Calculated Stresses (ksi) Designation	Value W[b]	3W	5W	Material Allowable (ksi) S_y[c]	S_{ult}[d]
2	Lifting Block Lug ASTM A516 Grade 70	Tensile Stress @ 4.015 Dia. Hole	4.7	14.1	23.5	38	70
		Bearing Stress @ 4.015 Dia. Hole	7.9	23.7	39.5		
		Tension @ Lug Root	6.6	19.8	33.0		
		Shear Tear-out @ 4.015 Dia. Hole	4.5	13.5	22.5		
		Shear @ Lug Root	1.9	5.7	9.5		

(a) See figure 5-2 for location of item number and section

(b) W is the total static weight of the component and the lifting device

(c) S_y is the yield strength of the material (ksi)

(d) S_{ult} is the ultimate strength of the material (ksi)

TABLE 5-2 (cont)

SUMMARY OF RESULTS

REACTOR VESSEL INTERNALS LIFT RIG

Item[a] No.	Part Name And Material	Designation	Calculated Stresses (ksi)			Material Allowable (ksi)	
			Value				
			W[b]	3W	5W	S_y[c]	S_{ult}[d]
3	Clevis Pin	Shear	5.0	15.0	25.0	105	135
	ASTM A564	Bearing on Lifting Block Lug	7.9	23.7	39.5		
	Type 630	Bending	23.9	71.7	119.5		
	17-4 pH H1150	Bearing on Clevis Lugs	6.6	19.8	33.0		
4	Clevis	Tension @ 4.018 Dia. Hole	5.1	15.3	25.5	95	110
	ASTM A471	Bearing @ 4.018 Dia. Hole	6.6	19.8	33.0		
	Class 3	Shear Tear-out @ 4.018	5.1	15.3	25.5		
	Steel Forging	Dia. Hole					
		Thread Shear	5.3	15.9	26.5		

(a) See figure 5-2 for location of item number and section

(b) W is the total static weight of the component and the lifting device

(c) S_y is the yield strength of the material (ksi)

(d) S_{ult} is the ultimate strength of the material (ksi)

TABLE 5-2 (cont)

SUMMARY OF RESULTS

REACTOR VESSEL INTERNALS LIFT RIG

Item[a] No.	Part Name And Material	Designation	Calculated Stresses (ksi) Value W[b]	3W	5W	Material Allowable (ksi) S_y[c]	S_{ult}[d]
5	Sling Rod	Thread Shear	5.3	15.9	26.5	85	110
	ASTM A434	Tension @ Thread Relief	12.0	36.0	60.0	or	or
	Class BC	Tension @ Thread	11.4	34.2	57.0	46	67
	AISI 4340 (or)						
	ASTM A588						
6	Lower Sling	Bearing	39.1	117.3	195.5	95	110
	Rod Clevis	Tension @ 4.018 Dia. Hole	29.7	89.1	148.5		
	ASTM A471	Thread Shear	5.4	16.2	27.0		
	Class 3						
	Steel Forging						

(a) See figure 5-2 for location of item number and section

(b) W is the total static weight of the component and the lifting device

(c) S_y is the yield strength of the material (ksi)

(d) S_{ult} is the ultimate strength of the material (ksi)

TABLE 5-2 (cont)

SUMMARY OF RESULTS

REACTOR VESSEL INTERNALS LIFT RIG

Item[a] No.	Part Name And Material	Calculated Stresses (ksi)				Material Allowable (ksi)	
		Designation	Value				
			W[b]	3W	5W	S_y[c]	S_{ult}[d]
7	Clevis Pin ASTM A564 Type 630 17-4 pH H 1150	Bearing Shear Bending	39.1 5.1 19.0	117.3 15.3 57.0	195.5 25.5 95.0	105	135
8	Spreader Lug ASTM A516 GR 70 STL Plate Normalized	Combined Stresses, Bending and Tensile Bearing Stress	19.7 29.4	59.1 88.2	98.5 147.0	38	70

(a) See figure 5-2 for location of item number and section

(b) W is the total static weight of the component and the lifting device

(c) S_y is the yield strength of the material (ksi)

(d) S_{ult} is the ultimate strength of the material (ksi)

TABLE 5-2 (cont)

SUMMARY OF RESULTS

REACTOR VESSEL INTERNALS LIFT RIG

Item[a] No.	Part Name And Material	Calculated Stresses (ksi)				Material Allowable (ksi)	
		Designation	Value				
			W[b]	3W	5W	S_y[c]	S_{ult}[d]
9	Spreader Block ASTM A350 LFI Forging Steel	Bearing from Arm	4.4	13.2	22.0	30	60
10	Spreader Arm ASTM A500 GR B	Nominal Compression Stress	4.4	13.2	22.0	F_a = 22.9[e]	
11	Leg Lug ASTM A516 Grade 70 Steel, Normalized	Combined Stress Bending & Tensile @ 4.015 Dia. Hole	13.5	40.5	67.5	38	70
		Bearing	25.1	75.3	125.5		
		Weld Stresses	11.3	33.9	56.5	21[f]	

(a) See figure 5-2 for location of item number and section

(b) W is the total static weight of the component and the lifting device

(c) S_y is the yield strength of the material (ksi)

(d) S_{ult} is the ultimate strength of the material (ksi)

(e) F_a = allowable compression stress to prevent buckling in absence of bending moment

(f) Stress limit for fillet welds from ASME Boiler and Pressure Vessel Code, Section III, Division 1 - Subsection NF 1980 Edition, Table NF-3292.1-1, page 43.

5462B:1/101182

TABLE 5-2 (cont)

SUMMARY OF RESULTS

REACTOR VESSEL INTERNALS LIFT RIG

Item[(a)] No.	Part Name And Material	Designation	Calculated Stresses (ksi) Value $W^{(b)}$	3W	5W	Material Allowable (ksi) S_y [(c)]	S_{ult} [(d)]
12	Leg Channels ASTM A36 CS, HR	Tensile	7.7	23.1	38.5	36	58
13	Mounting Block ASTM A350 LF1 Forging Steel	Bearing to Load Nut Shear in Welds	13.7 3.7	41.4 11.1	68.5 18.5	30 18[(f)]	60

(a) See figure 5-2 for location of item number and section

(b) W is the total static weight of the component and the lifting device

(c) S_y is the yield strength of the material (ksi)

(d) S_{ult} is the ultimate strength of the material (ksi)

(f) Stress limit for fillet welds from ASME Boiler and Pressure Vessel Code, Section III, Division 1 - Subsection NF 1980 Edition, Table NF-3292.1-1, page 43.

TABLE 5-2 (cont)

SUMMARY OF RESULTS

REACTOR VESSEL INTERNALS LIFT RIG

Item[a] No.	Part Name And Material	Designation	Calculated Stresses (ksi) Value			Material Allowable (ksi)	
			W[b]	3W	5W	S_y[c]	S_{ult}[d]
14	Load Nut ASTM A276 Type 304	Bearing to Mounting Block	13.7	41.4	68.5	30	75
		Thread Shear	5.3	15.9	26.5		
15	Rod Housing ASTM A276 Type 304	Tension @ Thread Relief	10.9	32.7	54.5	35[g]	81[g]
		Thread Shear on Upper Threads	5.3	15.9	26.5		
		Lower Threads Shear	4.9	14.7	24.5		
16	Guide Sleeve ASTM A276 Type 304 SST	Thread Shear	4.9	14.7	24.5	35[g]	61[g]
		Tension @ Thread Relief	11.6	34.8	58.0		
		Bearing to Stud	14.2	42.6	71.0		

(a) See figure 5-2 for location of item number and section

(b) W is the total static weight of the component and the lifting device

(c) S_y is the yield strength of the material (ksi)

(d) S_{ult} is the ultimate strength of the material (ksi)

(g) These are actual S_y and S_{ult} taken from material certifications.

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TABLE 5-2 (cont)

SUMMARY OF RESULTS

REACTOR VESSEL INTERNALS LIFT RIG

Item[a] No.	Part Name And Material	Designation	Calculated Stresses (ksi) Value W[b]	3W	5W	Material Allowable (ksi) S_y[c]	S_{ult}[d]
17	Rotolock Stud ASTM A564 Type 630 17-4 pH H 1100	Tensile Stress @ Cross-Section	19.0	57.0	95.0	115	140
		Combined Shear Stress on Land Root	23.4	70.2	117.0		
		Bearing on Land Surfaces	24.9	74.9	124.5		
		Bearing on Steel Head	14.2	42.6	71.0		

(a) See figure 5-2 for location of item number and section

(b) W is the total static weight of the component and the lifting device

(c) S_y is the yield strength of the material (ksi)

(d) S_{ult} is the ultimate strength of the material (ksi)

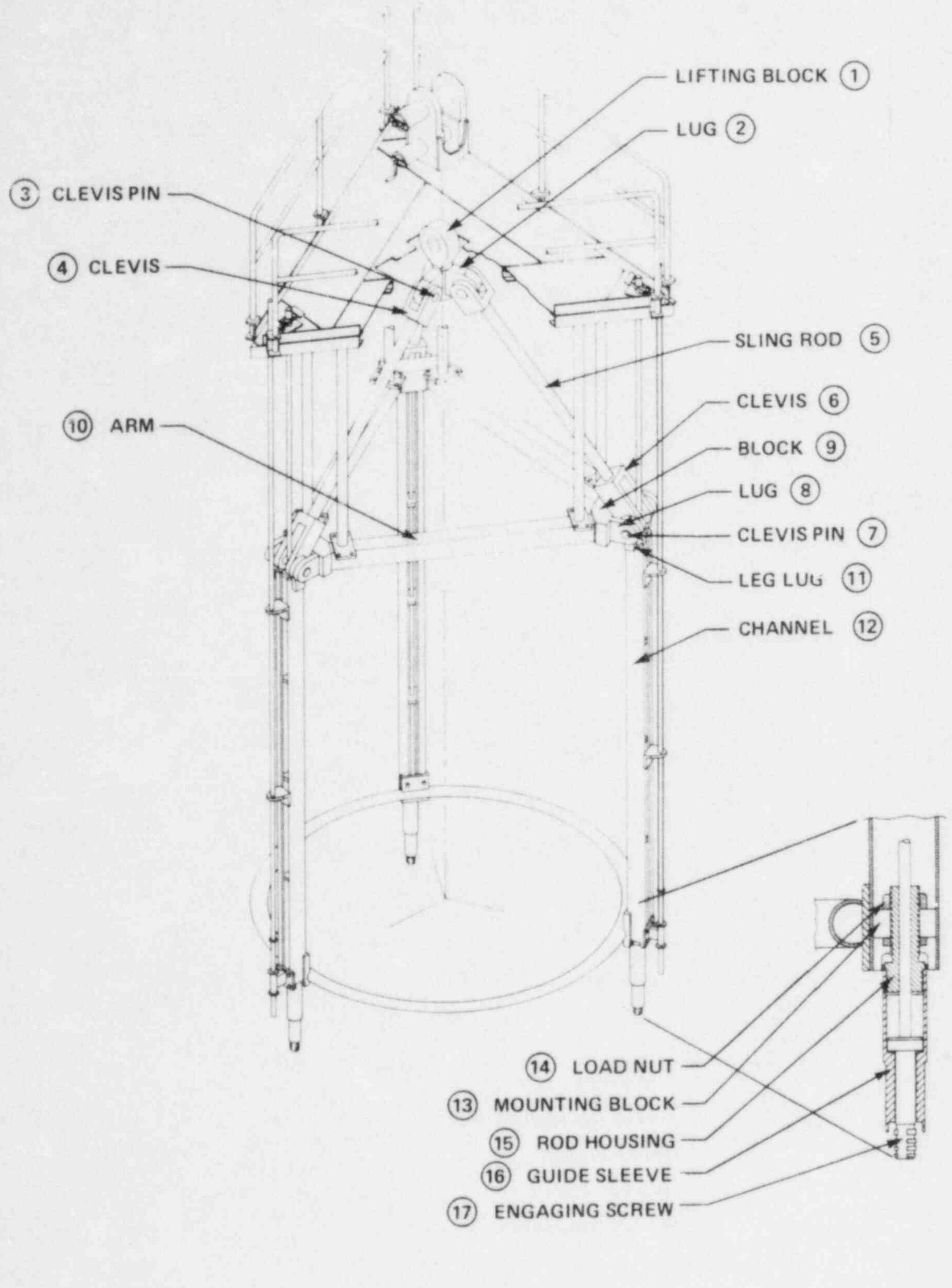


Figure 5-2. Reactor Vessel Internals Lift Rig, Load Cell, and Linkage

APPENDIX A

DETAILED STRESS ANALYSIS - REACTOR VESSEL HEAD LIFT RIG, LOAD CELL AND LOAD CELL LINKAGE

This appendix provides the detailed stress analysis for the Comanche Peak reactor vessel head lift rig and the load cell and load cell linkage, in accordance with the requirements of ANSI N14.6. Acceptance criteria used in evaluating the calculated stresses are based on the material properties given in Section 4.

SKETCH SHEET
WESTINGHOUSE FORM 54202

S.O.	PROJECT	PAGE
TYGP-188	Comanche Peak	1 OF 31

TITLE	CALCULATIONS NO.
R.V. Head Lift Load Cell & Linkage Rig Analysis	PDC -

AUTHOR & DATE	CHECKED BY & DATE
J. Urban [signature] 9-22-82	H. Sandner [signature]

PURPOSE AND RESULTS:

1. The purpose of this analysis is to determine the acceptability of this rig to the requirements of ANSI N14.6.

2. The results show that all stresses are within the allowable stresses.

COMMONWEALTH OF PENNSYLVANIA
REGISTERED PROFESSIONAL
H. Howard Sandner, Jr.
ENGINEER
NO 23941 E

REVISION NO.	DATE	DESCRIPTION	BY
		Original Issue	J. Urban

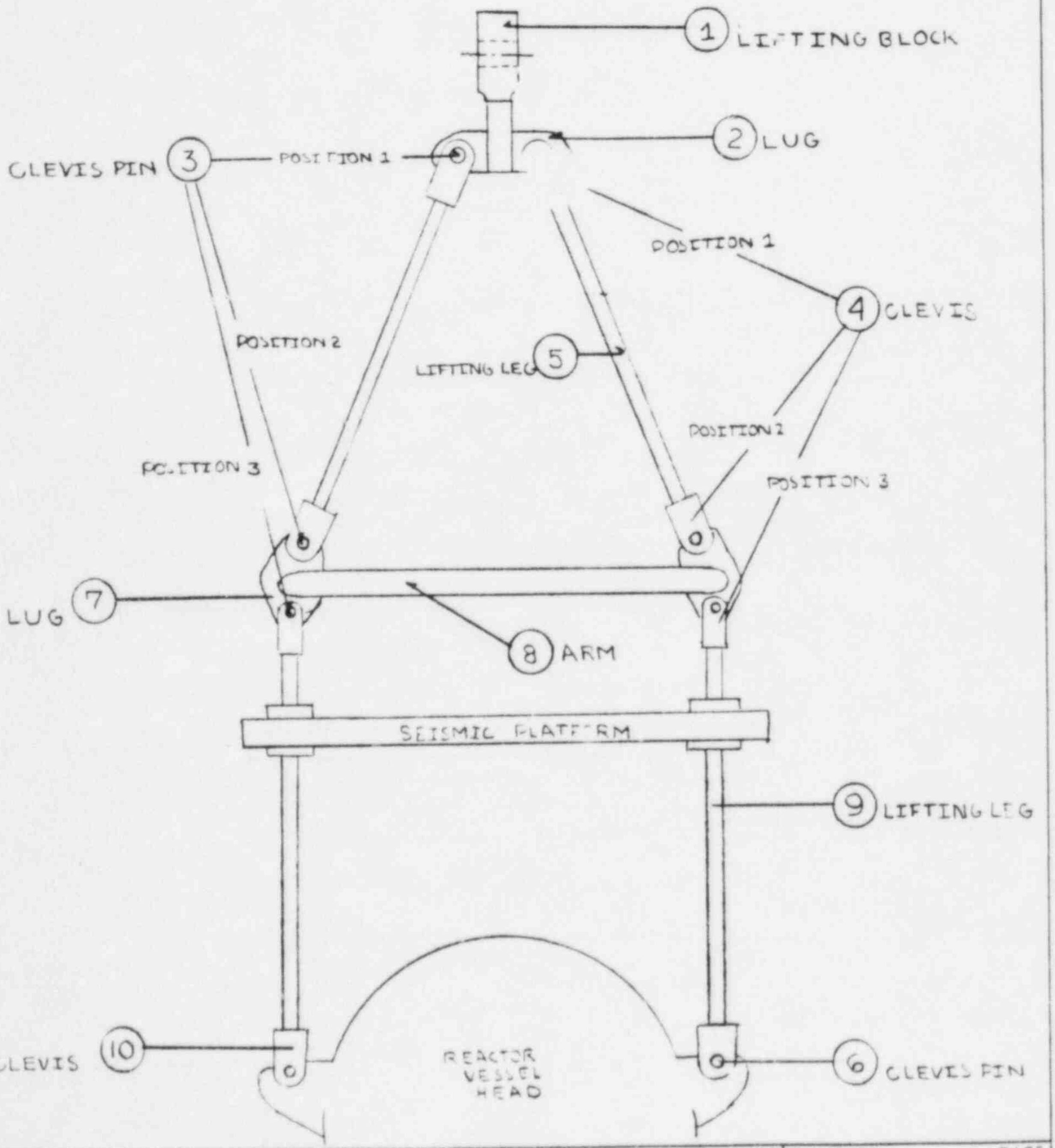
RESULTING REPORTS, LETTERS OR MEMORANDA:

WESTINGHOUSE NUCLEAR TECHNOLOGY DIVISION

TITLE HEAD LIFTING RIG STRESS ANALYSIS			PAGE 2 OF 31
PROJECT TEX	AUTHOR [signature] DATE 5/82	CHK'D BY H Sandner DATE 8/20/82	CHK'D. BY DATE
S.O. T46P-188	CALC. NO.	FILE NO.	GROUP CHE

HEAD LIFTING RIG ASSEMBLY

DWG 1212E27

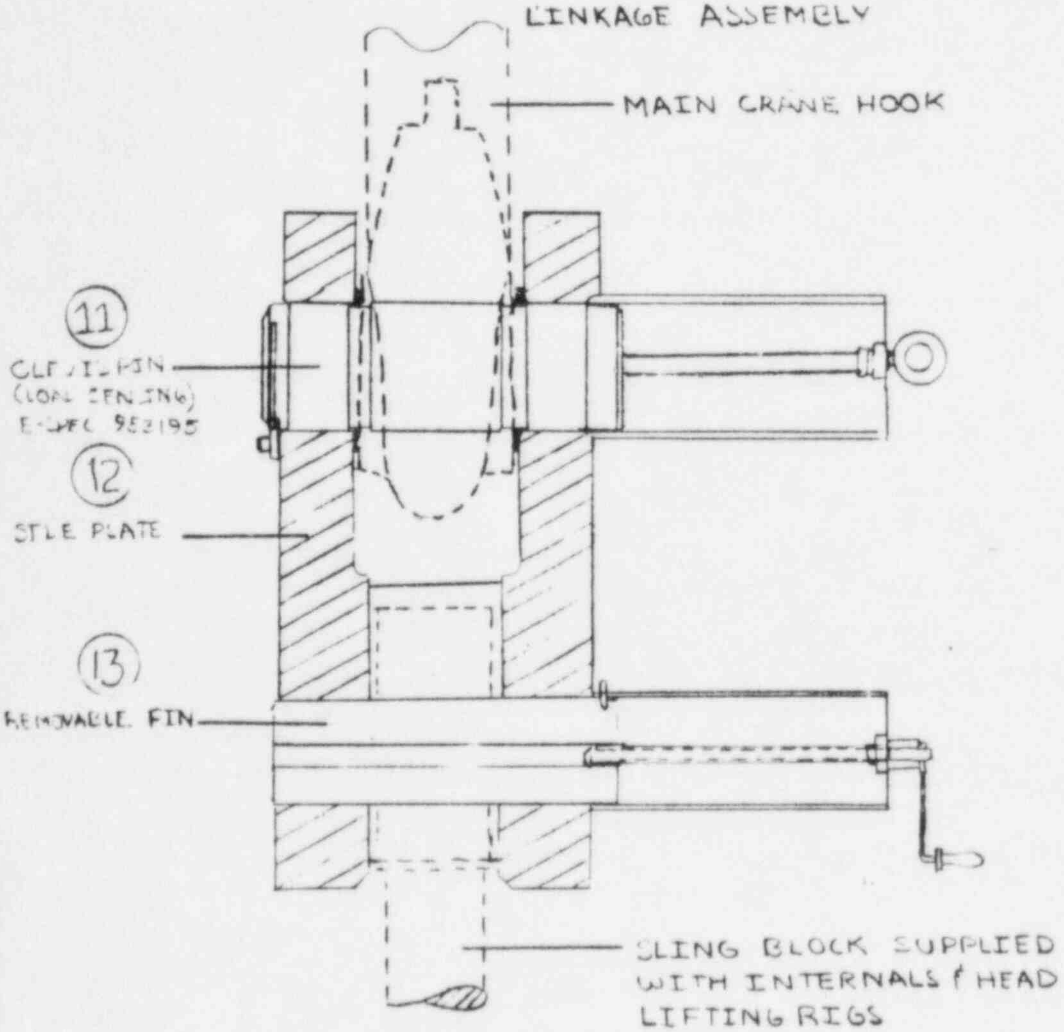


REV. NO.	REV. DATE	AUTHOR DATE	CHK'D. BY DATE	CHK'D. BY DATE

WESTINGHOUSE FORM 55213D

TITLE LOAD CELL LINKAGE STRESS ANALYSIS			PAGE 3 OF 31
PROJECT TBX	AUTHOR [signature] DATE 5/82	CHK'D BY [signature] DATE 8/20/82	CHK'D BY DATE
S.O. TYGP-188	CALC. NO.	FILE NO.	GROUP CHE

HEAD & INTERNALS LIFTING RIG LOAD CELL LINKAGE ASSEMBLY



SLING BLOCK ANALYSIS INCLUDED IN HEAD AND INTERNALS LIFT RIG ANALYSIS.

WEIGHT = GREATER OF INTERNALS OR HEAD LIFT RIG DESIGN WEIGHTS = 336,218

REV. NO. 1	REV. DATE 2/14/83	AUTHOR [signature] DATE 2/83	CHK'D BY [signature] DATE 2/83	CHK'D BY DATE

WESTINGHOUSE NUCLEAR TECHNOLOGY DIVISION

TITLE			PAGE
HEAD LIFTING RIG STRESS ANALYSIS			4 OF 31
PROJECT: TBX	AUTHOR / DATE: [signature] 5/82	CHK'D BY / DATE: [signature] 8/21/82	CHK'D BY / DATE:
S.O.: TYGP-188	CALC. NO.:	FILE NO.:	GROUP: CHE

WEIGHT OF HEAD ASSEMBLY & LIFT RIG

WEIGHTS:	POUNDS
R.V. HEAD	165,150
STUDS, NUTS, & WASHERS	37,150
CRDM'S:	
FULL LENGTH	74,100
PART LENGTH	0
ROD POSITION INDICATOR COIL STACK	14,895
COOLING SHROUD	5,250
DUMMY CANS	848
LIFT RIG	15,125
STUD TENSIONER HOIST	900
SEISMIC PLATFORM	11,100
HEAD INSULATION	1,700
CONTINGENCIES	10,000
	336,218 POUNDS

REV. NO.	REV. DATE	AUTHOR / DATE	CHK'D BY / DATE	CHK'D BY / DATE

WESTINGHOUSE FORM 55213D

TITLE			PAGE
HEAD LIFTING RIG STRESS ANALYSIS			5 OF 31
PROJECT: TBX	AUTHOR / DATE: 5/82	CHK'D. BY / DATE: 8/24/82	CHK'D. BY / DATE
S.O.: TYGP-138	CALC. NO.	FILE NO.	GROUP: CHE

CONSTANTS USED THROUGHOUT THE CALCULATIONS

α = angle upper sling leg makes to vertical

$\alpha = 25.142°$ from DWG 1212E27

W = weight of head assembly plus rig assembly

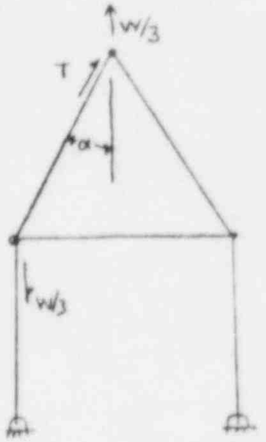
$T_r = 1$ W = 336,218 pounds

W = 2 T = tension in sling leg

$$T\cos\alpha = \frac{W}{3}$$

$$T = \frac{W}{3\cos\alpha} = \frac{336{,}218}{3\cos 25.142°} =$$

$T = 123{,}902$ lb



REV. NO.	REV. DATE	AUTHOR	DATE	CHK'D. BY	DATE	CHK'D. BY	DATE

WESTINGHOUSE NUCLEAR TECHNOLOGY DIVISION

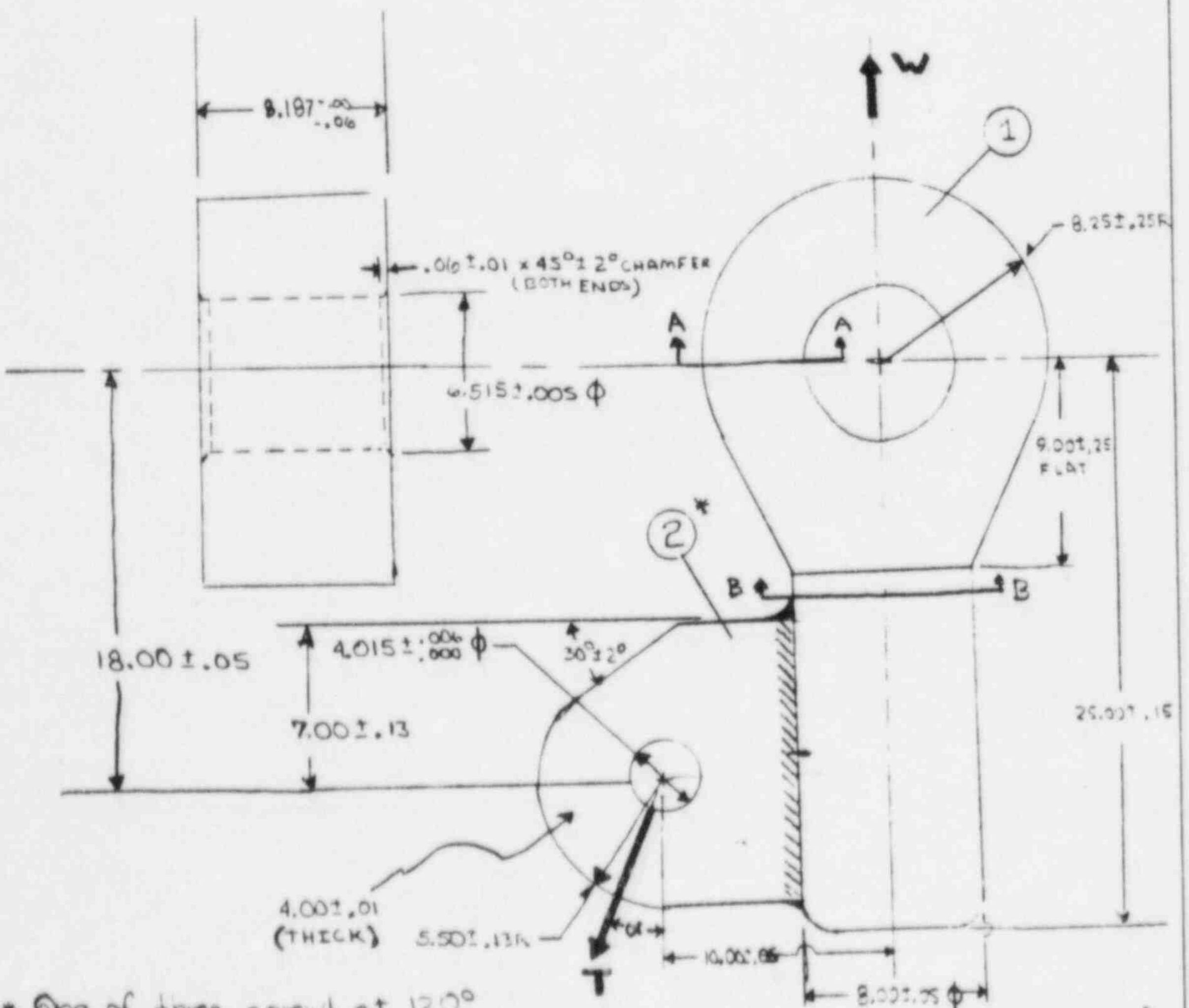
TITLE HEAD LIFTING RIG STRESS ANALYSIS			PAGE 6 OF 31
PROJECT TBX	AUTHOR [signature] DATE 5/82	CHK'D BY [signature] DATE 8/20/82	CHK'D. BY DATE
S.O. TYGP-188	CALC. NO.	FILE NO.	GROUP CHE

(1)(2)

LIFTING BLOCK ASSEMBLY

MAT'L - LIFTING BLOCK, IT1 = ASTM A350 GRADE LF2
- LUG IT2 = ASTM A516 GRADE 70
- WELDS E7018 ELECTRODES

EST. WT. 940#



* One of three spread at 120°

(LUG ROTATED INTO VIEW)

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WESTINGHOUSE FORM 55213D

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HEAD LIFTING RIG STRESS ANALYSIS			7 OF 31
PROJECT: TBX	AUTHOR: [signature] DATE: 5/82	CHK'D BY: [signature] DATE: 8/20/82	CHK'D BY / DATE
S.O.: TYGP-188	CALC. NO.	FILE NO.	GROUP: CHE

LIFTING BLOCK (1)

TENSILE @ A-A

$W = 336{,}218$ lb

$f_t = P/A_t$

$P = W/2$

$A_t = (8.25 - \frac{6.515}{2})(8.187) - (.06)^2$

$= 40.87\ in^2$

$f_t = W/(2 \times 40.87)$

$f_t =$ 4113 psi

TENSILE @ B-B

$W = 336{,}218$ lb

$f_t = P/A_t$

$P = W$

$A_t = \pi(8.00)^2/4$

$= 50.265\ in^2$

$f_t = W/50.265$

$f_t =$ 6689 psi

BEARING @ A-A

$W = 336{,}218$ lb

$f_c = P/A_c$

$P = W$

$A_c = d\,l$

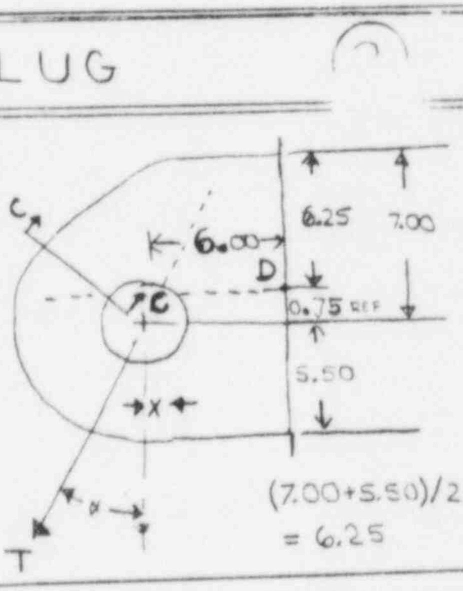
$= 6.515(8.187 - 2(.06))$

$= 52.56\ in^2$

$f_c = W/52.56$

$f_c =$ 6397 psi

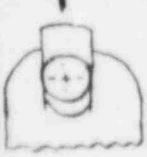
LUG



$(7.00 + 5.50)/2$

$= 6.25$

SHEAR tear-out



$W = 336{,}218$ lb

$f_v = P/2A_v$

$P = W$

$A_v = 40.87\ in^2$

$f_v = W/(2 \times 40.87)$

$f_v =$ 4113 psi

TENSION @ C-C

$T = 123{,}802$ lb

$f_t = P/A_t$

$P = T/2$

$A_t = (5.50 - \frac{4.015}{2})(4.00)$

$= 13.97\ in^2$

$f_t = T/(2 \times 13.97)$

$f_t =$ 4431 psi

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S.O.: TYGP-188	CALC NO:	FILE NO:	GROUP: CHE

BEARING

$T = 123{,}802\ lb$

$f_c = P/A_c$

$P = T$

$A_c = d\,l$

$= 4.015(4.00)$

$= 16.06\ in^2$

$f_c = T/16.06$

$f_c = \underline{7709}\ psi$

SHEAR - tear-out

$T = 123{,}802\ lb$

$f_v = P/2A_v$

$P = T$

$A_v = (5.50 - \frac{4.015}{2})(4.00)$

$= 13.97\ in^2$

$f_v = T/(2 \times 13.97)$

$f_v = \underline{4431}\ psi$

STRESSES @ LUG ROOT

$T = 123{,}802\ lb$

Bending moment about point D: ccw +

$\alpha = 25.142°$

$X = .75 \tan\alpha$

$X = 0.3520\ in$

$M = T\cos\alpha\,(6 - X)$

$M = 632{,}987\ in\text{-}lb$

$c_{max} = 6.25\ in$

$I = bh^3/12$

$= 4.00\,(12.5)^3/12$

$= 651.0\ in^4$

$f_b = Mc/I$ tensile

$= \underline{6077}\ psi$

TENSILE @ LUG ROOT

$f_t = P/A_t$

$P = T\sin\alpha = 123{,}802^{\#} \sin 25.142°$

$A_t = bh$

$= 4.00\,(7.00 + 5.50)$

$= 50\ in^2$

$f_t = T\sin\alpha/50$

$f_t = \underline{1052}\ psi$

$f_b + f_t = \underline{7129}\ psi$

SHEAR @ LUG ROOT

$T = 123{,}802^{\#};\ \alpha = 25.142°$

$f_v = P/A_v$

$P = T\cos\alpha$

$A_v = bh = 50\ in^2$

$f_v = T\cos\alpha/50$

$f_v = \underline{2241}\ psi$

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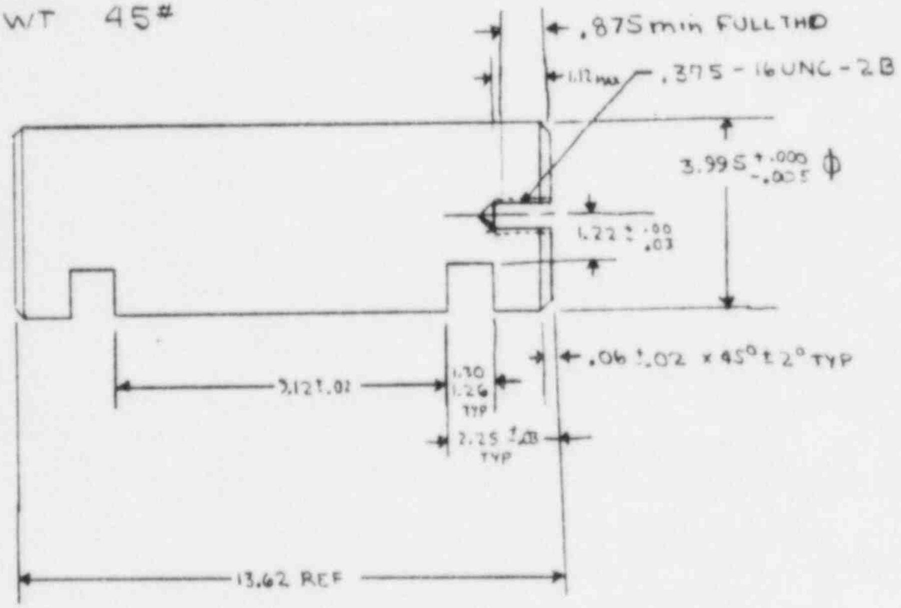
S.O. TYGP-188	CALC NO.	FILE NO.	GROUP CHE

(3)

CLEVIS PIN

MAT'L ASTM A-434
AISI 4340 STEEL
CLASS BD
140,000 PSI MIN TENSILE STRENGTH

EST WT 45#



KEEPER PLATES ARE 1.00 ±.02 THICK

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THIS SAME PIN IS USED TO CONNECT THE SLING BLOCK TO THE LIFTING LEG (POSITION 1), LIFTING LEG TO SPREADER ASSEMBLY (POSITION 2) AND SPREADER ASSEMBLY TO VERTICAL LIFTING LEG (POSITION 3).

SHEAR

T = 123,802 #
W = 336,218 #

$f_v = P/A_v$

$A_v = \pi d^2/4$

$= \pi (3.995)^2/4$

$= 12.5350 \text{ in}^2$

POSITIONS ① & ② $P = \frac{T}{2}$

POSITION ③ $P = \frac{(W/3)}{2}$

②① f_v = 4938 psi

③ f_v = 4470 psi

BEARING

$f_c = P/A_c$

POSITION ①

$A_{cI} = d\ell = 3.995(2.5-2(.045)) = 9.6280 \text{ in}^2$

$P_I = T/2 = 61,901$ #

$A_{cII} = d\ell = 3.995(4.00) = 15.980 \text{ in}^2$

$P_{II} = T = 123,802$ #

f_{cI} = 6,429 psi f_{cII} = 7747 psi

POSITION ②

$A_{cI} = d\ell = 3.995(2.44-2(.045)) = 9.388 \text{ in}^2$

$P_I = T/2 = 61,901$ #

$A_{cII} = d\ell = 3.995(3.88) = 15.501 \text{ in}^2$

$P_{II} = T = 123,802$ #

f_{cI} = 6,594 psi f_{cII} = 7,987 psi

POSITION ③

$A_{cI} = d\ell = 3.995(2.44-2(.045)) = 9.388 \text{ in}^2$

$P_I = (W/3)/2 = 56,036$ #

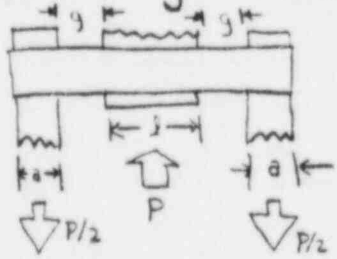
$A_{cII} = d\ell = 3.995(3.88) = 15.501 \text{ in}^2$

$P_{II} = (W/3) = 112,073$ #

f_{cI} = 5969 psi f_{cII} = 7230 psi

BENDING

$f_b^* = \left(\frac{P}{2}\right)\left[\frac{a}{2} + g + \frac{\ell}{4}\right]\frac{32}{\pi d^3}$



POSITION ①

$a = 2.50 - 2(.045) = 2.41$ in

$\ell = 4.00 = 4.00$ in

$d = 3.995 = 3.995$ in

$g = [4.38 + 2(.045) - 4.00]/2 = 0.235$ in

$P = T = 123,802$ lb

$f_b = \frac{P}{2}\left(\frac{2.41}{2} + .235 + \frac{4}{4}\right)\frac{32}{\pi(3.995)^3}$

$= T(.19490)$

$= 24,129$ psi

* derivation in appendix

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POSITION (2)

$a = 2.44 - 2(.045) = 2.35$ in

$l = 3.88 = 3.88$ in

$d = 3.995 = 3.995$ in

$g = [4.50 + 2(.045) - 3.88]/2 = 0.355$ in

$P = T = 123,802$ lb

$$f_b = P\left(\frac{1}{2}\right)\left(\frac{a}{2} + g + \frac{l}{4}\right)\frac{32}{\pi d^3}$$

$$= T(.5)\left(\frac{2.35}{2} + .355 + \frac{3.88}{4}\right) \Big/ \frac{32}{\pi(3.995)^3}$$

$$= T(.19969)$$

f_b = 24,722 psi

POSITION (3)

$a = 2.44 - 2(.045) = 2.35$ in

$l = 3.88 = 3.88$ in

$d = 3.995 = 3.995$ in

$g = [4.50 + 2(.045) - 3.88]/2 = 0.355$ in

$P = W/3 = 112,073$ lb

$f_b = \frac{W}{3}(.19969)$

f_b = 22,380 psi

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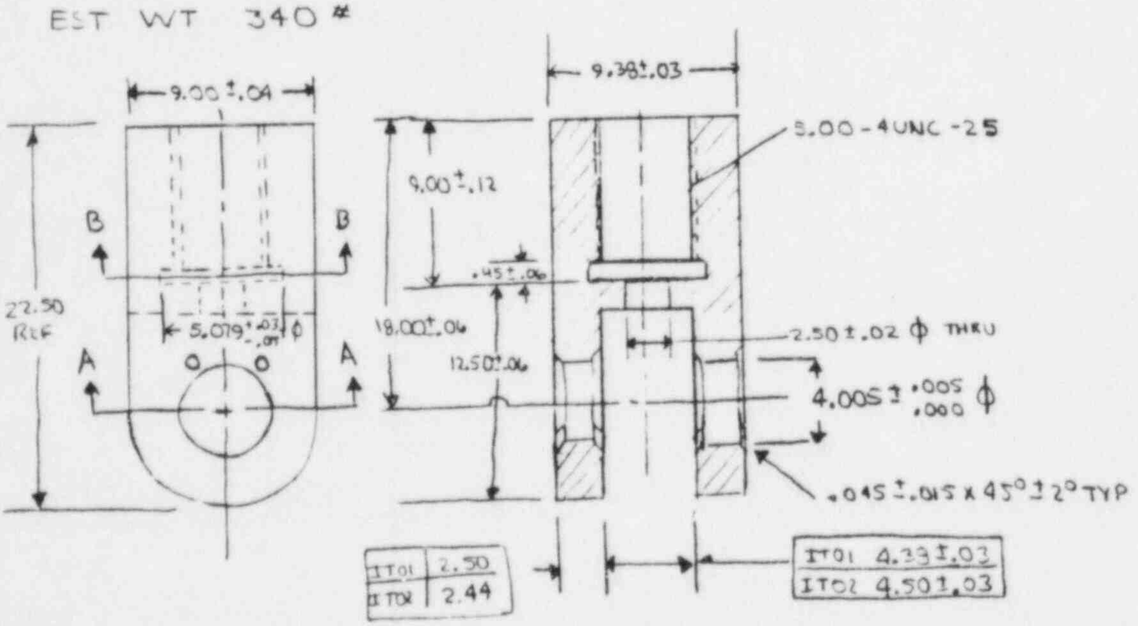
(4)

CLEVIS

MAT'L... ASTM A668 FORGING & CLASS L, AISI 4340 STEEL
MINIMUM YIELD STRENGTH... 85,000 PSI.

EST WT 340 #



RH 1T02 AT BOTTOM OF LIFTING LEG
LH 1T01 AT TOP OF LIFTING LEG

7.00 MIN THD ENGAGEMENT (DWG 1212E27 VIEW S-S)

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$T = 123{,}802 \quad W = 336{,}218$

TENSION @ A-A

$f_t = P/A_t$

$A_{t\,item\,1} = 2.50 \times (9-4.005)/2 - .045^2$
$= 6.242\ in^2$

A_t

$A_{t\,item\,2} = 2.44 \times (9-4.005)/2 - .045^2$
$= 6.092\ in^2$

ITEM 1 IS USED TO CONNECT THE SLING BLOCK TO THE LIFTING LEG...

① $P = T/4 = 30{,}951$ lb

ITEM 2 IS USED TO CONNECT THE SLING LIFTING LEG TO THE SPREADER ASSEMBLY...

② $P_1 = T/4 = 30{,}951$ lb

AND TO CONNECT THE SPREADER ASSEMBLY TO THE HEAD LIFTING LEG (VERTICAL)...

③ $P = \frac{W/3}{4} = 28{,}018$ lb

① $f_t = (T/4)/6.242$
$= 4958$ psi

② $f_t = (T/4)/6.092$
$= 5081$ psi

③ $f_t = W/3/6.092/4$
$= 4{,}599$ psi

BEARING @ A-A

$f_c = P/A_c$

① $P = T/2 = 61{,}901$ lb
$A_c = d\ell = 4.005 \times (2.50 - 2(.045))$
$= 9.652\ in^2$

② $A_c = d\ell = 4.005 \times (2.44 - 2(.045))$
$= 9.412\ in^2$
$P = T/2 = 61{,}901$ lb

③ $A_c = d\ell = 4.005 \times (2.44 - 2(.045))$
$= 9.412\ in^2$
$P = \frac{W/3}{2} = 56{,}037$ lb

$f_{c1} = (T/2)/9.652$
$f_{c1} = 6413$ psi
$f_{c2} = (T/2)/9.412$
$f_{c2} = 6{,}577$ psi
$f_{c3} = (W/3)/2/9.412$
$f_{c3} = 5954$ psi

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$T = 123{,}802^{\#}$; $W = 336{,}218^{\#}$

TENSION @ B-B

$f_t = P/A_t$

②① $P = T = 123{,}802$ lb

$A_t = 9.00(9.38) - \pi(5.079)^2/4$

$= 64.160 \text{ in}^2$

③ $P = W/3$

$A_t = 64.160 \text{ in}^2$

②① $f_t = T/64.160$

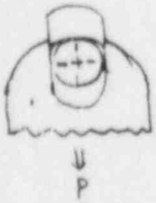
$f_t = 1930$ psi

③ $f_t = (W/3)/64.160$

$f_t = 1747$ psi

SHEAR - tear-out

$f_v = P/2A_v$



① $P = T/2 = 61{,}901$ lb

$A = 2.50\left(\frac{9.00 - 4.005}{2}\right) - .045^2$

$= 6.242 \text{ in}^2$

② $P = T/2 = 61{,}901$

$A = 2.44(9.00 - 4.005)/2 - .045^2$

$= 6.092 \text{ in}^2$

③ $P = (W/3)/2 = 56{,}036$

$A = 6.092 \text{ in}^2$

① $f_{v_1} = (T/2)/[2(6.242)]$

$f_v = 4958$ psi

② $f_v = (T/2) \div (2 \times 6.092)$

$f_v = 5081$ psi

③ $f_v = (W/3) \div (2 \times 6.092)$

$f_v = 9198$ psi

THREAD SHEAR

$f_v = P/A_v$

$A_v = \pi D_{pitch}\, l/2$

$D_{pitch} = D_s - \frac{.064952}{n}$

D_s = major diameter = 5.00 in

n = threads per inch = 4

$D_{pitch} = 4.8376$ in

$l = 7.00$ in

$A_v = \pi(4.8376)7.00/2$

$= 53.19 \text{ in}^2$

②① $P = T$

$A_v = 53.19 \text{ in}^2$

③ $P = W/3$

$A_v = 53.19 \text{ in}^2$

②① $f_v = T/53.19$

$f_v = 2328$ psi

③ $f_v = (W/3)/53.19$

$f_v = 2107$ psi

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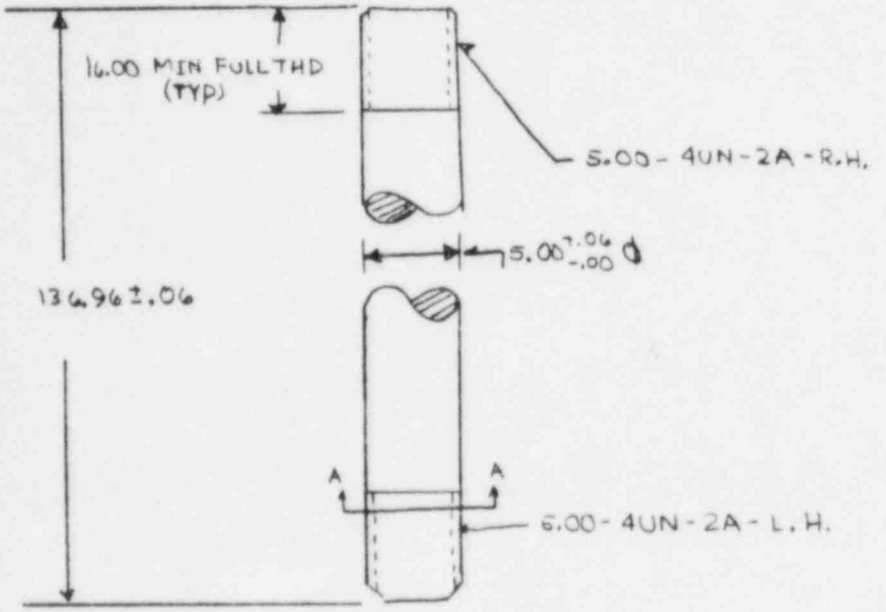
LIFTING LEG

(5)

MAT'L ASTM - A434 CLASS BC AISI 4340 STEEL.
TURNED, GROUND, & POLISHED. MINIMUM YIELD STRENGTH 85,000

EST WT 770 #



7.00 MIN THD ENGAGEMENT (VIEW S-S DWG 1212E27)

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THREAD SHEAR

$f_v = P/A_v$

$P = T = 123,802$ lb

$A_v = \pi D_{pitch} \times l/2$

from page 61 of American Standards unified screw threads (1960)

for external threads

D_s = major diameter

n = number of threads per inch

$D_{pitch} = \left(D_s - \frac{0.64952}{n}\right)$

$D_p = \left(5.00 - \frac{0.64952}{4}\right)$

$= 4.8376$ in

$A_v = \pi(4.8376) \times 7.00/2$

$= 53.19\ in^2$

$f_v = T/53.19$

$=$ 2328 psi

TENSION @ A-A

$f_t = P/A_t$

from page 59 of A.S.U.S.T. (1960)

TENSILE STRESS AREA

$A = \frac{\pi}{4}\left(D - 0.9743/n\right)^2$

D = basic major diameter

n = number of threads per inch

$A_t = \frac{\pi}{4}\left(5.00 - \frac{0.9743}{4}\right)^2$

$= 17.769\ in^2$

$P = T = 123,802$ lb

$f_t = T/A_t =$ 6967 psi

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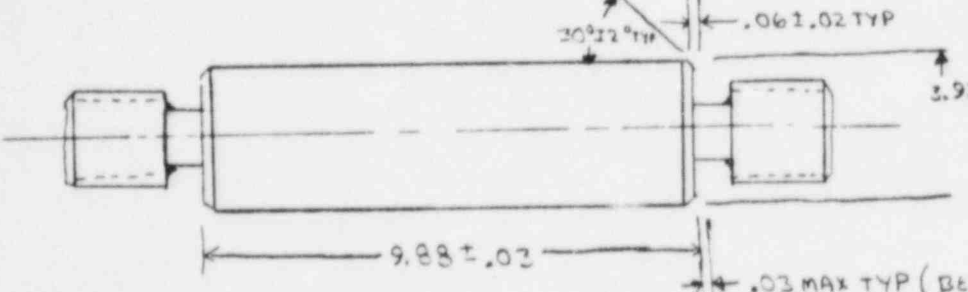
(6)

CLEVIS PIN

MAT'L ASTM A 434 AISI 4340 STEEL, CLASS BD, 140,000 PSI MINIMUM TENSILE STRENGTH

EST WT 50#



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T = 123,802 ; W = 336,218

SHEAR

$f_v = P/A_v$

$A_v = \pi d^2/4$

$= \pi(3.937)^2/4$

$= 12.1736 \text{ in}^2$

$P = (W/3)/2$

$f_v = \underline{4603}$

BEARING

$f_c = P/A_c$

$A_{cI} = [2.50 - 2(.045)]\,3.937 \text{ in}^2$

$P_I = (W/3)/2 = 56{,}036 \text{ lb}$

$A_{cII} = [4.00]\,3.937 = 15.748 \text{ in}^2$

$P_{II} = (W/3) = 112{,}073 \text{ lb}$

$f_{cI} = \underline{5{,}906} \text{ psi}$

$f_{cII} = \underline{7{,}117} \text{ psi}$

BENDING

$a = 2.50 - 2(.045) = 2.41 \text{ in}$

$l = 4.00 \text{ in}$

$g = [4.50 + 2(.045) - 4.00]/2$

$= 0.295 \text{ in}$

$d = 3.937 \text{ in}$

$P = (W/3) = 112{,}073 \text{ lb}$

$f_b^* = \frac{P}{2}\left(\frac{a}{2} + g + \frac{l}{4}\right)\frac{32}{\pi d^3}$

*SEE APPENDIX

$f_b = \frac{W}{3}\left(\frac{1}{2}\right)\left(\frac{2.41}{2} + .295 + \frac{4}{4}\right)\frac{32}{\pi(3.937)^3}$

$= \frac{W}{3}(.19969)$

$f_b = \underline{23{,}380} \text{ psi}$

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(7) (8)

4-LOOP SPREADER ASSEMBLY

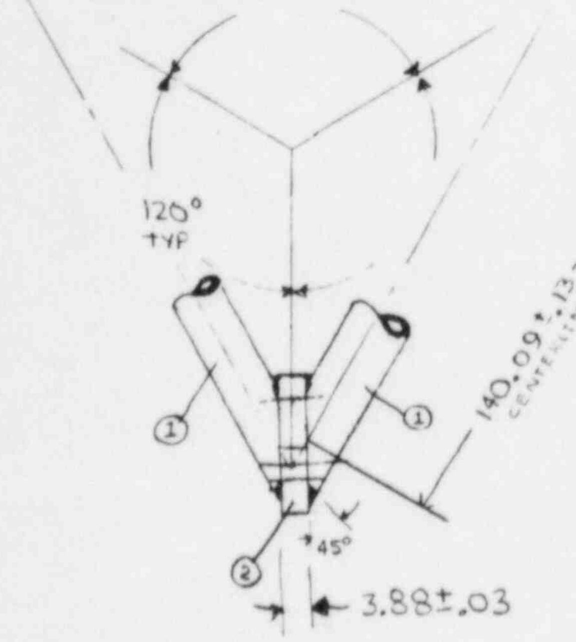
MAT'L:

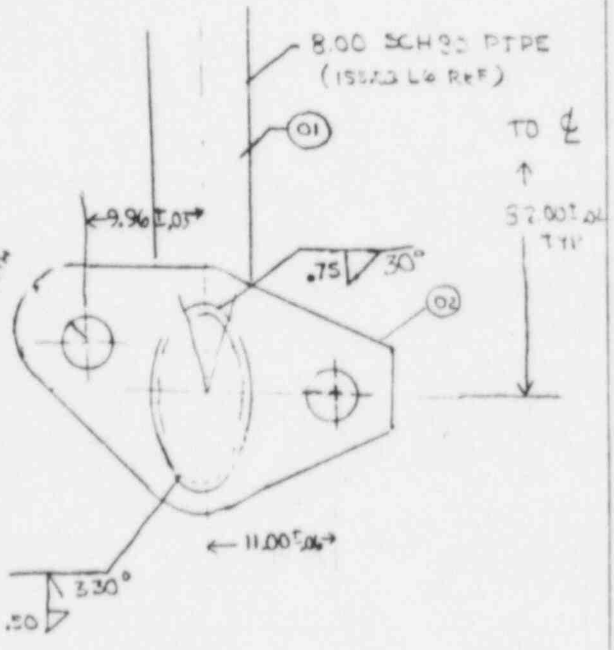
01 ARM ASTM A106 GRADE B SEAMLESS

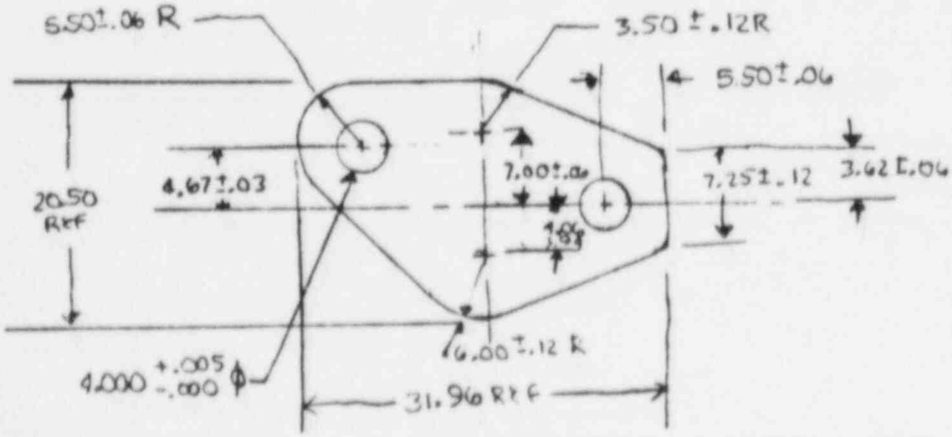
02 LUG ASTM A516 GRADE 70

WELDS E 7018 ELECTRODES

EST. WT 2800#







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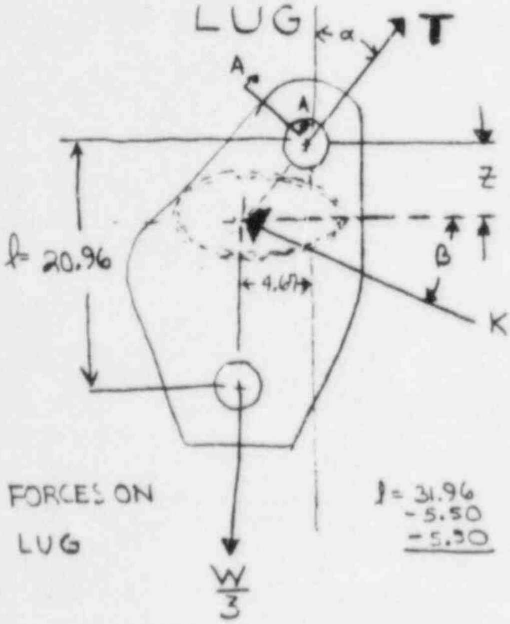


$K_{HORIZONTAL} = T \sin\alpha$

$K_{VERTICAL} = T\cos\alpha - \frac{W}{3}$

$\tan\beta = \frac{K_V}{K_H} = \frac{0}{52{,}599}$

$\beta =$ 0°

$K = \sqrt{K_H^2 + K_V^2}$

K = 52,599 lb

$\frac{4.67}{Z} = \tan\alpha$

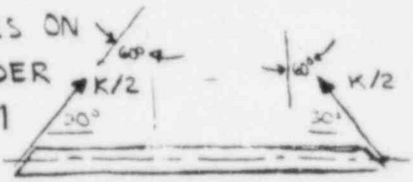
$Z = \frac{4.67}{\tan\alpha}$

= 9.950 in

centroid of ellipse is also (20.96 − 11 = 9.96) same distance from upper hole.

∴ K acts through centroid of ellipse and is horizontal

FORCES ON SPREADER ARM



R = axial force

$R\cos 30° = K/2$

$R = K/(2\cos 30°)$

$= 52{,}599/(2 \times .8660)$

R = 30,368 lb

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TENSILE STRESS @ UPPER HOLE

$f_t = P/A_t$

$P = T = 123{,}802\#$

$A_t = (5.50(2) - 4.00)\,3.88 = 27.16\ in^2$

$f_t = 123{,}802/27.16$

$f_t = 4558$ psi

SHEAR STRESS @ UPPER HOLE

$f_v = P/2A_v$

$P = T = 123{,}802\#$

$A_v = (5.50 - \frac{4.00}{2})\,3.88 = 13.58\ in^2$

$f_v = 123{,}802/(2 \times 13.58)$

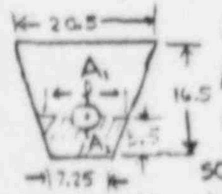
$f_v = 4558$ psi

TENSILE STRESS @ LOWER HOLE

$A = \frac{1}{2}(a+b)h$

$f_t = P/A_t$

$P = W/3 = 336{,}812/3 = 112{,}271$ lb



$A_1 = \frac{1}{2}(20.5 + l)\,11.0$

$A_2 = \frac{1}{2}(l + 7.25)\,5.5$

$A_3 = A_1 + A_2 = \frac{1}{2}(20.5 + 7.25)\,16.5$

solving simultaneously $l = 11.67$

$A_t = (l - d)\,t = (11.67 - 4)\,3.88 = 29.75\ in^2$

(7)

$f_t = 112{,}271 / 29.75\ in^2$

$f_t = 3{,}774$ psi

SHEAR @ LOWER HOLE

$f_v = P/2A_v$

conservatively

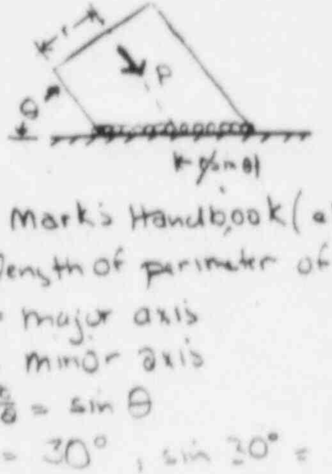
$A_v = (5.5 - \frac{4.00}{2})(3.88) = 13.58\ in^2$

$P = W/3 = 112{,}271$

$f_v = 112{,}271/(2 \times 13.58)$

$f_v = 4134$ psi

STRESS @ WELD



from Mark's Handbook (ellipse)

l = length of perimeter of weld

$2a$ = major axis

$2b$ = minor axis

$\frac{b}{a} = \sin\theta$

$\theta = 30°$, $\sin 30° = 0.5$

$b = 4$

$a = 8$

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$$\frac{a-b}{a+b} = \frac{1}{3}$$

$\therefore\ K = 1.029$

$l = \pi(a+b)K$

$= 12\pi(1.029)$

$= 38.79$

throat$_{min}$ height =

$.50 \times .707 = .3535$ in

$A_{weld} = 38.79 \times .3535$

$= 13.71\ in^2$

R = axial force in pipe

$= 30,368$ lb

$f_v = 30,368/13.71$

$f_v = 2215$ psi

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(8)

BUCKLING STRESS IN SPREADER ARM

R = axial force in spreader arm
= 30,368 lb

K = .5 (from AISC Handbook, pg-138, table 1)
= effective length factor for fixed-fixed ends

ℓ = length = 140.09 in

r = 2.878 for 8.00 SCH 80 Pipe

A = 12.76 in²

I = 105.7 in⁴

$K\ell/r = .5(140.09)/2.878$
$= 24.338$

$$C_c = \sqrt{\frac{2\pi^2 E}{F_y}} = \sqrt{\frac{2\pi^2\, 29{,}000{,}000}{35{,}000}} = 127.89$$

$K\ell/r < C_c$

∴ FROM AISC HANDBOOK (pg 5-16) 1.5.1.3 COMPRESSION

let $(K\ell/r)/C_c = A$

F_a = Allowable axial stress permitted in the absence of bending moment

$$F_a = \frac{(1 - [\tfrac{1}{2}]A^2)F_y}{(\tfrac{5}{3} + \tfrac{3}{8}A - \tfrac{1}{8}A^3)}$$

where F_y = yield stress

$$A = \frac{24.338}{127.89} = 0.19030$$

F_y = 35,000 psi

F_a = 19,783 psi

f_a = computed nominal compres. stress

$f_a = R/A$
$= 30{,}368/12.76$

<u>f_a = 2,380 psi</u>

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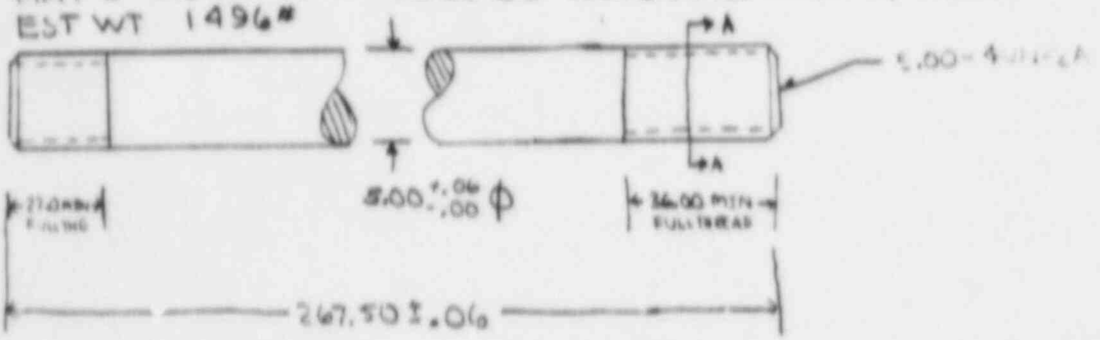
LIFTING LEG (VERTICAL) (9)

MAT'L ASTM A434 CLASS BC AISI 4340, TURNED, GROUND, & POLISHED.
EST WT 1496#



MINIMUM YIELD STRENGTH .... 85,000 PSI.

MINIMUM THD ENGAGEMENT... 7.00 INCHES

7.00 MIN THD ENGAGEMENT (VIEW SS - DWG 1212E27)

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THREAD SHEAR

$f_v = P/A_v$

$P = (W/3) = 112{,}073 \text{ lb}$

$A_v = \pi D_{pitch} \times l/2$

from page 61 of American Standards unified screw threads (1960)

for external threads

D_s = major diameter

n = number of threads per inch

$$D_{pitch} = \left(D_s - \frac{0.64952}{n}\right)$$

$$D_p = \left(5.00 - \frac{0.64952}{4}\right) = 4.8376$$

$$A_v = \pi(4.8376) \times 7.00/2 = 53.19 \text{ in}^2$$

$$f_v = P/53.1 = \underline{2107 \text{ psi}}$$

TENSION @ A-A

$f_t = P/A_t$

from page 59 of A.S.U.S.T. (1960)

TENSILE STRESS AREA

$$A = \frac{\pi}{4}\left(D - 0.9743/n\right)^2$$

D = basic major diameter

n = number of threads per inch

$$A_t = \frac{\pi}{4}\left(5.00 - \frac{0.9743}{4}\right)^2 = 17.769 \text{ in}^2$$

$P = (W/3) = 112{,}073 \text{ lb}$

$$f_t = P/A_t = \underline{6307 \text{ psi}}$$

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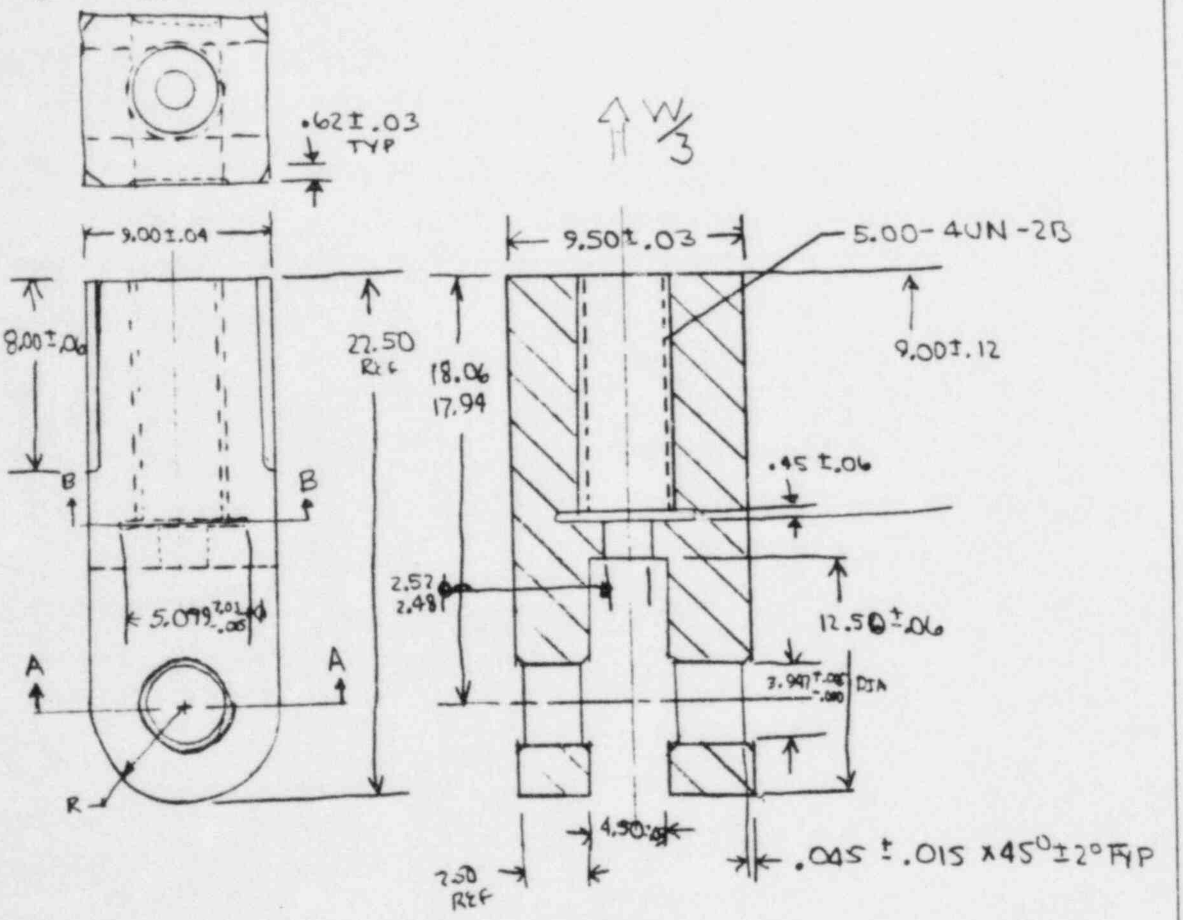
CLEVIS

MAT'L ASTM A668 FORGING GRADE L, AISI 4340 STEEL
MINIMUM YIELD STRENGTH 85,000 PSI

EST WT 340#



7.00 MIN THD ENGAGEMENT (VIEW S-S OF 1212E27)
HEAD LUG THICKNESS = 4.00

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$T = 123{,}802^{\#}$; $W = 336{,}218^{\#}$

TENSION @ A-A

$f_t = P/A_t$

$P = (W/3)/4$

$= 28{,}018^{\#}$

$A_t = (9.00 - 3.947)(\frac{1}{2})(2.50) - (.045)^2$

$= 6.285 \text{ in}^2$

$f_t = (\frac{W}{3})(\frac{1}{4})/6.285$

$f_t = \underline{4458} \text{ psi}$

TENSION @ B-B

$f_t = P/A_t$

$P = (W/3)$

$A_t = (9.00)(9.50) - \pi(5.079)^2/4$

$= 65.24 \text{ in}^2$

$f_t = (\frac{W}{3})/65.24$

$f_t = \underline{1718} \text{ psi}$

BEARING @ A-A

$f_c = P/A_c$

$P = (W/3)/2$

$A = d\,l$

$A_c = 3.947\,(2.50 - 2(.045))$

$= 9.512 \text{ in}^2$

$f_c = (\frac{W}{3})(\frac{1}{2})/9.512$

$f_c = \underline{5891} \text{ psi}$

THREAD SHEAR

$f_v = P/A_v$

$A_v = \pi D_{pitch}\, l/2$

$D_{pitch} = 4.8376 \text{ in}$

$l = 7.00 \text{ in}$

$A_v = 53.19 \text{ in}^2$

$P = (W/3)$

$f_v = (\frac{W}{3})/53.19$

$f_v = \underline{2107} \text{ psi}$

SHEAR – tear-out

$f_v = (P)/2A_v$

$P = (W/3)/2$

$A_v = (9.00 - 3.947)(\frac{1}{2})(2.50) - (.045)^2$

$= 6.285 \text{ in}^2$

$f_v = (\frac{W}{3})(\frac{1}{2})/(2 \times 6.285)$

$f_v = \underline{4458} \text{ psi}$

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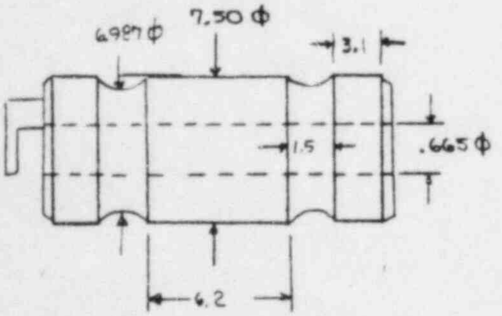
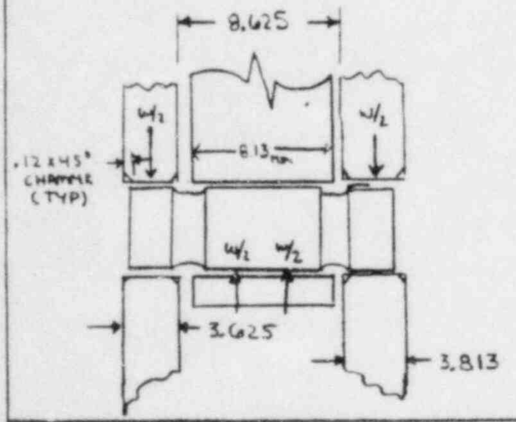
CLEVIS PIN (LOAD SENSING) (11)

MAT'L:

ASTM A 564 TYPE XM12

T_{min} = 135,000 PSI





PIN SHEAR

$f_v = P/A_v = (W/2)/A_v$

$A_{min} = \frac{\pi}{4}(6.987^2 - .665^2) = 37.99 \text{ in}^2$

$f_v = W/2/37.99 = W(.013160)$

f_v = 4425 PSI

BEARING ON HOOK

$f_c = P/A_c$

$P = W$

$A_c = 7.50(6.2) = 46.5 \text{ in}^2$

$f_c = W/46.5$

$= W(.02151)$

f_c = 7230 PSI

MAX BEARING ON SIDE PLATE

$f_c = P/A_c$

$P = W/2$

$A_c = 7.50(3.1)$ [3.1 < 3.625 - 2(.12)]

$= 23.25$

$f_c = W/(2 * 23.25)$

$= W(.021505)$

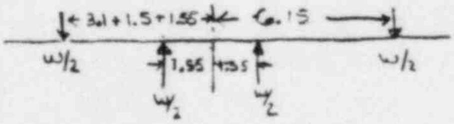
f_c = 7230 PSI

PIN BENDING

COMBINING THE WORST DIMENSIONS OF THE PIN

$I_{min} = \frac{\pi}{64}(6.987^4 - .665^4) = 116.98 \text{ in}^4$

$C_{max} = 7.50/2 = 3.75 \text{ in}$



$M = \frac{W}{2}(6.15 - 1.55) = 2.3\,W$

$f_b = Mc/I = 2.3W * 3.75/116.97$

$= W(.07373)$

f_b = 24,790 PSI

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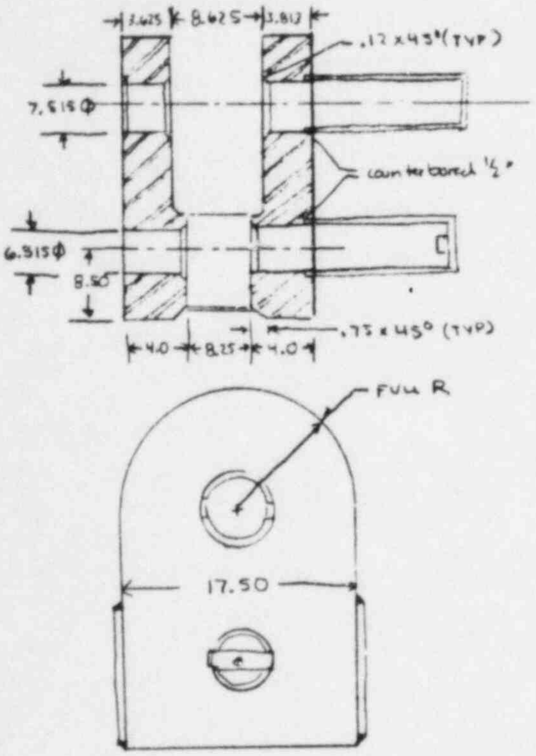
SIDE PLATES (12)

MAT'L:
ASTM A 533 TYPE B
CLASS 1, 50 KSI. MIN Y.S.



BEARING AT 7½ Φ HOLE

f_c IS THE SAME AS FOR THE BEARING OF THE CLEVIS PIN (11) ON THE SIDE PLATE

$f_c = W(.021505)$

$f_c = 7230$ PSI

TENSION @ 7½ Φ HOLE

$f_t = P/A_t$

$P = W/2$

$A_{t_{min}} = (17.50 - 7.515)(3.625) - 2(.12)^2$

$= 36.167 \text{ in}^2$

$f_t = W/2/36.167$

$= W(.013825)$

$f_t = 4648$ PSI

SHEAR - TEAR-OUT @ 7½ Φ HOLE

$f_v = P/2A_v = (W/2)/(2A_v)$

$2A_{v_{min}} = (17.50 - 7.515)(3.625) - 2(.12)^2$

$\therefore f_v = f_t = W(.013825)$

$f_v = 4648$ PSI

SHEAR TEAR-OUT @ 6½ Φ HOLE

$f_v = P/2A_v = (W/2)/(2A_v)$

$A_v = (8.5 - \frac{6.515}{2})(4.00) - .75^2/2 - .12^2/2 - .500(.375)$

$= 20.494 \text{ in}^2$

$f_v = W/(4 * 20.494)$

$= W(.012199)$

$f_v = 4101$ PSI

BEARING AT 6½ Φ HOLE

f_c IS THE SAME AS FOR THE BEARING OF THE REMOVABLE PIN (13) ON THE SIDE PLATE

$f_c = W(.019826)$

$f_c = 6666$ PSI

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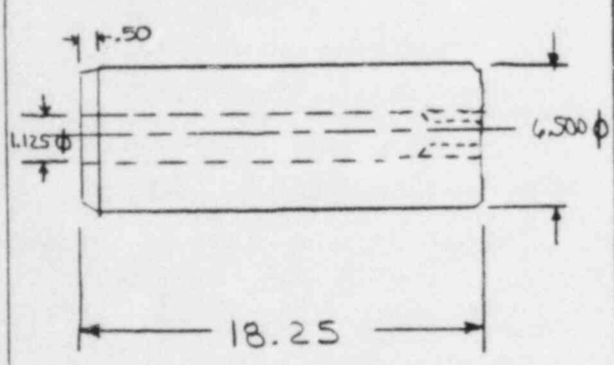
REMOVABLE PIN (13)

MAT'L: ASTM A564, TYPE 630
PRECIPITATION HARDENING SS, AGE TREATED
@ 1150°F FOR 4 HRS, AIR COOLED. 135,000 PSI
MIN TENSILE STRENGTH Rc 28-32



SHEAR

$f_v = P/A_v$

$P = W/2$

$A_v = (6.5^2 - 1.125^2)\,\pi/4$

$= 32.189\ in^2$

$f_v = W/2/32.189$

$= W(.01553)$

$f_v = 5223$ PSI

BEARING ON SIDE PLATE

THE END CHAMFER OF THE PIN FALLS ON THE LINE WITH THE SIDE PLATE CHAMFER WHEN THE PIN IS INSERTED ∴

$f_c = P/A_c$

$P = W/2$

$A_c = 6.500\,(4.00 - .12)$

$= 25.22\ in^2$

$f_c = W/2/25.22$

$= W(.019826)$

$f_c = 6666$ PSI

BEARING ON SLING BLOCK

$f_c = P/A_c$

$P = W$

$A_c = dt$

$t = 8.187 - 2(.06) = 8.067$

$A_c = 8.067(6.500) = 52.42\ in^2$

$f_c = W/52.42$

$= W(.0190758)$

$f_c = 6414$ PSI

BENDING

$l = 8.187 - 2(.06) = 8.067$

$a = 4.00$

$g = [8.25 - 8.067 + 2(.12)]/2 = .2115\ in$

$P = W$

$f_b = \frac{P}{2}\left(\frac{a}{2} + g + \frac{l}{4}\right)\frac{d_o}{2} \times \frac{64}{\pi(d_o^4 - d_i^4)}$

$= W(.07848)$

$f_b = 26,388$ PSI

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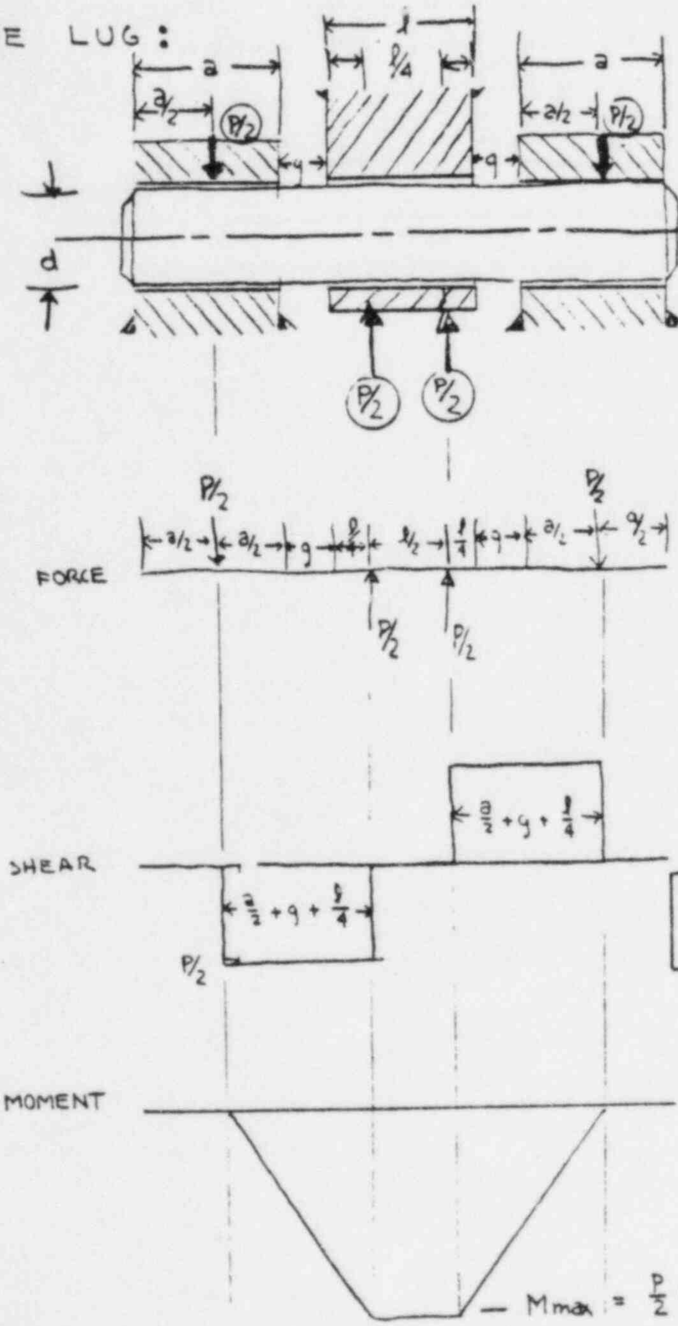
— BENDING STRESS FORMULA DERIVATION —

ASSUMING FORCES IN DOUBLE LUG TO ACT AT THE LUG CENTERS AND THE FORCE IN THE CENTER LUG TO ACT AT TWO PLACES 1/4 WAY INTO THE LUG:



g = gap between bearing surfaces

a = length of one side of double-lug bearing surface

l = length of bearing surface of center lug

P = force acting on assembly

d = diameter of pin

$$f_b = \frac{Mc}{I}$$

$$c = d/2$$

$$I = \pi d^4/64$$

$$f_b = M_{max}\, c / I$$

$$\boxed{f_b = \left(\frac{P}{2}\right)\left(\frac{a}{2} + g + \frac{l}{4}\right)\frac{32}{\pi d^3}}$$

N.B. ... This same maximum moment also occurs where the forces are assumed evenly distributed across the lug surfaces

$$M_{max} = \frac{P}{2}\left(\frac{a}{2} + g + \frac{l}{4}\right)$$

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APPENDIX B

DETAILED STRESS ANALYSIS - REACTOR VESSEL INTERNALS LIFT RIG

This appendix provides the detailed stress analysis for the Comanche Peak reactor vessel internals lift rig in accordance with the requirements of ANSI N14.6. Acceptance criteria used in evaluating the calculated stresses are based on the material properties given in Section 4.

SKETCH SHEET
WESTINGHOUSE FORM 54202

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R. V. Internals	PDC -

AUTHOR & DATE	CHECKED BY & DATE
J. S. Urban J S Urban 9-22-82	H. Sandner H. H. Sandner

PURPOSE AND RESULTS:

1. The purpose of this analysis is to determine the acceptability of this rig to the requirements of ANSI N14.6.

2. The results show that all stresses are within the allowable stresses.

COMMONWEALTH OF PENNSYLVANIA
REGISTERED PROFESSIONAL
H. Howard Sandner, Jr.
ENGINEER
NO. 23941-E

H. Howard Sandner Jr

REVISION NO.	DATE	DESCRIPTION	BY
		Original Issue	J. S. Urban

RESULTING REPORTS, LETTERS OR MEMORANDA:

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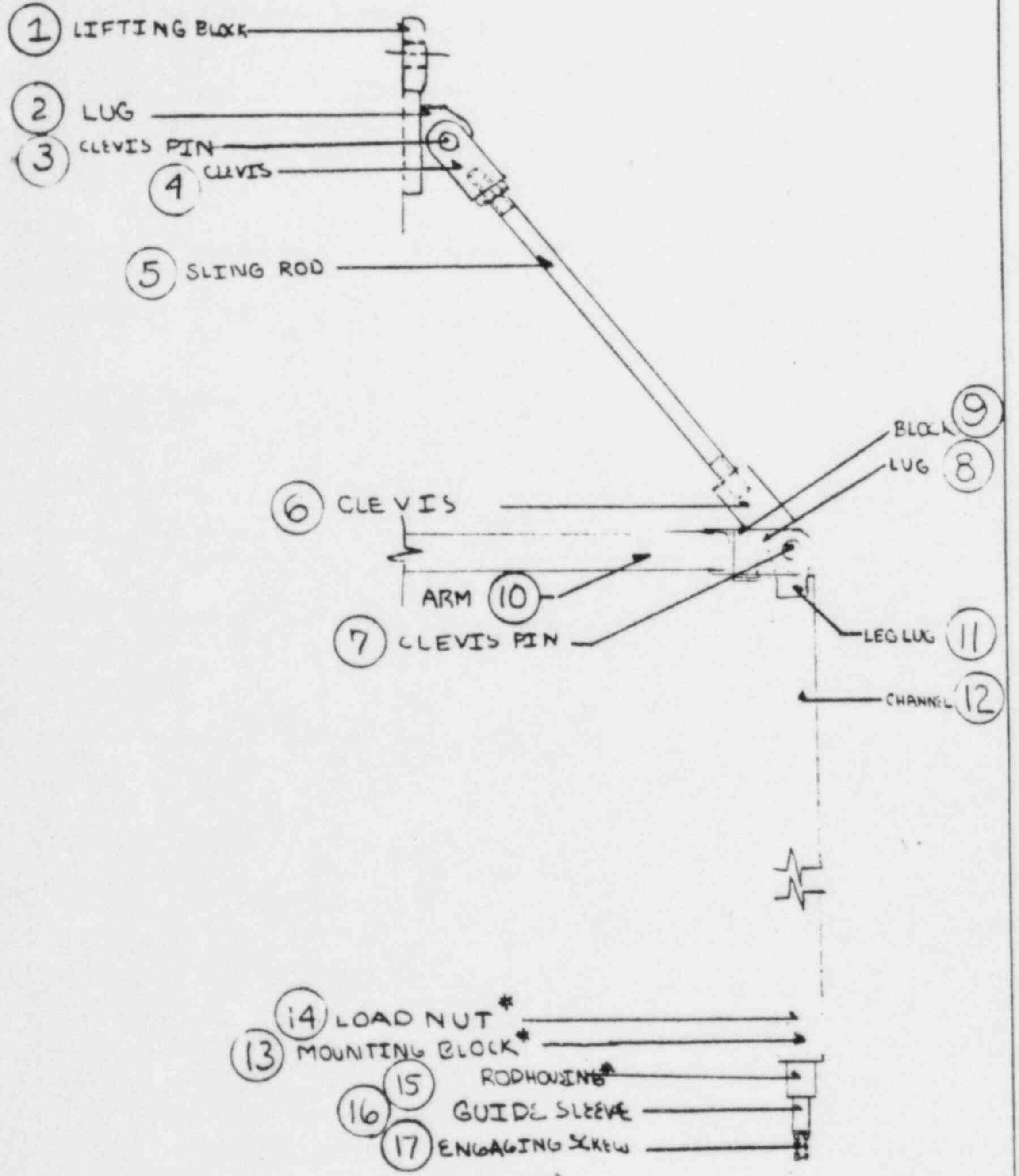

* SEE DETAIL SKETCHES & POINT OF ANALYSIS IN CALCULATIONS FOR DETAILS - THESE ITEM NUMBERS GIVE GENERAL LOCATION IN ASSY. ONLY.

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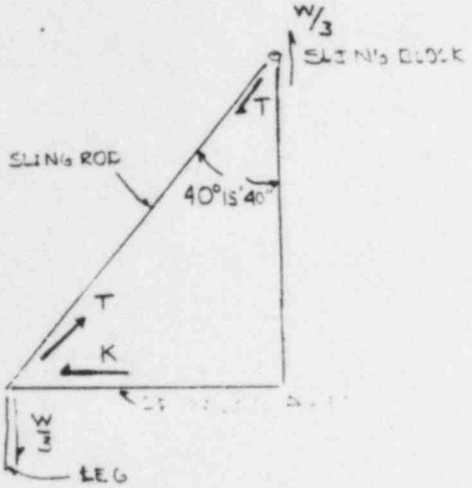

T = TENSION IN SLING ROD

K = COMPRESSION FORCE IN SPREADER ARM

W* = WEIGHT OF LOWER INTERNALS, LIFTING RIG, AND LOAD CELL LINKAGE COMBINED

W = 290,000 lb

40°15'40" = 40.2611°

$T \cos 40.2611° = W/3$

$\therefore T = W(0.43681)$ lb

$= 126,675^{\#}$

$K = T \sin 40.2611°$

$\therefore K = W(.28230)$ lb

$81,867^{\#}$

WEIGHT OF LOWER INTERNALS =	260,000
WEIGHT OF LIFTING RIG =	18,350
WEIGHT OF [illegible] =	2,930
[illegible]	+ [illegible]
	290,000

VARIABLES USED THROUGHOUT THESE CALCULATIONS

P =	A GENERAL FORCE	LB
f_t =	TENSILE STRESS	PSI
f_c =	COMPRESSIVE STRESS OR BEARING STRESS	[illegible]
f_b =	BENDING STRESS	[illegible]
f_v =	SHEAR STRESS	PSI
A =	AREA	[illegible]
d =	DIAMETER	[illegible]
I =	MOMENT OF INERTIA	IN^4
S =	SECTION MODULUS	[illegible]
b =	BREADTH	[illegible]
h =	HEIGHT	[illegible]
c =	DISTANCE FROM NEUTRAL AXIS TO EXTREME FIBER	[illegible]
M =	MOMENT	[illegible]

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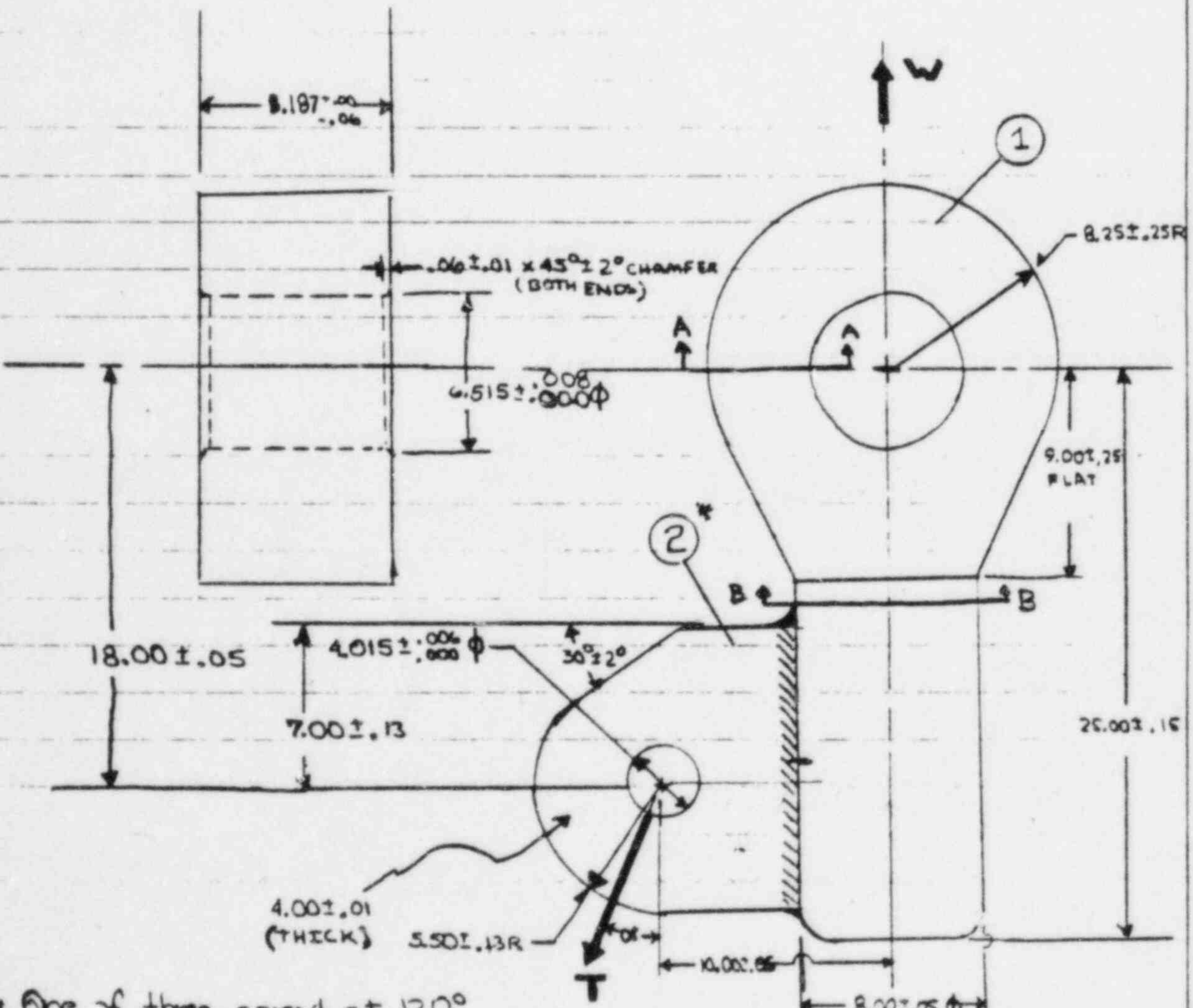
(1) (2)

LIFTING BLOCK ASSEMBLY-33

MAT'L - LIFTING BLOCK, IT1 = ASTM A350 GRADE LF2
- LUG IT2 = ASTM A516 GRADE 70
- WELDS E7018 ELECTRODES

EST. WT. 940#



* One of three spread at 120°

(LUG ROTATED INTO VIEW)

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LIFTING BLOCK ①

● TENSILE STRESSES @ SECTION A-A

$f_t = P/A_t$

$P = W/2$

$A_t = (8.00 - \frac{6.523}{2})8.181 - (.07)^2$

$= 38.76$

$f_t = W/(2 \times 38.76)$

$= W(.012900)$

$W = 290,000$*

$f_t = 3741$ psi

● BEARING STRESSES @ SECTION A-A

$W = 290,000$ lb

$f_c = P/A_c$

$P = W$

$A_c = d\,l = 6.515(8.181 - 2(.07))$

$= 52.39\ in^2$

$f_c = W(0.019089)$

$f_c = 5536$ psi

● TEAR-OUT SHEAR @ 6.515 ϕ HOLE

$W = 290,000$ lb

$f_v = P/2A_v$

$P = W$

$A_v = 38.76\ in^2$

$f_v = W(.012900)$

$f_v = 3741$ psi

● TENSILE STRESSES @ SECTION B-B

$W = 290,000$ lb

$f_t = F/A_t$

$F = W$

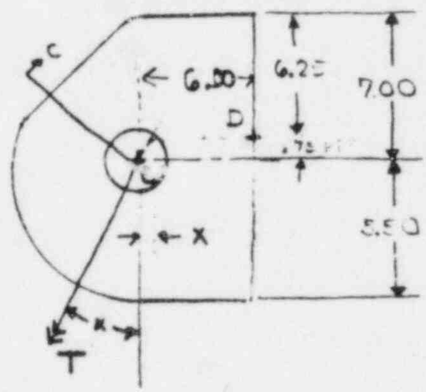
$A_t = \pi(7.95)^2/4$

$= 49.64\ in^2$

$f_t = W(0.02015)$

$f_t = 5849$ psi

LUG ②



● TENSION STRESSES @ SECTION C-C

$T = 126,675$ lb

$f_t = P/A_t$

$P = T/2$

$A_t = (5.37 - \frac{4.027}{2})(3.99)$

$= 13.40\ in^2$

$f_t = T(.03730)$

$f_t = 4725$ psi

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● BEARING @ 4.015 Φ HOLE

$T = 126{,}675$ lb

$f_c = P/A_c$

$P = T$

$A_c = dl = 4.015(3.99)$

$= 16.020 \text{ in}^2$

$f_t = T(0.06242)$

$f_t = \underline{7907}$ psi

TEAR-OUT SHEAR @ 4.015 Φ HOLE

$T = 126{,}675$

$f_v = P/(2A_v)$

$P = T$

$A_v = (5.50 - \frac{4.018}{2})(4.00)$

$= 13.97 \text{ in}^2$

$f_v = T(0.03579)$

$f_v = \underline{4534}$ psi

STRESSES @ LUG ROOT

1) BENDING STRESSES

$T = 126{,}675$

BENDING MOMENT ABOUT POINT D.

ccw+

$\alpha = 40.2611°$

$x = .75 \tan\alpha$

$= 0.6352$ in

$M = T\cos\alpha\,(6.00 - 0.6352)$

$M = 4.094T$ in-lb

$c_{max} = 6.25$

$I = bh^3/12$

$= 4.00(12.5)^3/12$

$= 651.0 \text{ in}^4$

$f_b = Mc/I$

$= 4.094T(6.25)/651 = T(.03930)$

$f_b = \underline{4978}$ psi

2) TENSION @ LUG ROOT

$f_t = P/A_t$

$P = T\sin\alpha$

$A_t = bh$

$= 4.00(7.00 + 5.50)$

$= 50 \text{ in}^2$

$f_t = T\sin\alpha/50$

$f_t = \underline{1637}$ psi

$f_b + f_t = \underline{6615}$ psi

SHEAR @ LUG ROOT

$T = 126{,}675\#$, $\alpha = 40.26°$

$f_v = P/A_v$

$P = T\cos\alpha$

$A_v = bh = 50 \text{ in}^2$

$f_v = T\cos\alpha/50$

$f_v = \underline{1934}$ psi

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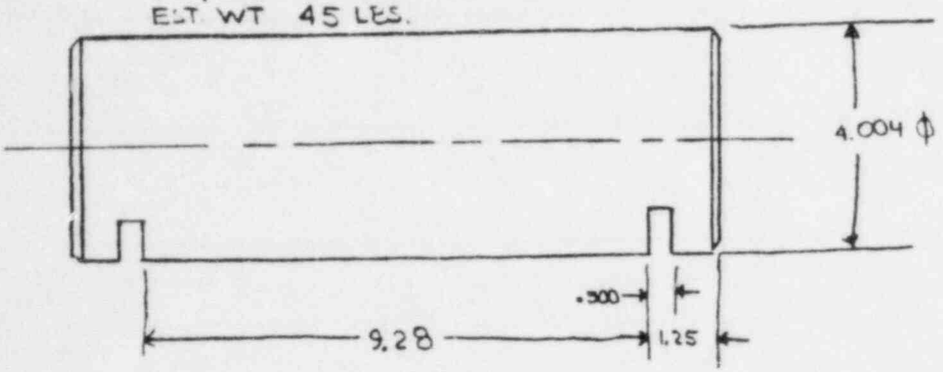
(3)

CLEVIS PIN - 32

MAT'L ASTM A564 TYPE 630 PRECIPITATION HARDENING STAINLESS STEEL, AGE TREATED @ 1150°F FOR 4 HOURS, AIR COOLED.
135,000 PSI MIN TENSILE STRENGTH R_c 28-31
EST. WT 45 LBS.



KEEPER PLATE THICKNESS = .375 in

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CLEVIS PIN ③

SHEAR

$f_v = P/A_v$

$P = T/2$

$A_v = (4.004)^2 \pi/4$

$= 12.5915 \text{ in}^2$

$f_v = T(0.03971)$

$f_v =$ 5030 psi

BEARING

$f_c = P/A_c$

$P_1 = T/2$

$A_{c_1} = [(9.25 - 4.266)/2 - .09]\,4.004$

$= 9.6176 \text{ in}^2$

$f_{c_1} = T(.05199)$

$f_{c_1} =$ 6586 psi

$P_2 = T$

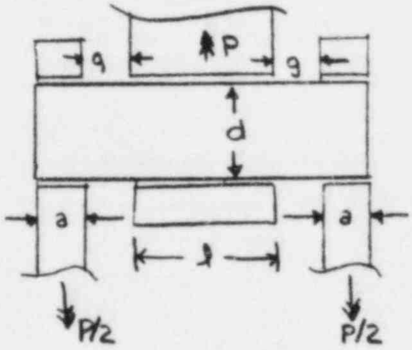
$A_{c_2} = (4.00)(4.004)$

$= 16.016 \text{ in}^2$

$f_{c_2} = T(0.06244)$

$f_{c_2} =$ 7910 psi

BENDING



$l = 4.00$

$a = (9.25 - 4.266)/2 = 2.492$

$g = (4.266 - 4.00)/2 = 0.133$

$d = 4.004$

$P = T$

$f_b = \frac{P}{2}\left(\frac{a}{2} + g + \frac{l}{4}\right)\frac{32}{\pi d^3}$

$= T(0.18875)$

$f_b =$ 23,910 psi

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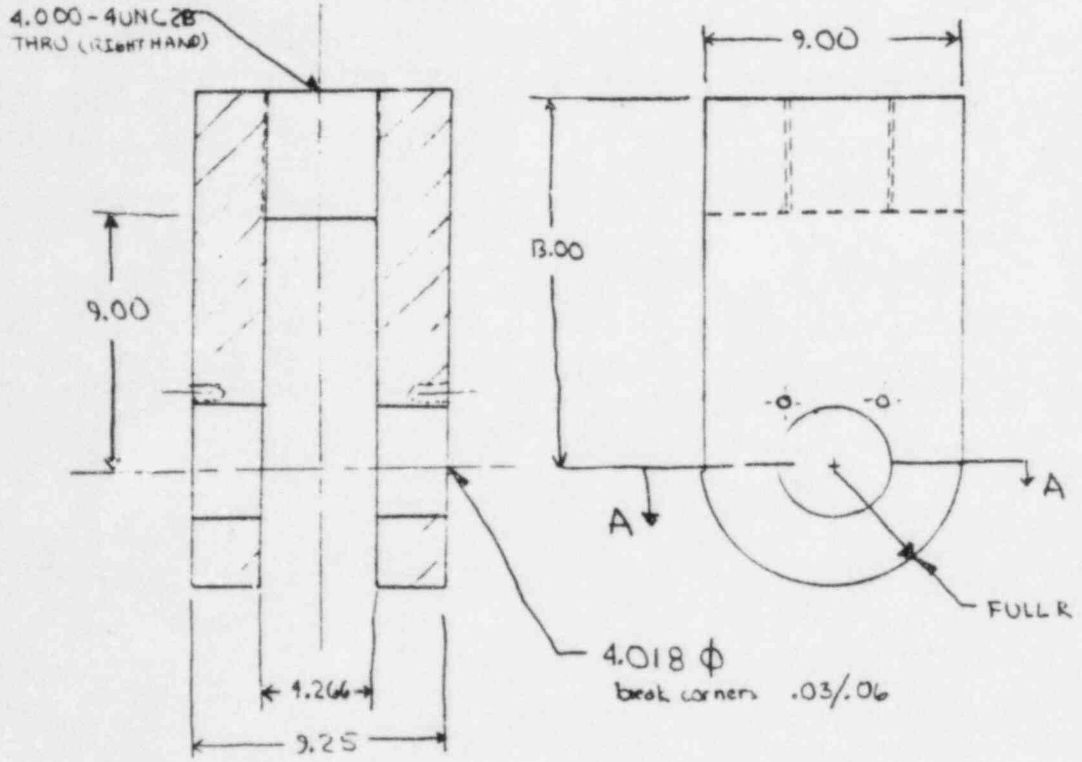
CLEVIS - 31

(4)

MAT'L ASTM A471 STEEL FORGING CLASS 3
EST WT 240 LB



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CLEVIS (4)

TENSION STRESS @ SECTION A-A

$f_t = P/A_t$

$P = T/4$

$A = (9.00 - 4.018)/2 \times (9.25 - 4.266)/2 - (.045)^2$

$= 6.2060 \text{ in}^2$

$f_t = T(.04029)$

$f_t = \underline{5103}$ psi

BEARING STRESS @ SECTION A-A

$f_c = P/A_c$

$P = T/2$

$A_c = (9.25 - 4.266)/2 - 2(.045) \times 4.018$

$= 9.651 \text{ in}^2$

$f_c = T(.05181)$

$f_c = \underline{6563}$ psi

SHEAR TEAR-OUT

$f_v = P/2A_v$

$P = T/2$

$A_v = 6.2060 \text{ in}^2$

$f_v = T(.04029)$

$f_v = \underline{5103}$ psi

THREAD SHEAR

$f_v = P/A_v$

$A_v = \pi D_{pitch} \ell/2$

for 4.000 - 4UNC 2B

$D_{pitch}^{*} = 3.8376$ in

$A_v = \pi(3.8376)(13-9)/2$

$= 24.112 \text{ in}^2$

$P = T$

$f_v = T(.04147)$

$= \underline{5253}$ psi

* MARKS 8-10

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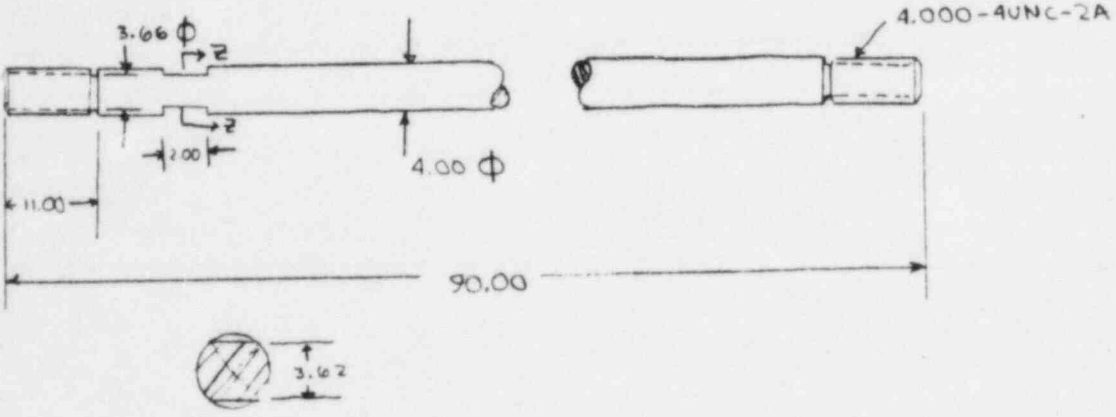
(5)

SLING ROD - 30

MAT'L - ASTM-A434 CLASS BC AISI 4340 STEEL, TURNED, GROUND, & POLISHED. MINIMUM YIELD STRENGTH 85,000 PSI; OR ASTM A588 NORMALIZED, TURNED, GROUND, AND POLISHED. MINIMUM YIELD STRENGTH 46,000 PSI.

EST WT - 320 LB



SECTION Z-Z

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SLING ROD (5)

THREAD SHEAR

$f_v = P/A_v$

$P = T$

$A_v = \pi D_{pitch} \times l/2$

MARKS 8-10: $D_{pitch} = 3.8376$

$l = (13-9) = 4$ in

$A_v = 24.112$ in²

$f_v = T(.04147)$

$f_v =$ **5253 psi**

TENSION @ THREAD RELIEF

$f_t = P/A_t$

$P = T$

$A_t = (3.66)^2 \pi/4$

$= 10.521$ in²

$f_t = T(0.09505)$

$f_t =$ **12,041 psi**

TENSION @ THREAD

$f_t = F/A_t$

$P = T$

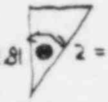
MARKS 8-10 $A_t = 11.0805$ in²

$f_t = T(0.09025)$

$f_t =$ **11,433 psi**

AREA @ Z-Z

$A_{z-z} = \pi(4.00)^2/4 - 2A_s$



$\frac{3.62}{2} = 1.81$, $2 = \frac{4.00}{2}$, $\theta = 25.177°$

$\sqrt{2^2 - 1.81^2} = 0.8508$

$A_s = \frac{2(25.18)}{360}\left(\frac{\pi}{4}\right) 4^2 - [0.8508(1.81)/2]2$

$= 1.758 - 1.540$

$A_s = 0.2179$ in²

$A_{zz} = 12.13$

$A_{z-z} > A_{THREAD\ RELIEF}$

$\therefore f_{t_{z-z}} < f_{t_{THREAD\ RELIEF}}$

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The spreader joint consists of

(6) - the clevis
(7) the clevis pin
(8) the spreader block lug
(11) the leg lug

The bearing stresses acting between these items are calculated on the following three pages, entitled spreader joint. The resulting moments forces and stress distributions are then used as inputs ~~to~~ determine the listed items' stresses in the following calculations on these items.

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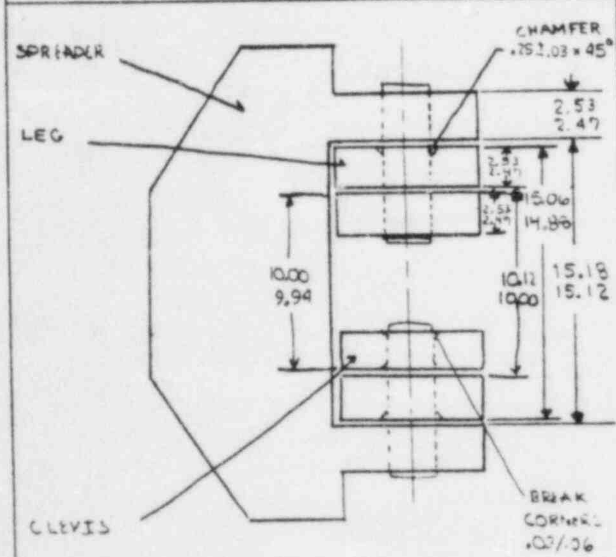
SPREADER JOINT



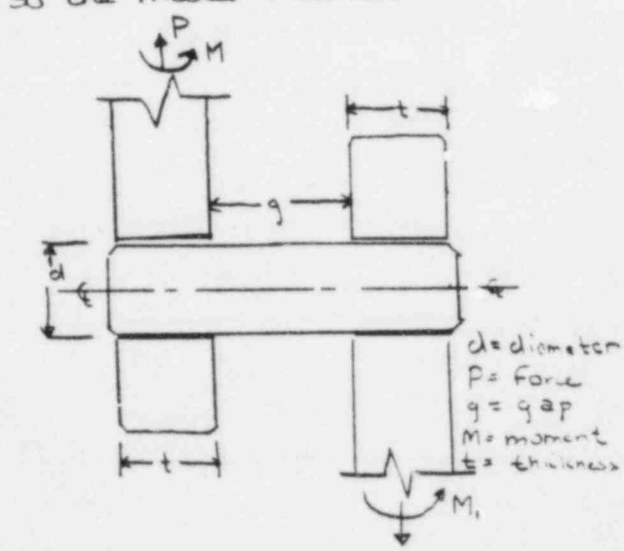
W = Weight to be lifted = 290,000#
T = force on clevis = 126,675#
K = force on spreader = 81,867#
L = force on leg = 96,667#

*The distribution of the bearing stess between lug and pin is assumed to be similiar to the stess distribution that would be obtained in a rectangular cross-section of width d and depth t subjected to a load P and moment M.

* As assumed in section 9.5.1" Lug Bearing Strength for Single Shear Joints Under Uniform Axial Load"

from TECHNOLOGY INC, REPORT TI-219-69-24

All lugs are of similiar thickness so the model becomes:



Only two lugs are needed in the model as the leg carries only vertical forces and the spreader carries only horizontal forces. The clevis has both horizontal and vertical components acting on it, so the stresses will be superimposed for the clevis.

The stress due to the force P would be

$f_t = P/(dt)$

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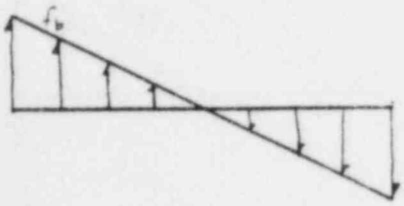
SPREADER JOINT

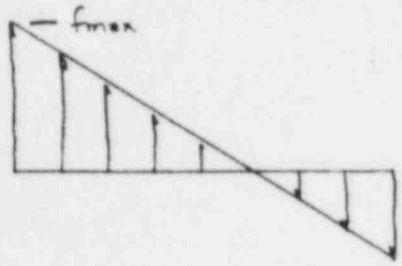
The stresses due to the moment M would be

f_b = bending stress = Mc/I

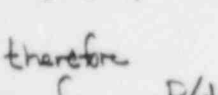


When these stresses are combined the result is

$f_{max} = P/dt + Mc/I$



For a rectangular section



$I_x = bh^3/12$

and $c = h/2$

therefore

$f_{max} = P/dt + 6M/dt^2$

The moment produced by the joint will be

$M_{TOTAL} = P(t+g)$

Dividing the joint moment between the two ends

$M = P/2(t+g)$

LEG MOMENT:

In the vertical plane

$M_{LEG} = \left(\frac{96,667}{2}\right)\left(\frac{1}{2}\right)(2.50+0) = 60,416$ in-lb

In the horizontal plane

$M_{SPREADER} = \left(\frac{81,867}{2}\right)\left(\frac{1}{2}\right)(2.5+2.5) = 102,334$ in-lb

The combined effects of the horizontal (spreader) and vertical (leg) moments acting on the sling leg lug are obtained using the method of sec 10-11, page 336, of E.P. Popov's Mechanics of Material, 2nd Edition.

Clevis Moment $= \sqrt{60,416^2 + 102,334^2}$

$= 118,837$ in-lb

Therefore the bearing stress component due to the moment is $f_b = 6M/dt^2$ where M is given above.

Clevis: $d_{pin} = 3.992"$ $t_{min} = 2.47 - 2(.06) = 2.35"$

Leg: $d_{pin} = 3.992"$ $t = 2.44 - (.28) = 2.16"$

Spreader: $d_{pin} = 3.992"$ $t = 2.47$ in

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SPREADER JOINT

The combined bearing stresses are ($f_{max} = f_{b_3} + f_{b_2}$)

CLEVIS:

$P/dt + 6M/dt^2$

$\left(\frac{126,675}{2}\right) / (3.992 * 2.35) + 6(118,837) / (3.992 * 2.35^2)$

$f_B = 39,095$ psi

SPREADER:

$\left(\frac{81,867}{2}\right) / (3.992 * 2.47) + 6(102,334) / (3.992 * 2.47^2)$

$f_B = 29,362$ psi

LEG:

$\left(\frac{290,000}{3 * 2}\right) / (3.992 * 2.16) + 6(60,416) / (3.992 * 2.16^2)$

$f_B = 25,068$ psi

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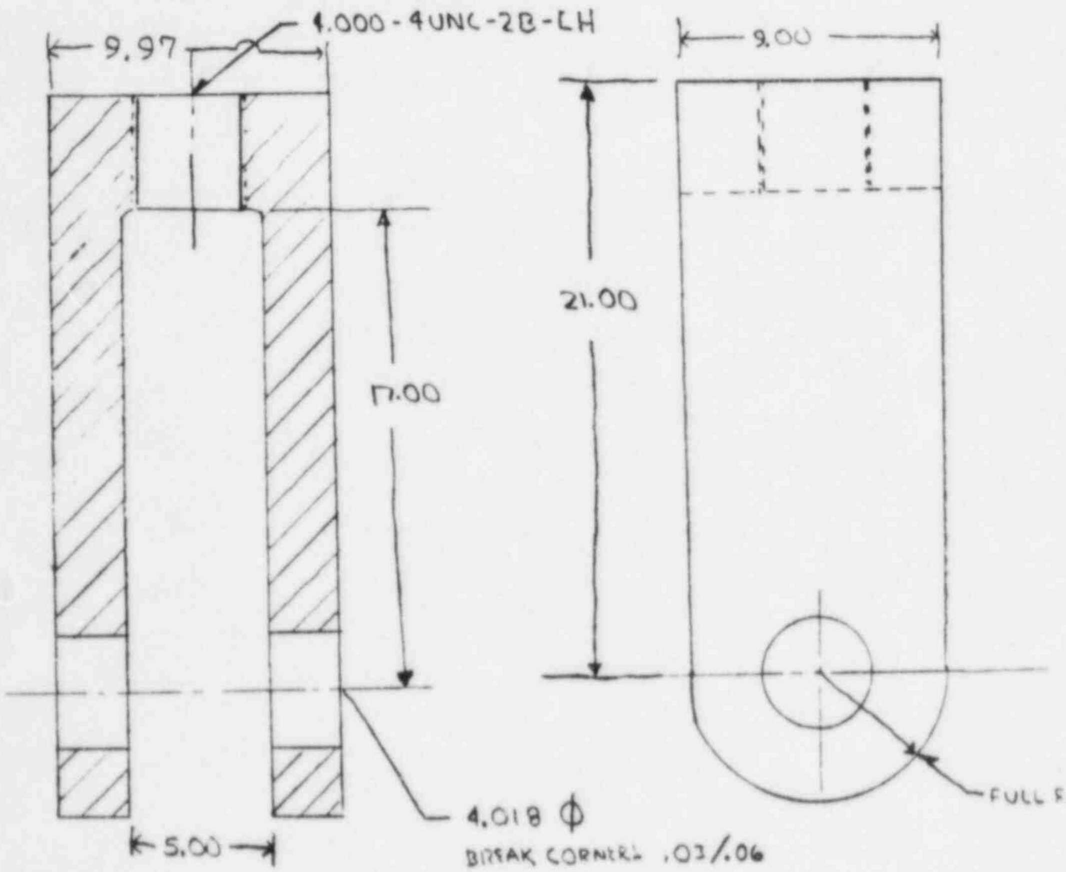
(6)

CLEVIS-27

MAT'L - ASTM A471 STEEL FORGING CLASS 3
EST WT 375 LB



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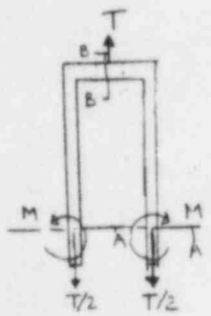


FORCES ON CLEVIS

FROM BEARING STRESS CALCS

M_{max} = 118,837 in-lb

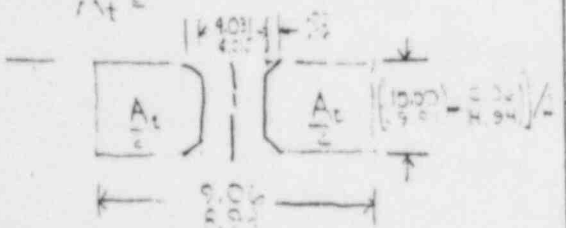
T = 126,675#

TENSION STRESS @ SEC A-A

$f_t = P/A_t$

P = T/2 = 126,675/2 = 63,338#

A_t =



A_t = [8.94 − 4.031] * [9.94 − 5.06]/2 − (.06²)(2) = 11.97 in²

f_t = 63,338/11.97

f_t = 5291 psi

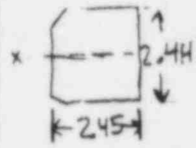
BENDING STRESS @ A-A

$f_b = Mc/I$

M = 118,837 in-lb/2

c = (9.94 − 5.06)/2/2

= 1.22 in



I_x = 2.45 * 2.44³/12 = 2.966 in⁴

f_b = 118,837 * 1.22 / 2.966 · 2

f_b = 24,440 psi

COMBINED MAX. BENDING AND TENSILE @ SEC A-A

$f_b + f_t$ = 24,440 + 5291

$f_{combined}$ = 29,741

THREAD SHEAR

$f_v = F/A_v$

$A_v = \pi D_{pitch}\, l/2$

l_{min} = 20.94 − 17.06 = 3.88

for 4.000 − 4UNC − 2B

D_{pitch}* = 3.3276

* MARKS HANDBOOK

A_v = 23.39 in²

P = T = 126,675#

f_v = 5416 psi

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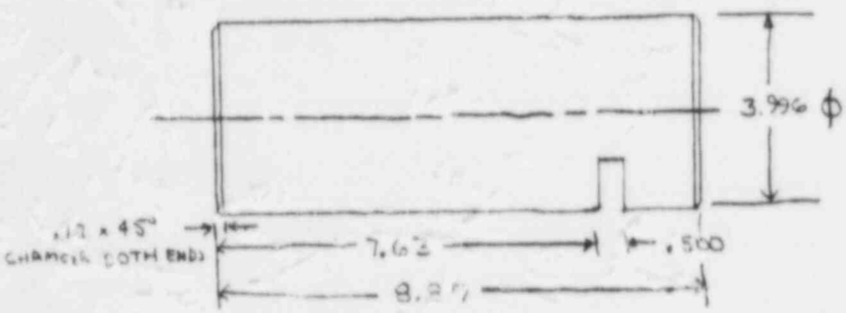
(7)

CLEVIS PIN - 28

MAT'L · ASTM A564 TYPE 630 PRECIPITATION HARDENING STAINLESS STEEL, AGE TREATED @ 1150°F FOR 4 HRS, AIR COOLED. 135,000 PSI MIN TENSILE STRENGTH Rc 27-31

EST WT 32 LB



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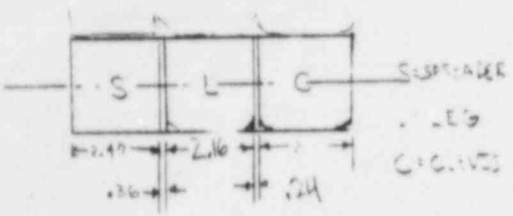
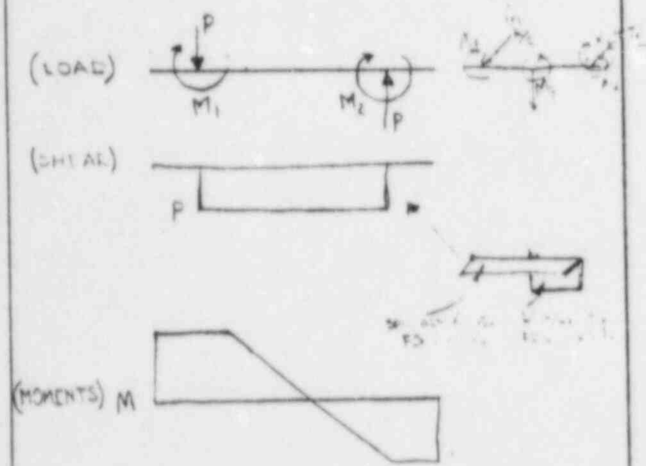
PIN (07)**

WORST-CASE DIMENSIONS





FOR THE SP[illegible]-CLEVIS FORCE PLANE

M = 102,334 in-lb

FOR THE LEG-CLEVIS FORCE PLANE

M = 60,416 in-lb

COMBINED MOMENTS ON THE CLEVIS IS

M = 118,837 in-lb

THE SHEAR STRESS IS

$f_v = P/A_v$ where

$A_v = \pi d^2/4 = \pi(3.992)^2/4$

$= 12.516 \text{ in}^2$

$f_v = 81,867/2/12.516$

$= 3,270$ psi

BY SIMILIAR AN[illegible]
(SEE B[illegible])
FOR THE LEG-CLEVIS PLANE

$f_v = 290,000/3/2/12.516$

$f_v = 3862$ psi

$M_{max} = 60,416$ in-lb

COMBINING STR[illegible] DUE TO TH[illegible] MOMENTS AND S[illegible]

FOR THE CLEVIS

$M_{max} = 118,837$ in-lb

$c = d/2 = 3.992/2 = 1.996$

$I = \pi d^4/64 = \pi(3.992)^4/64$

$= 12.466 \text{ in}^4$

$f_{b_{max}} = Mc/I = 118,837(1.996)/12.466$

$= 19,027$ psi

$f_{v_{max}} = \sqrt{3270^2 + 3862^2}$

$= 5,060$ psi

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S.O.: TY6P-188	CALC. NO.	FILE NO.	GROUP: CHE

THE BENDING STRESS IS CONSERVATIVE IN THAT THE OTHER LUGS (SPREADER AND LEG) WILL CARRY SOME OF THE MOMENT; AND THE LUGS WOULD PROVIDE SUPPORT PREVENTING LARGE DEFLECTIONS. ALSO NOTE THAT BENDING OF [illegible] [illegible] HAS [illegible] [illegible] CF 1.70 ([illegible] 44)

THE MAXIMUM BENDING STRESS WOULD BE THE SAME AS THE MAXIMUM LUG [illegible]

f_b 39,095 PSI

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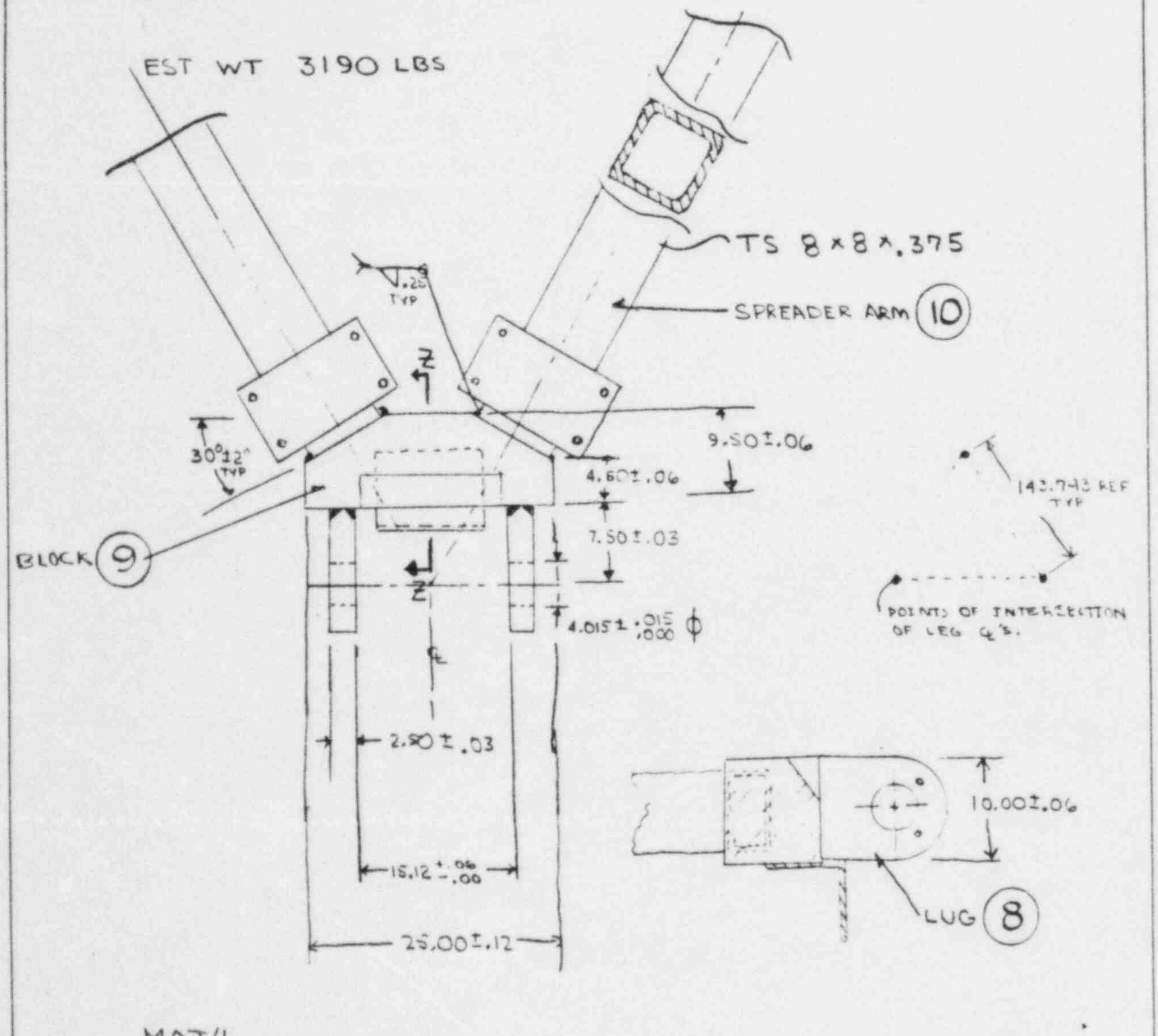
(8) (9) (10)

SPREADER ASSEMBLY



MAT'L

(8) LUG: ASTM A-516 GR. 70 STL PLATE. NORMALIZED

(10) SPREADER ARM: ASTM A-500 GR. B

(9) BLOCK: ASTM A-350 LF1 FORGING STL.

WELDS: E7018 ELECTRODES

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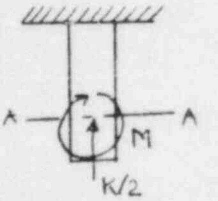
SPREADER LUG (08)



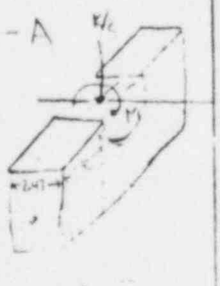
$M_{max} = 102,334$ in-lb
$K = 81,867$ #

TENSILE @ A-A

$f_t = P/A_t$
$A_t = 9.94 - 4.030) .48$ [illegible]
$= 14.599$ in
$P = K/2 = 81,867$ #/2

$f_t = 81,867/2 / 14.599$
$= 2,802$ psi

BENDING @ A-A



$f_b = Mc/I$

$M = 102,334$ in-lb/2
$c = 2.47/2 = 1.235$
$I = bh^3/12 = 2.93 (3.4[illegible])^3/12$
$= 3.742$ in^4

$f_b = (102,334/2) \times 1.235 / 3.742$
$= 16,887$ psi

COMBINED TENSILE AND MAXIMUM BENDING

$f_{t_{com}} = f_b + f_t$
$16,887 + 2802$
$\underline{19689 \text{ psi}}$

BEARING STRESS
Calculated at Spreader Joint bearing stress calculations
$\underline{f_t = 29,362 \text{ psi}}$

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SPREADER ARM

(10)

FROM AISC MANUAL OF STEEL CONSTRUCTION 7TH ED. P 5-48

ASSUMING L = 143.742

AND $K_\ell' = 1$

K_ℓ = EFFECTIVE LENGTH FACTOR

EFFECTIVE LENGTH ≈ 12 FT

$P_{ALLOWABLE}$ = 248,000 LBS

A = 10.8 in²

I (in⁴) = 102 in⁴

r (in) = 3.06 in

– ALLOWABLE [illegible]

P 5-138

$K_\ell = 1$

$f_{ALLOWABLE}$ = 248,000/10.8 = 22,936 psi

COMPRESSIVE STRESS IN SPREADER ARM

$f_c = P/A_c$

$P = S = 47{,}266^{\#}$

$A_c = 10.8\ in^2$

$f_c = 47{,}266^{\#}/10.8$

f_c = 4,376 psi

S = compressive stress in spreader arm

$K = 81{,}867^{\#}$

$K/2 = S \cos 30°$

$S = 47{,}266^{\#}$

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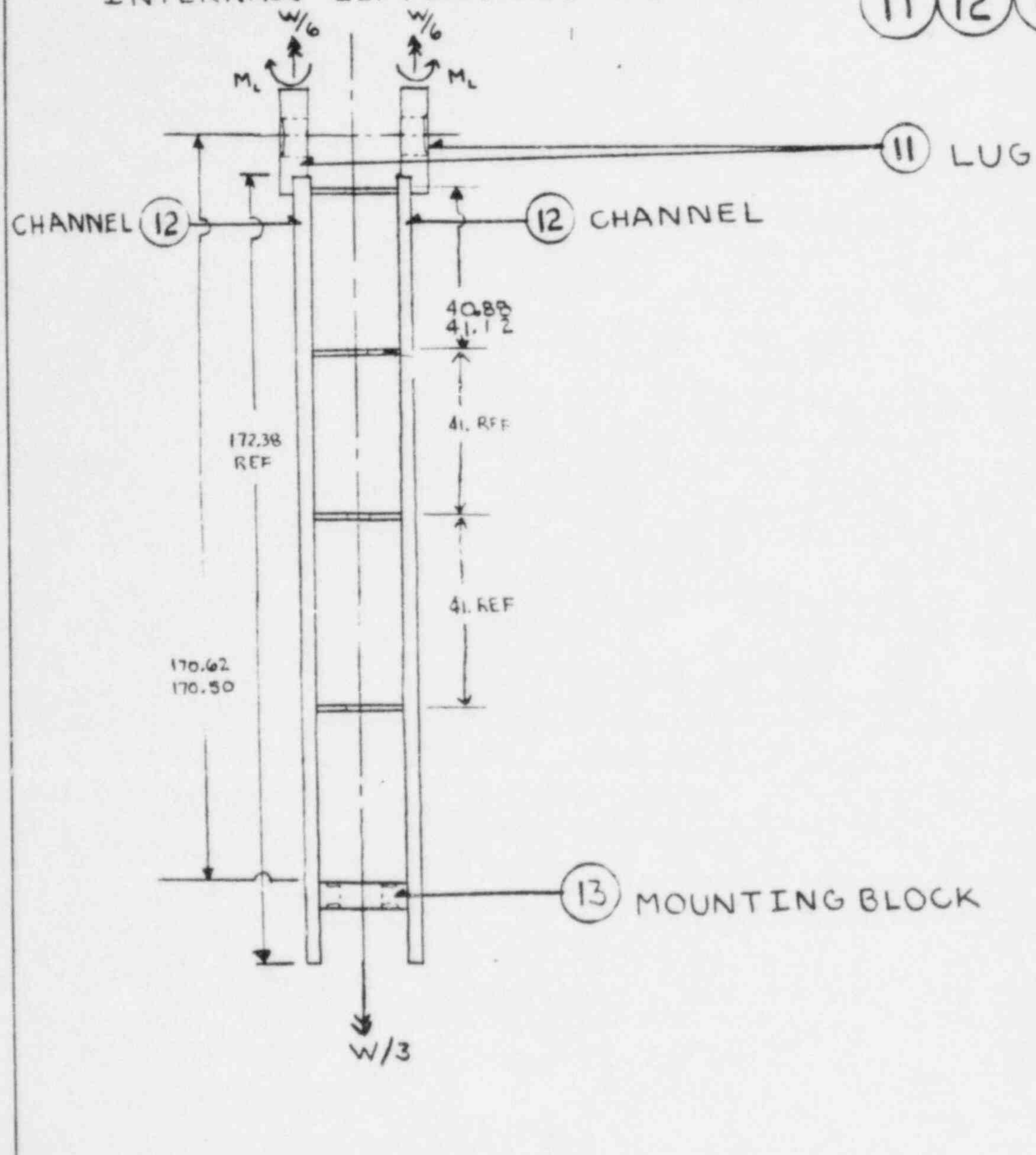
INTERNALS LIFTING RIG LEG ASSEMBLY (11) (12) (13)



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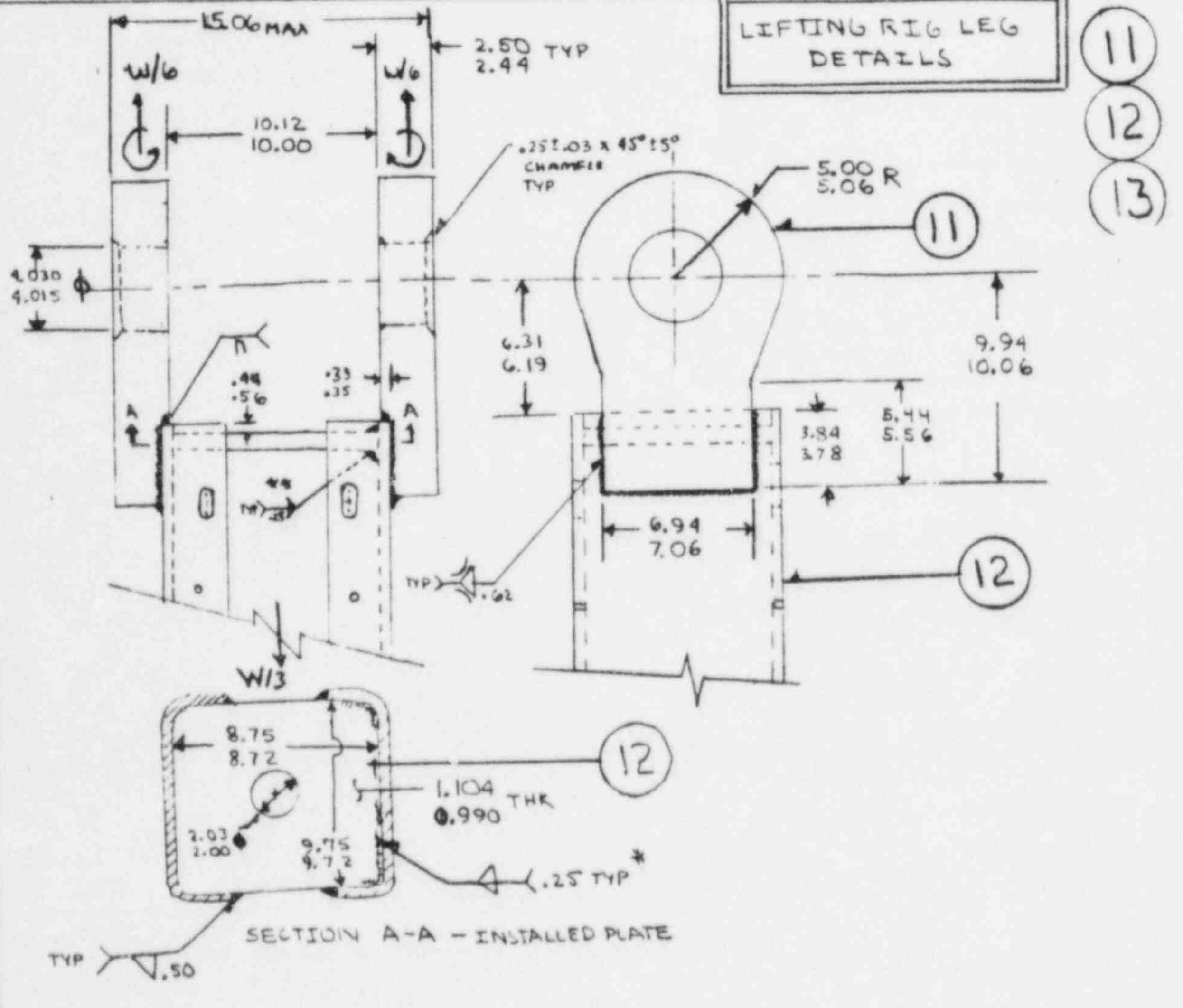

(11) LEG LUGS

MAT'L ASTM A516, GRADE 70 STEEL, NORMALIZED

(12) PLATES AND CHANNELS

MAT'L ASTM A 36 CS, HR

(13) MOUNTING BLOCK

MAT'L ASTM A 350, LF 1 FORGING STEEL (NO CVN TEST REQ'D)

** is same weld as *

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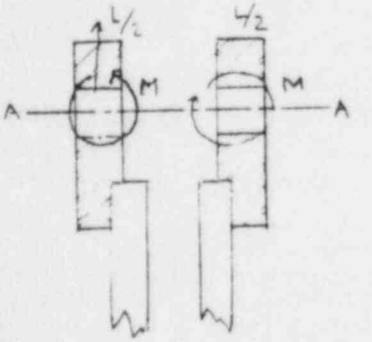
LEG LUG (11)



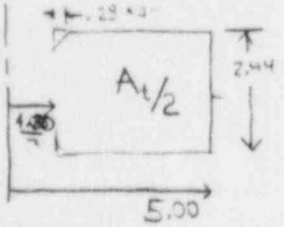
M = 60,416 in-lb
L = 96,666#

TENSILE STRESS @ A-A

$f_t = P/A_t$

$P = L/2 = 48{,}333\#$

$\frac{1}{2}A_t = 2.44\,(5.00 - \frac{4.030}{2}) - .28^2/2$



$A_t = 14.53\ in^2$

$f_t = 48{,}333 / 14.53$

$f_t = 3{,}327\ psi$

BENDING @ A-A

$f_b = Mc/I$

$M = (60{,}416\ in\text{-}lb/2)$

$c = (2.44/2)$

$I = bh^3/12$

$= 2.955 * 2.44^3/12$

$= 3.614\ in^4$

$f_b = 60{,}416 * 2.44/2/2/[illegible]$

$= 10{,}198\ psi$

COMBINED MAX BENDING AND TENSILE AT A-A

$f_{t\,comb} = 10{,}198 + 3{,}327$

$f_{t\,comb} = \underline{13{,}525\ psi}$

BEARING

$f_b = 25{,}068\ psi$

Which is the same as the clevis pin-to-leg bearing stress calculated in the spreader joint calculation.

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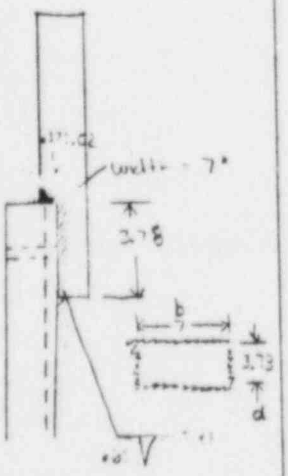
LEG LUG WELD

REFERENCE:

LINCOLN ELECTRIC CO.
[illegible]
[illegible]
D 910.17 page 3
E 70-18 ELECTRODES

If the upper weld, which is a penetration weld, is assumed equivalent to the [illegible] fillet weld for simplicity, (and it is conservative) assume that the throat width is .37
.37 < .62(.707))



$$S_w = \frac{d}{3}(2b+d)$$

$$= \frac{3.78}{3}(3(7)+3.78)$$

$$= 31.22$$

$$S = 31.22(.37)$$

$$= 11.55 \text{ in}^3$$

$$f_{v_{bend}} = M/S = 60{,}416/11.55$$

$$= \underline{5231 \text{ psi}}$$

$$f_{v_{shear}} = \frac{290{,}000/3/2}{[2(7)+2(3.78)].37}$$

$$= 6059$$

for fillets, both stresses are treated as shear, so

$$f_{v_{combined}} = 6059 + 5231$$

$$\underline{f_{v_{comb}} = 11{,}290 \text{ psi}}$$

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LEGS

(12)

- CROSS-SECTIONAL AREA OF LEG CHANNELS*

$$A = (2.97 - 1.00 - 0.490)(14)(.490) + (2)(8.78 - 2)(.490) + \frac{\pi}{4}(2.98^2 - 2.00^2) = 13.379\ in^2$$

* SEE MOUNTING BRACKET ... (13)

TENSILE STRESS IN LEGS

$f_t = P/A_t$

A_t 13.379 in²

$P = W/3$

$f_t = W(0.024915)$

f_t = 7724 psi

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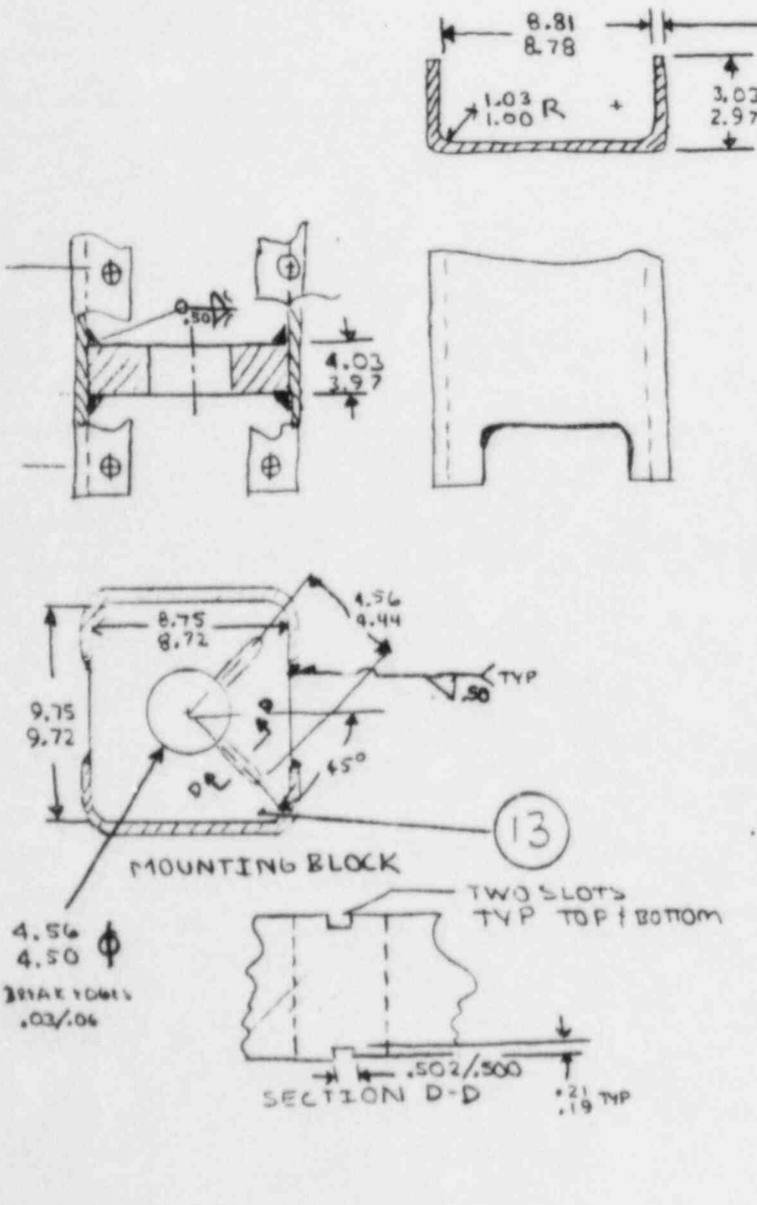
MOUNTING BLOCK DETAILS

(13)



THE LOWER ASSEMBLY SEES ONLY THE INTERNAL'S WEIGHT W= 260,000#
SO ITEMS 13 THROUGH 19 WILL USE THIS DESIGN WEIGHT INSTEAD OF THE 290,000# ASSUMED FOR THE PREVIOUS ITEMS, AS TABULATED ON PAGE 3

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MOUNTING BLOCK

(13)

- BEARING OF LOAD NUT TO MOUNTING BLOCK

$D_1 = (5.995 - 2(.21))$

$D_2 = (4.56 + 2(.06))$

$A_1 = D_1^2 \pi/4 = 24.4107 \text{ in}^2$

$A_2 = D_2^2 \pi/4 = 17.2021 \text{ in}^2$

$A_3 \approx (D_1 - D_2)(2)(.502)$

$= .8986 \text{ in}^2$

$f_c = P/A_c$

$A_c = A_1 - A_2 - A_3$

$= 6.310 \text{ in}^2$

$P = W/3$

$f_c = W(.05283)$

$f_c =$ 13,736 psi

- SHEAR IN MOUNTING BLOCK WELDS.

$f_v = P/A_v$

$P = W/3$

$A_v = 2(.707)[\pi(2.) + 2(8.78 - 2.) + 4(2.97 - .585 - 1.)] \times .50 + .707(.50)(4)(3.97)$

$= 14.587 \text{ in}^2$

$f_v = W(0.014149)$

$f_v =$ 3,679 psi

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1	2/14/83	[signature] 2/83	[signature] 2/83	

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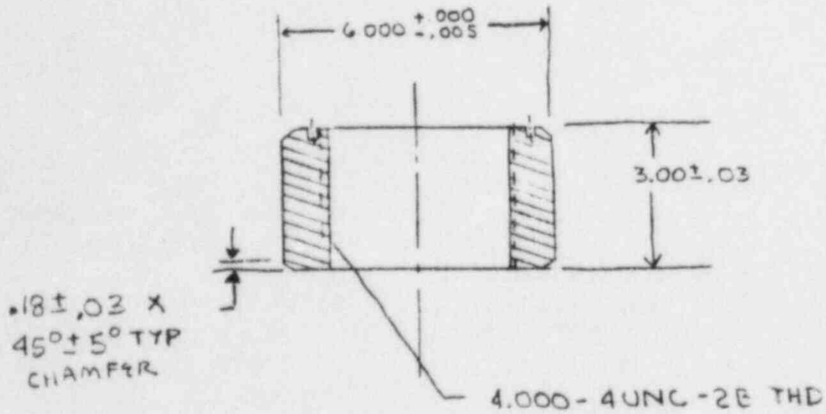
(14)

LOAD NUT- 08

EST WT 17#

MAT'L - ASTM A 276, TYPE 304, HOT ROLLED, COND A



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LOAD NUT

(14)

- THREAD SHEAR

$f_v = P/A_v$

$A_v = \pi D_{pitch}\, l/2$

for 4.000 - 4UNC-2B THD

[M-8-10] $D_{pitch} = 3.8376$

$l = 2.97$

$A_v = \pi(D_p)\,2.97/2 - 2.97(.52)^*$

$A_v = 16.359\ in^2$

$P = W/3$

$f_v = W/3A_v$

$= W(.02038)$

f_v = 5299 psi

* for notch cut out of rod housing

- BEARING OF LOAD NUT TO MOUNTING BLOCK

$A_1 = (5.995 - 2(.21))^2 \frac{\pi}{4}$

$= 24.4107\ in^2$

$A_2 = (4.56 + 2(.06))^2 \frac{\pi}{4}$

$= 17.2021\ in^2$

$A_3 \approx (D_1 - D_2)(2)(.502) =$

$.8986\ in^2$

$f_c = P/A_c$

$P = W/3$

$A_c = A_1 - A_2 - A_3$

$= 6.310\ in^2$

$f_c = W(.05283)$

f_c = 13,736 psi

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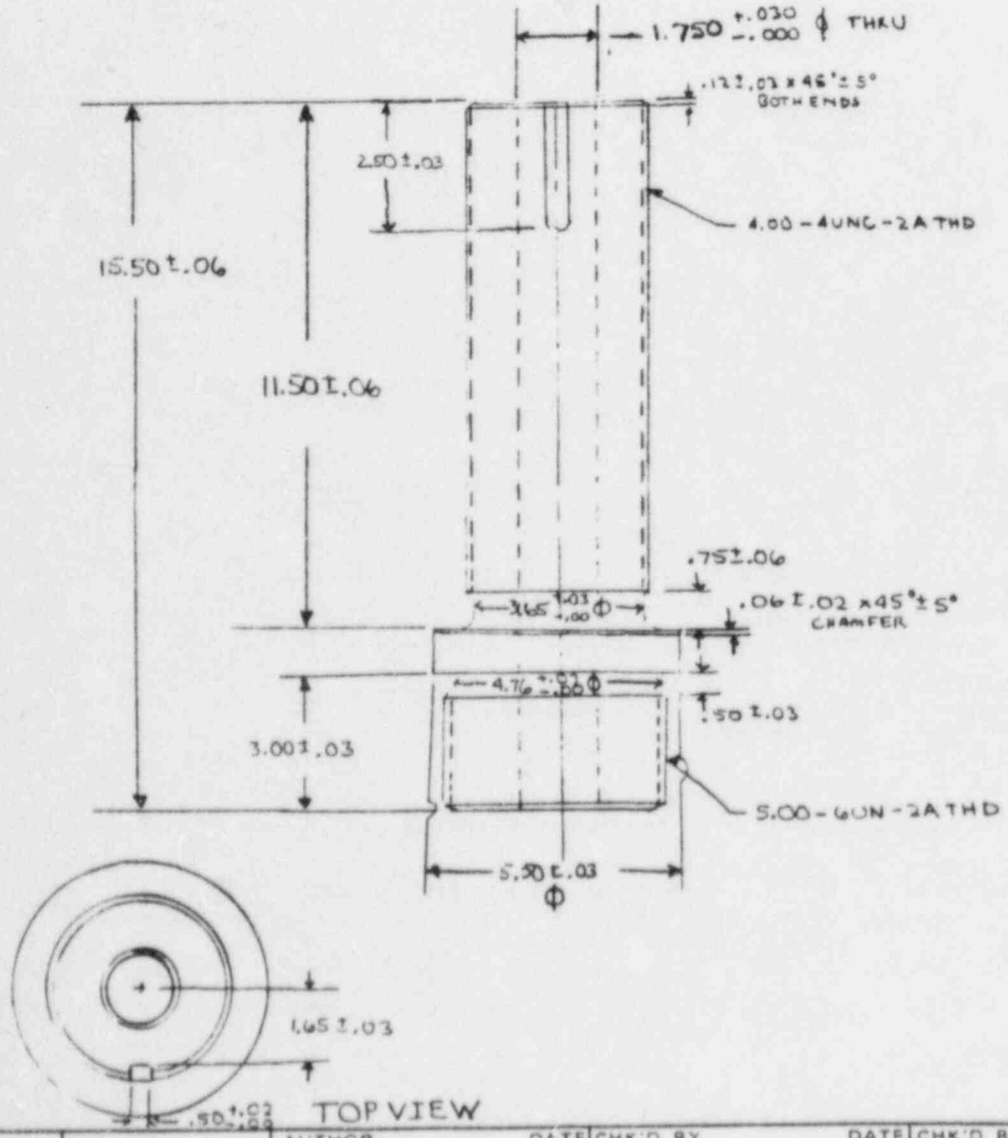
(15)

ROD HOUSING - 06

EST WT 55#

MAT'L - ASTM A 276, TYPE 304, HOT ROLLED, COND A.



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ROD HOUSING

(15)

- TENSION AT THREAD RELIEF

$f_t = P/A_t$

$P = W/3$

$A_t = \frac{\pi}{4}(3.65^2 - 1.78^2)$

$= 7.975 \text{ in}^2$

$f_t = W(0.04180)$

$f_t =$ 10,868

- THREAD SHEAR ON LOWER THREADS

$f_v = P/A_v$

$A_v = \pi D_{pitch}\, l/2$

for 5.00 - 6UN - 2A THD

(M 8-10) $D_{pitch} = D - \frac{3\sqrt{3}}{8N} = 4.8917$

$l = 2.97 - .53 - .15$

$A_v = \pi(D_p)(2.29)/2$

$= 17.596 \text{ in}^2$

$f_v = \frac{W}{3A_v} = W(0.01894)$

$f_v =$ 4,924 psi

- THREAD SHEAR ON UPPER THREADS

$f_v = P/A_v$

$A_v = \pi D_{pitch}\, l/2 - l(.52)$

for 4.000 - 4UNC - 2B THD

$D_{pitch} = 3.8376$

$l = 2.97$

$A_v = \pi(D_p)(2.97)/2 - 2.97(.52)$

$A_v = 17.903 \text{ in}^2$

$P = W/3$

$f_v = W/3A_v$

$= W(.02038)$

$f_v =$ 5,299 psi

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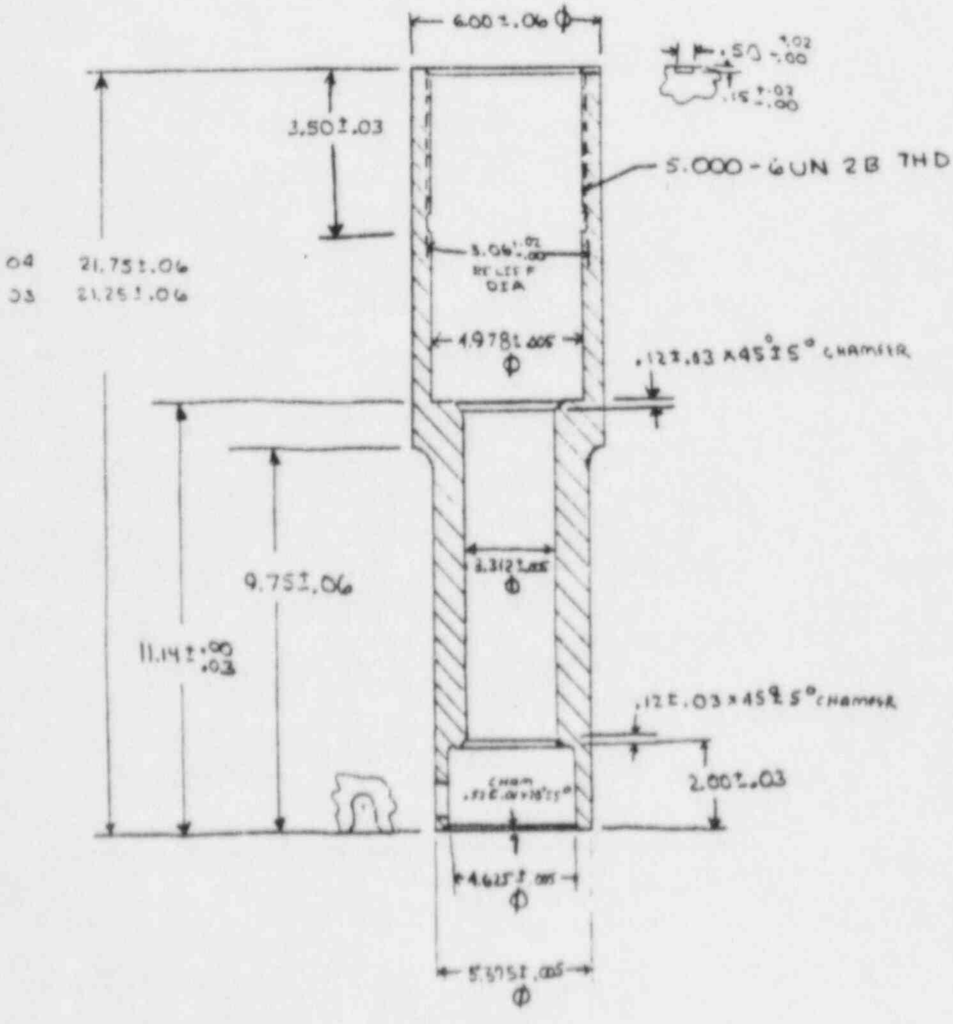
(16)

GUIDE SLEEVE - 04 - 60

MAT'L - ASTM A 276, TYPE 304 SST,
HOT ROLLED, ANNEALED, & PICKLED COND A.



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S.O.: TYGP-188	CALC. NO.	FILE NO.	GROUP: CHE

GUIDE SLEEVE

(16)

- THREAD SHEAR

$f_v = P/A_v$

$P = W/3$

$A_v = \pi D_{pitch}\, l/2$

$l = 2.97 - .53 - .15$

for 5.00-6UN-2A THD

$D_{pitch} = 4.8917$

$A_v = \pi(4.8917)(2.29)/2$

$= 17.596 \text{ in}^2$

$f_v = \frac{W}{3A_v} = W(0.01894)$

$f_v = \underline{4,924} \text{ psi}$

- TENSION AT THREAD RELIEF

$f_t = P/A_t$

$P = W/3$

$A_t = \frac{\pi}{4}(5.94^2 - 5.08^2)$

$= 7.443 \text{ in}^2$

$f_t = W(0.04478)$

$f_t = \underline{11,643} \text{ psi}$

- BEARING OF GUIDE SLEEVE TO BOLT

$A_1^* = [4.785 - 2(.11)]^2 \frac{\pi}{4}$

$A_2 = [3.317 + 2(.15)]^2 \frac{\pi}{4}$

$A_c = A_1 - A_2 = 6.092 \text{ in}^2$

$f_c = P/A_c$

$P = W/3$

$f_c = W(0.05472)$

$f_c = \underline{14,227} \text{ psi}$

* Nominal dimensions, and centroidally aligned

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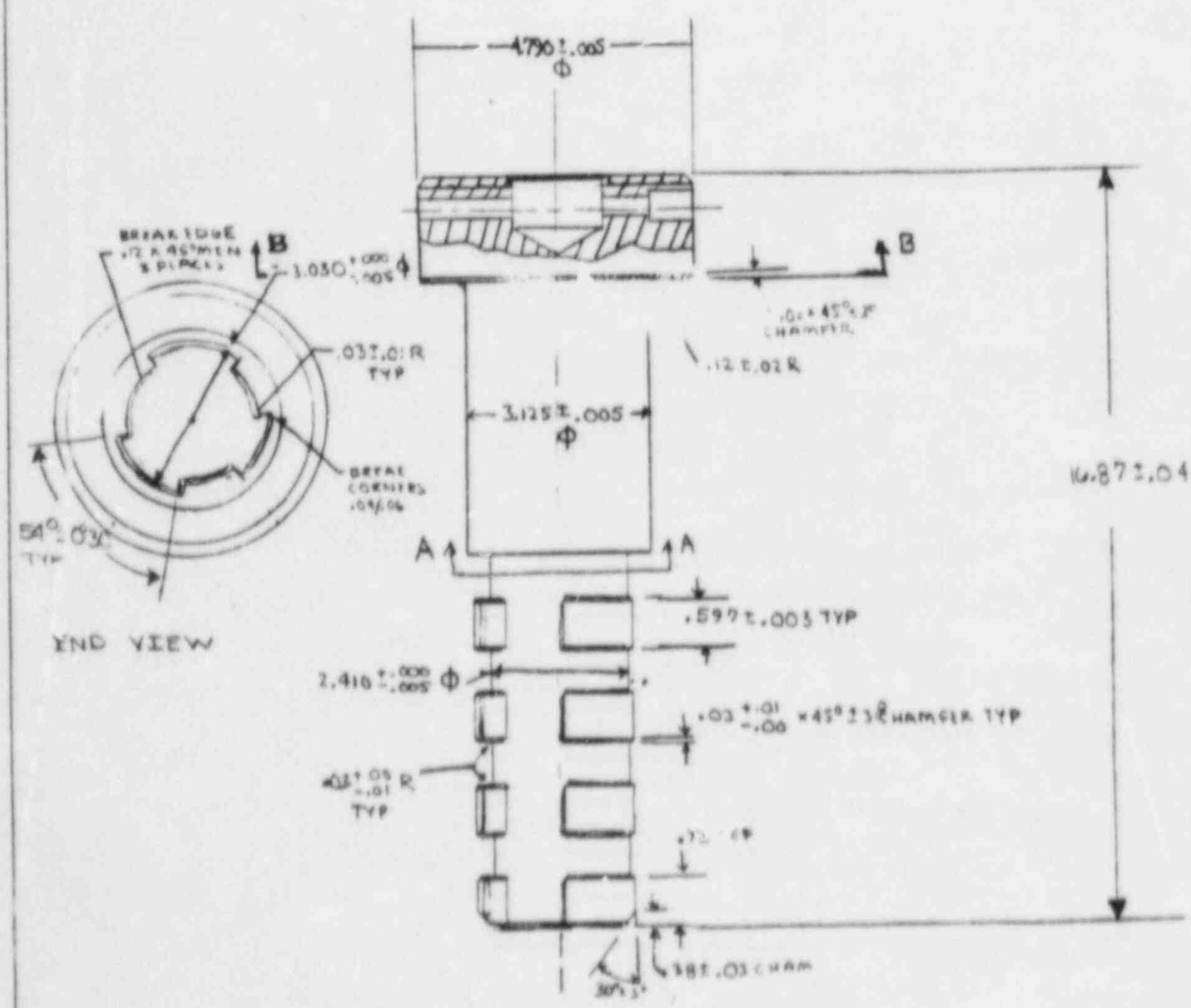
ROTO-LOCKSTUD-05

(17)

EST WT 32#

MAT'L- ASTM A564 TYPE 630 17-4 PRECIPITATION HARDENING STAINLESS STEEL. AGE TREATED @ 1100°F FOR 4 HRS AND AIR COOLED. 140,000 PSI MIN TENSILE STRENGTH



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ROTO-LOCK STUD*

(17)

$f_v = (W/N)(0.4920)$

$f_v =$ 10,560 psi

TOTAL LOAD IS W

LOAD PER STUD IS W/3

N = NUMBER OF LANDS

TENSILE STRESS AT SEC A-A

$f_t = P/A$

$P = W/3$

$A = \pi d^2/4$

$= \pi (2.408)^2/4$

$= 4.554\ in^2$

$f_t = W/(3 \times 4.554)$

$= W(.07319)$

$f_t =$ 19,029 psi

SHEAR OF STUD LANDS

$f_v = P/A_v$

$A = L_c d$

L_c = LENGTH OF LANDS

d = DEPTH OF LANDS

$d = .597$

$L_c = \frac{54}{360} \pi (2.408) \times N$

$P = W/3$

$A = 0.6774\ N$

COMBINED SHEAR AND BENDING IN LANDS

$f_b = M/Z$

$Z = L_c d^2/6$

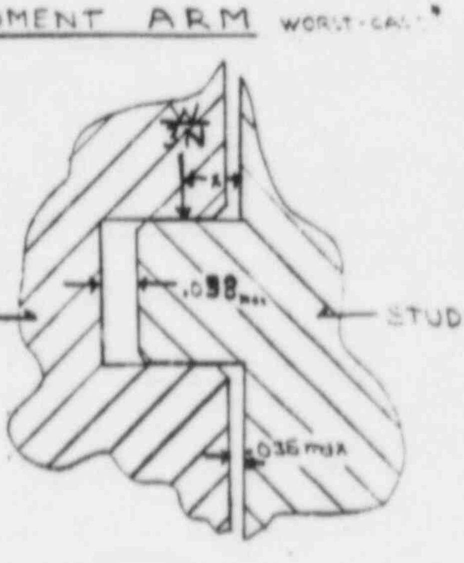
$= N \frac{54}{360} \pi (2.408)(.597)^2/6$

$= N(.06740)$

M = BENDING MOMENT = Px

P = W/3

MOMENT ARM WORST-CASE*



CHAMFERS .04 × 45° MAX

* ASSUMING MINIMUM DIMENSIONS ON THE STUD AND MAXIMUM DIMENSIONS ON THE INSERT, AND THAT STUD IS TIGHT AGAINST RIGHT SIDE.

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w = width of bearing surface

$= (3.025 - 2.405)/2 - .035 - 2(.04)$

$w = .195_{min}$

x = moment arm of force

$= \frac{W}{2} + .04 + .035$

$x = .1725_{max}$

$f_b = \frac{W}{3}(.1725)/(.06740\,N)$

$= \frac{.1725}{.06740}\frac{W}{(N)3}$

$f_b = \frac{W}{N}(.8531)$

$f_{v_{max}} = \left[\left(\frac{f_b}{2}\right)^2 + f_v^2\right]^{1/2} + \frac{f_b}{2}$

$= \frac{W}{N}\left(\left[\frac{.8531}{2}\right]^2 + 0.4920^2\right]^{1/2} + \frac{.8531}{2}$

$= \frac{W}{N}\left[(0.6512) + .8531/2\right]$

$f_{v_{max}} = $ 23,351 psi

$A_1 = \left[3.028 - 2(.035)\right]^2\frac{\pi}{4}$

$= 6.8720\ in^2$

$A_2 = \left[2.438 + 2(.035)\right]^2\frac{\pi}{4}$

$= 4.9402\ in^2$

$A_c = A_1 - A_2$

$= 1.932\ in^2$

$A_c' = N\,\frac{54}{360}A_c$

$f_c = P/A_c'$

$P = W/3$

$f_c = \frac{W}{N}/\left(3 \times \frac{54}{360} \times A_c\right)$

$= \frac{W}{N}(1.150)$

$f_c = $ 24,917 psi

COMPRESSIVE BEARING STRESS ON LAND SURFACES

COMPRESSIVE BEARING STRESS ON STUD HEAD - SEC B-B

$A_1 = \left[4.785 - 2(.11)\right]^2\frac{\pi}{4}$

$A_2 = \left[3.317 + 2(.15)\right]^2\frac{\pi}{4}$

$A_c = A_1 - A_2 = 6.092\ in^2$

$f_c = P/A_c$

$P = W/3$

$f_c = W(0.0547)$

$f_c = $ 14,222 psi

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