WCAP-10233

WESTINGHOUSE CLASS 3

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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
SOUTH CAROLINA ELECTRIC AND GAS COMPANY
VIRGIL C. SUMMER PLANT

APRIL, 1983

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6260B:1/031783

ABSTRACT

An evaluation of the Virgil C. Summer 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 South Carolina Electric and Gas Company, Virgil C. Summer Plant.

B. Stress Report - Reactor Vessel Head Lift Rig, Reactor Vessel Internals Lift Rig, Load Cell and Load Cell Linkage for South Carolina Electric and Gas Company, Virgil C. Summer Plant.

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 1098E56 - 3-Loop Lifting Rig - Head, General Assembly

4. Westinghouse Drawing 1143E65 - South Carolina Electric and Gas Company, Virgil C. Summer 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 Loads 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 Virgil C. Summer 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 Virgil C. Summer Plant circa 1974-76. 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 43 feet high and 12 feet in diameter, weighing approximately 21,000 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 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 13 feet in diameter weighing approximately 20,000 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.

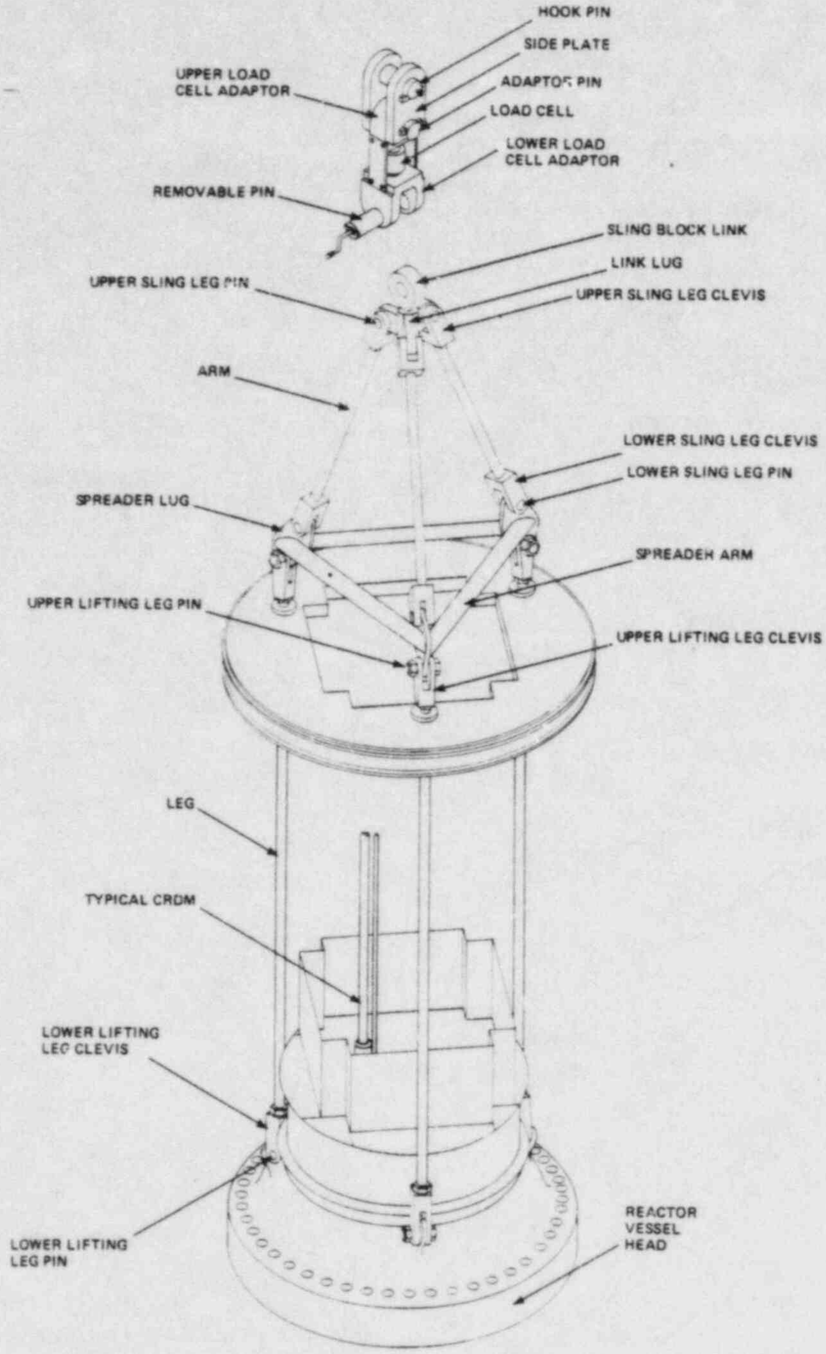

Figure 2-1. Reactor Vessel Head Lift Rig

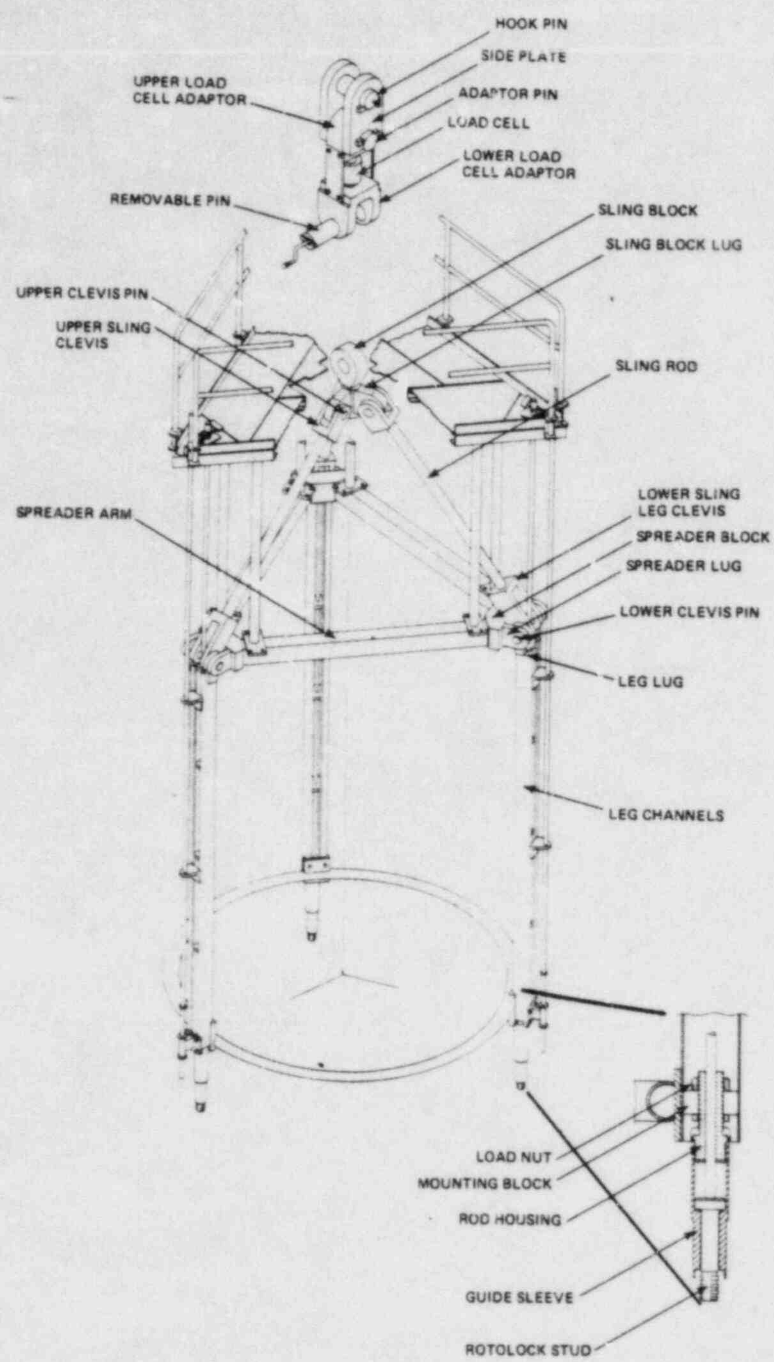

Figure 2-2. Reactor Vessel Internals Lift Rig

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.

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 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 13 feet diameter by 43 feet 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.

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ATTACHMENT A
to WCAP-10233

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
South Carolina Electric and Gas Company
Virgil C. Summer Plant

APRIL, 1983

H. H. Sandner, P.E.

Approved [signature]
J. R. Marshall, P.E., Manager
Refueling Equipment Engineering

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 Virgil C. Summer 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 Virgil C. Summer lifting devices has been prepared.

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REFERENCES

1. Westinghouse Drawing 1098E56 - 3-Loop Lifting Rig - Head, General Assembly.

2. Westinghouse Drawing 1143E65 - South Carolina Electric and Gas Company, Virgil C. Summer 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 Loads 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 head and internals lifting rigs were designed and built for the Virgil C. Summer Nuclear Power Plant, circa 1974-76. 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 43 feet high and 12 feet in diameter, weighing approximately 21,000 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 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 13 feet in diameter weighing approximately 20,000 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

VIRGIL C. SUMMER 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

VIRGIL`C. SUMMER 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

VIRGIL C. SUMMER 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 its 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.

TABLE 2-1 (cont)

COMPARISON OF THE REQUIREMENT OF ANSI N14.6 AND

VIRGIL C. SUMMER 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

VIRGIL C. SUMMER 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	Lubricants - 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 and neolube are used where applicable as indicated on the drawings.
4 4.1 4.1.1 to 4.1.12	Fabrication Fabricators Responsibilities -These sections contain specific requirements for proper quality assurance, document control, deviation control, procedure control, material identification and certificate of compliance.	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

VIRGIL C. SUMMER 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 particle 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.

TABLE 2-1 (cont)

COMPARISON OF REQUIREMENT OF THE ANSI N14.6 AND

VIRGIL C. SUMMER 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.

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TABLE 2-1 (cont)

COMPARISON OF THE REQUIREMENT OF ANSI N14.6 AND

VIRGIL C. SUMMER 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

VIRGIL C. SUMMER 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 Virgil C. Summer operating and maintenance procedures.

Upon completion of the field assembly of the reactor vessel head lifting 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
1,3,7	Hook Pin Adaptor Pin Removable Pin	ASTM A564, Type 630	Ultrasonic	Magnetic Particle
2	Side Plate	ASTM A588 Gr. A Q&T	Ultrasonic	Magnetic Particle
4,6,8	Upper Load Cell Adaptor Lower Load Cell Adaptor Sling Block	ASTM A508 Class 2	Ultrasonic	Magnetic Particle
5	Load Cell	17-4 pH, SS Cond. H-1100	Ultrasonic	Liquid Penetrant
9	Link Lug Spreader Lug	ASTM A588, Gr. A, Q&T	Ultrasonic	Magnetic Particle
10,14, 18,21	4" Dia. Upper Sling Leg Pin 4" Dia Lower Sling Leg Pin Upper Lifting Leg Pin 3 1/2" Lower Lifting Leg Pin	ASTM A434 AISI 4340, Cl. BD	Ultrasonic	Magnetic Particle
11,13, 17,20	Upper Sling Leg Clevis Lower Sling Leg Clevis Upper Lifting Leg Clevis Lower Lifting Leg Clevis	ASTM A237, AISIE 4340 Steel, Cl. G.	Ultrasonic	Magnetic Particle

[a] See figure A-1

TABLE A-1 (cont)

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
12,19	Arm Leg	ASTM A306 Gr. 70	Ultrasonic	Magnetic Particle
16	Spreader Arm	ASTM A106, Gr. B	--	--

[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
8,9	Lugs to Lifting Block (Full Penetration)	Magnetic Particle	Magnetic Particle Radiograph
15,16	Spreader Arm Lug to Spreader Arm (fillet)	Magnetic Particle	Magnetic Particle

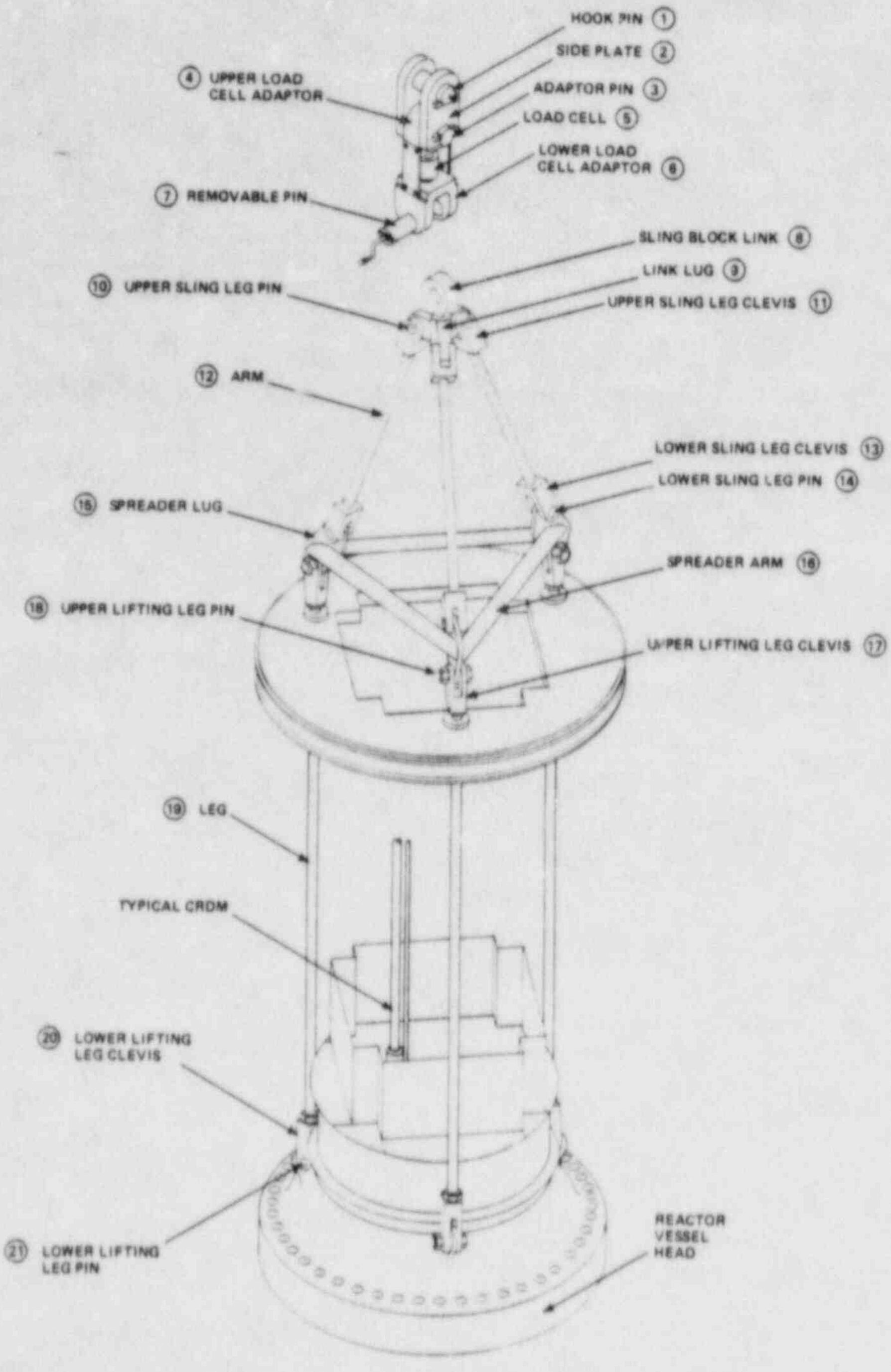

Figure A-1. Reactor Vessel Head Lift Rig

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	Sling Block	ASTM A508, Class 2	Ultrasonic	Magnetic Particle
2	Sling Block Lug	ASTM A588, Grade A	Ultrasonic	Magnetic Particle
3,7	Upper Clevis Pin Lower Clevis Pin	ASTM A564, Type 630	Ultrasonic	Liquid Penetrant
4,6	Upper Sling Clevis Lower Sling Clevis	ASTM A471 Steel Forging, Class 3	Ultrasonic	Magnetic Particle
5	Sling Rod	ASTM A306 Grade 70 or 80	Ultrasonic	Magnetic Particle
8	Spreader Lug	ASTM A516 normalized or ASTM A637, Grade B Q&T	Ultrasonic	Magnetic Particle
9,13	Spreader and Mounting Block	ASTM A350 LFI Forging	-- Ultrasonic	-- Magnetic Particle
10,12	Spreader Arm Leg Channel	ASTM A36	-- --	-- Visual
11	Leg Lug	ASTM A516, Grade 70	Ultrasonic	Magnetic Particle

(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	Load Nut	ASTM A276, Type 304, Hot Rolled, Condition A	--	--
15,16	Rod Housing Guide Sleeve	ASTM A276, Type 304, Hot Rolled, Annealed & Pickled, Condition A	Ultrasonic --	-- Liquid Penetrant
17	Rotolock Stud	ASTM A564, Type 630, 17-4 pH H-1100	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

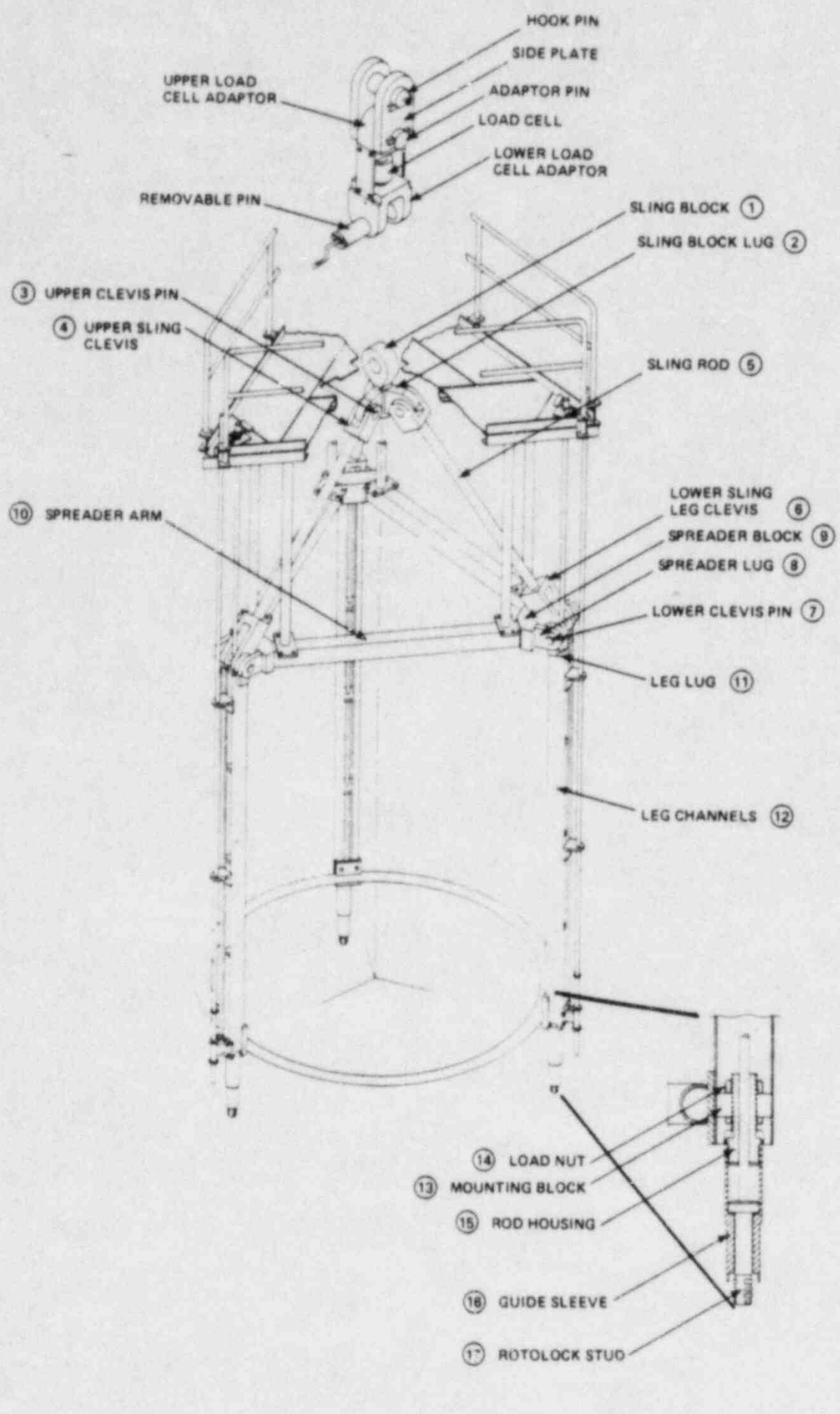

Figure A-2. Reactor Vessel Internals Lift Rig

APPENDIX B

TABULATION OF ANSI N14.6-1978 REQUIREMENTS INCOMPATIBLE WITH THE VIRGIL C. SUMMER 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 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 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 particle 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.

WESTINGHOUSE CLASS 3

ATTACHMENT B to
WCAP-10233

STRESS REPORT
REACTOR VESSEL HEAD LIFT RIG, REACTOR VESSEL INTERNALS LIFT RIG AND THE LOAD CELL LINKAGE FOR SOUTH CAROLINA ELECTRIC AND GAS COMPANY VIRGIL C. SUMMER PLANT

April, 1983

H. H. Sandner, P. E.

Approved: ____________________
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Refueling Equipment Engineering

6265B:1/032483

ABSTRACT

A stress analysis of the Virgil C. Summer 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

J. Richard

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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 Virgil C. Summer 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 Virgil C. Summer Nuclear Power Plant, circa 1974-1976. 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 43 feet high and 12 feet in diameter, weighing approximately 21,000 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 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 13 feet in diameter weighing approximately 20,000 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:

$$3 \times (\text{weight}) < \text{Yield Strength}$$
$$5 \times (\text{weight}) < \text{Ultimate Strength}$$

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 270,000 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 17 of calculations; is 202,000 pounds.

b. The design weight for the rest of the rig is 230,000 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)
1,3,7	Hook Pin Adaptor Pin Removable Pin	ASTM A564, Type 630	105	135
2	Side Plate	ASTM A588, Grade A, Q&T	60	80
4,6,8	Upper Load Cell Adaptor Lower Load Cell Adaptor Sling Block	ASTM A508, Class 2	50	80
5	Load Cell	17-4 pH, SS Condition H-1100	115	140
9,15	Link Lug	ASTM A588, Grade A, Q&T	60	80
10,14, 18,21	4" Dia. Upper Sling Leg Pin 4" Dia. Lower Sling Leg Pin Upper Lifting Leg Pin 3 1/2" Lower Lifting Leg Pin	ASTM A434 AISI 4340 Class BD	110	140
11,13, 17,20	Upper Sling Leg Clevis Lower Sling Leg Clevis Upper Lifting Leg Clevis Lower Lifting Leg Clevis	ASTM A237, AISI 4340 Steel, Class G	110	135

(a) See figure 5-1.

TABLE 4-1 (cont)

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)
12,19	Arm Leg	ASTM A306 Grade 70	35	70
16	Spreader Arm	ASTM A106 Grade B	35	60

(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	Sling Block	ASTM A508, Class 2	50	80
2	Sling Block Lug	ASTM A588, Grade A	60	80
3,7	Upper Clevis Pin Lower Clevis Pin	ASTM A564, Type 630	105	135
4,6	Upper Sling Clevis Lower Sling Clevis	ASTM A471, Steel Forging, Class 3	95	110
5	Sling Rod	ASTM A306, Grade 70 or 80	35	70
8	Spreader Lug	ASTM A516 Normalized or ASTM A637, Grade B, Q&T	38	70
9,13	Spreader and Mounting Block	ASTM A350 LFI Forging	30	60
10,12	Spreader Arm Leg Channels	ASTM A36	36	58
11	Leg Lug	ASTM A516, Grade 70	38	70
14	Load Nut	ASTM A276, Type 304 Hot Rolled, Cond. A	30	75
15,16	Rod Housing Guide Sleeve	ASTM A276, Type 304 Hot Rolled, Annealed and Pickled, Cond. A	30	75
17	Rotolock Stud	ASTM A564, Type 630, 17-4 pH, H-1100	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.

5.1.2 Structures Loaded in Bearing

The parts of the internals lift rig that do not meet the ANSI N14.6 criteria (3 and 5) when analyzed for bearing stresses are the lower sling leg clevis (item 6), the lower clevis pin (item 7), the spreader lug (item 8), the leg lug (item 11), and the rotolock stud (item 17).

However, since bearing stresses 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.

5.1.3 Combined Stresses

The combined tensile stress from bending and tension, in the spreader lug (item 8), of the internals lift rig exceeds the Section 3.2.1.1 criteria.

Bending, however, is not a uniform stress, but a local fiber stress, and is at maximum at the outermost fiber. Even if the fiber stress reached anywhere near the yield stress, the rest of the cross-section could assume the additional load. As indicated above, bending too can be considered under Section 3.2.1.2. Bending contributes to the major portion of the stress shown in the table, and, as a result, as shown, the tensile stress without bending is extremely low and well within the Section 3.2.1.1 criteria. The combined stress also meet the AISC code criteria.

5.1.4 Fillet Weld Stresses

The fillet weld connecting the leg lug (item 11) to the leg channel (item 12) on the internals lift rig meets the ASME criteria for weld stresses based on base material properties. However, when applying the ANSI N14.6 3W and 5W criteria to the nominal stress value, the ASME allowable stress value is exceeded. But, since the ANSI N14.6 criteria is satisfied for this weld, it is considered acceptable.

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, these 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	Hook Pin	Shear	3.1	9.3	15.5	105	135
	ASTM A564,	Bearing on Pin	4.1	12.3	20.5		
	Type 630	Bearing on Side Plate	4.5	13.5	22.5		
		Bending	11.8	35.4	59.0		
2	Side Plate	Tension at 7.515" hole	3.8	11.4	19.0	60	80
	ASTM A588	Bearing at 6.515" hole	5.2	15.6	26.0		
	Gr. A, Q&T	Shear Tear-out					
		at 7.515" hole	3.8	11.4	19.0		
		at 6.515" hole	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	Calculated Stresses (ksi)				Material Allowable (ksi)	
		Designation	Value				
			W[b]	3W	5W	S_y[c]	S_{ult}[d]
3	Adaptor Pin	Shear	4.1	12.3	20.5	105	135
	ASTM A564	Bearing on Pin	5.2	15.6	26.0		
	Type 630	Bearing on Upper Load Cell Adaptor	5.4	16.2	27.0		
		Bending	19.5	58.5	97.5		
4	Upper Load Cell Adaptor ASTM A508, Class 2	Tension at 6.515 hole	3.3	9.9	16.5	50	80
		Bearing	5.4	16.2	27.0		
		Thread Shear	7.0	21.0	35.0		
		Shear Tear-out at 6.515" hole	3.3	9.9	16.5		

(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)	
			Value				
		Designation	W[b]	3W	5W	S_y[c]	S_{ult}[d]
5	Load Cell 17-4 pH S/S	Tension	14.4	43.2	72.0	115	140
		Thread Shear	7.0	21.0	35.0		
6	Lower Load Cell Adaptor ASTM A508 Class 2	Tension at Pin Hole	3.3	9.9	16.5	50	80
		Bearing	6.9	20.7	34.5		
		Thread Shear	6.7	20.1	33.5		
		Shear Tear-out at Pin Hole	3.3	9.9	16.5		
7	Removable Pin ASTM A564 Type 630	Shear	4.2	12.6	21.0	105	135
		Bearing on Pin	5.1	15.3	25.5		
		Bearing on Link	5.7	17.1	28.5		
		Bending	16.9	50.7	84.5		

(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]
8	Sling Block Link ASTM A508, Class 2	Tension at 6.515" hole	3.3	9.9	16.5	50	80
		Shear at 6.515" hole	3.3	9.9	16.5		
		Bearing on Pin	5.1	15.3	25.5		
		Tension at Cylindrical Section	5.4	16.2	27.0		
9	Link Lug ASTM A588 Gd.A, Q&T	Tension at 4.015" hole	3.5	10.5	17.5	60	80
		Shear Tear at hole	3.5	10.5	17.5		
		Bearing at 4.015" hole	6.1	18.3	30.5		
		Combined Stress from Tension and Bending	5.7	17.1	28.5		
		Vertical Shear	1.8	5.4	9.0		

(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	Calculated Stresses (ksi)				Material Allowable (ksi)	
			Value				
		Designation	W[b]	3W	5W	S_y[c]	S_{ult}[d]
10	4" Dia. Upper	Shear	3.8	11.4	19.0	110	140
	Sling Leg	Bearing on Pin	6.1	18.3	30.5		
	Pin	Bearing on Upper	6.4	19.2	32.0		
	ASTM A434	Sling Leg Clevis					
		Bending	14.6	.43.8	73.0		
11	Upper Sling	Bearing	6.4	19.2	32.0	110	135
	Leg Clevis	Thread Shear	2.7	8.1	13.5		
	ASTM A237	Tension at Thd Relief	1.7	5.1	8.5		
	AISI E4340	Tension at Pin Hole	5.4	16.2	27.0		
	Steel, Cl. G	Shear Tear-out	5.4	16.2	27.0		
12	Arm	Thread Shear	2.7	8.1	13.5	35	70
	ASTM A306	Thread Tension	8.9	26.7	44.5		

(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	Calculated Stresses (ksi)				Material Allowable (ksi)	
			Value				
		Designation	W[b]	3W	5W	S_y[c]	S_{ult}[d]
13	Lower Sling	Bearing	6.4	19.2	32.0	110	135
	Leg Clevis	Thread Shear	2.7	8.1	13.5		
	ASTM A237	Tension at Thd Relief	1.8	5.4	9.0		
	AISI E4340	Tension at Pin Hole	5.4	16.2	27.0		
	Steel, Class G	Shear Tear-out	5.4	16.2	27.0		
14	4" Dia. Lower	Shear	3.9	11.7	19.5	110	140
	Sling Leg	Bearing on Pin	6.9	20.7	34.5		
	Pin	Bearing on Spreader Lug	6.4	19.2	32.0		
	ASTM A434	Bending	13.6	40.8	68.0		

(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	Calculated Stresses (ksi)				Material Allowable (ksi)	
		Designation	Value				
			W[(b)]	3W	5W	S_y [(c)]	S_{ult} [(d)]
15	Spreader Lug	Bearing on 4.005" Hole	7.0	21.0	35.0	60	80
	ASTM A588	Tension at Upper Hole	4.7	14.1	23.5		
	Gd.A Steel	Shear Tear-out	4.7	14.1	23.5		
	Plate						
16	Spreader Arm	Nominal Compression	1.7	5.1	8.5	35	60
	ASTM A106	Stress				F_a = 19545[(e)]	
	Gd.B Seamless	Weld Shear	1.0	3.0	5.0	18[(f)]	

(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) F_a is the compressive buckling strength of the material (ksi)

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

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)	
			Value				
		Designation	W[b]	3W	5W	S_y[c]	S_{ult}[d]
17	Upper Lifting	Bearing	5.9	17.7	29.5	110	135
	Leg Clevis	Thread Shear	2.5	7.5	12.5		
	ASTM A237	Tension at Thd Relief	1.7	5.1	8.5		
	AISI E4340	Tension at Pin Hole	5.0	15.0	25.0		
	Steel, Class G	Shear Tear-out	5.0	15.0	25.0		
18	Upper Lifting	Shear	3.6	10.8	18.0	110	140
	Leg Pin	Bearing on Pin	6.4	19.2	32.0		
	ASTM A434	Bearing on Clevis	5.9	17.7	29.5		
		Bending	12.5	37.5	62.5		

(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)	
			Value				
		Designation	W[b]	3W	5W	S_y[c]	S_{ult}[d]
19	Leg ASTM A306 Gd.70	Thread Shear	2.5	7.5	12.5	35	70
		Thread Tension	8.1	24.3	40.5		
20	Lower Lifting Leg Clevis ASTM A237 AISI E4340 Steel, Class G	Bearing	6.7	20.1	33.5	110	135
		Thread Shear	2.5	7.5	12.5		
		Tension at Thd Relief	1.8	5.4	9.0		
		Tension at Pin Hole	4.5	13.5	22.5		
		Shear Tear-out	4.5	13.5	22.5		

(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)	
			Value				
		Designation	W[b]	3W	5W	S_y[c]	S_{ult}[d]
21	3 1/2" Lower Lifting Leg Pin ASTM A434 AISI 4340 Class BD	Shear	4.7	14.1	23.5	110	140
		Bearing on Lug	8.6	25.8	43.0		
		Bearing on Clevis	6.7	20.1	33.5		
		Bending	18.0	54.0	90.0		

(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)

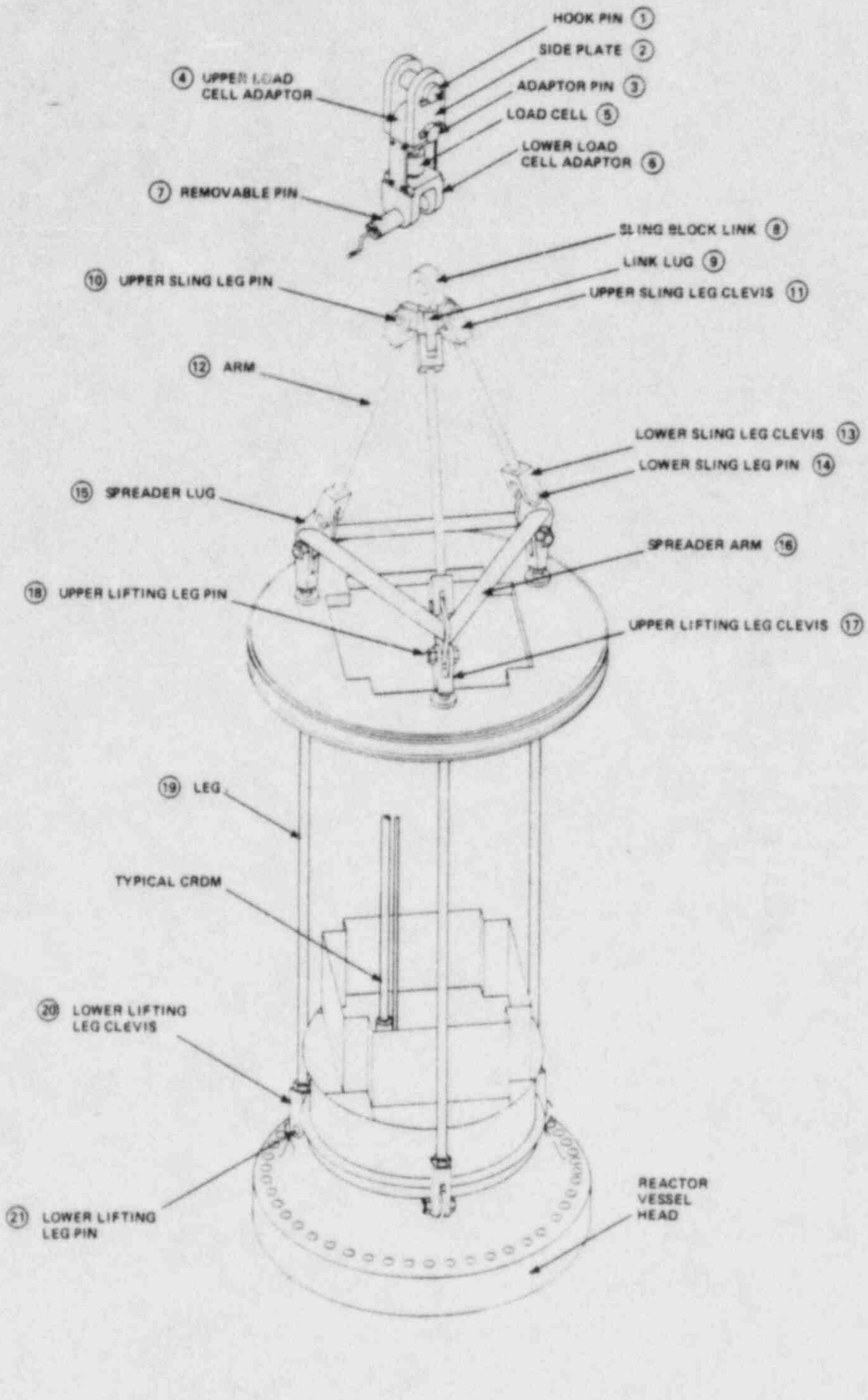

Figure 5-1. Reactor Vessel Head Lift Rig

TABLE 5-2

SUMMARY OF RESULTS

REACTOR VESSEL INTERNALS LIFT RIG

Item[a] No.	Part Name And Material	Calculated Stresses (ksi)				Material Allowable (ksi)	
			Value				
		Designation	W[b]	3W	5W	S_y[c]	S_{ult}[d]
1	Sling Block ASTM A508 Class 2	Tension at 6.515" Dia. Hole	2.8	8.4	14.0	50	80
		Bearing at 6.515" Dia. Hole	4.4	13.2	22.0		
		Shear Tear-out at 6.515" Dia. Hole	2.8	8.4	14.0		
		Tension at 8.00" Cylindrical Section	4.6	13.8	23.0		
2	Sling Block Lug ASTM A588 Grade A Steel	Tension at 4.015" Dia. Hole	3.6	10.8	18.0	60	80
		Bearing at 4.015" Dia. Hole	6.3	18.9	31.5		
		Shear Tear-out at 4.015" Dia. Hole	3.6	10.8	18.0		
		Vertical Shear at Lug Root Weld	1.5	4.5	7.5		
		Combined Tension from Bending and Tension at Lug Weld	5.2	15.6	26.0		

(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)

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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) $S_y^{(c)}$	$S_{ult}^{(d)}$
3	Upper Clevis Pin ASTM A564 Type 630	Shear Stress	4.0	12.0	20.0	105	135
		Bearing Stress on Sling Block Lug	6.3	18.9	31.5		
		Bearing on Upper Sling Clevis	5.2	15.6	26.0		
		Bending Stress	15.7	47.1	78.5		
4	Upper Sling Clevis ASTM A471 Steel Forging Class 3	Tension at 4.015" Dia. Hole	4.0	12.0	20.0	95	110
		Bearing at 4.015" Dia. Hole	5.2	15.6	26.0		
		Shear Tear-out at 4.015" Dia. Hole	4.0	12.0	20.0		
		Thread Shear	4.2	12.6	21.0		

(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)				Material Allowable (ksi)	
		Designation	Value				
			W[b]	3W	5W	S_y[c]	S_{ult}[d]
5	Sling Rod	Thread Shear	4.2	12.6	21.0	35	70
	ASTM A306	Thread Tension	9.0	27.0	45.0		
	Grade 70 or 80	Tension at Thread Relief	9.7	29.1	48.5		
6	Lower Sling	Tension at 4.015" Dia. Hole	4.0	12.0	20.0	95	110
	Leg Clevis	Bearing	30.0	90.0	150.0		
	ASTM A471	Bending at 4.015" Dia. Hole	17.8	153.4	89.0		
	Steel Forging	Combined Max. Bending and					
	Class 3	Tension at 4.015" Dia. Hole	21.9	65.7	109.5		
		Thread Shear	4.2	12.6	21.0		

(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)				Material Allowable (ksi)	
		Designation	Value: W[b]	Value: 3W	Value: 5W	S_y[c]	S_{ult}[d]
7	Lower Clevis Pin ASTM A564 Type 630 Precipitation Hardening Stainless Steel Age Treated at 1150°F for 4 hours, air-cooled 135,000 psi Min. Tensile Strength RC 28-31	Maximum Shear at Clevis	8.0	24.0	40.0	105	135
		Maximum Bearing at Clevis	30.0	90.0	150.0		
		Bending	15.3	45.9	76.5		

(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	Calculated Stresses (ksi)				Material Allowable (ksi)	
		Designation	Value				
			W[b]	3W	5W	S_y[c]	S_{ult}[d]
8	Spreader Lug ASTM A516 Steel Plate, Normalized, or A637, Gr. B, Q&T	Tension at 4.015" Dia. Hole	2.2	6.6	11.0	38	70
		Bending at 4.015" Dia. Hole	13.3	39.3	66.5		
		Combined Tension and Bending	15.4	46.2	77.0		
		Bearing	23.1	69.3	119.5		
9	Spreader Block ASTM A350 LFI Forging Steel	Bearing on Spreader Block	3.0	9.0	15.0	30	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)

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) $S_y^{(c)}$	$S_{ult}^{(d)}$
10	Spreader Arm ASTM A36 Steel	Nominal Compression Stress	3.0	9.0	15.0	36 $F_a = 18,929^{(e)}$	58
11	Leg Lug	Tension 4.015" Dia. Hole	2.6	7.8	13.0	38	70
	ASTM A516	Bending at 4.5" Dia. Hole	7.9	23.7	39.5		
	Grade 70 Steel	Comb. Max. Bending Tension at 4.015" Dia. Hole	10.4	31.2	52.0		
		Bearing	18.8	56.4	94.0		
		Weld Stresses	9.4	28.2	47.0	$21^{(f)}$	

(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.

TABLE 5-2 (cont)

SUMMARY OF RESULTS

REACTOR VESSEL INTERNALS LIFT RIG

Item[a] No.	Part Name And Material	Calculated Stresses (ksi) Designation	Value $W^{(b)}$	Value 3W	Value 5W	Material Allowable (ksi) S_y [c]	Material Allowable (ksi) S_{ult} [d]
12	Leg Channels ASTM A36 Steel	Tension in Legs	5.6	16.8	28.0	36	58
13	Mounting Block ASTM A350 LFI Forging Steel (No CVN Test Req'd.) Welds: E70-18 Electrodes	Bearing of Load Nut to Mounting Block	1.8	5.4	9.0	30	60
		Shear in Mounting Block Welds	3.1	9.3	15.5	18[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)

(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	Calculated Stresses (ksi) Designation	Value $W^{(b)}$	3W	5W	Material Allowable (ksi) S_y[c]	S_{ult}[d]
14	Load Nut	Thread Shear	4.1	12.3	20.5	30	75
	ASTM A276	Bearing of Load Nut					
	Type 304,	to Mounting Block	1.8	5.4	9.0		
	Hot Rolled,						
	Cond. A						
15	Rod Housing	Thread Shear	4.1	12.3	20.5	30	75
	ASTM A276,	at 4.00-4UNC-2A Thd.					
	Type 304 SST,	Thread Shear at	3.5	10.5	17.5		
	Hot Rolled,	5.0-6UN-2A Thd.					
	Annealed and	Tension at Thread Relief	8.4	25.2	42.0		
	Pickled,						
	Cond. A						

(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]
16	Guide Sleeve ASTM A276, Type 304 SST, Hot Rolled, Annealed, and Pickled, Cond. A	Thread Shear	3.5	10.5	17.5	30	75
		Tension at Thd Relief	8.2	24.6	41.0		
		Bearing of Guide Sleeve to Rotolock Stud	9.9	29.7	49.5		

(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)

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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)	
			Value				
		Designation	W[(b)]	3W	5W	S_y[(c)]	S_{ult}[(d)]
17	Rotolock Stud ASTM A564, Type 630, 17-4 Precipitation Hardening Stainless Steel Age Treated at 1100°F for 4 hours and air cooled T min = 140,000 psi	Tension at Section A-A	19.5	58.5	97.5	115	140
		Shear of Stud Lands	10.5	31.5	52.5		
		Bearing on Stud Head	9.9	29.7	49.5		
		Bending in Lands	14.4	43.2	72.0		
		Compressive Bearing Stress On Land Surfaces	29.8	89.4	149.0		

(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)

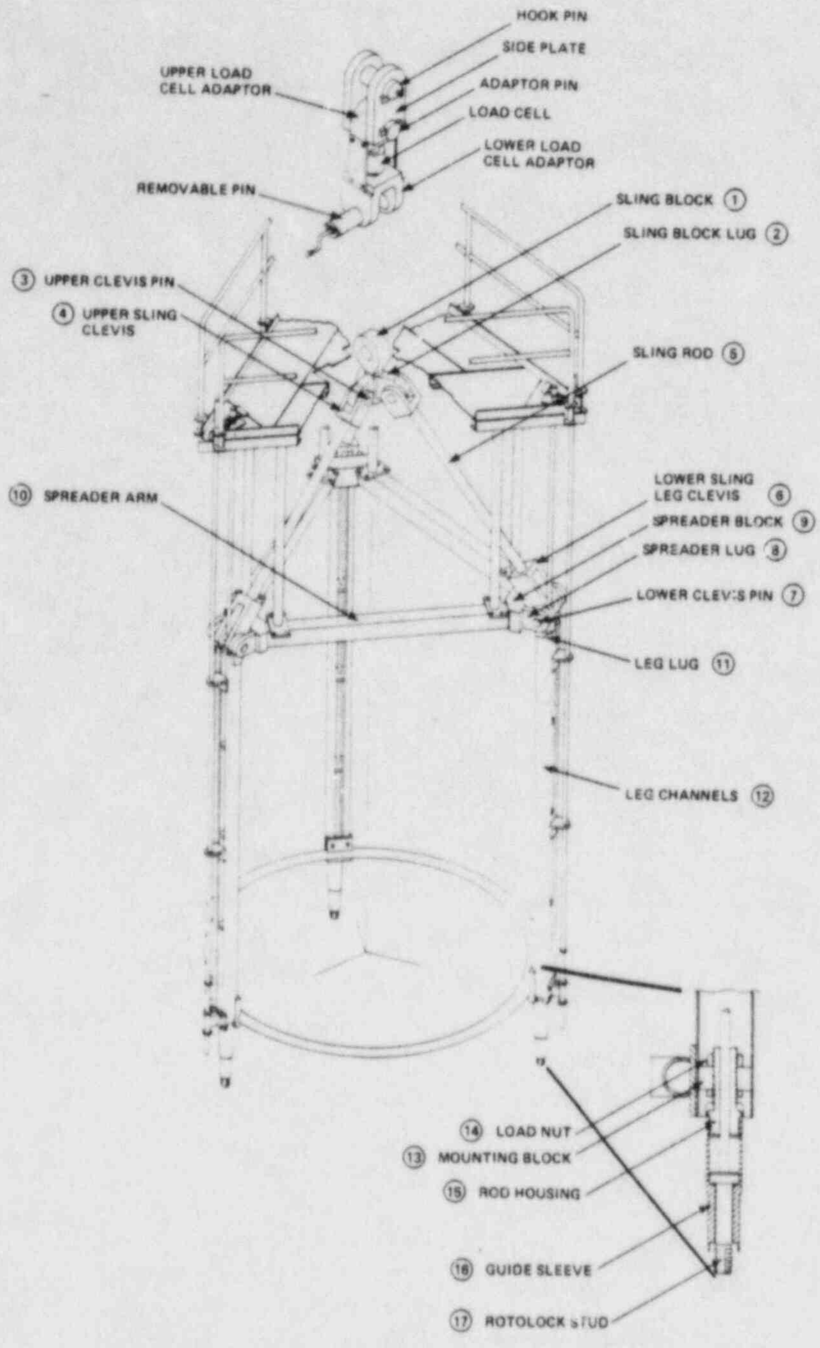

Figure 5-2. Reactor Vessel Internals Lift Rig, Load Cell, and Linkage

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 Virgil C. Summer 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
UCG-27694	Virgil C. Summer	1 OF 42

TITLE	CALCULATIONS NO.
R. V. Head Lift Rig Assembly	PDC --

AUTHOR & DATE	CHECKED BY & DATE
F. Peduzzi F. C. Peduzzi 2/83	J. Richard J Richard 2/83

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
JOSEPH W. RICHARD
ENGINEER
NO. 007167-E

J W Richard

REVISION NO.	DATE	DESCRIPTION	BY
		Original Issue	F. Peduzzi

RESULTING REPORTS, LETTERS OR MEMORANDA:

WESTINGHOUSE NUCLEAR TECHNOLOGY DIVISION

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Reactor Vessel Head Lift Rig			
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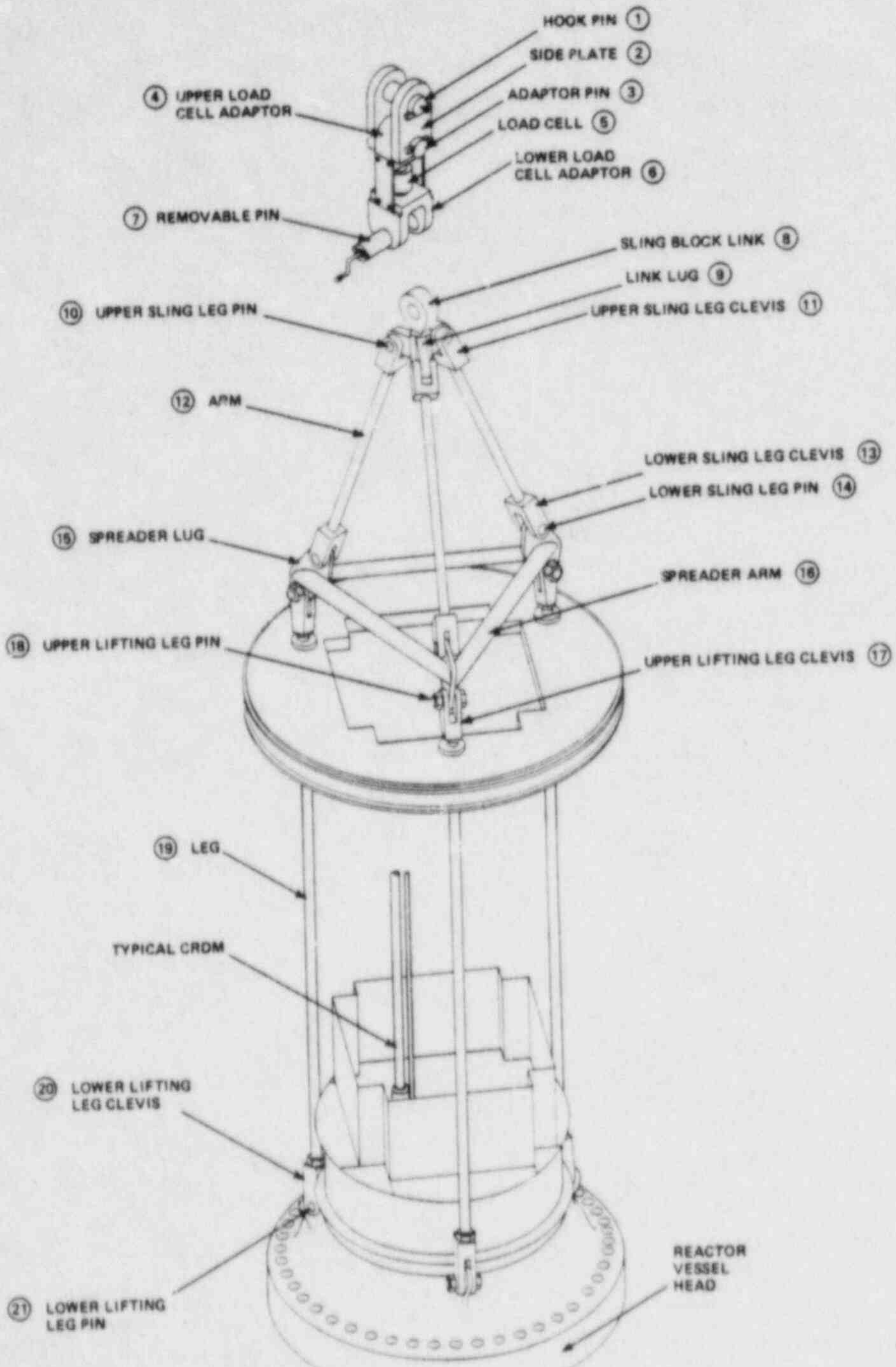

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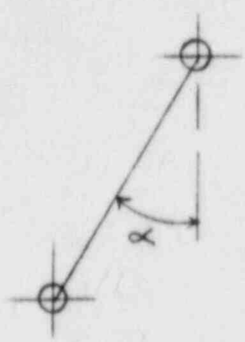
DESIGN WEIGHT

240,000 lbs from ASSY DWG (1098E56)
21,000 lbs Rig and Platform ASSY Weight
9,000 lbs Contingencies
270,000 lbs

SLING LEG ANGLE



$\alpha = 22.8°$

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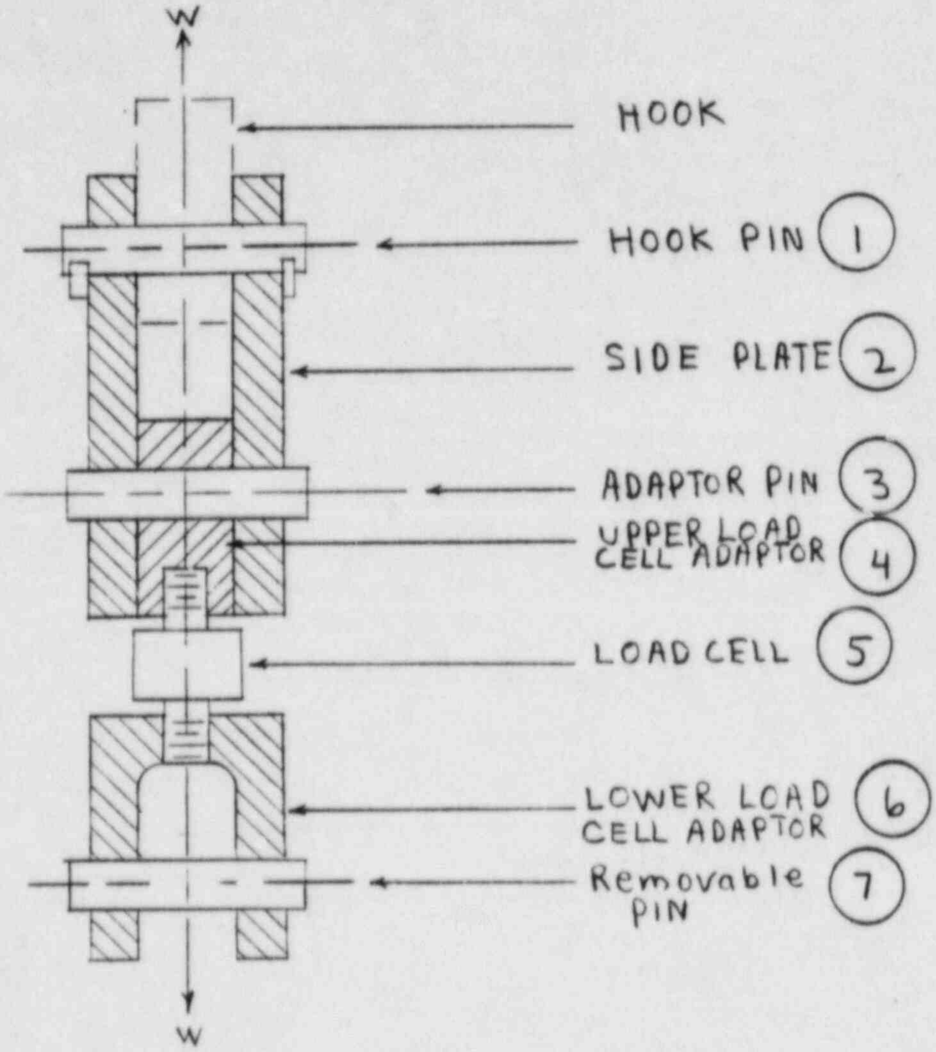
LOAD CELL LINKAGE ASSEMBLY



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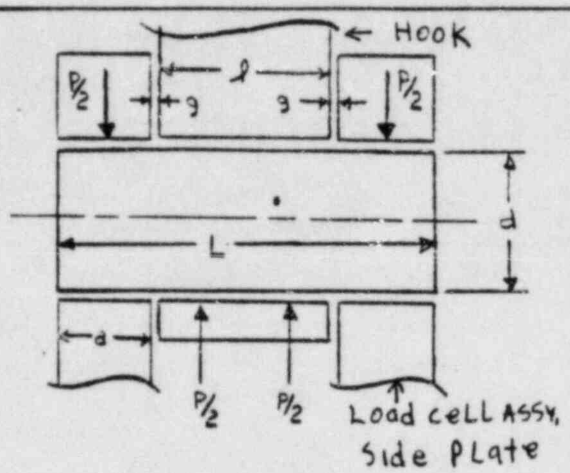
HOOK PIN (1)

MAT'L: ASTM A 564, TYPE 630



P = force acting on assembly, lb.
d = diameter of pin, in.
ℓ = length of bearing surface of center body, in.
a = length of bearing surface one side of outer body, in
g = gap between bearing surfaces, in.
L = total active length of pin, in
 $= \ell + 2(a + g)$

$P = 270{,}000$ lb.
$d = 7.5$ in.
$\ell = 8.875$ in
$a = 4.00$ in
$g = .0625$ in
$[16.25 - 2(4.00) - (8.875) + .75]/2$

SHEAR STRESS

$f_v = P/2A_v$
$P = 270{,}000$
$A_v = \pi d^2/4$
$A_v = \pi(\ 7.5\ )^2/4$
$A_v = 44.18\ in^2$

$f_v = (\ 270{,}000)/(2 * 44.18\ )$

$f_v = 3056$ PSI

BEARING STRESS

$f_c = P/A_v$
$P = 270{,}000$

INNER

$A_v = d\ell = (\ 7.5\ )(\ 8.875)$
$= (\ 66.56)\ in^2$
$f_c = (\ 270{,}000)/(\ 66.56)$

$f_c = 4056$ PSI

OUTER

$A_v = 2ad = 2(\ 4.00\ )(\ 7.5\ )$
$= (\ 60.0\ )\ in^2$
$f_c = (\ 270{,}000)/(\ 60.0\ )$

$f_c = 4500$ PSI

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PIN ①

BENDING STRESS (1)

$M_{max} = \frac{P}{2}\left(\frac{1}{3}a + g + \frac{1}{4}l\right)$

$f_b = Mc/I$

$I = \pi d^4/64$

$c = d/2$

$f_b = \frac{P}{2}\left(\frac{1}{3}a + g + \frac{1}{4}l\right)\left(\frac{d}{2}\right)\left(\frac{64}{\pi d^4}\right)$

$= 16P\left(\frac{1}{3}a + g + \frac{1}{4}l\right)/(\pi d^3)$

$= 16P\left(\frac{4.0}{3} + .0625 + \frac{8.875}{4}\right)/\pi\, 7.5^3$

$= 270{,}000\,(.04363)$

$= 11{,}780$ PSI

(1) ADAPTED FROM FASTENING AND JOINING, 4th Ed, A REFERENCE ISSUE OF MACHINE DESIGN, PENTON PUBLISHERS PAGE 27

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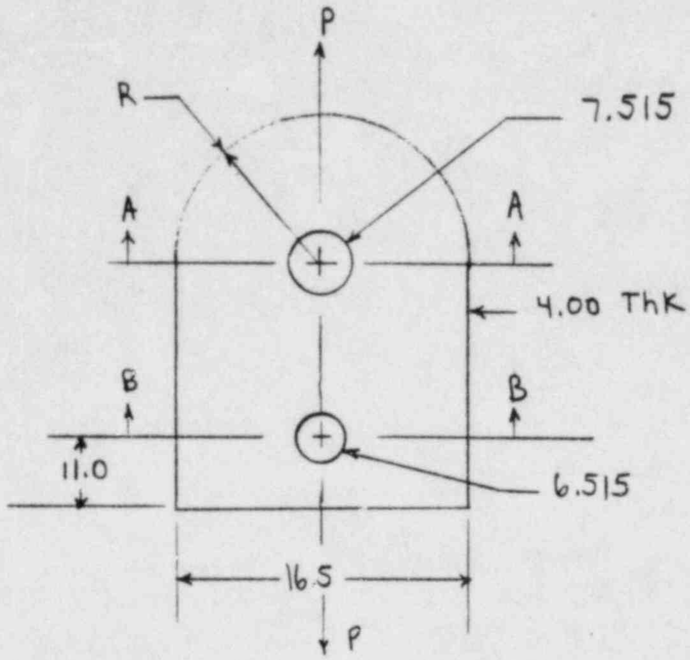
(2) SIDE PLATE - ASTM - A588 GR. A Q & T



Tension @ 7.515 ϕ Hole

$f_t = \frac{P/2}{A_t}$ $A_t = (16.5 - 7.515)(4.0) = 35.94 \text{ in}^2$

$f_t \; \frac{135,000}{35.94} = 3756 \text{ PSI}$

Bearing @ 6515 ϕ Hole

$f_c = \frac{P/2}{A_c} = \frac{135,000}{(6.515)(4)} = 5180 \text{ PSI}$

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Shear Tear-out

$$f_v = \frac{P/2}{2A_V}$$

@ 7.515 ϕ Hole

$$f_v = \frac{135{,}000}{2\left(8.25 - \frac{7.515}{2}\right)4} = 3756 \text{ PSI}$$

@ 6.515 ϕ Hole

$$f_v = \frac{135{,}000}{2\left(11.0 - \frac{6.515}{2}\right)(4)} = 2180 \text{ PSI}$$

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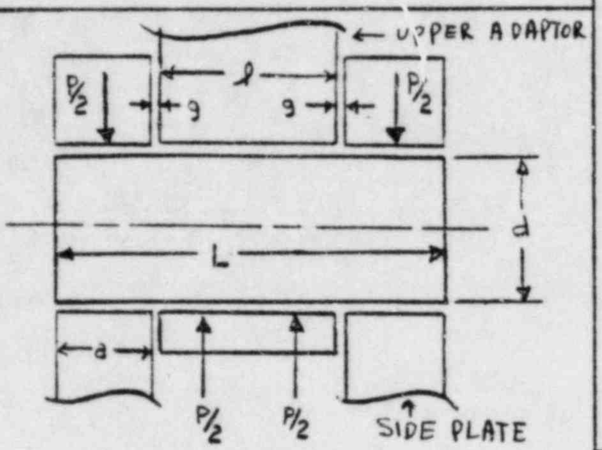
ADAPTOR PIN (3)

MAT'L: ASTM A 56' TYPE 630



P = force acting on assembly, lb.
d = diameter of pin, in.
l = length of bearing surface of center body, in.
a = length of bearing surface one side of outer body, in
g = gap between bearing surfaces, in.
L = total active length of pin, in $= l + 2(a+g)$

P = 270,000 lb.
d = 6.50 in.
l = 7.75 in. 8.25 - 2(.25)
a = 4.00 in
g = .625 in
[17.00 + 2(.25) - 2(4.00) - 8.25]/2

SHEAR STRESS

$f_v = P/2A_v$
$P = 270{,}000$ lb.
$A_v = \pi d^2/4$
$A_v = \pi(6.50)^2/4$
$A_v = 33.18$ in^2

$f_v = (270{,}000)/(2 * 33.18)$

$f_v = 4069$ PSI

BEARING STRESS

$f_c = P/A_v$
$P = 270{,}000$ lb.

INNER

$A_v = d\,l = (6.50)(7.75)$
$= (50.38)$ in^2
$f_c = (270{,}000)/(50.38)$

$f_c = 5359$ PSI

OUTER

$A_v = 2ad = 2(4.00)(6.50)$
$= (52.0)$ in^2
$f_c = (270{,}000)/(52.0)$

$f_c = 5192$ PSI

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PIN (3)

BENDING STRESS (1)

$$M_{max} = \frac{P}{2}\left(\frac{1}{3}a + g + \frac{1}{4}l\right)$$

$$f_b = Mc/I$$
$$I = \pi d^4/64$$
$$c = d/2$$

$$f_b = \frac{P}{2}\left(\frac{1}{3}a + g + \frac{1}{4}l\right)\left(\frac{d}{2}\right)\left(\frac{64}{\pi d^4}\right)$$
$$= 16P\left(\frac{1}{3}a + g + \frac{1}{4}l\right)/(\pi d^3)$$

$$= 16P\left(\frac{4.0}{3} + .625 + \frac{7.75}{4}\right)/\pi\, 6.5^3$$

$$= (270{,}000)(.07225)$$

$$= 19{,}508 \text{ PSI}$$

(1) ADAPTED FROM FASTENING AND JOINING, 4th Ed, A REFERENCE ISSUE OF MACHINE DESIGN, PENTON PUBLISHERS PAGE 27

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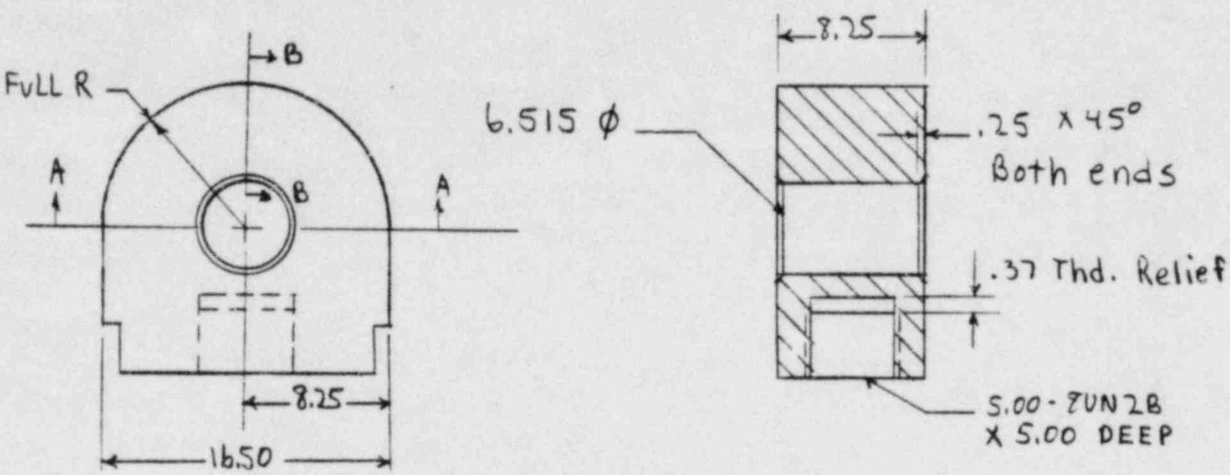
UPPER LOAD CELL ADAPTOR (4)

Mat'l. ASTM A-508, CLASS 2



Tension at Section A-A (Pin Hole)

$f_t = \frac{P}{A_t}$ $A_t = (16.5 - 6.515)(8.25) - 4(\frac{1}{2})(.25)^2 = 82.25 \text{ in}^2$

$f_t = \frac{270{,}000}{82.25} = 3283 \text{ PSI}$

Bearing stress

The bearing stress is the same as the inner bearing stress on the pin (3)

$f_c = \frac{270{,}000}{50.38} = 5359 \text{ PSI}$

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Thread Shear

$f_v = \frac{P}{A_v}$, $A_v = \pi D_{pitch} * l/2$

$D_{pitch} = D_{nom} - .64952/n$

$D_{pitch} = (5.00) - .64952/8$

$= 4.91881$ in.

D_{nom} = major diameter of extended thread

n = number of thread/in

l = Length of thread engagement

= 5.00 in.

Therefore $A_v = 38.63 \text{ in}^2$

$f_v = \frac{270{,}000}{38.63} = 6989$ PSI

Shear Tear-out Parallel to Section B-B (Pin Hole)

$f_v = \frac{P}{2A_v}$, $A_v = \left(8.25 - \frac{6.515}{2}\right)(8.25) - 2\left(\frac{1}{2}\right)(.25)^2 = 41.12$ in

$f_v = \frac{270{,}000}{2(41.12)} = 3283$ PSI

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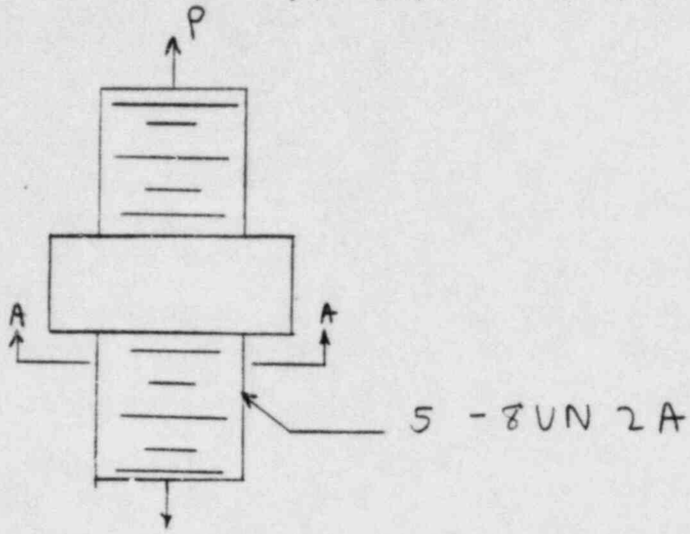
(5) LOAD CELL – Mat'L. 17-4 PH S/S BAR



Tension at A-A

$$f_t = \frac{P}{A_t}$$

From Mark's Handbook For MES 8th Ed, P 8-13

$A_t = 18.7 \text{ in}^2$

$$f_t = \frac{270{,}000}{18.7} = 14{,}439 \text{ PSI}$$

Thread Shear

The thread shearing stress is the same as for the adaptors.
$f_v = 6989$ PSI

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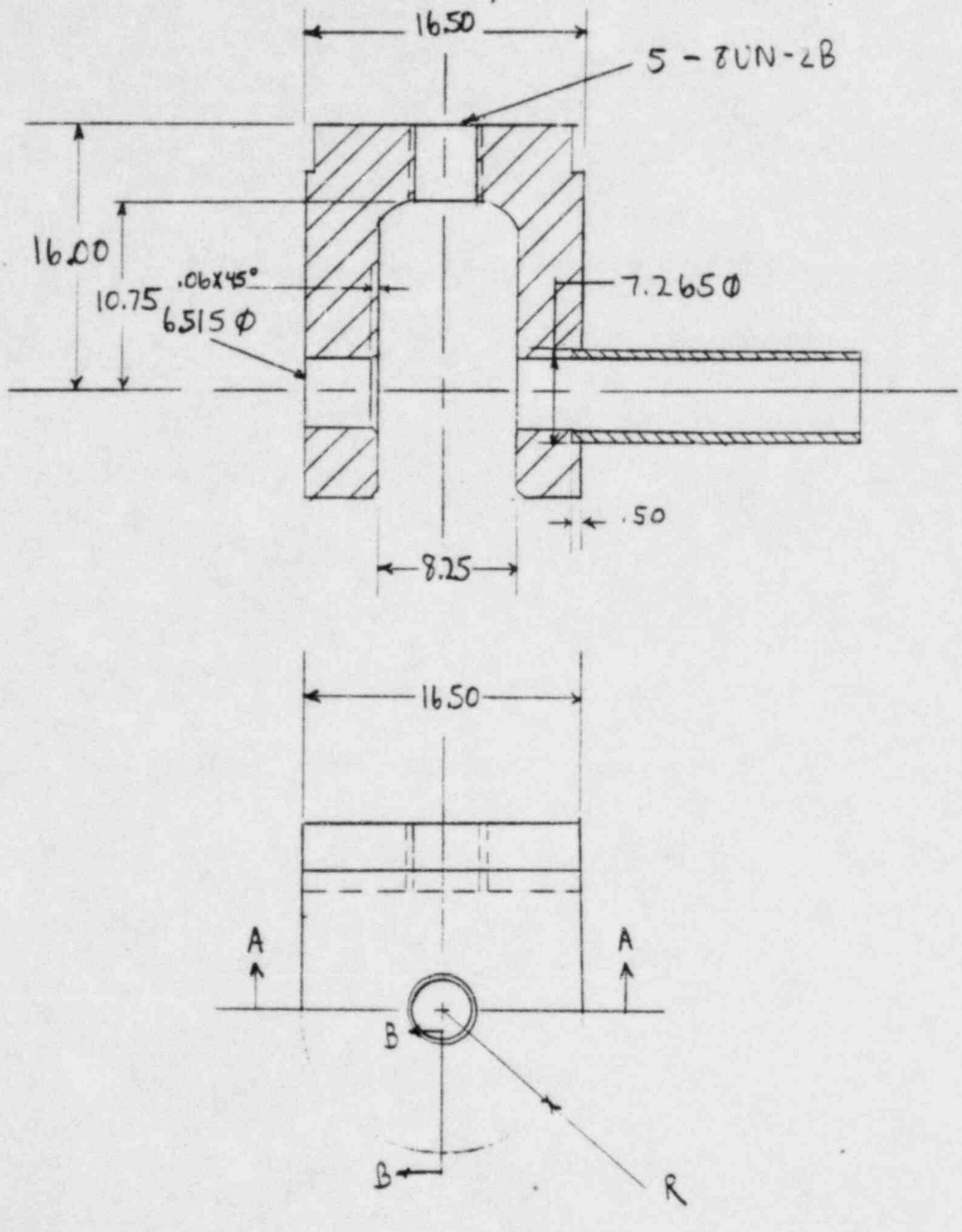
(6) LOWER LOAD CELL ADAPTOR

Mat'L. ASTM A-508, CLASS 2



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Tension at Section A-A (Pin Hole)

$ft = \frac{P/2}{At}$, $At = (16.5 - 6.515)(4.125) - (7.265 - 6.515)(.5) = 40.81 \text{ in}^2$

$ft = 135{,}000 / 40.81 = 3308$ PSI

Bearing stress @ Pin Hole

The bearing stress the same as the outer bearing stress on the pin (7)

$fc = \frac{270{,}000}{38.911} = 6939$ PSI

Thread Shear

$fv = \frac{P}{Av}$, $Av = \pi \, D_{pitch} * l/2$

$D_{pitch} = D_{nom} - .64952/n$

$D_{pitch} = (5.00) - .64952/8$

$= 4.91881$ in.

D_{nom} = major diameter of external thread

n = number of thread / in

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ℓ = Length of thread engagement

= 5.25 in

Therefore $A_v = 40.564 \text{ in}^2$

$$f_v = \frac{270{,}000}{40.564} = 6656 \text{ PSI}$$

Shear Tear-out Parallel to Sec B-B (Pin Hole)

$$f_v = \frac{P}{2A_v}, \quad A_v = \left(8.25 - \frac{6.515}{2}\right)(4.125) - (7.265 - 6.515)(.5)$$

$A_v = 20.22 \text{ in}^2$

$$f_v = \frac{135{,}000}{2(20.22)} = 3338 \text{ PSI}$$

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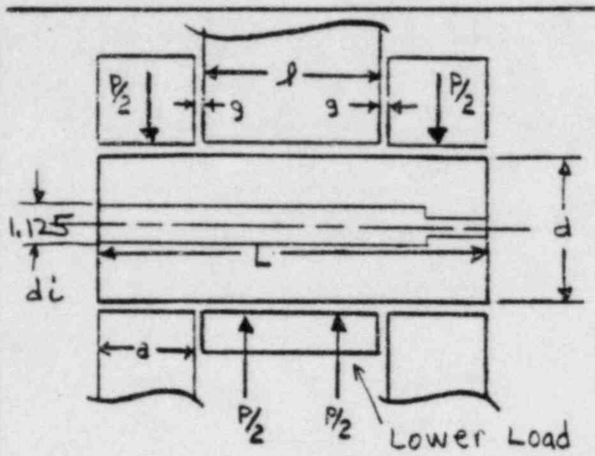
REMOVABLE PIN (7)

MAT'L: ASTM A-564 TYPE 630



P = force acting on assembly, lb.

d = diameter of pin, in.

l = length of bearing surface of center body, in.

a = length of bearing surface one side of outer body, in

g = gap between bearing surfaces, in.

L = total active length of pin, in $= l + 2(a+g)$

P = 270,000 lb.

d = 6.5 in. Being

l = 8.067 in. conservative,

a = 3.625 in (minimum a)

g = .1515 in (maximum g)

$(8.25 - 8.067)/2 + .06$

SHEAR STRESS

$f_v = P/2A_v$

$P = 270{,}000$ lb

$A_v = \pi(d_o - d_i)^2/4$

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

$A_v = 32.19$ in²

$f_v = (270{,}000)/(2 * 32.19)$

$f_v = 4194$ PSI

BEARING STRESS

$f_c = P/A_v$

$P = 270{,}000$ lb

INNER

$A_v = d\,l = (6.5)(8.067)$

$= (52.44)$ in²

$f_c = (270{,}000)/(52.44)$

$f_c = 5149$ PSI

OUTER

$A_v = 2ad = 2(3.625)(6.5)$

$= (47.13)$ in²

$f_c = (270{,}000)/(47.13)$

$f_c = 5729$ PSI

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REMOVABLE PIN (7)

BENDING STRESS[1]

$M_{max} = \frac{P}{2}\left(\frac{1}{3}a + g + \frac{1}{4}l\right)$

$f_b = Mc/I$

$I = \pi d^4/64$

$c = d/2$

$f_b = \frac{P}{2}\left(\frac{1}{3}a + g + \frac{1}{4}l\right)\left(\frac{d_o}{2}\right)\left(\frac{64}{d_o^4 - d_i^4}\right)$

$= 16\left(\frac{1}{3}a + g + \frac{1}{4}l\right)(d_o)/(d_o^4 - d_i^4)$

$= 16P\left(\frac{3.625}{3} + .1515 + \frac{8.061}{4}\right)(6.5)/\pi(6.5^4 - 1.125^4)$

$= 270{,}000(.06268)$

$= 16{,}924$ PSI

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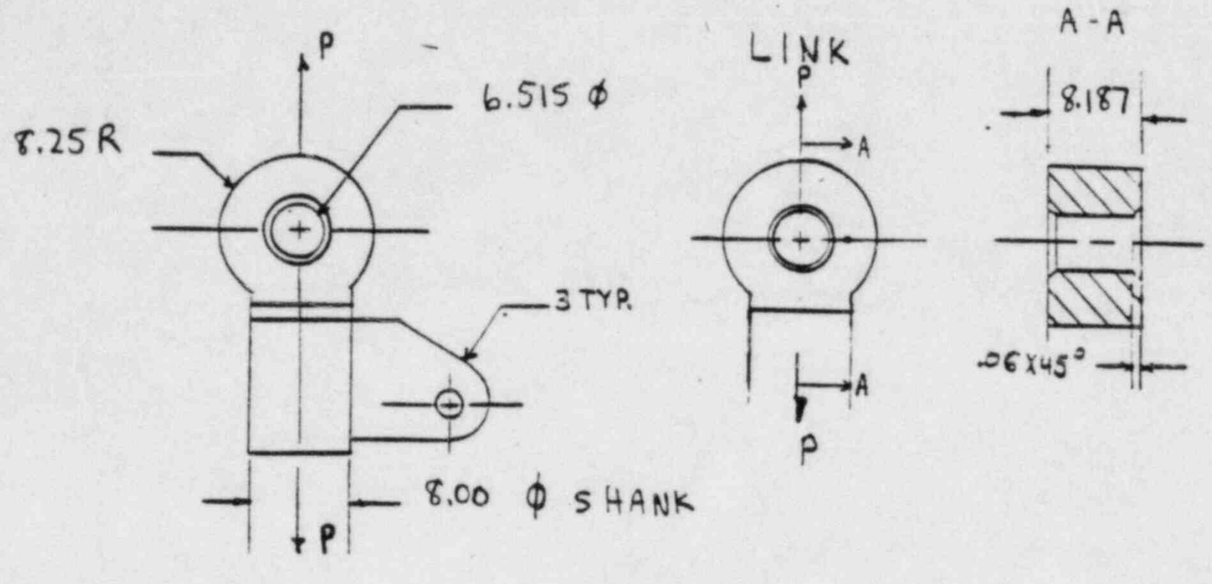
(8) SLING BLOCK LINK - ASTM A508 Class 2



Tension at 6.515 ϕ Hole

$f_t = \frac{P}{A_t}$ $\quad A_t = (8.25 - 3.258)(8.187)(2) - \frac{1}{2}4(.06)^2 = 81.73 \text{ in}^2$

$f_t = \frac{270{,}000}{81.73}$

$f_t = 3304$ PSI

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Shear at 6.515 ∅ Hole

$f_v = \frac{P}{2A_v}$ $A_v = (8.25 - 3.258)(8.187) - \frac{1}{2}2(.06)^2 = 40.87\,in^2$

$f_v = \frac{270,000}{2(40.87)} = 3312$ PSI

Bearing on 6.500 ∅ Pin.

The bearing stress is the same as the inner bearing stress on the removable pin. The pin is item (7).

$f_c = 270,000 / 52.44 = 5149$ PSI

Tension at 8.00 ∅ cylindrical section

$f_t = \frac{P}{A_t}$ $A_t = \pi \frac{(8.00)^2}{4} = 50.27\,in^2$

$f_t = \frac{270,000}{50.27} = 5371$ PSI

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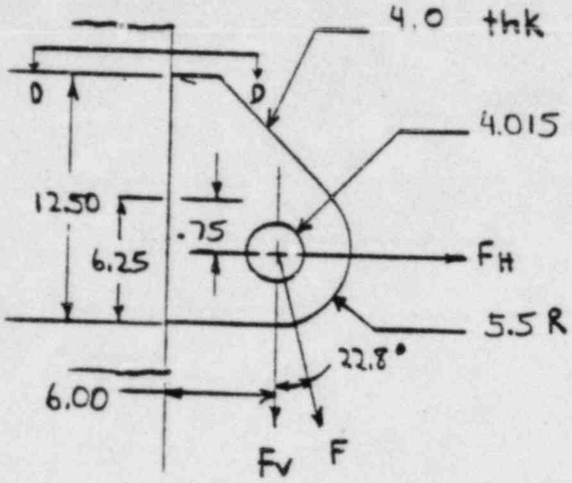
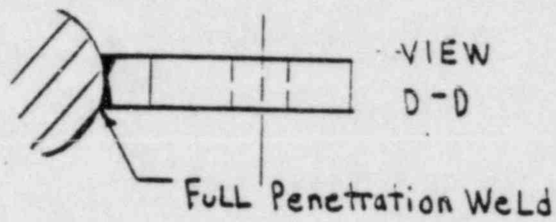
⑨ LINK LUG

Mat'L. ASTM A-588 GR.A





$F_v = \frac{270{,}000}{3} = 90{,}000$ lbs.

$F = \frac{F_v}{\cos 22.8°} = 97{,}628$ lbs

$F_H = F_v \tan 22.8° = 37{,}833$ lbs.

Tension at 4.015 ϕ Hole

$f_t = \frac{F}{2A_t}$ $\quad A_t = (5.50 - 2.008)4 - 2\frac{1}{2}(.06)^2 = 13.964 \text{ in}^2$

$f_t = \frac{97{,}628}{2(13.964)} = 3496$ PSI

Shear Tear at Hole

$f_v = \frac{F}{2A_v} = \frac{97{,}628}{2(13.964)}$ $\quad A = (5.50 - 2.008)4 - 2\frac{1}{2}(.06)^2 = 13.964 \text{ in}^2$

$f_v = 3496$ PSI

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Bearing at 4.015 ϕ hole

The bearing stress is the same as the inner bearing stress on the upper clevis pin item 10

$f_c = 97{,}628 / (3.995)(4.015) = 6109$ PSI

Combined stress from Tension and Bending

$M = 6.00\,F_V - .75\,F_H$

$M = 6.00(90{,}000) - .75(37{,}833)$

$M = 511{,}625$ in-lb

$$f_t = \frac{F_H}{A} + \frac{M}{Z}$$

$A = (12.5)(4) = 50 \text{ in}^2$

$$Z = \frac{1}{6}(4)(12.5)^2 = 104.17 \text{ in}^3$$

$$f_t = \frac{37{,}833}{50} + \frac{511{,}625}{104.17}$$

$f_t = 757 + 4911$

$f_t = 5668$ PSI

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Vertical Shear at Full Penetration Weld

$f_v = \frac{F_v}{A_v}$ $A_v = (4)(12.5) = 50\ in^2$

$f_v = \frac{90{,}000}{50} = 1800\ PSI$

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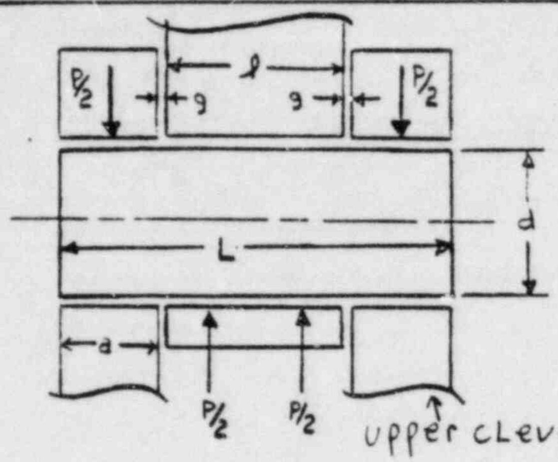
4" Ø UPPER SLING LEG PIN (10)

MAT'L: ASTM -A434, AISI 4340 CLASS BD



P = force acting on assembly, lb.
d = diameter of pin, in.
l = length of bearing surface of center body, in.
a = length of bearing surface one side of outer body, in
g = gap between bearing surfaces, in.
L = total active length of pin, in
= l + 2(a + g)

P = 97,628 lb.
d = 3.995 in.
l = 4.00 in.
a = 1.92 in 2 − 2(.04)
g = .23 in.
[8.38 + 2(.04) − 2(2.00) − 4.00]/2

SHEAR STRESS

$f_v = P/2A_v$
P = 97,628
$A_v = \pi d^2/4$
$A_v = \pi(3.995)^2/4$
$A_v = 12.53$ in²

$f_v = (97,628)/(2 * 12.53)$

$f_v = 3896$ PSI

BEARING STRESS

$f_c = P/A_v$
P =

INNER
$A_v = d\,l = (3.995)(4.00)$
$= (15.98)$ in²
$f_c = (97,628)/(15.98)$

$f_c = 6109$ PSI

OUTER
$A_v = 2ad = 2(1.92)(3.995)$
$= (15.34)$ in²
$f_c = (97,628)/(15.34)$

$f_c = 6364$ PSI

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PIN (10)

BENDING STRESS(1)

$$M_{max} = \frac{P}{2}\left(\frac{1}{3}a + g + \frac{1}{4}l\right)$$

$$f_b = Mc/I$$
$$I = \pi d^4/64$$
$$c = d/2$$

$$f_b = \frac{P}{2}\left(\frac{1}{3}a + g + \frac{1}{4}l\right)\left(\frac{d}{2}\right)\left(\frac{64}{\pi d^4}\right)$$
$$= 16P\left(\frac{1}{3}a + g + \frac{1}{4}l\right)/(\pi d^3)$$

$$= 16P\left(\frac{1.92}{3} + .23 + \frac{4}{4}\right)/(\pi 3.995^3)$$

$$= 97,628\,(.14937)$$

$$= 14,583 \text{ PSI}$$

(1) ADAPTED FROM
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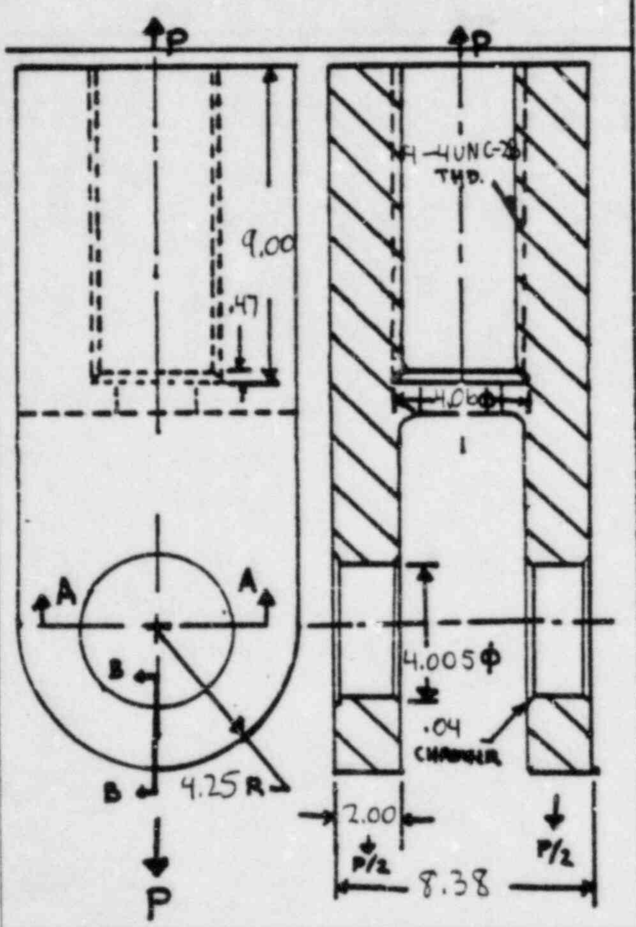
S.O.: UCG-27694	CALC. NO.	FILE NO.	GROUP: REE

UPPER SLING LEG CLEVIS (11)

MAT'L: ASTM A-237, AISI E-4340 CLASS G



SEC A-A BEARING STRESS

THE BEARING STRESS IS THE SAME AS outer Bearing STRESS ON THE PIN ITEM (10)

$f_c = 97{,}628 / 15.34$

$f_c = 6364$ PSI

THREAD SHEAR

THE THREAD SHEAR IS THE SAME AS FOR THE ARM IT. (12)

$f_v = 97{,}628 / 36.19$

$f_v = 2698$ PSI

TENSION @ THD RELIEF

$f_t = P/A_t$

$P = 97{,}628$ lb

$A_t = (7.50)(8.38) - \frac{\pi}{4}(4.06)^2$

$f_t = 97{,}628 / 58.28$

$f_t = 1675$ PSI

TENSION @ SEC A-A (PIN HOLE)

$f_t = P/A_t$

$P = 97{,}628$ lb

$\boxed{\frac{A_t}{4}}$ $A_t = [(8.5) - (4.005)] \times 2(2.00) - 4(.04)^2 = 17.97 \ in^2$

$f_t = 97{,}628 / 17.97$

$f_t = 5433$ PSI

SHEAR TEAR-OUT PARALLEL TO SEC-B-B (@PIN HOLE)

$f_v = P/A_v$

$P = 97{,}628$ lb

$A_v = A_t = 17.97 \ in^2$

$\therefore f_v = f_t$

$f_t = 5433$ PSI

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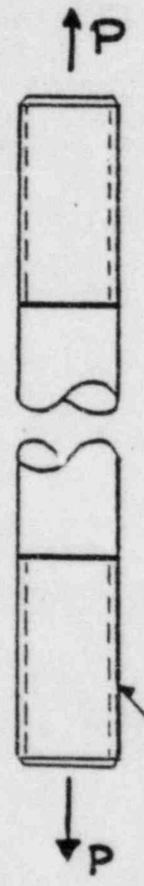
ARM (12)

MAT'L: ASTM A-306



THREAD SHEAR

$f_v = P/A_v$

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

FOR AN EXTERNAL THREAD

$D_{pitch} = D_{nom} - .64952/n$

$D_{pitch} = (4.00) - .64952/(4)$

$= (3.8376)$ in.

D_{nom} = major diameter of external thread

n = number of threads/in

l = length of thread engagement = 6.00

THEREFORE $A_v = (36.169)$ in²

$P = 97,628$ lbs

$f_v = 2698$ PSI

THREAD TENSION

$f_t = P/A_t$

FOR EXTERNALLY THREADED PARTS

$A_t = \frac{\pi}{4}(D_{nom} - .9743/n)^2$

$= \frac{\pi}{4}(4 - .9743/4)^2 = 11.083$ in²

$f_t = (97,628)/(11.083)$

$f_t = 8809$ PSI

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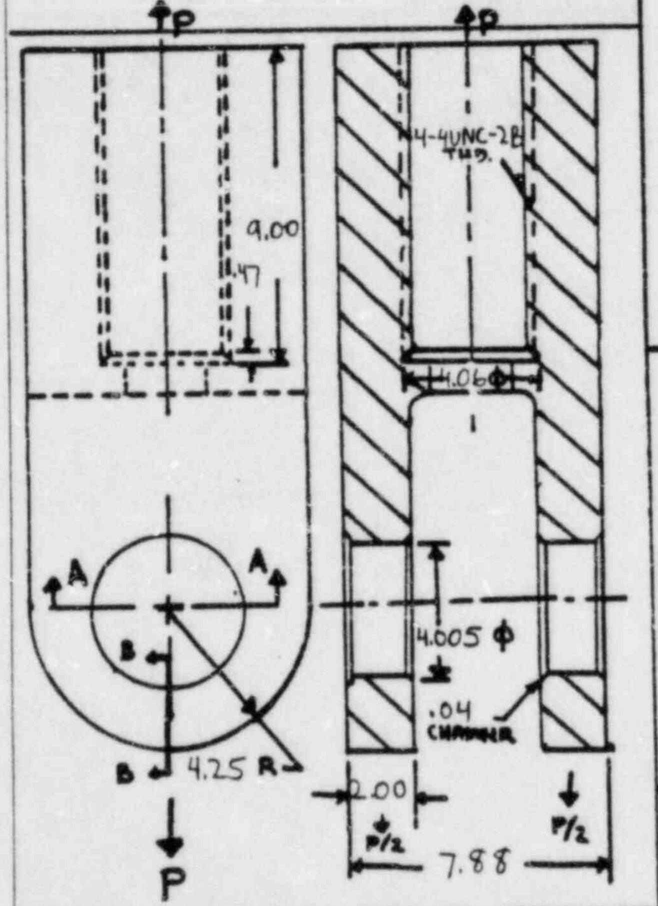
LOWER SLING LEG CLEVIS (13)

MAT'L: ASTM A-237
AISI E-4340
CLASS G



SEC. A-A BEARING STRESS

THE BEARING STRESS IS THE SAME AS THE OUTER BEARING STRESS ON THE PIN ITEM (14)

$f_c = 97628 / 15.34$

$f_c = 6364$ PSI

THREAD SHEAR

THE THREAD SHEAR IS THE SAME AS FOR THE ARM (12)

$f_v = 97,628 / 36.19$

$f_v = 2698$ PSI

TENSION @ THD RELIEF

$f_t = P/A_t$

$P = 97,628$

$A_t = (8.50)(7.88) - \frac{\pi}{4}(4.06)^2$

$f_t = 97,628 / 54.03$

$f_t = 1807$ PSI

TENSION @ SEC A-A (@ PIN HOLE)

$f_t = P/A_t$

$P = 97,628$ lb

$A_t = [(8.500) - (4.005)] \times 2(2.00) - 4(.04)^2 = 17.97$ in²

$f_t = 97,628 / 17.97$

$f_t = 5433$ PSI

SHEAR TEAR-OUT PARALLEL TO SEC-B-B (@ PIN HOLE)

$f_v = P/A_v$

$P = 97,628$ lb

$A_v \approx A_t = 17.97$ in²

$\therefore f_v = f_t$

$f_t = 5433$ PSI

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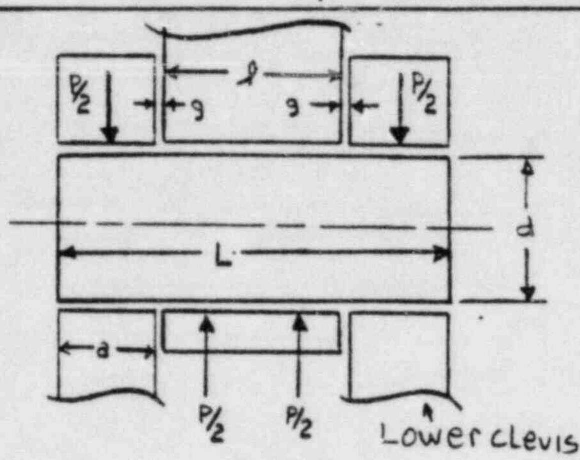
4" ϕ LOWER SLING LEG PIN (14)

MAT'L: ASTM A-434 AISI 4340 CLASS BD



P = force acting on assembly, lb.
d = diameter of pin, in.
l = length of bearing surface of center body, in.
a = length of bearing surface one side of outer body, in
g = gap between bearing surfaces, in.
L = total active length of pin, in
$= l + 2(a+g)$

P = 97,628 lb.
d = 3.995 in.
l = 3.50 in.
a = 1.92 in 2-2(.04)
g = .23 in
[7.88 + 2(.04) - 2(2.00) - 3.50]/2

SHEAR STRESS

$f_v = P/2A_v$
P = 97,628
$A_v = \pi d^2/4$
$A_v = \pi(3.995)^2/4$
$A_v = 12.53$ in²

$f_v = (97,628)/(2 * 12.53)$

$f_v = 3896$ PSI

BEARING STRESS

$f_c = P/A_c$
P = 97,628

INNER
$A_v = d\,l = (3.995)(3.5)$
$= (13.98)$ in²
$f_c = (97,628)/(13.98)$

$f_c = 6983$ PSI

OUTER
$A_v = 2ad = 2(1.92)(3.995)$
$= (15.34)$ in²
$f_c = (97,628)/(15.34)$

$f_c = 6364$ PSI

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PIN (14)

BENDING STRESS (1)

$M_{max} = \frac{P}{2}\left(\frac{1}{3}a + g + \frac{1}{4}l\right)$

$f_b = Mc/I$

$I = \pi d^4/64$

$c = d/2$

$f_b = \frac{P}{2}\left(\frac{1}{3}a + g + \frac{1}{4}l\right)\left(\frac{d}{2}\right)\left(\frac{64}{\pi d^4}\right)$

$= 16P\left(\frac{1}{3}a + g + \frac{1}{4}l\right)/(\pi d^3)$

$= 16P\left(\frac{1.92}{3} + .23 + \frac{3.5}{4}\right)/(\pi 3.995^3)$

$= 97{,}628\ (.13938)$

$= 13{,}607$ PSI

(1) ADAPTED FROM FASTENING AND JOINING, 4th Ed, A REFERENCE ISSUE OF MACHINE DESIGN, PENTON PUBLISHERS PAGE 27

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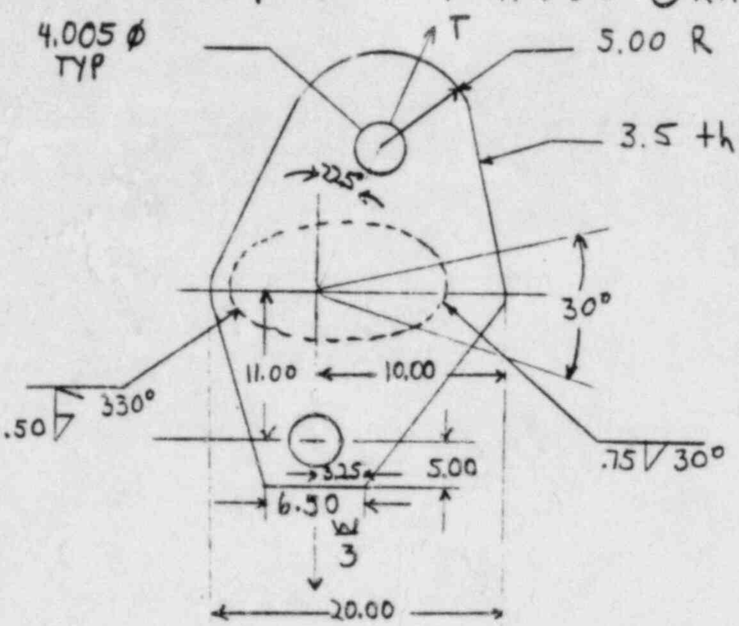
(15) SPREADER LUG

Material: ASTM A588 GRADE A STEEL PLATE



Bearing stress

The bearing stress for the upper hole is the same as the bearing stress on the sling leg's lower pin (14). Using the inner stress:

$f_c = 97{,}628 / 13.98 = 6983$ PSI

The bearing stress for the lower hole is the same as the bearing stress on the lifting leg's upper pin (18). Using the inner stress:

$f_c = 90{,}000 / 13.98 = 6438$ PSI

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Tension at upper Hole

$ft = \frac{P}{At}$ $At \approx (5.00(2) - 4.005)3.5 = 20.983 \text{ in}^3$

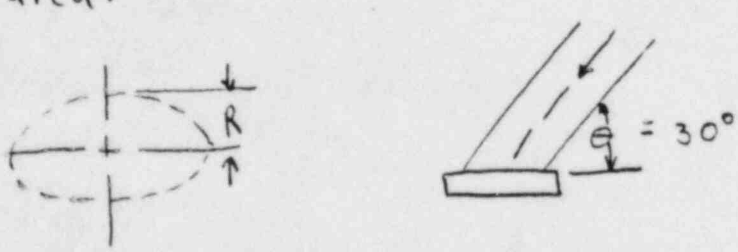
$ft = \frac{97{,}628}{20.983} = 4653 \text{ PSI}$

Shear Tearout at upper Hole

$fv = \frac{P}{2Av}$, $Av \approx \frac{1}{2} At$, $fv = ft = 4653 \text{ PSI}$

SPREADER ARM WELD

Be generously consertative & assume that the weld is all .75 V and that the lug and arm do not contact so that all the force treated as acting through the weld. All stress in fillets are traditionally treated as shear across the throat area.



R = outside Radius of pipe = (ID + 2t)/2 where

t = wall thickness

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*$R = (7.625 + 2(.500))/2 = 4.3125$ in.

ℓ = perimeter length

$\simeq R\pi(1/\sin\theta + 1) = 40.644$ in

$f_v = \frac{P}{A_v}$, $A_v = .707\,w\ell$ where w = weld Leg width

$= .707(.75)(40.644) = 21.55\ in^2$

P = 21,843 lbs (from spreader arm calculation)

$f_v = \frac{21,843}{21.55} = 1014$ PSI

* From Mark's Handbook 8th ed, P 8-160 For 8.00 SCH 80 pipe t = .50, ID = 7.625

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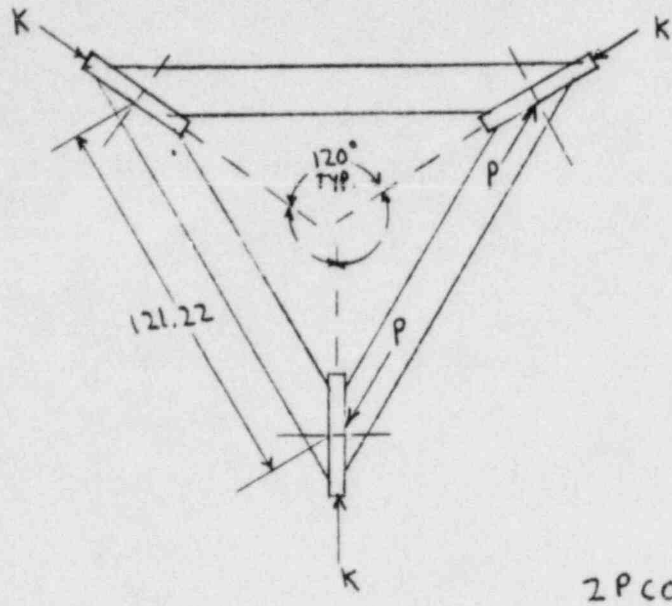
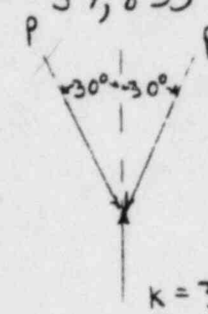
(16) SPREADER ARM - ASTM A106 GRADE B SEAMLESS



$K = F_V \tan 22.8°$

$= 90{,}000 \tan 22.8°$

$= 37{,}833$ lbs



$2P\cos 30° = K = 37{,}833$ lbs.

$P = \dfrac{37{,}833}{2\cos 30°} = 21{,}843$ lbs

NOMINAL COMPRESSIVE STRESS IN SPREADER ARM
FOR 8.00 SCH. 80 PIPE
(Mark's Handbook, 8th Ed., P8-158)

$A_t = 12.76 \text{ in}^2$ = cross sectional area
$I = 105.7 \text{ in}^4$ = moment of Inertia
$S = 24.52 \text{ in}^3$ = Section Modulus
$r = 2.878$ in = radius of gyration

$F_t = \dfrac{P}{A_t} = \dfrac{21{,}843}{12.76} = 1712$ PSI

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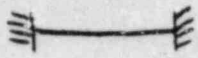
Allowable Compressive stress
(AISC Manual) 7th Ed. PS-138

$k = .65$  Recommended for Fixed - Fixed Ends

$$\therefore \frac{kl}{r} = \frac{(.65)(122.22)}{2.878} = 27.604$$

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

$$= 127.888$$

case: $\frac{kl}{r} < C_c \quad \therefore$

F_a = allowable compressive stress in the abscence of bending moments

Let $A = \left(\frac{kl}{r}\right) / C_c$

then $F_a = \left(1 - \frac{A^2}{2}\right) F_y \Big/ \left(\frac{5}{3} + \frac{3}{8}A - \frac{1}{8}A^3\right)$

$A = \frac{27.604}{127.888} = .215845 \qquad F_y = 35,000 \text{ PSI}$

$F_a = 34184.69 / 1.749 = 19545 \text{ PSI}$

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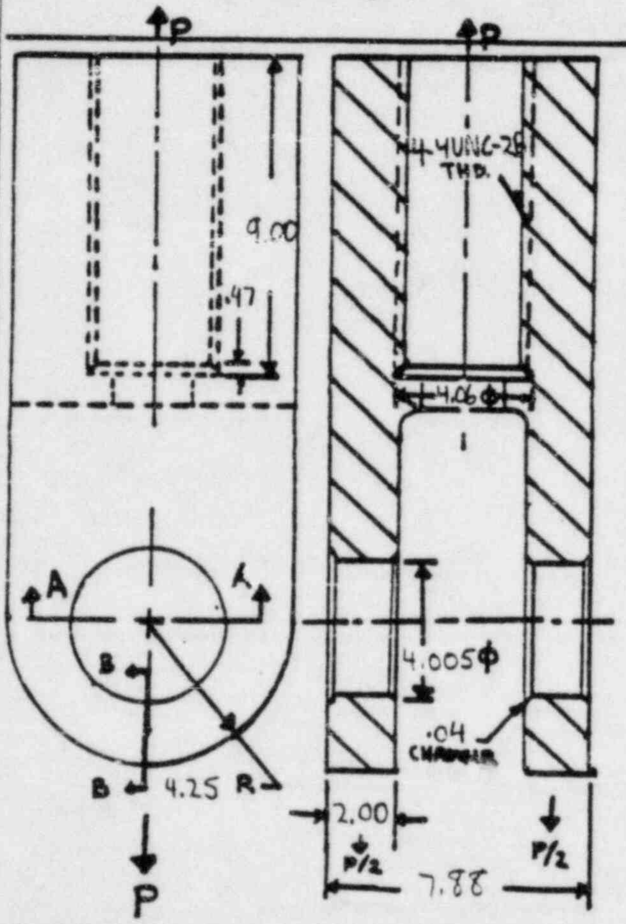
UPPER LIFTING

LEG CLEVIS (17)

MAT'L: ASTM A-237
AISI E-4340
CLASS G.



SEC A-A BEARING STRESS

THE BEARING STRESS IS THE SAME AS THE OUTER BEARING STRESS ON THE PIN (18)

$f_c = 90{,}000 / 15.34$

$f_c = 5867$ PSI

THREAD SHEAR

THE THREAD SHEAR IS THE SAME AS FOR THE LEG ROD

$f_v = 90{,}000 / 36.169$

$f_v = 2488$ PSI

TENSION @ THD RELIEF

$f_t = P/A_t$

$P = 90{,}000$ lb

$A_t = (8.50)(7.88) - \frac{\pi}{4}(4.06)^2$

$f_t = 90{,}000 / 54.03$

$f_t = 1666$ PSI

TENSION @ SEC A-A (PIN HOLE)

$f_t = P/A_t$

$P = 90{,}000$ lb

A/4 $A_t = [(7.5) - (4.005)] \cdot 2(2.00) - 4(.04)^2 = 17.97$ in²

$f_t = 90{,}000 / 17.97$

$f_t = 5008$ PSI

SHEAR TEAR-OUT PARALLEL TO SEC-B-B (@ PIN HOLE)

$f_v = P/A_v$

$P = 90{,}000$ lb

$A_v \approx A_t = 17.97$ in²

$\therefore f_v = f_t$

$f_t = 5008$ PSI

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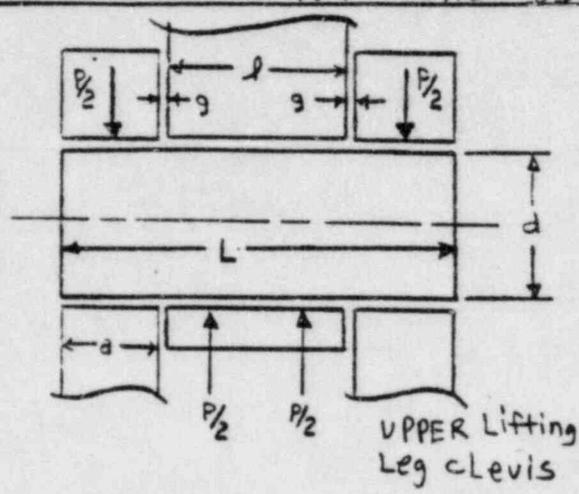
4"Ø UPPER LIFTING LEG PIN ---- (18)

MAT'L: ASTM A-434 AISI 4340 CLASS BD



P = force acting on assembly, lb.
d = diameter of pin, in.
l = length of bearing surface of center body, in.
a = length of bearing surface one side of outer body, in
g = gap between bearing surfaces, in.
L = total active length of pin, in
= l + 2(a + g)

$P = 90{,}000$ lb.
$d = 3.995$ in.
$l = 3.5$ in
$a = 1.92$ in $2 - 2(.04)$
$g = .23$ in
$[7.88 + 2(.04) - 2(1.92) - 3.50]/2$

SHEAR STRESS

$f_v = P/2A_v$
$P = 90{,}000$ lb
$A_v = \pi d^2/4$
$A_v = \pi(3.995)^2/4$
$A_v = 12.53$ in²

$f_v = (90{,}000)/(2 * 12.53)$

$f_v = 3591$ PSI

BEARING STRESS

$f_c = P/A_v$
$P = 90{,}000$ lb

INNER

$A_v = dl = (3.995)(3.5)$
$= (13.98)$ in²
$f_c = (90{,}000)/(13.98)$

$f_c = 6438$ PSI

OUTER

$A_v = 2ad = 2(1.92)(3.995)$
$= (15.34)$ in²
$f_c = (90{,}000)/(15.34)$

$f_c = 5867$ PSI

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UPPER LIFTING LEGPIN

(18)

BENDING STRESS (1)

$$M_{max} = \frac{P}{2}\left(\frac{1}{3}a + g + \frac{1}{4}l\right)$$

$$f_b = Mc/I$$
$$I = \pi d^4/64$$
$$c = d/2$$

$$f_b = \frac{P}{2}\left(\frac{1}{3}a + g + \frac{1}{4}l\right)\left(\frac{d}{2}\right)\left(\frac{64}{\pi d^4}\right)$$
$$= 16P\left(\tfrac{1}{3}a + g + \tfrac{1}{4}l\right)/(\pi d^3)$$

$$= 16P\left(\frac{1.92}{3} + .23 + \frac{3.5}{4}\right)/\pi\, 3.995^3$$

$$= 90{,}000(.13938)$$

$$= 12{,}544 \text{ PSI}$$

(1) ADAPTED FROM FASTENING AND JOINING, 4th Ed, A REFERENCE ISSUE OF MACHINE DESIGN, PENTON PUBLISHERS PAGE 27

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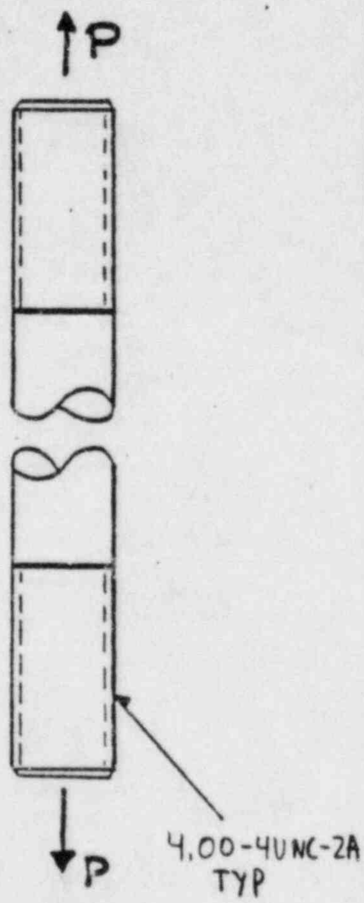
LEG (19)

MAT'L: ASTM A-306 GRADE 70



THREAD SHEAR

$f_v = P/A_v$

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

FOR AN EXTERNAL THREAD

$D_{pitch} = D_{nom} - .64952/n$

$D_{pitch} = (4) - .64952/(4)$

$= (3.8376)$ in.

D_{nom} = major diameter of external thread

n = number of threads/in

ℓ = length of thread engagement = 6.00

THEREFORE $A_v = (36.169)$ in^2

P = 90,000 lb

f_v = 2488 PSI

THREAD TENSION

$f_t = P/A_t$

FOR EXTERNALLY THREADED PARTS

$A_t = \frac{\pi}{4}(D_{nom} - .9743/n)^2$

$= \frac{\pi}{4}(4 - .9743/4)^2 = 11.083$

$f_t = (90,000)/(11.083)$

f_t = 8121 PSI

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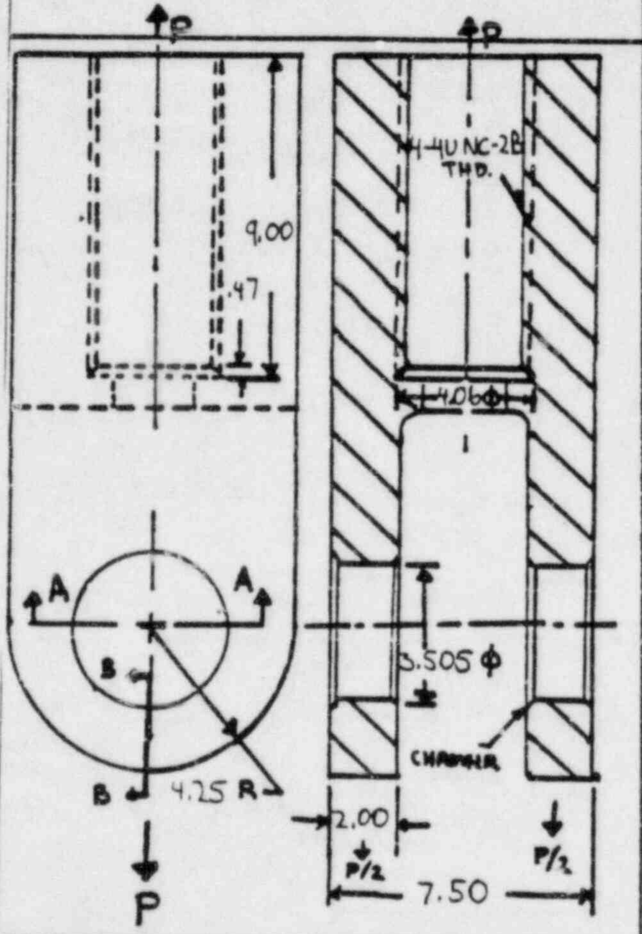
LOWER LIFTING

LEG CLEVIS (20)

MAT'L: ASTM A-237
AISI E-4340
CLASS G



SEC A-A BEARING STRESS

THE BEARING STRESS IS THE SAME AS OUTER BEARING STRESS ON THE PIN (21)

$f_c = 90,000 / 13.44$

$f_c = 6696$ PSI

THREAD SHEAR

THE THREAD SHEAR IS THE SAME AS FOR THE LEG IT. (19)

$f_v = 90,000 / 36.169$

$f_v = 2488$ PSI

TENSION @ THD RELIEF

$f_t = P/A_t$

$P = 90,000$ lb

$A_t = (8.50)(7.50) - \frac{\pi}{4}(4.06)^2$

$f_t = 90,000 / 50.804$

$f_t = 1772$ PSI

TENSION @ SEC A-A (@PIN HOLE)

$f_t = P/A_t$

$P = 90000$

[A4/1] $A_t = [(8.50) - (3.505)] \times 2(2.00) - 4(.04)^2 = 19.974$ in²

$f_t = 90000 / 19.974$

$f_t = 4506$ PSI

SHEAR TEAR-OUT PARALLEL TO SEC-B-B (@PIN HOLE)

$f_v = P/A_v$

$P = 90,000$ lb

$A_v \approx A_t = 19.974$ in²

$\therefore f_v = f_t$

$f_t = 4506$ PSI

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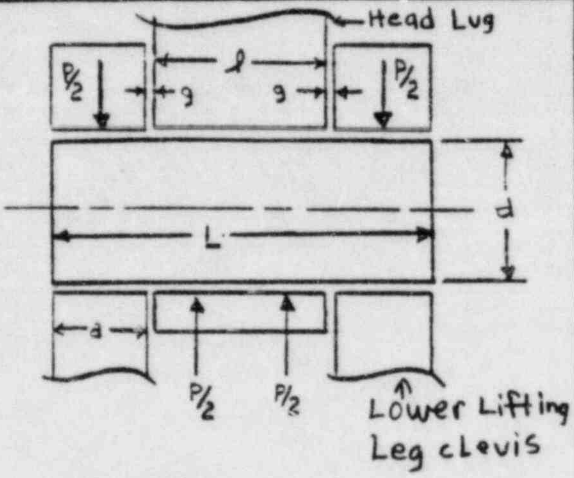
3.5" LOWER LIFTING LEG PIN (21)

MAT'L: ASTM A434, AISI 4340 STEEL CLASS BD



P = force acting on assembly, lb.
d = diameter of pin, in.
l = length of bearing surface of center body, in.
a = length of bearing surface one side of outer body, in
g = gap between bearing surfaces, in.
L = total active length of pin, in
= l + 2(a + g)

P = 90000 lb.
d = 3.50 in.
l = 3.00 nom. in
a = 1.92 in 2.00 - 2(.04)
g = .29 in
[7.5 + 2(.04) - 2(2.00) - 3.00]/2

SHEAR STRESS

$f_v = P/2A_v$
$P = 90{,}000\ lb$
$A_v = \pi d^2/4$
$A_v = \pi(3.50)^2/4$
$A_v = 9.62\ in^2$

$f_v = (90{,}000)/(2 * 9.62)$

$f_v = 4678\ PSI$

BEARING STRESS

$f_c = P/A_v$
$P = 90{,}000\ lb$

INNER

$A_v = d\,l = (3.50)(3.00)$
$= (10.5)\ in^2$
$f_c = (90{,}000)/(10.5)$

$f_c = 8571\ PSI$

OUTER

$A_v = 2ad = 2(1.92)(3.500)$
$= (13.44)\ in^2$
$f_c = (90{,}000)/(13.44)$

$f_c = 6696\ PSI$

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PIN (21)

BENDING STRESS[1]

$$M_{max} = \frac{P}{2}\left(\frac{1}{3}a + g + \frac{1}{4}l\right)$$

$$f_b = Mc/I$$

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

$$c = d/2$$

$$f_b = \frac{P}{2}\left(\frac{1}{3}a + g + \frac{1}{4}l\right)\left(\frac{d}{2}\right)\left(\frac{64}{\pi d^4}\right)$$

$$= 16P\left(\frac{1}{3}a + g + \frac{1}{4}l\right)/(\pi d^3)$$

$$= 16P\left(\frac{1.92}{3} + .29 + \frac{3.0}{4}\right)/\pi\, 3.5^3$$

$$= 90{,}000\,(.19956)$$

$$= 17{,}960 \text{ PSI}$$

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APPENDIX B

DETAILED STRESS ANALYSIS -

REACTOR VESSEL INTERNALS LIFT RIG

This appendix provides the detailed stress analysis for the Virgil C. Summer 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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TITLE	CALCULATIONS NO.
R.V. Internals Lift Rig Assembly	PDC-

AUTHOR & DATE	CHECKED BY & DATE
F. Peduzzi F.C. Peduzzi 3/83	J. Richard J Richard 3/83

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
JOSEPH W. RICHARD
ENGINEER
NO 007167 E

J W Richard

REVISION NO.	DATE	DESCRIPTION	BY
		Original Issue	F. Peduzzi

RESULTING REPORTS, LETTERS OR MEMORANDA:

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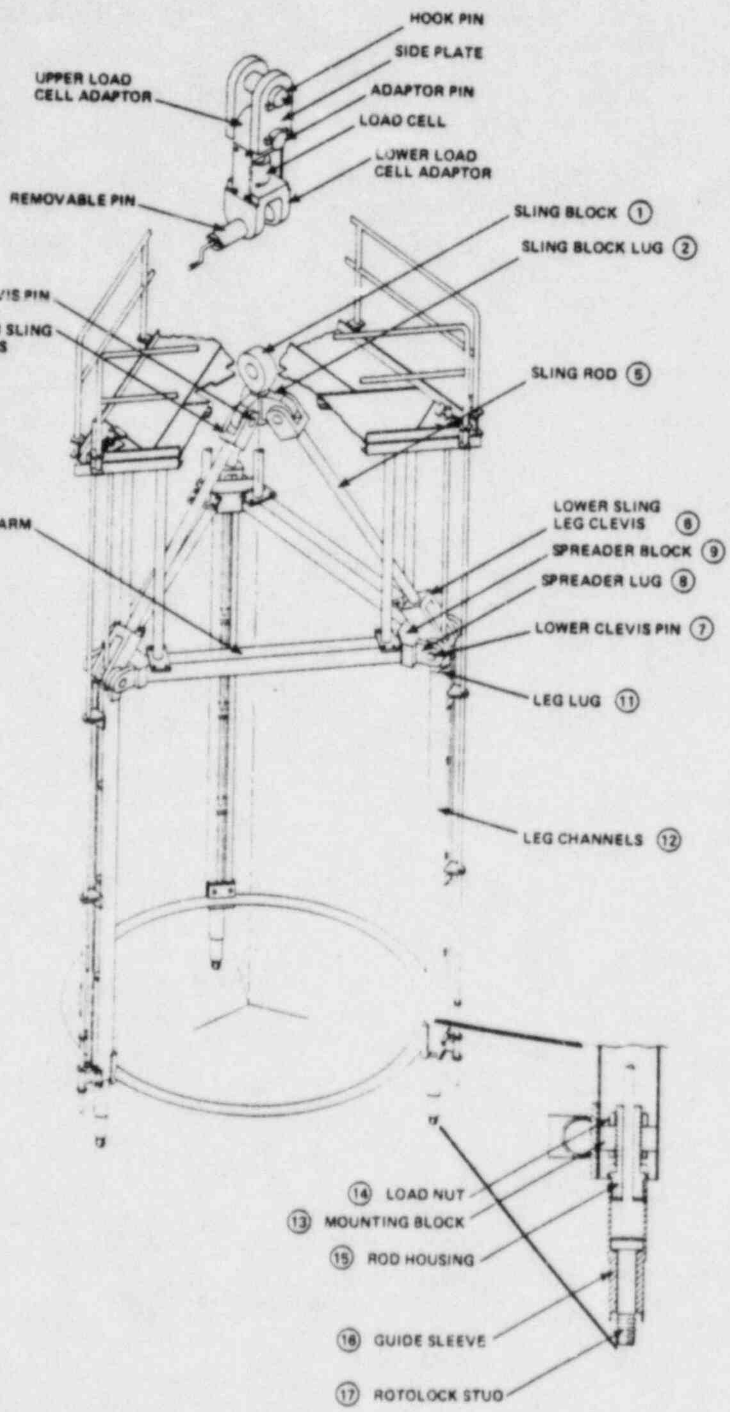

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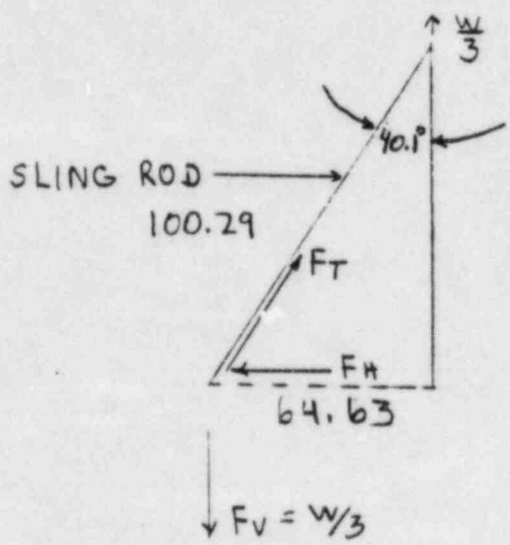
DESIGN weight

202,000 lbs. WT. OF Lower Internals
19,800 lbs. EST. WT. of RIG.
8,200 lbs. Contingencies
230,000 lbs Total *

SLING LEG ANGLE



$F_V = \frac{230,000}{3} = 76,667$ lbs.

$F_T = \frac{F_V}{\cos 40.1} = 100,229$ lbs.

$F_H = F_V \tan 40.1° = 64,561$ lb.

$\sin\theta = .6444$, $\theta = 40.1°$

FT = TENSION IN SLING ROD

FH = FORCE EXERTED OUTWARD SPREADER BLOCK

Fv = FORCE EXERTED ON EACH LEG ASSEMBLY

* ITEMS 13 THROUGH 17 USE W = 202,000 lbs

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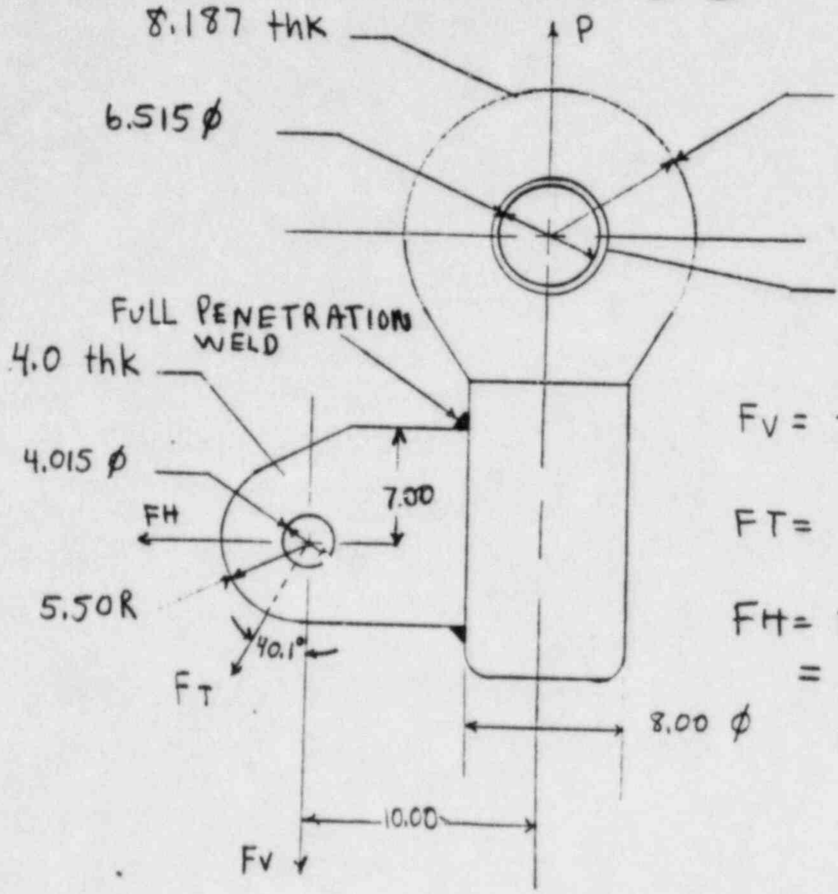
SLING BLOCK and LUG ① ②



$F_V = \frac{230,000}{3} = 76,667$ lbs.

$F_T = \frac{76,667}{\cos 40.1°} = 100,229$ lbs.

$F_H = \tan 40.1° \; 76,667$
$= 64,560$ lbs.

SLING BLOCK - Mat'L. ASTM A 508 Class 2

Tension @ 6.515 ϕ Hole

$[(8.25)(2) - 6.515]\, 8.187 - 4(\tfrac{1}{2})(.06)^2 = A_t$

$A_t = 81.740 \text{ in}^2$

$f_t = \frac{P}{A_t} = \frac{230,000}{81.740} = 2814$ PSI

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Bearing @ 6.515 ϕ Hole

$f_c = \frac{P}{A_c}$, $A_c = d\,l = (6.515)(8.187 - 2(.06)) = 52.56\,in^2$

$f_c = \frac{230{,}000}{52.56} = 4376$ PSI

Shear Tear-out @ 6.515 Hole

$f_v = \frac{P}{2A_v}$, $A_v = \left(8.25 - \frac{6.515}{2}\right)(8.187) - 2(\tfrac{1}{2})(.06)^2 = 40.87\,in^2$

$f_v = \frac{230{,}000}{2(40.87)} = 2814$ PSI

Tension @ 8.00ϕ CYLINDRICAL SECTION

$f_t = \frac{P}{A_t}$, $A_t = \frac{\pi d^2}{4} = \frac{\pi(8^2)}{4} = 50.27\,in^2$

$f_t = \frac{230{,}000}{50.27} = 4575$ PSI

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SLING BLOCK LUG ② MAT'L. ASTM A588 GRADE A STEEL

Tension @ 4.015 ϕ Hole, $P = F_T$

$$f_t = \frac{P}{A_t} \quad A_t = 2\left(5.5 - \frac{4.015}{2}\right)4 = 27.94 \text{ in}^2$$

$$f_t = \frac{100,229}{27.94} = 3587 \text{ PSI}$$

Bearing @ 4.015 ϕ Hole, $P = F_T$

The bearing stress is equal to the inner bearing stress on the upper clevis pin ③

$$f_c = \frac{100,229}{16.00} = 6264 \text{ PSI}$$

Shear Tear-out @ 4.015 ϕ Hole, $P = F_T$

$$f_v = \frac{P}{2A_v} \quad A_v = \left(5.50 - \frac{4.015}{2}\right)(4.00) = 13.97$$

$$f_v = \frac{100,229}{2(13.97)} = 3587 \text{ PSI}$$

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Vertical shear @ LUG ROOT WELD, $P = F_V$

$$f_v = \frac{P}{A_v}, \quad A_v = (7.00 + 5.50)(4) = 50 \text{ in}^2$$

$$f_v = \frac{76{,}667}{50} = 1533 \text{ PSI}$$

Combined Tension from bending and tension @ LUG weld

$$f_t = \frac{P}{A_t} + \frac{Mc}{I}$$

$$I = \frac{bh^3}{12} = \frac{(4)(12.5)^3}{12} = 651.04 \text{ in}^4$$

$$c = \frac{(5.50 + 7.00)}{2} = 6.25 \text{ in.}$$

$$A_t = bh = (4)(12.5) = 50 \text{ in}^2$$

$$P = F_H = 64{,}560 \text{ lbs}$$

$$M = F_V\left(10.00 - \frac{8.00}{2}\right) - F_H(7.00 - 6.25)$$

$$= 76{,}667(6) - 64{,}560(.75)$$

$$= 411{,}582 \text{ in-lb.}$$

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$$ft = \frac{64{,}560}{50} + \frac{(411{,}582)(6.25)}{651.04}$$

$$ft = 1293 + 3951 = 5244 \text{ PSI}$$

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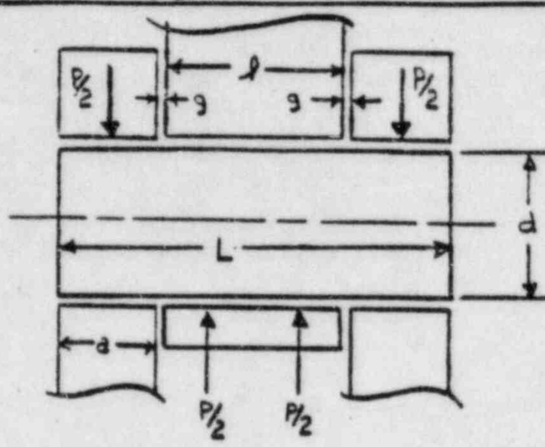
UPPER CLEVIS

PIN (3)

MAT'L: ASTM A 564 TYPE 630



P = force acting on assembly, lb.
d = diameter of pin, in.
l = length of bearing surface of center body, in.
a = length of bearing surface one side of outer body, in
g = gap between bearing surfaces, in.
L = total active length of pin, in
$= l + 2(a+g)$

$P = 100,229$ lb.
$d = 4.00$ in.
$l = 4.00$ in
$a = 2.41$ in $2.5 - 2(.045)$
$g = .170$ in
$[9.25 + 2(.045) - 2(2.5) - 4.00]/2$

SHEAR STRESS

$f_v = P/2A_v$
$P = 100,229$ lb
$A_v = \pi d^2/4$
$A_v = \pi(4.00)^2/4$
$A_v = 12.57$ in^2

$f_v = (100,229)/(2 * 12.57)$

$f_v = 3987$ PSI

BEARING STRESS

$f_c = P/A_v$
$P = 100,229$ lb

INNER
$A_v = d\,l = (4.00)(4.00)$
$= (16.00)$ in^2
$f_c = (100,229)/(16.00)$

$f_c = 6264$ PSI

OUTER
$A_v = 2ad = 2(2.41)(4.00)$
$= (19.28)$ in^2
$f_c = (100,229)/(19.28)$

$f_c = 5199$ PSI

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PIN (3)

BENDING STRESS (1)

$M_{max} = \frac{P}{2}\left(\frac{1}{3}a + g + \frac{1}{4}l\right)$

$f_b = Mc/I$

$I = \pi d^4/64$

$c = d/2$

$f_b = \frac{P}{2}\left(\frac{1}{3}a + g + \frac{1}{4}l\right)\left(\frac{d}{2}\right)\left(\frac{64}{\pi d^4}\right)$

$= 16P\left(\frac{1}{3}a + g + \frac{1}{4}l\right)/(\pi d^3)$

$= 16P\left(\frac{2.41}{3} + .170 + \frac{4}{4}\right)/\pi 4^3$

$= 100{,}229(.157031)$

$= 15{,}739$ PSI

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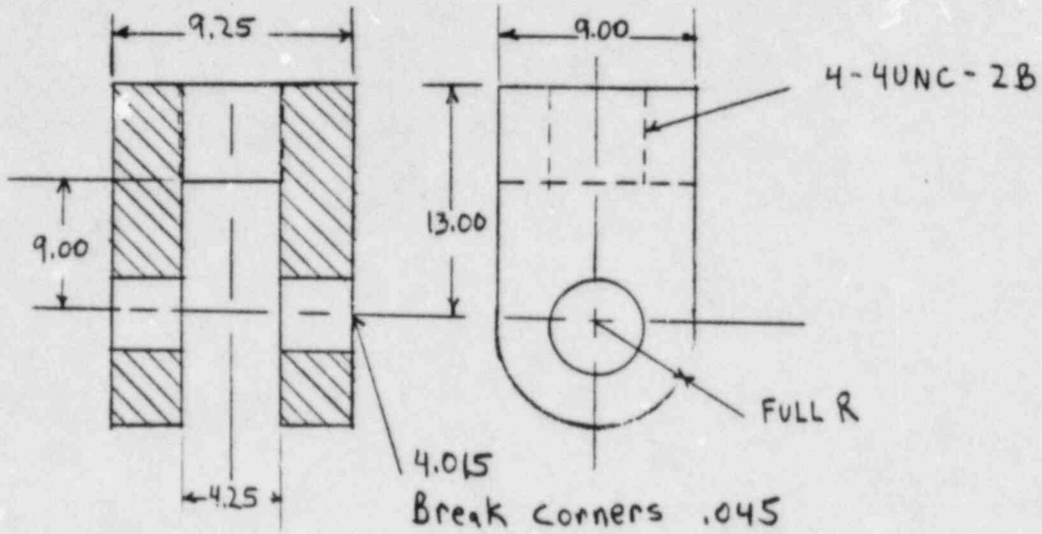
UPPER SLING CLEVIS (4)

MAT'L: ASTM A471 STEEL FORGING CLASS 3



Tension @ 4.015 ϕ Hole

$ft = \frac{P}{Av}$, $Av = (9.25 - 4.25)(9.00 - 4.015) - 4(.045)^2$

$Av = 24.92\ in^2$

$ft = \frac{100,229}{24.92} = 4022$ PSI

Bearing stress @ 4.015 ϕ Hole

The Bearing stress @ the 4.015 ϕ Hole is the same as the outer bearing stress on the PIN (3)

$fc = 100,229 / 19.28 = 5199$ PSI

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Shear Tear-out @ 4.015 ϕ Hole

$$f_v = \frac{P}{2A_v}, \quad A_v = \left(\frac{9.00-4.015}{2}\right)(9.25-4.25) - 2(.045)^2$$

$$A_v = 12.46 \text{ in}^2$$

$$f_v = \frac{100{,}229}{2(12.46)} = 4022 \text{ PSI}$$

Thread Shear

The thread shear is the same as the sling rod's thread shear (5)

$$f_v = \frac{100{,}229}{24.112} = 4157 \text{ PSI}$$

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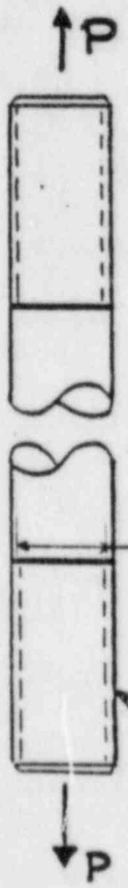
SLING ROD (5)

MAT'L: ASTM A-306
GRADE 70 or 80



THREAD SHEAR

$f_v = P/A_v$

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

FOR AN EXTERNAL THREAD

$D_{pitch} = D_{nom} - .64952/n$

$D_{pitch} = (4.0) - .64952/(4)$

$= (3.8376)$ in.

D_{nom} = major diameter of external thread

n = number of threads /in

l = length of thread engagement = 4.00

THEREFORE $A_v = (24.112)$ in^2

P = 100,229 lbs

$f_v = 4157$ PSI

THREAD TENSION

$f_t = P/A_t$

FOR EXTERNALLY THREADED PARTS

$A_t = \frac{\pi}{4}(D_{nom} - .9743/n)^2$

$= \frac{\pi}{4}(4.0 - .9743/4)^2 = 11.083$ in^2

$f_t = 100,229)/(11.083)$

$f_t = 9043$ PSI

Tension @ thread relief

$ft = P/At$

$At = \pi d^2/4 = \pi(3.63)^2/4$

$At = 10.349$ in^2

$ft = \frac{100,229}{10.349} = 9685$ PSI

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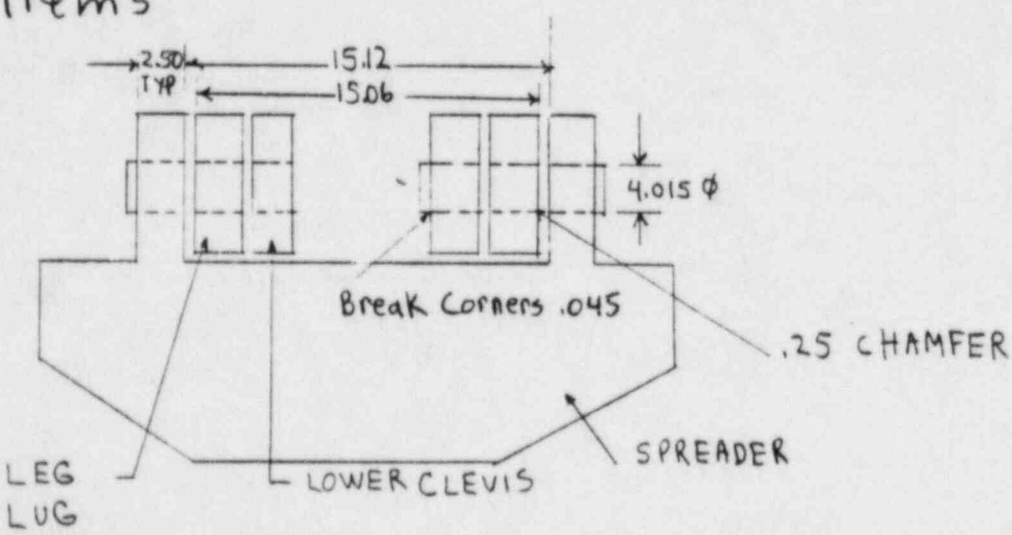
SPREADER JOINT

The Spreader Joint
Consists of the
1) Lower clevis
2) Lower clevis pin
3) Spreader Block Lug
4) The Leg Lug

The bearing stresses acting between these items are calculated on the following pages. 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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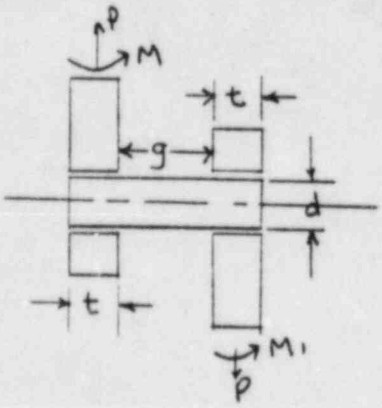
The distribution of the bearing stress between Lug and pin is assumed to be similiar to the stress distribution that would be obtained in a rectangular cross section of width d and depth t subjected to a load P and Moment M, as assumed in section 9.5.1 "Lug bearing strength for single shear joints under uniform axial Load", from Technology Inc, Report TI-219-69-24, Dayton, Ohio; wright-Patterson AFB sponsered.

ALL Lugs are of similiar thickness, so the model becomes



d = diameter
P = Force
g = gap
t = thickness of Lug

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 + vertical components acting on it, so that in any one plane only two lugs are interacting.

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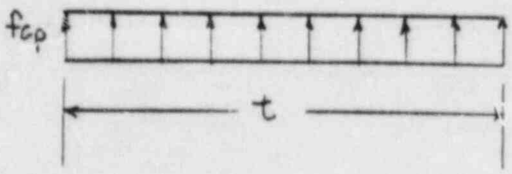
SPREADER JOINT

The clevis has both horizontal and vertical components acting on it, so the stresses will be superimposed for the clevis.

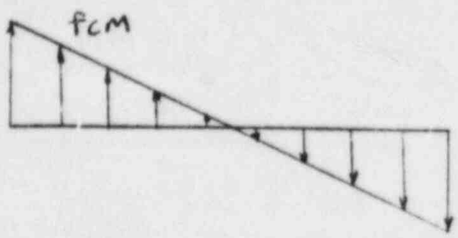
The contact stress due to the force P would be

$f_{cp} = P/dt$



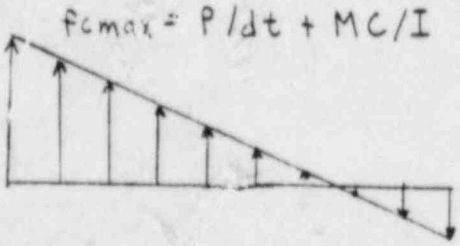
The contact stress due to the moment M would be

$f_{cM} = MC/I$



when these stresses are combined, the result is

$f_{cmax} = P/dt + MC/I$



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For a retangular Section

$I_x = bh^3/12$ and $c = h/2$

Therefore $f_{c\,max} = P/dt + 6M/dt^3$

There entire moment acting on the Joint will be
$M_{total} = P(t+g)$
Dividing the Joint moment between the two ends
$M = (P/2) * (t+g)$

In the vertical plane

$P = W/6 = 230{,}000/6 = 38{,}333$ lbs.

$t+g = 2.50 + .06 = 2.56$ in

$\therefore M_{Leg} = \left(\frac{38{,}333}{2}\right)(2.56) = 49{,}066$ in-lb.

In the horizontal plane

$P = 64{,}560/2 = 32{,}280$ lb.

$t+g = 5.00 + .06 + .06 = 5.12$

$M_{spreader} = (16{,}140)(5.12)$

$M_{spreader} = 82{,}637$ in-lb.

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SPREADER JOINT.

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. Popovis <u>MECHANICS OF MATERIALS</u>, 2ND Edition.

$$M_{clevis} = \sqrt{M^2_{spreader} + M^2_{Leg}}$$

$$M_{clevis} = \sqrt{82,637^2 + 49,066^2}$$

$$M_{clevis} = \sqrt{9.23 \times 10^9} = 96,072 \text{ in-lb}$$

The combined bearing stresses are $f_{cmax} = f_{c,M} + f_{cP}$

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

For the clevis: ⑥

$P = 100,229/2 = 50,115$ lbs $\quad d = d_{pin} = 4.00$ in.
$t = 2.50 - 2(.045) = 2.41$ in.

$$f_{cmax} = \frac{50,115}{(4.00)(2.41)} + \frac{6(96,072)}{(4.00)(2.41)^2}$$

$$f_{cmax} = 5199 + 24,812$$

$$f_{cmax} = 30,011 \text{ PSI}$$

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FOR the spreader ⑧

$P = 64,560/2 = 32,280$ lb.
$d = d_{pin} = 4.00$ in.
$t = 2.50$ in.

$$f_{c\,max} = \frac{32,280}{(4)(2.5)} + \frac{6(82,637)}{(4.00)(2.5)^2}$$

$$f_{c\,max} = 3,228 + 19833 = 23,061 \text{ PSI}$$

For the Leg ⑤

$$P = \frac{W}{6} = \frac{230,000}{6} = 38,333 \text{ lbs}$$

$d = 4.00$ in

$t = 2.50 - .25 = 2.25$ in.

$$f_{c\,max} = \frac{38,333}{(4)(2.25)} + \frac{6(49,066)}{4(2.25)^2}$$

$$f_{c\,max} = 4,259 + 14,538$$

$$f_{c\,max} = 18,797 \text{ PSI}$$

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Check of extreme fiber stresses to AISC CRITERIA

Bearing

The bearing stress calculations for the lower clevis, item (6), the Lower clevis pin item (7), the spreader lug, item (8), and the leg lug item (11), are done to determine the stress field, the only criteria being that they be below yield.

Traditionally bearing of pin joints is done ignoring such local concentrations and so the appropriate Calculations for which reference allowables are obtainable is $f_c = P/A_t$; The AISC allowable is $f_c = 0.90 F_y$ where F_y = The yield strength of material

Lower clevis and lower clevis pin Bearing

$f_c = P/A_c = F_T/2/A_c$

$A_c = dt = 4.00(2.50 - 2(.045))$

$= 9.64 \text{ in}^2$

$F_T = 100{,}229 \text{ lbs}/2 = 50{,}115 \text{ lbs}$

$f_c = \frac{50{,}115}{9.64} = 5199 \text{ PSI}$

SPREADER LUG Bearing

$f_c = P/A_c$, $A_c = dt = 4(2.5) = 10 \text{ in}^2$

$f_c = \frac{(64{,}560/2)}{10} = 3228 \text{ PSI}$

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LEG LUG Bearing

$fc = \frac{P}{Ac}$, $Ac = dt = (4.00)(2.5 - .25) = 9 \, in^2$

$fc = \frac{W/6}{Ac} = \frac{38,333}{9} = 4259$ PSI

Clevis	.9(105,000) = 94,500	≥	5199
Lower clevis pin	.9(95,000) = 85,500	≥	5199
Spreader Lug	.9(38,000) = 34,200	≥	3228
Leg Lug	.9(38,000) = 34,200	≥	4259

∴ All of the above items satisfy the AISC Bearing Criteria and are acceptable.

However, in order to be conservative, the higher numbers generated in the first set of calculations will be used to determine the stresses for items 6, 7, 8 and 11.

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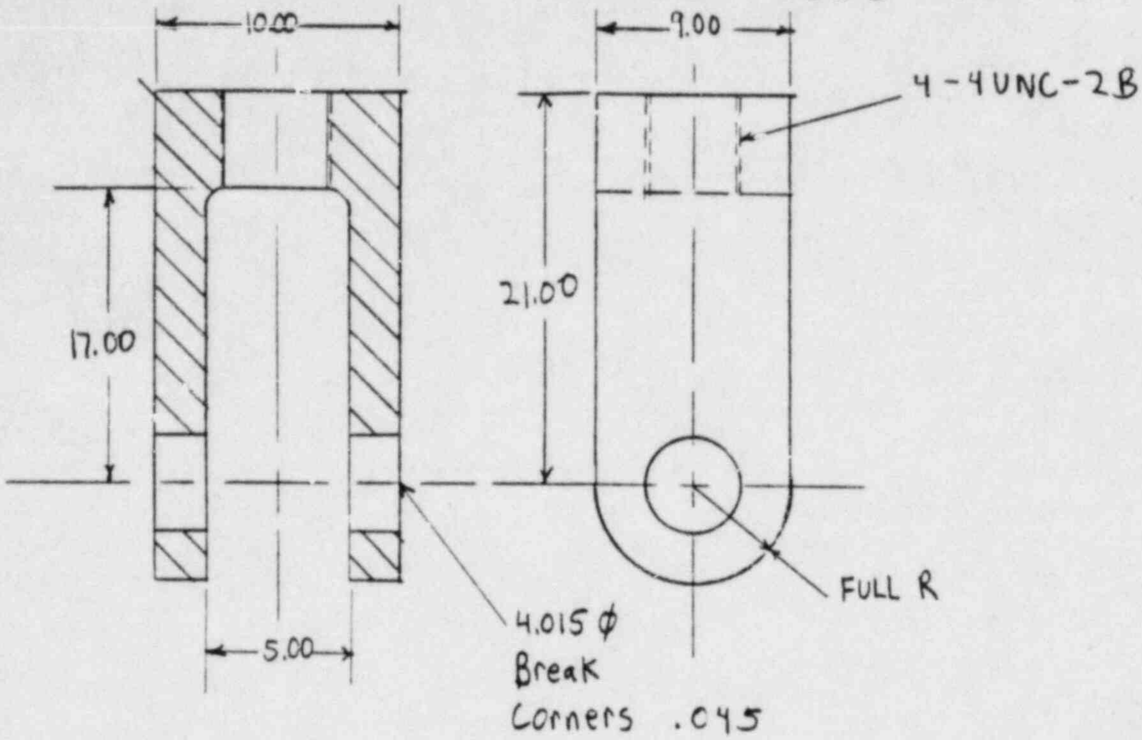
LOWER SLING LEG CLEVIS (6)

Mat'L: ASTM A471 STEEL FORGING CLASS 3



Tension @ 4.015 ϕ Hole

$f_t = \frac{P}{A_v}$, $A_v = (10.00 - 5.00)(9.00 - 4.015) - 4(.045)^2$

$A_v = 24.92 \text{ in}^2$

$f_t = \frac{100{,}229}{24.92} = 4022$ PSI

From Spreader Joint calculation M = 96,072 in-lb.

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Bending stress @ Section A-A (PIN Hole)

$$f_b = \frac{MC}{I}, \quad M = 96{,}072 \text{ lb-in}, \quad C = \frac{2.5 - 2(.045)}{2} = 1.205 \text{ in}$$

$$I = \frac{bh^3}{12} = \frac{(9 - 4.015)(2.5)^3}{12} = 6.4909 \text{ in}^4$$

$$f_b = \frac{(96{,}072)(1.205)}{6.4909} = 17{,}835 \text{ PSI}$$

Combined max. bending & tension @ 4.015 ϕ Hole

$$f_{max} = f_b + f_t = 17{,}835 + 4{,}022 = 21{,}857 \text{ PSI}$$

Bearing stress
From the Spreader Joint calculation:

$$f_{c\,max} = 5{,}199 + 24{,}812 = 30{,}011 \text{ PSI}$$

Thread shear

The thread shear is the same as the sling rod's thread shear ⑤

$$f_v = \frac{100{,}229}{24.112}$$

$$f_v = 4157 \text{ PSI}$$

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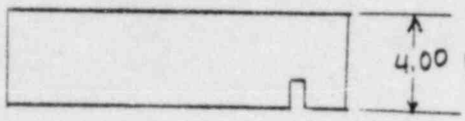
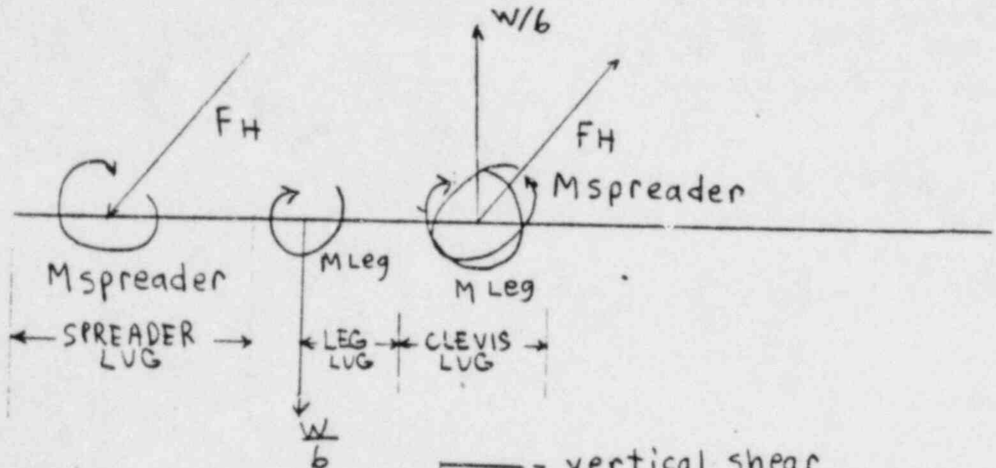
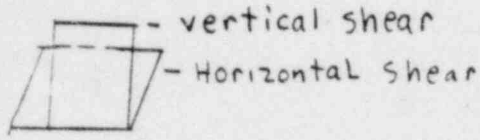
LOWER CLEVIS PIN (7)

MatIL: ASTM A 564 TYPE 630 Precipitation Hardening stainless steel AGE TREATED AT 1150°F for 4 hours, aircooled 135,000 PSI MIN TENSILE Strength RC 28-31



Forces and moments acting on Pin





SHEAR


MOMENTS

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The maximum shear occurs @ the clevis

$$fv = \frac{P}{Av}, \quad P = F_T, \quad Av = \frac{\pi d^2}{4} = \frac{\pi 4^2}{4} = 12.57 \text{ in}^2$$

$$fv = \frac{100,229}{12.57} = 7974 \text{ PSI}$$

The maximum Bearing stress occurs at the clevis and is calculated in the spreader Joint analysis

$$fc_{max} = 5199 + 24,812$$

$$fc_{max} = 30,011 \text{ PSI}$$

Bending stress
From the spreader-joint analysis, the maximum Moment is M_{clevis} = 96,072 in-lb.

$$fb = \frac{Mc}{I}, \quad c = \frac{d}{2} = \frac{4.00}{2} = 2.00 \text{ in}$$

$$I = \frac{\pi d^4}{64} = \frac{\pi (4.00)^4}{64} = 12.57 \text{ in}^4$$

$$fb = \frac{96,072(2.00)}{12.57}$$

$$fb = 15,286 \text{ PSI}$$

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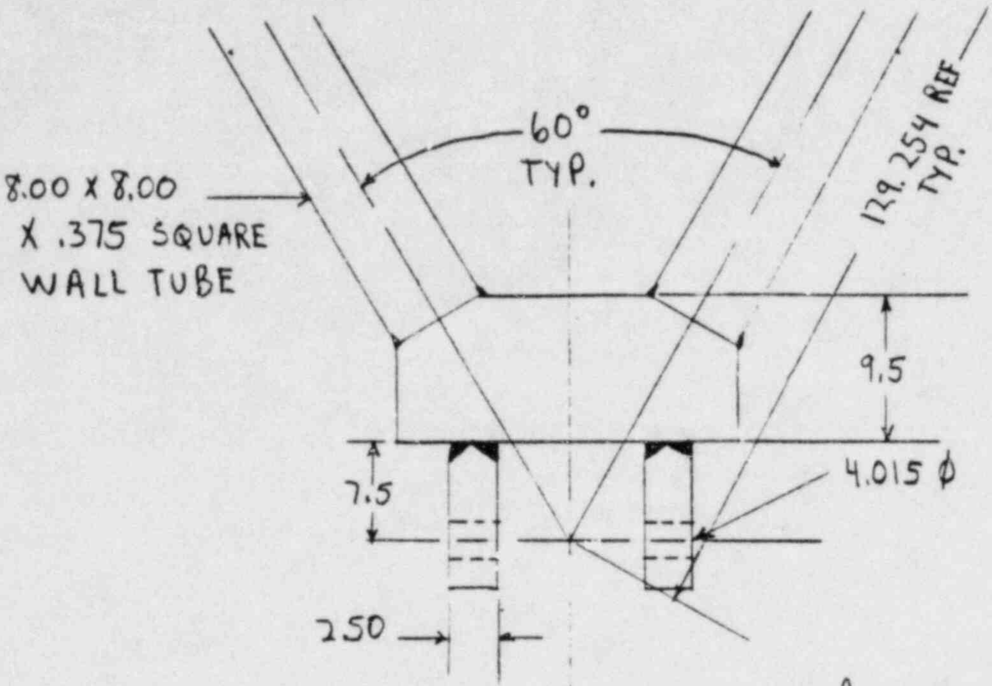
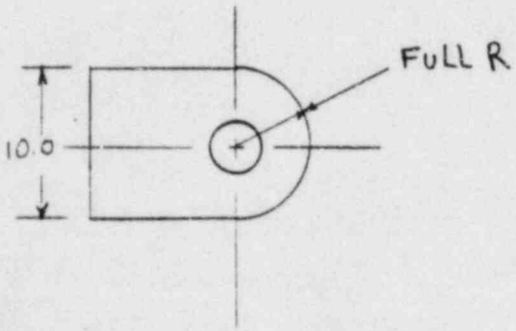
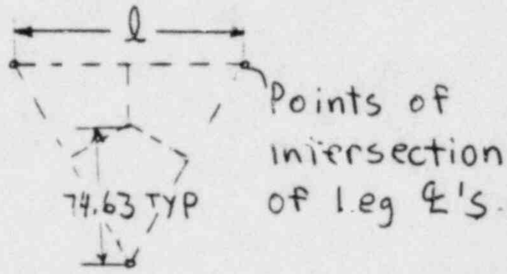
SPREADER ASSEMBLY







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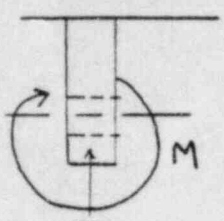
SPREADER ARM - MAT'L.: ASTM A-36 STEEL
BLOCK - ASTM A350 LFI FORGING STEEL
(NO CVN TEST REQ'D)

SPREADER LUG (8) MAT'L: ASTM A-516 GRADE 70
STEEL PLATE, NORMALIZED, OR A537, GR. B, Q&T
F_H = 64,560 lbs (PAGE 3), M = 96,072 in-lbs (PAGE 16)



BEARING STRESS
The bearing stress is calculated in the spreader joint calculation

$$f_{c\,max} = 3228 + 19,833 = 23,061 \text{ PSI}$$

Tension @ 4.015 ϕ Hole (PIN HOLE)

$$f_t = \frac{P}{A_t} = \frac{F_H/2}{A_t}, \quad A_t = (10.00 - 4.015)(2.50) = 14.963 \text{ in}^2$$

$$f_t = \frac{64,560/2}{14.963} = 2,157 \text{ PSI}$$

BENDING @ 4.015 ϕ Hole

$$f_{b\,max} = \frac{MC}{I} = \frac{82,637(2.5/2)}{I}$$

$$I = \frac{bh^3}{12} = \frac{(10.00 - 4.015)(2.5)^3}{12} = 7.79 \text{ in}^4$$

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$$fb_{max} = \frac{(82{,}637)(2.5/2)}{7.79} = 13{,}260 \text{ PSI}$$

Combined Tension and Bending

$$f_{t\,comb} = f_t + f_b = 2157 + 13{,}260 = 15{,}417 \text{ PSI}$$

SPREADER BLOCK (9)

MAT'L. ASTM A350 LF1 FORGING STEEL
(NO CVN TEST REQ'D)

BEARING ON SPREADER BLOCK

The bearing on the spreader block is equal to the compressive stress in the spreader arm

$$P = \frac{FH/2}{\cos 30^\circ} = \frac{64{,}560/2}{.8660} = 37{,}275 \text{ lbs}$$

$$f_c = \frac{32{,}275}{10.83} = 2980 \text{ PSI}$$

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SPREADER ARM (10) - MAT'L. ASTM A-36 STEEL

[FROM AISC MANUAL OF STEEL CONSTRUCTION 7TH ED, P 3-41]

Let $L = 74.63(2\cos 30°) = 129.26$ in.

$\simeq 11.0$ ft.

Let K_E = Effective Length factor

= 1 for a pin-pin Beam

∴ EFFECTIVE LENGTH = $LK_E = 10.8$ ft.

From the AISC Table

$P_{allowable} = 205{,}000$ lb.
For $F_{yield} = 36{,}000$ PSI

$A = 10.83\ in^2$

$F_{allowable} = P_{allowable} / A$

$F_{allowable} = 205{,}000 / 10.83$

$F_{allowable} = 18{,}929$ PSI

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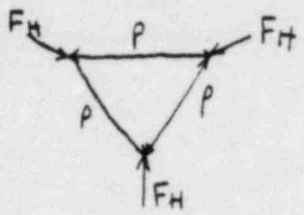
COMPRESSIVE STRESS IN SPREADER ARM



$2P\cos 30° = F_H$

$$P = \frac{F_H/2}{\cos 30}$$

$$P = \frac{64,560/2}{\cos 30°} = 37,275 \text{ lbs}$$

$$f_c = \frac{32,275}{10.83} = 2980 \text{ PSI}$$

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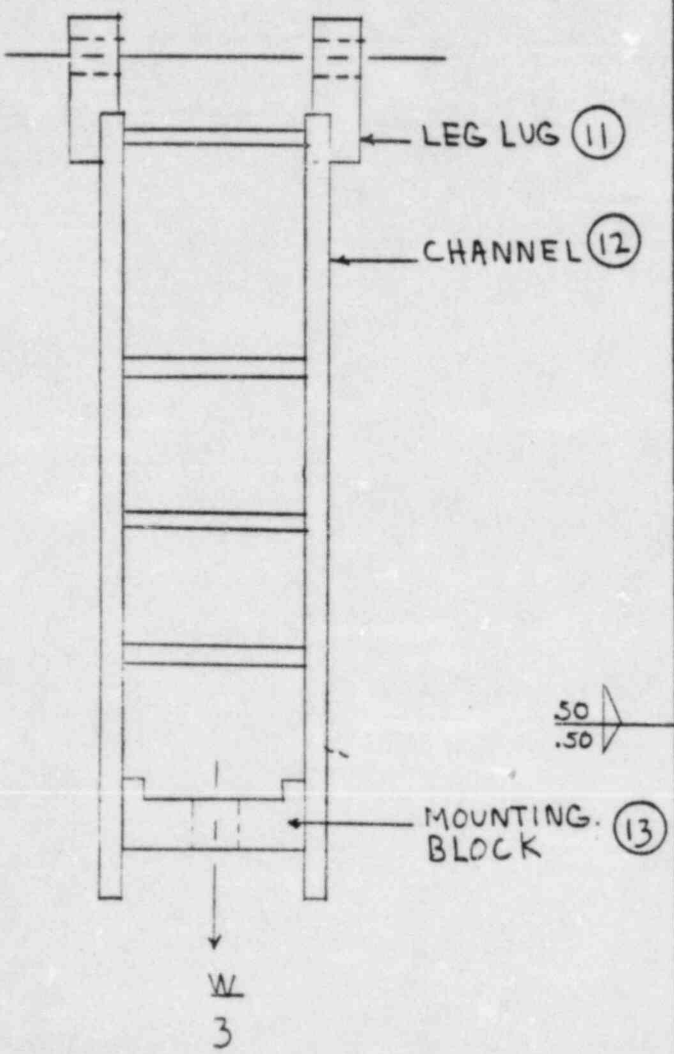
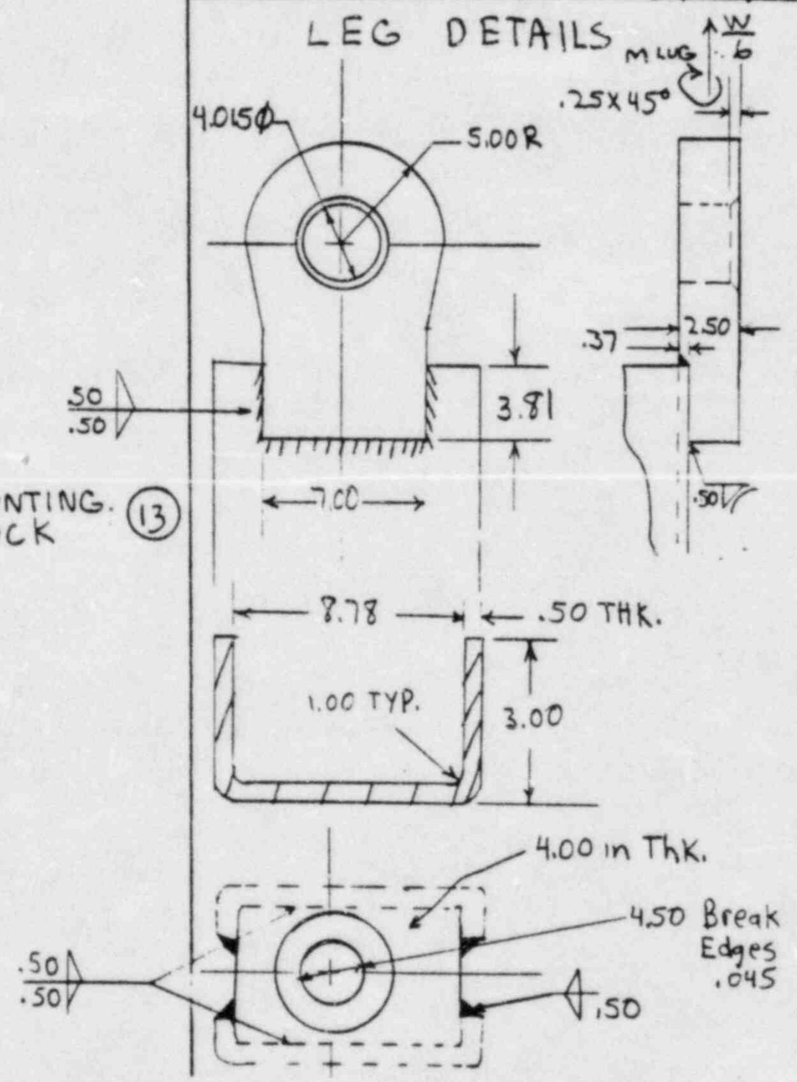
LEG ASSEMBLY



MAT'L:
LEG LUG: ASTM A516 GRADE 70 STEEL, NORMALIZED
CHANNELS: ASTM A-36 STEEL, H. R.
MOUNTING BLOCK: ASTM A350, LFI FORGING STEEL (NO CVN TEST REQ'D)
WELDS: E-7018 ELECTRODES

LEG DETAILS



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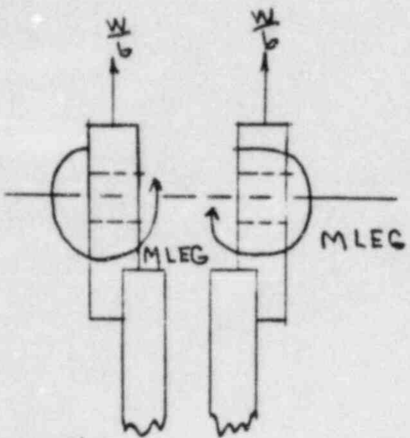
LEG LUG (11)



MLEG = 49,066 in-lb

TENSION @ 4.015 ⌀ Hole

$f_t = \frac{P}{A_t}$, $P = \frac{W}{6} = \frac{230,000}{6} = 38,333$ lbs.

$A_t = 2.5(10.00 - 4.015) - .25^2 = 14.90 \text{ in}^2$

$f_t = \frac{W/6}{14.90} = \frac{38,333}{14.90} = 2573$ PSI

BENDING @ 4.015 ⌀ Hole

$f_b = \frac{MC}{I}$, $I = \frac{bh^3}{12} = \frac{(10.00-4.015)(2.5)^3}{12} = 7.793 \text{ in}^4$

$f_b = \frac{49,066(2.5/2)}{7.793} = 7870$ PSI

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COMBINED MAX. BENDING AND TENSION
① 4.015 ϕ HOLE

$f_{t\,comb} = f_b + f_t$

$f_{t\,comb} = 7870 + 2573 = 10{,}443$ PSI

BEARING

The bearing stress is calculated in the spreader joint calculations and is

$f_{c\,max} = 4{,}259 + 14{,}538 = 18{,}797$ PSI

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CHECK OF EXTREME FIBER STRESS TO AISC CRITERIA
COMBINED TENSION AND BENDING

Combined stresses - Section 5-1.6
For Lower clevis (6)

f_a = 4,022 PSI
f_b = 17,835 PSI
F_y = 105,000 PSI

For spreader Lug (8)

f_a = 2,157 PSI
f_b = 13,260 PSI
F_y = 38,000 PSI

For Leg Lug (11)

f_a = 2573 PSI
f_b = 7870 PSI
F_y = 38,000

f_a = computed axial stress
f_b = computed compressive bending
F_b = compressive bending stress that would be permitted if bending moment alone existed.
F_a = axial stress that would be permitted if axial force alone existed

Section 1.6.2 Axial Tension & Bending governs, ∴
Formula (1.6-1b) governs

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$$\frac{f_a}{0.60 F_y} + \frac{f_{bx}}{F_{bx}} + \frac{f_{by}}{F_{by}} \le 1.0$$

For ALL Three members with combined loads the cross-section is solid so
$F_b = .75 F_y$ per Sec 1.5.1.4.3

Lower clevis (6)

$$\frac{f_a}{.6F_y} + \frac{f_b}{.75F_b} + 0 = \frac{4{,}022}{.6(105{,}000)} + \frac{17{,}835}{.75(105{,}000)} = .290$$

$.290 \le 1.0$

Spreader Lug (8)

$$\frac{f_a}{.6F_y} + \frac{f_b}{.75F_b} + 0 = \frac{2{,}157}{.6(38{,}000)} + \frac{13{,}260}{.75(38{,}000)} = .560$$

$.560 \le 1.0$

LEG LUG (11)

$$\frac{f_a}{.6F_y} + \frac{f_b}{.75F_b} + 0 = \frac{2573}{.6(38{,}000)} + \frac{7870}{.75(38{,}000)} = .389$$

$.389 \le 1.0$

REF: MANUAL OF STEEL CONSTRUCTION
7th EDITION

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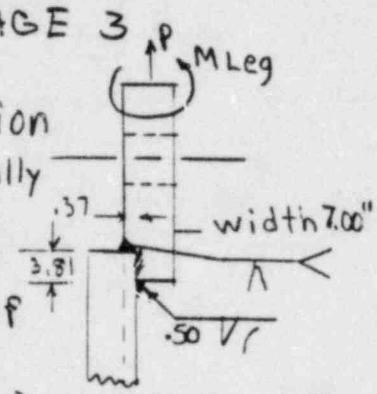
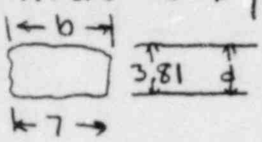
LEG LUG WELD

REFERENCE: LINCOLN ELECTRIC COMPANY, SOLUTION TO DESIGN OF WELDMENTS D 810.17 PAGE 3



If the upper weld, which is a penetration weld, is assumed equivalent to the generically weaker fillet weld for simplicity, and it is conservatively assumed that the throat width is .37, use the smaller of .37 or .50(.707), so the weld may be modeled by a simple case ∴ .50(.707)=.3535 < .37



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

$$= \frac{3.81}{3}(3(7)+3.81) = 31.509$$

$S = 31.509(.3535) = 11.138 \text{ in}^3$

$$f_v \text{ bending} = \frac{M_{Leg}}{S} = \frac{49,066}{11.138} = 4405 \text{ PSI}$$

f_v shear force $= P/A_t$, $P = w/6$, $A = [2(7)+2(3.81)].3535 = 7.64 \text{ in}^2$

$$f_v \text{ shear force} = \frac{230,000/6}{7.64} = 5017 \text{ PSI}$$

For fillet welds, both stresses are treated as shear stresses, so $f_{v\,comb\,max} = f_v \text{ bending} + f_v \text{ shear force}$

$f_{v\,comb\,max} = 4405 + 5017 = 9422 \text{ PSI}$

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LEG CHANNELS (12)

MAT'L. ASTM A-36 STEEL H.R.

Calculation of cross-sectional area of Leg Channels

For one channel

$$A = [8.78 - 2(1.00)](.50) + 2[3.00 - 1.00 - .5](.50) + \frac{\pi}{4}\left(\tfrac{1}{2}\right)(3.0^2 - 2.0^2)$$

$$A = 6.583 \text{ in}^2$$

TENSION IN LEGS

$$f_t = \frac{P}{A_t}, \quad P = \frac{W}{6}$$

$$A_t = A_{CHANNEL} = 6.853 \text{ in}^2$$

$$f_t = \frac{230{,}000/6}{6.853} = 5594 \text{ PSI}$$

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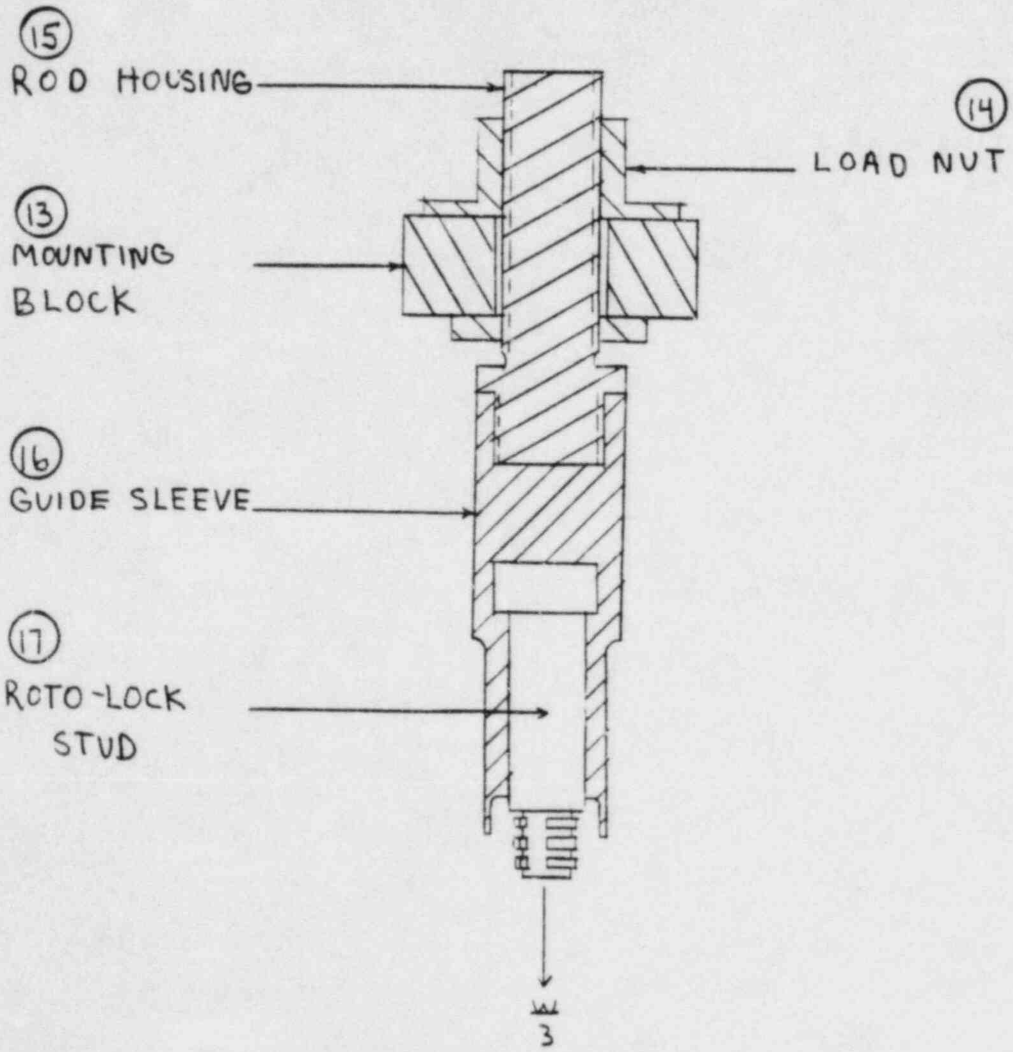
ROTO-LOCK ASSEMBLY

The ROTO-LOCK ASSEMBLY sees only the internals weight W = 202,000 lb. so the remaining items will use this design weight instead of the weight assumed for the previous items



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MOUNTING BLOCK (13)

MAT'L. ASTM A-350 LF1 FORGING STEEL (NO CVN TEST REQ'D)
WELDS: E 70-18 ELECTRODES

BEARING OF LOAD NUT TO MOUNTING BLOCK

$f_c = P/A_t$, $P = W/3$, $A_t = \frac{\pi}{4}(D_1^2 - D_2^2)$

$A_t = \frac{\pi}{4}(D_1^2 - D_2^2) = \frac{\pi}{4}(8.25^2 - 4.50^2) = 37.55 \text{ in}^2$

$f_c = \frac{202{,}000/3}{37.55} = 1793 \text{ PSI}$

SHEAR IN MOUNTING BLOCK WELDS

$F_v = \frac{\ell}{A_v}$ $A_v = \ell(.50)(.707)$

$\ell = 4[6.78 + 2(\frac{1}{4} 2\pi(1)) + (3.00 - 1.5)] + 4(4)$

$\ell = 61.69 \text{ in}^2$

$A_v = (61.69)(.50)(.707) = 21.81 \text{ in}^2$

$F_v = \frac{202{,}000/3}{21.81} = 3087 \text{ PSI}$

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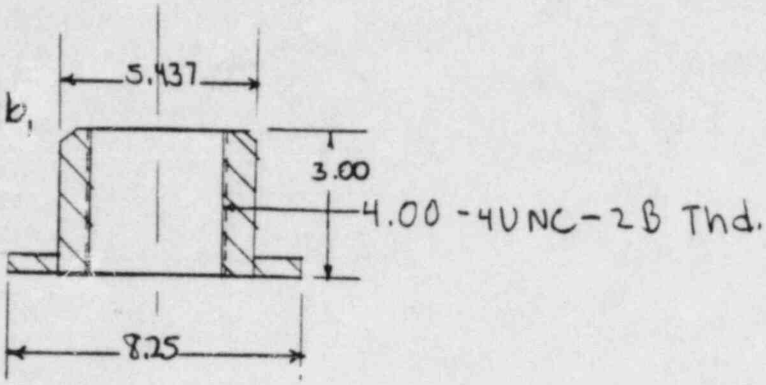
LOAD NUT (14)

MAT'L. ASTM A276, TYPE 304, HOT ROLLED, COND A



Thread shear

$f_v = \frac{P}{A_v}$ $\quad A_v = \pi D_{pitch} \ell/2 - A_{slots}$*

For a 4 - 4UNC-2B THD, FROM MARKS HANDBOOK,
$D_{pitch} = 3.8376$ in , $\ell = 3.00$ in
$A_v = \frac{\pi(3.8376)(3)}{2} - 3.25(.5) = 16.459 \text{ in}^2$

$f_v = \frac{202,000/3}{16.459} = 4091$ PSI

Bearing of Load Nut to Mounting Block

The bearing stress is calculated for the mounting Block and is

$f_c = \frac{202,000/3}{37.55} = 1793$ PSI

* Subtracted for slot cut for locking tab in rod housing

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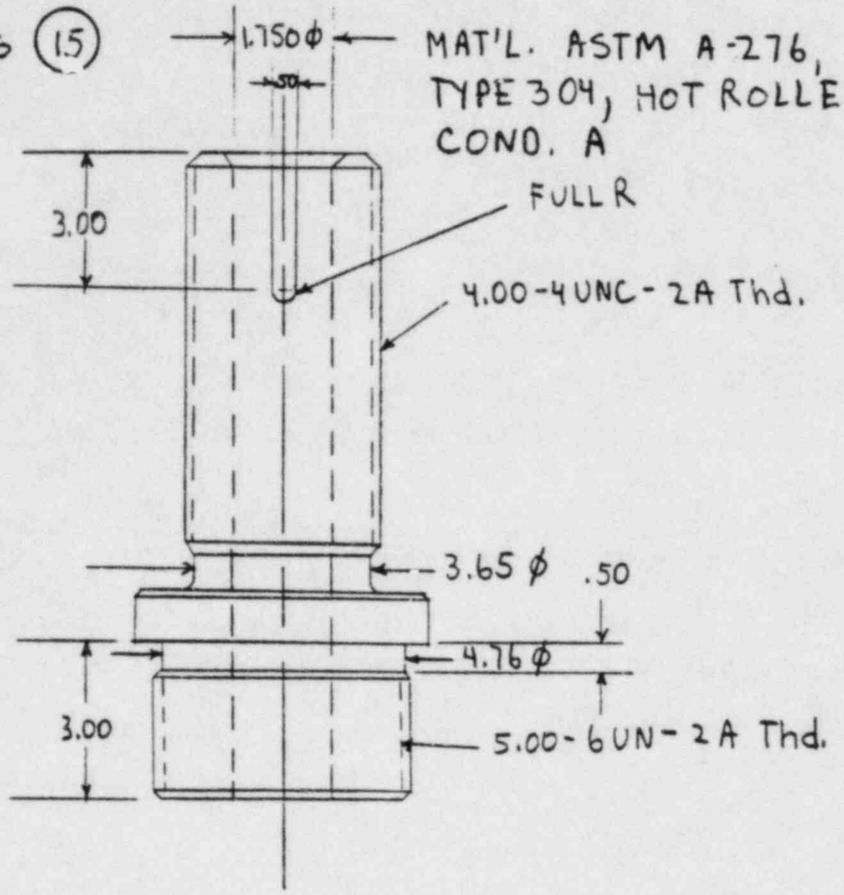
ROD HOUSING (15)



Thread shear on upper 4.00-4UNC-2A-Thd
The upper threads shear stress is the same as the load nut's

$$f_v = \frac{202{,}000/3}{16.459} = 4091 \text{ PSI}$$

Thread shear on Lower 5.00-6UN-2A THDS.

$$f_v = \frac{P}{A_v} = \frac{W/3}{A_v}, \quad A_v = \pi\, D\, \text{pitch}\, \ell/2$$

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FOR 5.00- 6UN-2A THD

(MARK'S 8-10) $D_{pitch} = D - \frac{3\sqrt{3}}{8N} = 5 - \frac{3\sqrt{3}}{8(6)}$

$D_{pitch} = 4.8917$ in

$l = 3.00 - .50 = 2.50$ in

$A_v = \frac{\pi(4.8917)(2.50)}{2} = 19.210 \text{ in}^2$

$f_v = \frac{P}{A_v} = \frac{W/3}{A_v} = \frac{202{,}000/3}{19.21} = 3505$ PSI

TENSION @ THREAD RELIEF

$f_t = \frac{P}{A_t} = \frac{W/3}{A_t}$, $A_t = \frac{\pi}{4}(d_o^2 - d_i^2) = \frac{\pi}{4}(3.65^2 - 1.75^2) = 8.058 \text{ in}^2$

$F_t = \frac{202{,}000/3}{8.058} = 8356$ PSI

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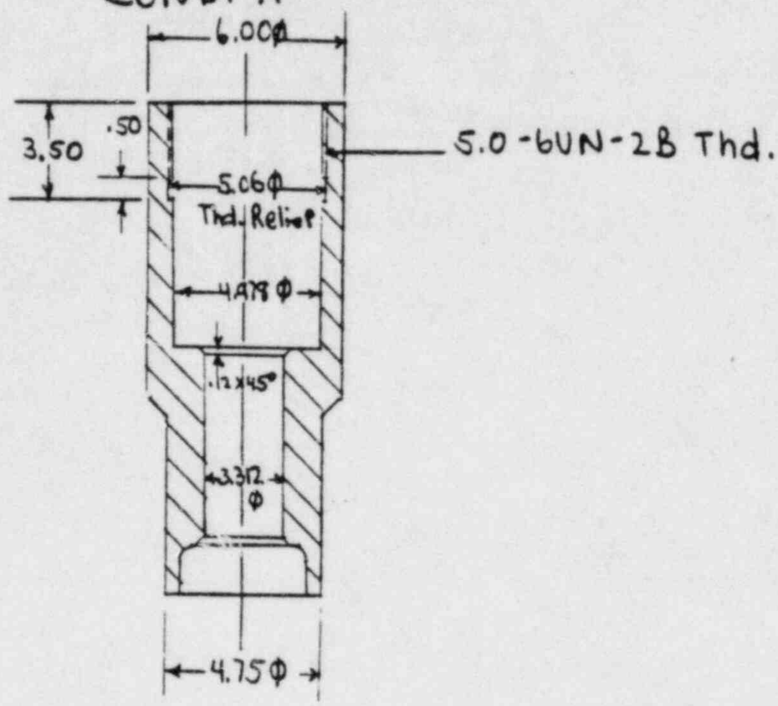
GUIDE SLEEVE (16) MAT'L. ASTM A-276, TYPE 304 SST, HOT ROLLED, ANNEALED, AND PICKLED, COND. A



Thread Shear

The thread shear is the same as the lower thd. shear on the rod housing

$$f_v = \frac{P}{A_v} = \frac{W/3}{A_v} = \frac{202{,}000/3}{19.21} = 3505 \text{ PSI}$$

TENSION @ THD RELIEF

$$f_t = \frac{P}{A_t}, \quad P = \frac{W}{3}, \quad A_t = \frac{\pi}{4}(6.00^2 - 5.06^2) = 8.165 \text{ in}^2$$

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$$ft = \frac{202{,}000/3}{8.165} = 8247 \text{ PSI}$$

Bearing of Guide Sleeve to Roto-lock Stud

$$fc = \frac{P}{At}, \quad P = W/3, \quad Ac = \frac{\pi}{4}(d_o^2 - d_i^2)$$

$$d_i = 3.312 + 2(.12) = 3.552 \text{ in.}$$
$$d_o = 4.790 + - 2(.09) = 4.61 \text{ in.}$$

$$Ac = \frac{\pi}{4}(4.61^2 - 3.552^2) = 6.782 \text{ in}^2$$

$$fc = \frac{202{,}000/3}{6.782}$$

$$fc = 9{,}928 \text{ PSI}$$

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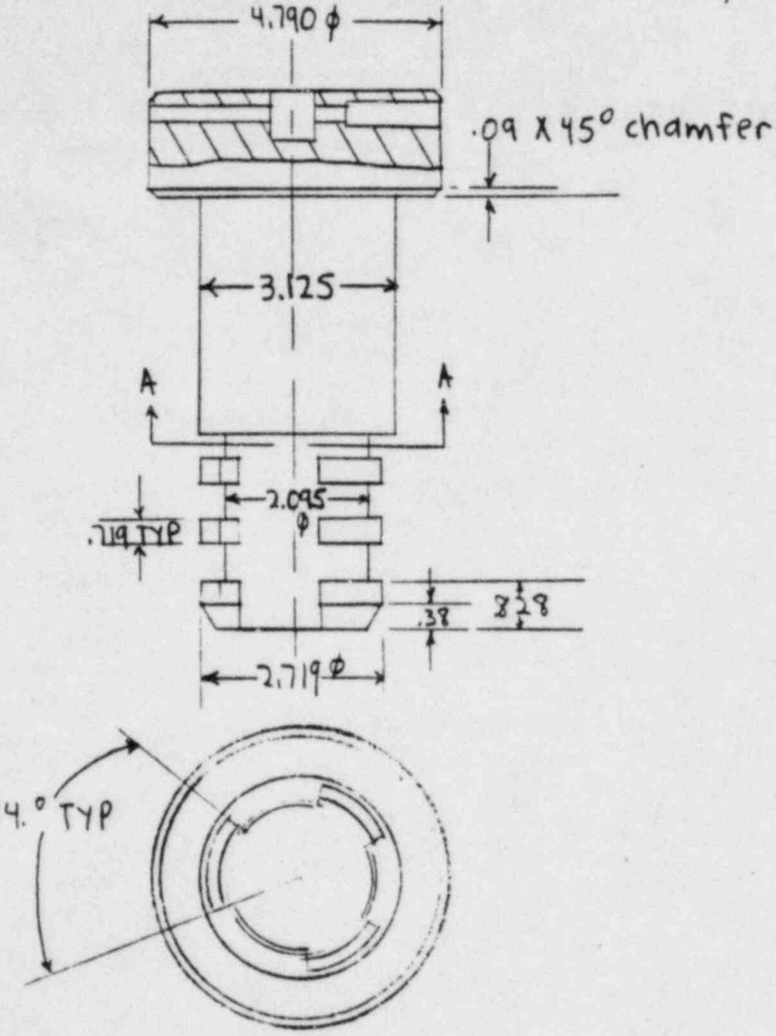
ROTO-LOCK STUD (17)

MAT'L. ASTM A564, TYPE 630, 17-4 PRECIPITATION HARDENING STAINLESS STEEL AGE TREATED AT 1100°F FOR 4 HOURS AND AIR COOLED Tmin = 140,000 PSI



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N = NUMBER OF LANDS = 9

TENSION @ SECTION A-A

$f_t = \frac{P}{A_t}$, $P = W/3$, $A_t = \pi d^2/4 = \pi (2.095)^2/4 = 3.447 \text{ in}^2$

$f_t = \frac{W/3}{A_t} = \frac{202,000/3}{3.447} = 19,534$ PSI

SHEAR OF STUD LANDS

$f_v = \frac{P}{A_v}$, $A = L_c d$

L_c = Length of Lands d = Depth of Lands

$L_c = \frac{54}{360} \pi (2.095) \times N = 8.885$ $d = .719$ in

$A = (8.885)(.719) = 6.388 \text{ in}^2$

$f_v \ \frac{202,000/3}{6.388} = 10,541$ PSI

BEARING STRESS ON STUD HEAD

The head's bearing stress is calculated @ the guide sleeve.

$f_c = \frac{202,000/3}{6.782}$ 9,928 PSI

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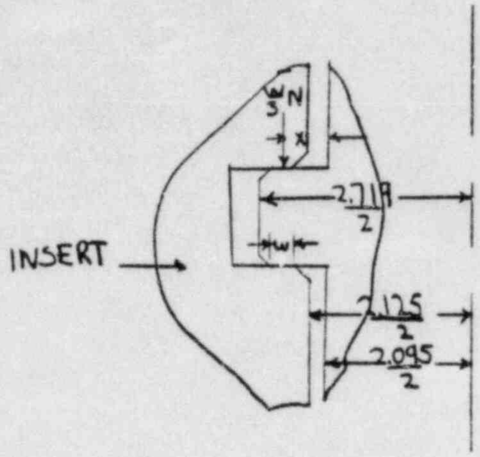
BENDING IN LANDS



Chamfers .03 X 45°

w = width of bearing surface

$w = \frac{2.719}{2} - .03 - \left(\frac{2.125}{2} + .03\right) = .237$ in.

$X = \frac{2.719}{2} - .03 - \frac{2.095}{2} - \frac{w}{2}$ = moment arm of force

$X = \frac{2.719}{2} - .03 - \frac{2.095}{2} - \frac{.237}{2} = .1635$ in

$f_b = M/Z$

$Z_{Land} = Lcd^2/6$

$= \frac{54}{360}\pi(2.095)(.719)^2/6 = .085 \text{ in}^3$

M = Bending Moment

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$P_x = [(W/3)/N](.1635) = [(202{,}000/3)/9](.1635) = 1223\ lb$

$f_b - \frac{1223}{.085} = 14{,}388\ PSI$

COMPRESSIVE BEARING STRESS ON LAND SURFACES

$A_1 \simeq [2.719 - 2(.03)]^2 \frac{\pi}{4} = 5.553\ in^2$

$A_2 \simeq [2.125 + 2(.03)]^2 \frac{\pi}{4} = 3.750\ in^2$

$A_c = A_1 - A_2 = 1.803\ in^2$

$A'_c = N \frac{54}{360} A_c - 2N(W)(.04) = 2.263\ in^2$

$F_c = \frac{P}{A'_c} = \frac{W/3}{A'_c} = \frac{202{,}000/3}{2.263}$

$f_c = 29{,}754\ PSI$

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