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SUBJECT: Potential deficiency rept re CRDM svc support structure (SSS).Initially detected in course of preparing stress analysis in Apr 1993 at Oconee Unit 2.Calculation revised accounting for local moment results in stresses.

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JHT/93-131
May 28, 1993

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U. S. Nuclear Regulatory Commission
Washington, D.C. 20555

Subject: Potential Safety Concern on
CRDM Service Support Structure

Gentlemen:

The purpose of this letter is to provide you with preliminary information on a Potential Safety Concern regarding the Control Rod Drive Mechanism Service Support Structure (SSS) installed in the B&W operating plants. The SSS supports the structure which surrounds and provides support to the Control Rod Drive Mechanisms.

A draft plan for the resolution of this concern has been submitted to the B&W operating plant owners. However, BWNT believes it is prudent to provide to the NRC at this time information on the nature of the concern. This letter is not a notification of a substantial safety hazard under 10CFR21.

The concern involves the calculated stresses in the lower flange of the SSS Skirt and the flange of the segments welded to the reactor vessel head. Also involved are the calculated stresses in the bolts attaching these flanges. In the course of preparing a stress analysis in April 1993 to justify addition of access and inspection holes to the Oconee-2 support skirt, a review of the original stress calculations revealed that a local bending moment was not accounted for. Revised calculations accounting for the local moment result in stresses in the support skirt and bolts that exceed the allowable stresses as set forth by the ASME Boiler and Pressure Vessel Code. All B&W operating plants are affected by this concern.

BWNT believes that a re-analysis of the stresses in these components based on updated design conditions and techniques will show that the stresses are, in fact, within the allowables and that no safety concern exists.

Attached is a more detailed description of the concern including an evaluation which explains why no real safety concern is believed to exist. As described in that evaluation, this conclusion is preliminary and requires further analytical work to document this conclusion.

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BWNT will provide information to the NRC later on the evaluation and resolution schedule for this concern.

If you have any questions concerning this matter, please contact the undersigned at 804/385-2817, or Mr. David Mars at 804/385-2852.

Very truly yours,

J. H. Taylor
Manager, Licensing Services

JHT/bcc

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Evaluation of Safety Significance

Service Support Structure Preliminary Safety Concern

I. Problem Statement

The CRDM Service Structure surrounds and provides support to the Control Rod Drive Mechanisms (CRDM). This structure rests on and is supported by a support skirt which in turn rests on segments of a slotted cylinder that is welded to the reactor vessel closure head. Figure 1 provides an overview of the support skirt and segments. The support skirt and segments together are called the Service Support Structure (SSS). The lower end of the support skirt is connected to the upper end of the segments by bolted flanges (see Figure 2). The bolts connecting these flanges are lightly preloaded to permit sliding of the flange faces as the reactor vessel head expands and contracts under thermal and pressure loading. Each segment is stiffened by two gussets, but no gussets exist on the lower flange of the support skirt. The support skirt is intended to be permanently bolted to the segments and is not routinely unbolted when the head is removed during refueling operations.

In the course of preparing a stress analysis in April 1993 to justify addition of access holes to the Oconee-2 SSS support skirt, a review of the original stress calculations revealed that a local bending moment created by the overturning moment due to Maximum Hypothetical Earthquake (MHE = now Safe Shutdown Earthquake (SSE)) and Loss of Coolant Accident

(LOCA) was not accounted for in the analysis. Stress analyses performed subsequently when asymmetric LOCA loads were incorporated and when modifications were made at two other plants similarly did not account for this moment.

In evaluating this concern, calculations performed in April 1993 using the same analytical technique employed in the original calculations but accounting for the local moment result in stresses in the skirt, segments, and bolts that exceed the allowable stresses for the two design basis load combinations: (1) Deadweight + Maximum Hypothetical Earthquake and (2) Deadweight + Maximum Hypothetical Earthquake + LOCA.

The potential safety concern is that violation of allowable stress limits could result in prevention of control rod insertion and could also result in loss of the CRDM pressure boundary. The safety concern derives from the two types of events which form the design basis for the SSS, i.e., the LOCA and the SSE. The original design basis LOCA was the LBLOCA, for which control rod insertion is not required. Also, with the operating plants now licensed for leak-before-break technology for the LBLOCA, that event is no longer pertinent to the SSS design basis. The design basis LOCA is now a core flood line break since flow restrictors installed in the RV nozzle for the CFL reduce the break opening size to 0.44 ft^2, which constitutes a SBLOCA. ECCS analysis of the CFL break credits insertion of 50 percent of the control rod worth during this event.

The SSE is the second type of SSS design basis event. All plants are required by the NRC design criteria to be capable of shutdown after an SSE event, and control rod insertion is required for reactor shutdown.

II. Detailed Description of Apparent Overstressed Condition

Seismic and LOCA events cause overturning moments, lateral shear forces, and vertical forces that induce compressive forces on one side of the skirt/segment flange and tensile bolt loads on the other side. Figure 3 indicates the loads acting on the structure.

The original stress calculations employed a technique developed for use in design of anchor bolts in which simplifying assumptions are made regarding load distribution and response of the structure. In the absence of external loads, the weight of the structure causes a compressive load between the support skirt and segment flanges. As the external loads are applied, this initial compressive load is partially overcome by the overturning moment. The skirt tends to lift off on one side (thus creating a tensile bolt load) while the compressive load increases on the other side. The result is a shift in the neutral axis that is dependent on the applied loads. The method consists of a procedure to determine the shift in neutral axis followed by calculation of the maximum compressive and bolt stresses.

In the original and subsequent calculations, the reported critical stress locations were vertical sections through the 1" thick flanges (Sections C-

C and D-D, Figure 4). The stresses included the bending moments at these locations due to the tensile bolt load (bolt load x L′ in Fig. 4). If the larger moment arm L is used to calculate the moment and the smaller thickness (3/4") for the skirt or segment used to calculate the stress, the critical sections become A-A and B-B in Fig. 4. Calculations on this basis performed in April 1993 result in stresses that exceed the specified allowable values.

Corrected calculations for the stresses in the bolts have not been completed, but it is estimated that they also exceed allowable stresses, although to a lesser extent than for the support skirt and segments.

III. Evaluation of Safety Significance

This evaluation of safety significance concludes that a combination of reduced loads and refined stress analysis will show compliance with ASME Section III stress limits for the design basis load combinations.

The existing stress calculations (original calculations and recent corrected calculations) are based on conservative assumptions regarding the magnitudes of the assumed loads and the response of the structure. Each of these subjects is addressed in the following sections.

Magnitude of Assumed Loads

The existing stress calculations for LOCA, which are the subject of the concern, are based on loads established during the asymmetric cavity loads project in 1980 and are documented in Topical Report BAW-1621. The loads used in that analysis and in the recent evaluation are for a break of the hot leg at the reactor vessel. Since the NRC has approved the leak-before-break concept for the hot and cold legs of the B&W operating plants, it is no longer necessary to assess the dynamic effects on structures for breaks in these lines and the LOCA loads for the next smaller line (the core flood line) should be used. However, core flood line LOCA loads have not been calculated.

To envelope the loads that would result from a core flood line LOCA, loads from the asymmetric cavity pressure project for a 0.46A (46% of pipe flow area) hot leg break were used.

The core flood line is a 14" Sch. 140 pipe. Considering the flow restrictors in the reactor vessel core flood nozzle, the total effective break area is 1.12 ft^2. In contrast, the flow area for the assumed hot leg break (0.46A) is 3.25 ft^2. Although LOCA loads are not directly proportional to the break area, loads resulting from a core flood line LOCA analysis are expected to be substantially smaller than the assumed loads.

In addition, the core flood line is fabricated from austenitic stainless steels, which are inherently tougher and more ductile than the ferritic steels used for the hot and cold legs. While leak-before-break analyses have not been performed for the core flood lines, successful application of this concept to the hot and cold legs indicates a high probability of success should such an analysis be undertaken for the core flood line. This would eliminate the need to consider core flood line LOCA loads.

Response of the Structure

As noted previously, the existing calculations are based on a method that includes simplifying assumptions regarding the response of the structure to applied loads. In particular, no consideration is given to the interaction among the bolts, flanges, support skirt, and segments.

To obtain an estimate of the effect of this interaction, a finite element model of a portion of the structure at one segment has been constructed; the model includes one segment and its flange, the support skirt shell and its flange, and the bolts. Gap elements between the flanges are included to account for separation of the flanges as they rotate relative to each other. An axial load was applied to the top of the model (the support skirt) to represent the tensile loads caused by an overturning moment. Preliminary results show that the worst primary membrane plus primary bending stress occurs in the support skirt at the junction with the flange (Section B-B in Fig. 4). The ratio of this maximum stress to the axial stress in the shell is 7.7. The same ratio calculated using the simplified method is 15.0. Thus, the more detailed modelling technique reduces the maximum stress by a factor of 2.

The same analysis results in an increase in average bolt stress by a factor of 2 due to the prying effect. The bolt stresses calculated using the simplified method are low enough to accommodate such an increase, but the bolt stresses due to the large-break LOCA loading would exceed the allowable value.

Although more accurate than the simplified method, the finite element model just described is also a simplified representation since it considers only the most highly loaded segment. Additional conservatism could be removed by modelling the entire structure (due to symmetry, only 180° would actually be modelled) and applying the loads at their actual point of application. This would permit a more realistic distribution of load among the segments.

The existing calculations and the more complex modelling just described are based on the assumption of elastic material behavior. Appendix F to ASME Section III permits the use of other techniques such as limit analysis and plastic analysis and defines corresponding acceptance criteria. These techniques provide more realistic representations of material behavior in the plastic region and would lead to less conservative results than elastic methods.

Conclusions

Despite the discrepancies in the stress analysis and the apparent overstressed condition, more refined stress analysis using less conservative loads will show that the existing design is adequate for the design basis loads.

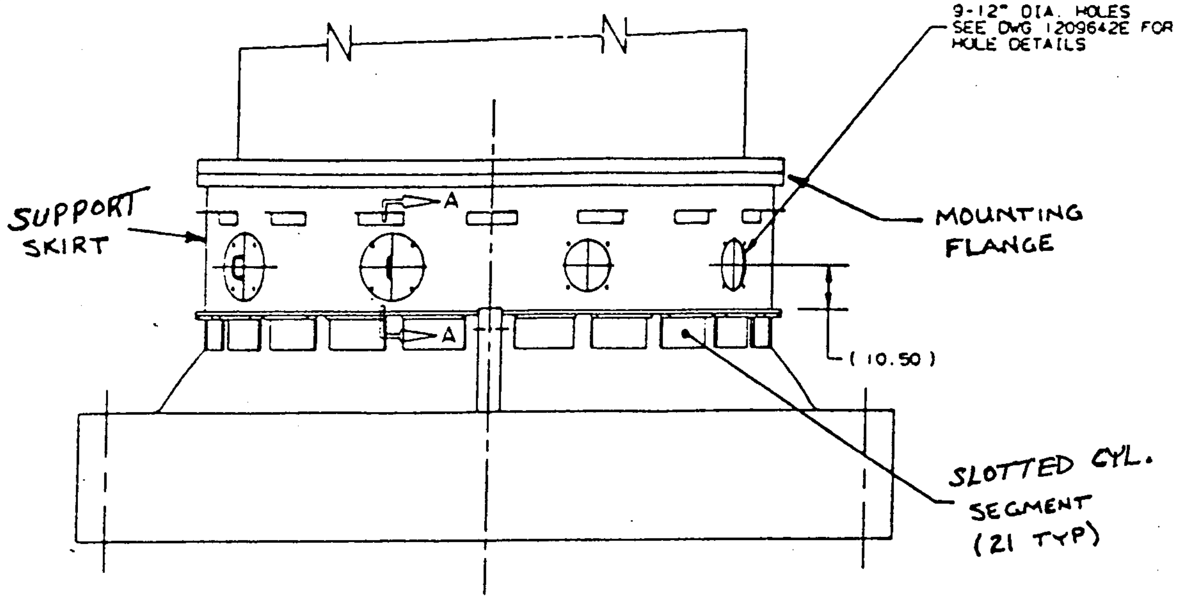
This conclusion is based on the following considerations:

a) The existing stress calculations are based on a simplified procedure. Preliminary results from a more detailed finite element analysis indicate that the maximum stress for a given set of loads are a factor of two lower than those estimated using the simplified method. Since the stress for the Maximum Hypothetical Earthquake are only 40% over the allowable, this would resolve the issue for this load.

b) The loads used in the stress analysis were those resulting from a break in the hot leg. Since the leak-before-break concept has been approved for both hot and cold legs, the loads for a core flood line LOCA should be used. These are expected to be significantly smaller than the loads used in the existing analyses.

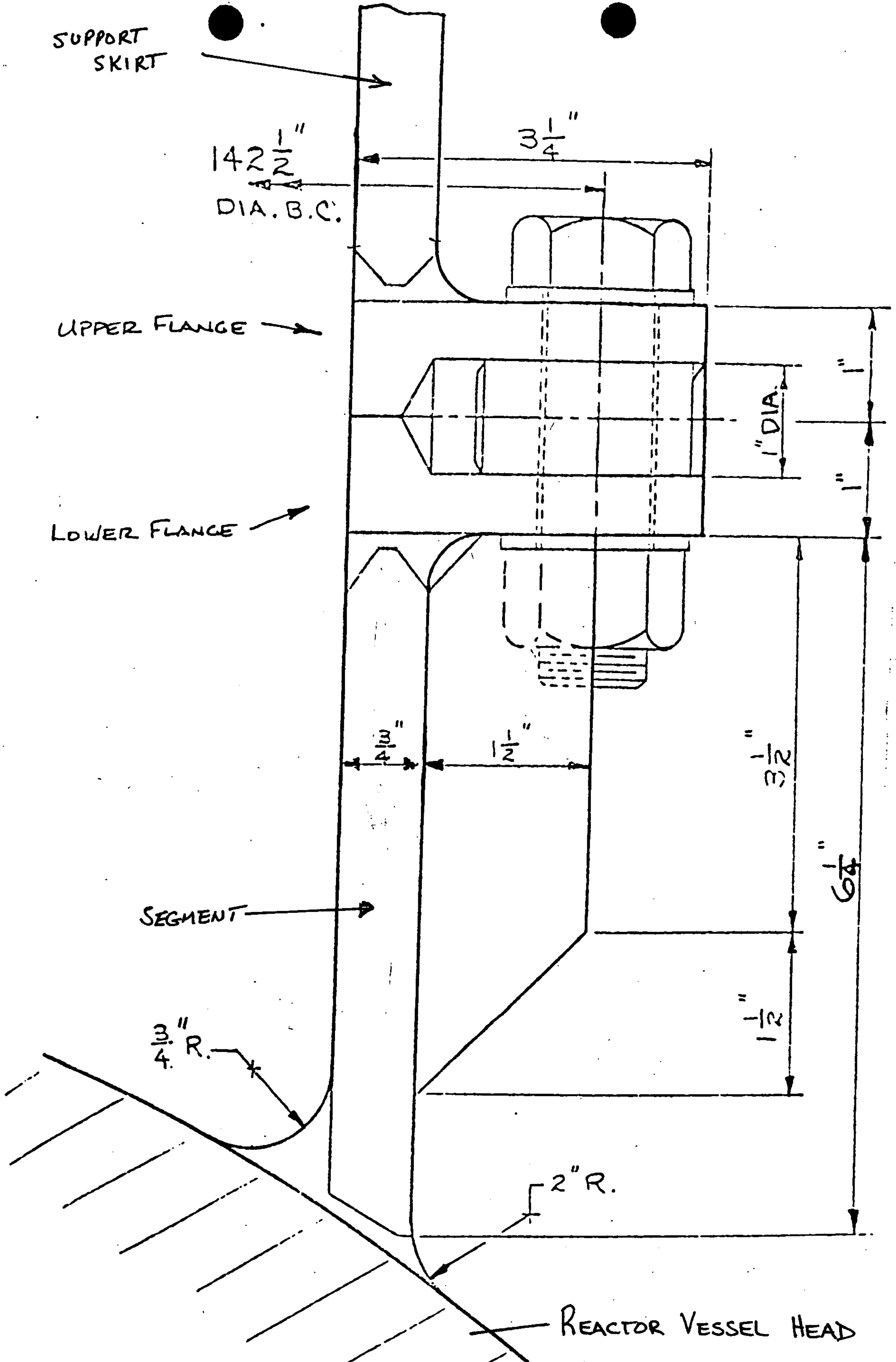
c) Less conservative plastic stress analysis methods are available, if needed.

d) The core flood line is fabricated from austenitic stainless steels, which are tougher and more ductile than the ferritic steels used for the hot and cold legs. Successful application of the leak-before-break concept to the hot and cold legs indicates a high probability of success should such an analysis be undertaken for the core flood line. This would eliminate the need to consider core flood line LOCA loads.



CLOSURE HEAD
ELEVATION VIEW

FIGURE 1



SUPPORT SKIRT
142 1/2"
DIA. B.C.
3 1/4"
UPPER FLANGE
LOWER FLANGE
1"
1" DIA.
1"
3/4"
1 1/2"
3 1/2"
6 1/4"
SEGMENT
1 1/2"
3/4" R.
2" R.
REACTOR VESSEL HEAD

FIGURE 2

P = Vertical Force
V = Horizontal Shear
M = Overturning Moment
My = Twisting Moment

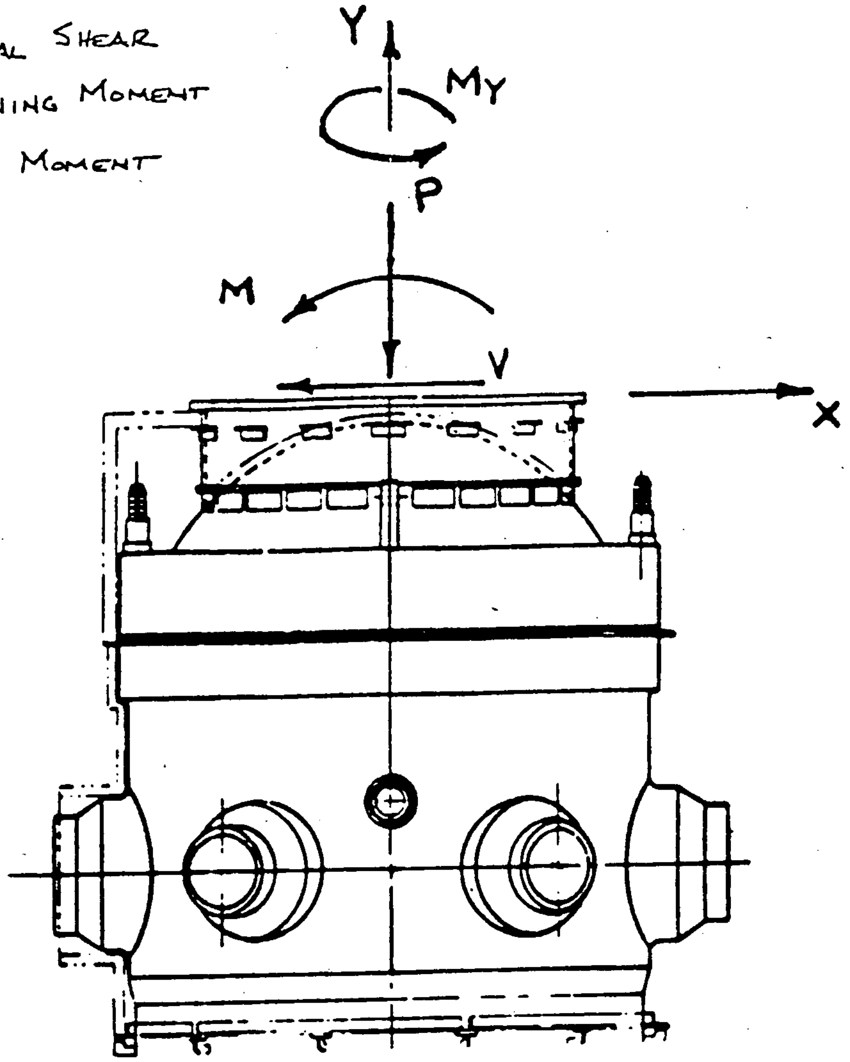
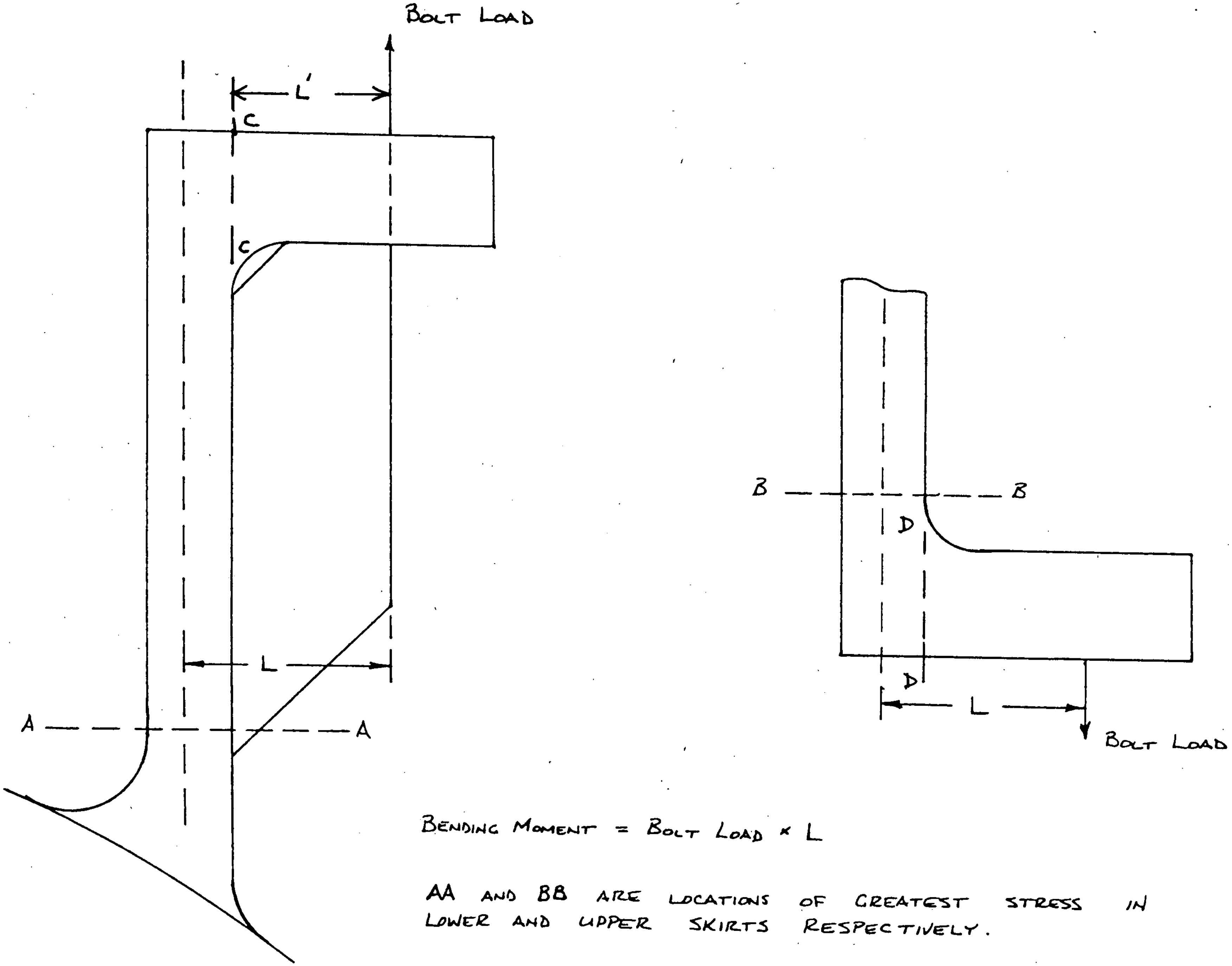


Figure 3



BENDING MOMENT = BOLT LOAD × L

AA AND BB ARE LOCATIONS OF GREATEST STRESS IN LOWER AND UPPER SKIRTS RESPECTIVELY.

LOWER FLANGE

UPPER FLANGE

FIGURE 4