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EMERGENCY DIESEL GENERATOR AIR START VALVE CAPSCREW DIMENSION AND STRESS ANALYSIS

Prepared for:

TDI OWNERS GROUP

Prepared by:
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EMERGENCY DIESEL GENERATOR

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AND

STRESS ANALYSIS

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SECTION 1

APPLICABILITY

This report is applicable to the TDI nuclear standby service diesel generators utilized at the Shoreham Nuclear Power Station. Other TDI nuclear standby service diesel engines have essentially the same air start valve capscrew design, based on incorporation of the 10CFR Part 21 Report issued by TDI on the old design. However, as part of the TDI Owners Group Design Review/Quality Revalidation effort, each nuclear service standby diesel engine air start valve will be reviewed to compare specified torque values, gasket material, etc., with those for the airstart capscrews on the Shoreham engines.

SECTION 2

EXECUTIVE SUMMARY

An analysis was conducted for the 2-3/4" capscrews utilized in the TDI nuclear standby service diesel generators in use at Shoreham.

The purpose of this analysis is to evaluate the capscrew design based on the criteria referenced in the component design review task description, (see Appendix C). This analysis concluded that the air start valve capscrews design is adequate for the given service conditions.

SECTION 3

OBJECTIVES

The objectives of this analysis are as follows:

1. Perform a dimension check on the Air Start Valve Capscrews to determine if adequate clearance exists within the cylinder head tapped hole.

2. Determine if the specified torque value ensures adequate capscrew preload.

3. Determine the total restart bolt stress.

4. Evaluate TDI's recommended retorquing requirements.

The details of this analysis are provided in SWEC calculation number 11600.60-245.1-M3 (Ref. 2).

SECTION 4

SUMMARY OF SERVICE CONDITIONS

The air start valve assembly is secured to the cylinder head via two capscrews. These capscrews are installed with a specified torque, which produces a tensile load in the capscrew and subsequent clamping force on the air start valve assembly. This clamping force opposes the cyclic forces induced by the cylinder pressures.

Initially, a stress (S_{pl}) is induced in the capscrew by preload. In addition to this preload stress, a cyclic fatigue stress is induced in the capscrews due to the cylinder firing pressure force.

SECTION 5

METHODS OF ANALYSIS

5.1 Air Start Valve Dimension Check

To ensure proper assembly of components, the capscrew must not "bottom out" within the cylinder head. This will not occur providing the minimum clearance available exceeds the maximum capscrew length. The minimum capscrew clearance is determined by taking dimensions of the various parts of the air start valve assembly penetrated by the Capscrew. As shown in Appendix B, Figure 1, the four items requiring measurement are the valve cap, valve housing, space between cylinder head and valve housing, and the cylinder head tapped hole. Thus by adding these four dimensions while considering the maximum tolerance in the direction to provide minimum length, the minimum capscrew clearance is determined.

5.2 Determination of Applied Stresses

In determining the stresses applied to the air start valve capscrews, the tensile preload resulting from the applied torque is first calculated by the relation

$F_{pl} = T/.2d$ Eq. 1 (Reference 3)

where T= applied torque, LB_f-in

d= nominal capscrew diameter, in

F_{pl}= capscrew preload, LB_f due to torque T

The resulting tensile load is taken to act uniformly over the minimum cross sectional area (A(min)) of the capscrew, located at the threads, so that the resulting preload stress is maximized.

The tensile loads produced in the capscrews are converted to a clamping force on the air start valve Assembly which serves to resist the pressure loadings. The pressure loads are calculated by multiplying a conservative cylinder firing pressure by the valve face area. This force is resolved into a single vector acting at the geometric center of the valve opposing the preload clamping forces.

The cyclic stress induced on the capscrews due to the alternating load is given by:

$$S_b = \frac{\pm F_{pb}/2}{A(min)} \qquad \text{(Reference 3)}$$

Where S_b = alternating stress

$F_{pb} = F_{cp}\left(\frac{K_b}{K_b+K_m}\right)$ = alternating load

and K_b = spring rate for the capscrew

K_m = spring rate for the section joined by the capscrews

F_{cp} = maximum resultant force due to cylinder pressure.

As per Reference 3 & 5, the spring rates K_b and K_m are determined by:

$$K_b = \frac{\pi d^2 E}{4L} \qquad \text{(Reference 3)}$$

$$K_{m1} = \frac{2\pi d^2 E}{L} \qquad \text{Where } D_j < 3D_h \quad \text{(Reference 3)}$$

$$K_{m2} = \frac{E}{L}\left[\frac{\pi}{4}\left(D_h^2-d^2\right)+\frac{\pi}{8}\left(\frac{D_j}{D_h}-1\right)\left(\frac{D_h L}{5}+\frac{L^2}{100}\right)\right]$$

Where $D_h<D_j<3D_h$ (Reference 5)

Where d = nominal capscrew diameter, in

D_h = capscrew head diameter, in

D_j = joint diameter, in

E = modulus of elasticity, lb_f/in^2

L = length of joined sections, in

K_{m1} = spring rate for cylinder head, $lb_f/in.$

K_{m2} = spring rate for valve cap and valve housing, $lb_f/in.$

Since a number of joint sizes occur, the individual spring rate must be calculated for each joint. The overall spring rate constant K_m is then determined by adding the individual rates in series as follows:

$$K_m = \frac{1}{\frac{1}{K_{m1}} + \frac{1}{K_{m2}}} \quad \text{(Reference 3)}$$

The spring rate for the copper gasket is relatively large compared to K_{m1} and K_{m2} and thus has an insignificant effect on the overall spring constant K_m.

Once the preload stress (S_{pl}) and the alternating stress ($\pm S_b$) are determined, the total applied mean stress (S_t) is defined as:

$$S_t = S_{pl} + S_b$$

5.3 Determination of Endurance Limits

The endurance limit (S_e) for the capscrew design is determined by:

$$S_e = K_a K_b K_c K_d K_e K_f S_e' \qquad \text{(Reference 3)}$$

where S_e' = the endurance limit of a rotating beam specimen
K_a = component surface factor
K_b = component size factor
K_c = reliability factor
K_d = temperature factor
K_e = modifying factor for stress concentration
K_f = miscellaneous effects factor

The endurance limit of the two designs is compared, as well as the total applied mean stress (S_t) and the yield strength (S_y) of the material in order to determine the suitability of the component design for the given service.

SECTION 6

DISCUSSION OF RESULTS

Per Reference 2, a dimension check indicates that a 0.2 inch minimum clearance exists within the cylinder tapped hole. As a result, the air start valve capscrew will not "bottom out" upon torquing.

Per reference 5, fatigue failure in capscrews is avoided if the total applied mean stress (S_t) is below the yield point for the component material and the endurance strength exceeds the cyclic stress by an acceptable margin. As per Appendix A Table 1, the total applied mean stress (S_t) taken at the minimum cross sectional areas A(min) is 37.5 ksi.

Per Reference 4, the yield strength for the capscrew material is 92 ksi minimum. As a result, the criteria for a fatigue resistant design, namely $S_t < S_y$ is satisfied.

As shown in Appendix A, Table 1, the capscrew design utilizes an endurance stress of 9.0 ksi with a cyclic stress of $\pm$1.6 ksi (see Appendix B, Figure 3) and therefore, satisfies the second criteria for a fatigue resistant design. The presence of the preload serves to reduce the range of stress cycling and subsequent fatigue effects on the capscrews. As a result, the specified torque which provides the preload is acceptable.

During start up of the engine, a stress is imposed on the capscrews due to starting air pressure within the air start valve assembly. This stress is insignificant compared to the greater alternating stress induced by cylinder firing pressures.

During engine operation, the valve assembly copper gasket is subjected to elevated temperatures. As a result, of the temperature rise and preload, creep occurs within the gasket which will decrease the total capscrew preload. To compensate, the existing diesel engine maintenance procedures require retorquing at specified intervals until no change is detected. At this time the gasket is fully compressed at its operating temperature with the required preload. Hence, capscrew preload is maintained during the full range of engine operation.

SECTION 7

CONCLUSIONS

Reference 2 provided a dimensional and fatigue analysis for the air start valve capscrews. Based on this analysis, the capscrew is adequately designed for the intended service.

The restart bolt stress has an insignificant effect on the capscrews. In addition, any possible loss of preload due to creep of the soft copper gasket is recovered through the existing retorque procedure.

APPENDIX A - STRESS SUMMARY

TABLE 1: STRESS SUMMARY

TABLE №1

STRESS SUMMARY

S_{PL} KSI	S_B KSI	S_E KSI	S_T KSI
35.9	±1.6	9.0	37.5

S_{PL} – PRELOAD STRESS

S_B – ALTERNATING STRESS

S_E – ENDURANCE LIMIT

S_T – TOTAL APPLIED MEAN STRESS

APPENDIX B - DRAWINGS - FATIGUE DIAGRAMS

FIGURE 1: AIR START VALVE ASSEMBLY

FIGURE 2: FATIGUE DIAGRAM

FIGURE Nº 1
(AIR START VALVE ASSY)

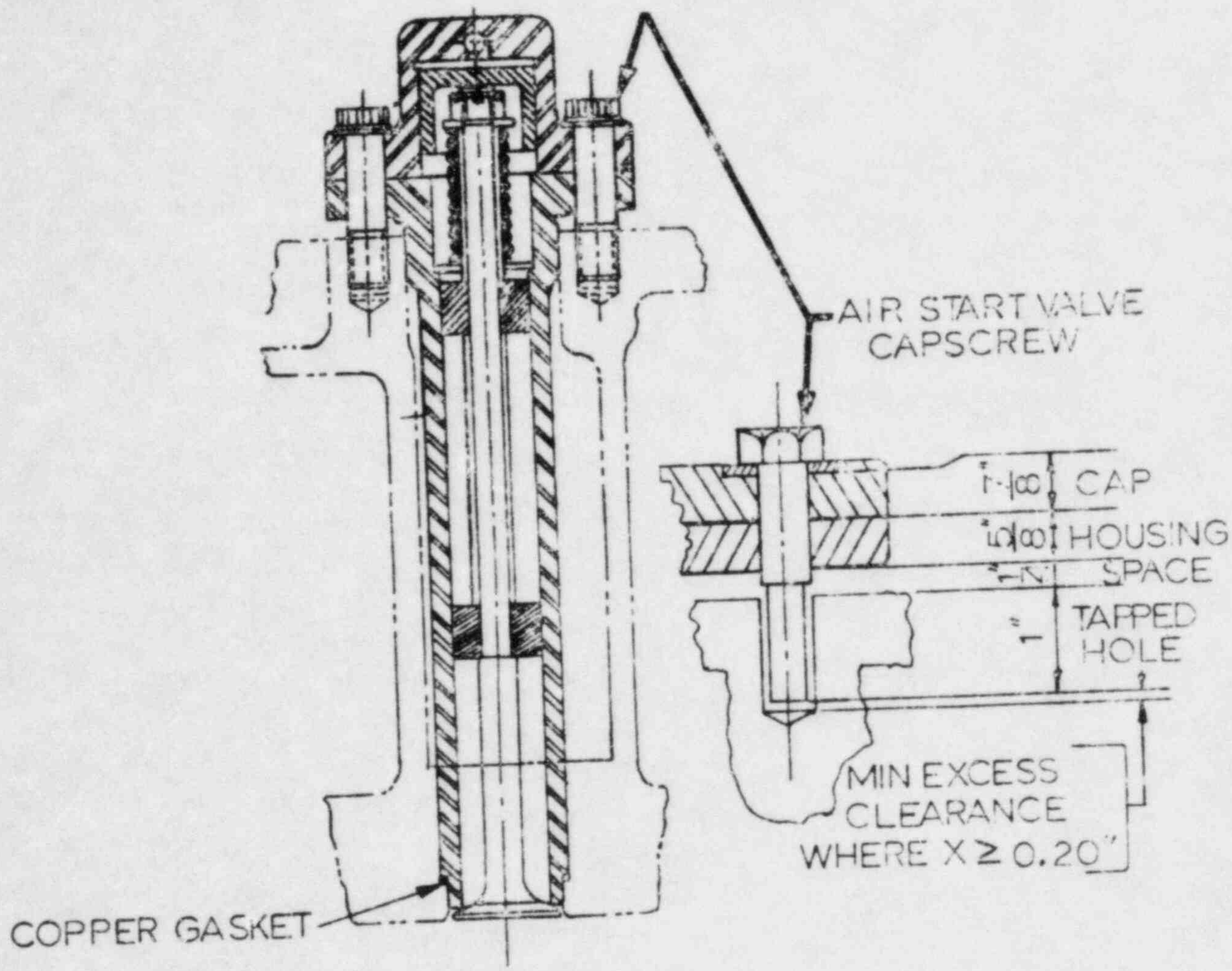
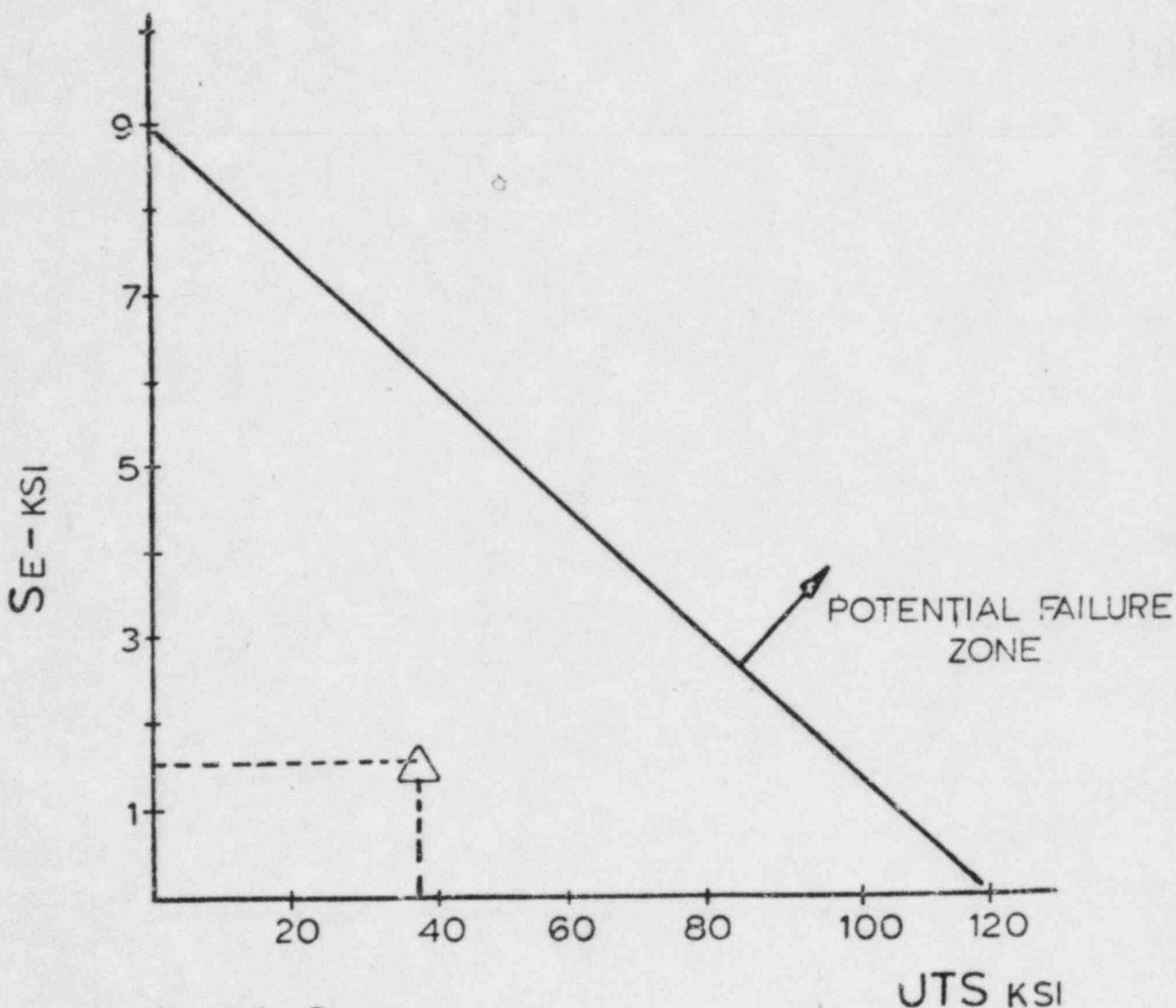


FIGURE №2

FATIGUE DIAG GOODMAN LINE



$S_B = \pm 1.6$ KSI

$S_T = 37.5$ KSI

APPENDIX C

TASK DESCRIPTION

COMPONENT DESIGN REVIEW
TASK DESCRIPTION

AIR START VALVE CAPSCREWS
PART NO. 03-359

Classification A
Completion 3/1/84

PRIMARY FUNCTION: The air start valve capscrews provide clamping force to hold air start valves in place on cylinder heads.

FUNCTIONAL ATTRIBUTES:

1. The air start valve capscrews must have sufficient strength to withstand the necessary preload and reaction air loading without yielding and resulting in loss of clamping force on the air start valves.

SPECIFIED STANDARDS: None

EVALUATION:

1. Verify adequacy of new capscrew length to prev[illegible] bottoming out of the capscrew during installatio[illegible]. Review to include maximum tolerance of capscrew length coupled with cylinder head minimum hole depth.
2. Evaluate adequacy of specified torque value.
3. Perform worst case analysis of reaction air loading in capscrews.
4. Determine the total restart bolt stress.
5. Evaluate the TDI recommended retorquing requirements after operation due to use of copper gaskets.

REVIEW TDI ANALYSES: Review load and deflection analyses if any.

INFORMATION REQUIRED:

1. Capscrews and washer materials and dimensions
2. Cylinder head drawings
3. Specified torque value and lubrication requirements

APPENDIX D - REFERENCES

Reference 1: TDI Drawing 03-359-02 - Air Start Valve Assembly

Reference 2: SWEC Calculation 11600.60-245.1-M3

Reference 3: Mechanical Engineering Design, J.E. Shigley, 3rd edition

Reference 4: ASM Metals Handbook, Vol. I, 9th Edition, Pg. 274.

Reference 5: Simple Diagrams Aid in Analyzing Forces in Bolted Joints, Assembly Engineering, G. Meyer 1972