Commonwealth Edison Company
1400 Opus Place
Downers Grove, IL 60515

ComEd

June 30, 1995

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

Attn: Document Control Desk

Subject: Quad Cities Station Units 1 and 2
Core Shroud Repair Hardware Inadvertent Loading
NRC Docket Nos. 50-254 and 50-265

Reference: (1) J.L. Schrage to USNRC letters dated June 19, 1995 and June 27, 1995

(2) Teleconferences between USNRC (R. Pulsifer, et al) and ComEd (J. Schrage, et al) on June 28, 1995 and June 29, 1995

In the Reference (1) letters, Commonwealth Edison (ComEd) provided information which demonstrated that the impact of an inadvertent loading event did not compromise the overall structural integrity of the Quad Cities Unit 2 shroud shell or the newly installed shroud repair hardware.

During the Reference (2) teleconferences, the NRC Staff identified several questions in regards to the methodologies used by ComEd in the calculations which were provided in Reference (1). ComEd has reviewed the information and technical references discussed during the Reference (2) teleconferences, and has identified an alternative design verification method to validate the Reference (1) calculations. This alternative method provides additional assurance that the core shroud hardware inadvertent loading event did not result in any inelastic deformation of the shroud repair hardware. Attachment 1 to this letter, and the associated Enclosures, provides the results of the alternative design verification. Attachment 2 to this letter provides free body diagrams of the reactions and applied loads used for the original finite element analysis of the core shroud repair hardware, and the reactions and applied loads used in the alternative design verification.

To the best of my knowledge and belief, the analyses and evaluations contained in these documents are true and correct. In some respects these documents are not based on my personal knowledge, but on information furnished by other Commonwealth Edison employees, contractor employees, and/or consultants. Such information has been reviewed in accordance with company practice, and I believe it to be reliable.

A001 per Darin Hoover
1/1

If there are any questions, please contact John L. Schrage at 708-663-7283.

Sincerely,

OFFICIAL SEAL
MARY JO YACK
NOTARY PUBLIC STATE OF ILLINOIS
MY COMMISSION EXPIRES: 11/29/87

John L. Schrage
Nuclear Licensing Administrator

Mary Jo Yack 6-30-95

Attachment (with Enclosures)

cc: J.B. Martin, Regional Administrator - Region III
R.M. Pulsifer, Project Manger - NRR
C. Miller, Senior Resident Inspector - Quad Cities
Office of Nuclear Facility Safety - IDNS

ATTACHMENT 1

Alternate Design Verification for Effects of Core Shroud Repair Hardware Inadvertent Loading

References:

1. Calculation No. GENE-771-111-0695, Rev. 0
2. Calculation No. GENE-771-113-0695, Rev. 0
3. Calculation No. 9389-64-DQ, Rev. 0
4. Calculation No. GENE-771-68-1094, Rev. 4
5. Calculation No. GENE-771-10-1094, Rev. 3

During the installation of the Shroud Head/Separator assembly at Quad Cities Unit 2, two of the Separator support leg extensions impacted two of the upper supports that are part of the shroud repair hardware assemblies. Evaluations, contained in References 1 and 2 were performed to determine the impact from this impingement. These evaluations demonstrate that the impact did not compromise the overall structural integrity of the shroud shell or the newly installed shroud repair hardware. Additionally, the Reference 3 evaluation was performed as an independent and alternate design verification of the conclusions drawn in the Reference 1 and 2 evaluations. The following is a discussion of the methodologies used in the Reference 3 evaluation.

The Reference 1 and 2 evaluations demonstrate that the inadvertent loading from the Separator support legs was resisted fully by the shroud head flange ring. This load transfer mechanism is analogous to the previous finite element analysis performed for the applied design basis loadings in the Reference 4 and 5 evaluations. The alternate design verification contained in the Reference 3 evaluation interpolates applied stresses, as a result of the inadvertent loading, from the results contained in the Reference 4 and 5 evaluations. As previously stated, the load transfer mechanism is analogous, and the interpolation of applied stresses is therefore deemed valid.

The simplified analysis in Reference 2 conservatively assumed that all of the separator weight, uncorrected for buoyancy effects, was impacted as the applied load on one support hardware bracket. It is more realistic to assume that one half of the separator weight was the actual impact load applied to the hardware because the procedure which is used to lower the separator, requires that the installation be stopped with the top of the separator at 12 inches above the cavity floor. At this point, a camera is installed to monitor the remaining movements, and the separator is carefully lowered to ensure that the guide rods are aligned. At the time the contact was made, the load was still being supported by the lifting rig. The load was then lowered further, until the cables on the rig were slack. A visual inspection at that time determined that the separator was resting on both the 103° and 283° repair hardware locations. The Reference 3 evaluation therefore, considers the sum of one half of the buoyant weight of the Shroud Head/Separator assembly multiplied by an dynamic impact factor of 1.15 plus one half of the tie rod mechanical preload (two long upper supports per tie rod) as an applied loading. The total applied loading from the impingement is therefore taken as 81.43 kips. The criteria for the 15% dynamic impact factor is attached as an enclosure to this document.

The Reference 3 evaluation demonstrates that the original design bases qualified the long upper support portions for a Normal/Upset loading equivalent to 102.5 kips. This design value exceeds the applied loading resulting from the impingement (81.43 kips). The Reference 3 evaluation concludes that applied stresses, resulting from the impingement, remain well within allowable limits. Additionally, the Reference 3 evaluation concludes that no permanent deformations nor gross yielding occurred as a result of the impingement.

Additionally, visual inspection of the upper long support portions utilizing underwater cameras were performed. This inspection was performed while the Separator support legs were in contact with the Shroud repair hardware and also after they were removed. A review of this footage was performed by ComEd Site Engineering department ar Quad Cities Station. The review concluded that no apparent deformations or abnormalities in the repair hardware existed either while the Separator legs were in contact with the repair hardware, or after they were removed.

Based on the Reference 3 alternate design verification and the visual inspection, ComEd concurs with the conclusions drawn in the Reference 1 and 2 evaluations. Furthermore, ComEd has concluded that the analysis of the NRC Safety Evaluation for the Quad Cities Shroud Repair, dated June 8, 1995, remains valid and bounding for the in-service performance of the shroud repair hardware.

ENCLOSURE NO. 1 :

CALCULATION NO. 9389-64-DQ

1. Purpose and Objective

During the installation of the shroud head and separator assembly at Quad Cities Unit 2, two of the lifting rod extensions contacted two of the long upper supports that are part of the shroud modification hardware. The purpose of this calculation is to perform a verification by an alternate method of the GE evaluation (Reference 1) for the stresses in the critical section of the long upper support bracket.

2. Methodology and Acceptance Criteria

The two lifting rod extensions were lowered onto the top section of the long upper support (LUS) thus loading the LUS with the weight of the shroud head and separator assembly. Per Figure 1 of Reference 1 this applied load is resisted by the extension piece that rests on the shroud head flange ring. This load transfer mechanism is analogous to the previous finite element analysis (FEA) of the LUS (References 2 & 3) that was performed for the applied design basis loads. This calculation takes the stress results from the previous FEA of this support assembly and interpolates the stress results for the actual loads applied. The resultant stresses are compared to the ASME Section III, Subsection NG allowable limits and criteria (Reference 4) as provided in Figure NG-3221-1 and Table NG-3217-1. This type of ASME "Design by Analysis" approach is the same as was previously used for the core shroud repair hardware design.

3. Assumptions

There are no major assumptions that require verification, all key design inputs and assumptions are based on approved references or standard engineering practice. Minor assumptions related to specific items are noted in the calculation.

4. Design Input Parameters

1. Weight of shroud head and separator assembly = 141.9 Kips (dry weight, Reference 1)
2. Buoyant weight of the shroud head and separator assembly = 141.9 x 0.9 = 127.71 Kips (Submerged weight, Reference 5, page 14)
3. S_m of X-750 at room temperature = 50,900 psi. (Reference 6)
4. S_y of X-750 at room temperature = 102,300 psi. (Reference 6)
5. S_{ult} of X-750 at room temperature = 152,800 psi. (Reference 6)
6. Preload on the Tie Rod = 14,400 / 0.9 = 16,000 lbs. (Reference 7, page 8), neglecting the effect of any preload relaxation

7. Minimum Impact Factor for the QC Reactor Building 125 Ton Crane = 1.15 (References 8 & 9)

5. References

1. GENE-771-111-0695, Rev. 0, "Shroud Head Contact on Upper Support", DRF# B13-01740, June 15, 1995
2. GENE-771-68-1094, Revision 4, "Shroud and Shroud Repair Hardware Stress Analysis - Shroud Repair for H1 through H7 Welds for ComEd Quad Cities Stations Units 1 & 2.
3. GENE-771-70-1094, Revision 3, "Backup Calculations of Shroud and Shroud Repair Hardware Stress Analysis for ComEd Quad Cities Stations Units 1 & 2.
4. ASME Section III, Subsection NG, 1989 Edition, NG-3200.
5. GENE-771-69-1094, Revision 1, "Backup Calculations for Shroud andShroud Repair Shroud Stress Report for ComEd Quad Cities Stations Units 1 & 2
6. GE DRF-B13-01740, Section N, "CMTR's for X-750".
7. GENE-771-68-1094, Supplement A to Revision 4, "Supplement A to Shroud and Shroud Repair Hardware Stress Analysis", DRF B13-01740, April 1995.
8. SLE 95-005, Rev. 1, June 20, 1995, S. Eldridge - Determination of Impact Factor for QC Reactor Building Crane.
9. Whiting Crane Handbook, Whiting Corporation, 1979.

6. Calculation

The maximum loading that would have been applied to the top of the long upper support (equal in magnitude to the reaction force) is the sum of the one half of the buoyant weight of the shroud separator multiplied by an impact factor plus one half of the tie rod mechanical preload (two LUS per tie rod).

$P = (127.71/2)\ 1.15 + (16.0/2) = 81.43$ Kips

Per Reference 3 (pages 12 & 13, see Attachment A) the Finite Element stress analysis of the LUS was performed using the ANSYS program with STIF45 3-D Isoparametric Solid Elements. The results of this analysis at critical cross section A-A (the juncture of the horizontal to vertical elements) are summarized below for an applied concentrated reaction of 102.5 Kips.

<u>Resultant Stresses For R = 102.5 Kips (Reference 3, page 44.a, Attachment A)</u>

P_m = 31,540 psi (Primary Membrane)
P_b = 17,460 psi (Primary Bending)
Q = 9122 psi (Peak)
$P_m + P_b$ = 46,190 psi
$P_m + P_b + Q$ = 50,780 psi (Total Stress)

Interpolation of the results of this elastic analysis for a reaction force of 81.43 Kips results in the following critical stress distribution at Section A-A.

<u>Resultant Stresses For R = 81.43 Kips (81.43/102.5 = 0.794 ratio)</u>

P_m = 25,057 psi (Primary Membrane)
P_b = 13,871 psi (Primary Bending)
Q = 7247 psi (Peak)
$P_m + P_b$ = 36,695 psi
$P_m + P_b + Q$ = 40,342 psi (Total Stress)

7. Summary of Results and Conclusions

The following maximum stresses are compared to the code limits of Reference 4 for a Service Level A and B application.

P_m = 25,057 psi < 1.0 S_m = 50,900 psi
$P_m + P_b$ = 36,695 psi < 1.5 S_m = 76,350 psi
$P_m + P_b + Q$ = 40,342 psi < 3.0 S_m = 152,700 psi

All of the above code required limits are satisfied with a sufficient amount of margin, therefore the effect of the temporary one time placement of the shroud separator assembly of the long upper support is acceptable. The resistance of the hardware for this level of stress is sufficient without damage or gross yielding of the long upper support, as the maximum peak stress index of 40,342 psi is significantly less than the yield strength S_y = 102,300 psi.

See Attachment C for a verification of the FEA results using beam theory. This verification validates the results of the FEA and the extrapolation.

8. Recommendations

I concur with the GE conclusion (Reference 1) that the effect of this loading on the LUS is acceptable. I recommend that a visual inspection be performed of the LUS upper attachment point to verify no signs of significant deformation, or yielding as well as a visual inspection of the tie rod assembly to verify that it remains in a taught condition.

9. Attachments

A. Attachment A, selected sections of Reference 3.

B. Attachment B, Reference 8.

C. Verification of finite element analysis results using beam formulas.

SLE 95-005, Rev. 1

June 20, 1995

Criteria Used to determine Impact factor.

References:

1. Whiting Crane Handbook, Whiting Corporation, 1979.
2. Response to Request for Information on the Control of Heavy Loads, Nov 1981. Rev 1. Section 2.1.7.c no. 13, page 2.1-12. Issued in response to Generic Letter 81-07.
3. AISC Code Section 1.3.3
4. Memo from K. Beardsley to S. Eldridge dated June 20, 1995

Reference 1, 2 and 3 provide justification for the use of 1/2% impact for each ft per minute of crane speed with a minimum of 15%. The maximum crane speed for the reactor building 125 Ton crane is 5.75 feet per minute (fpm) under full load or 17.25 fpm under no load. This would result in a maximum impact factor of approximately 8.6%. Reference 3 also recommends the use of 25% as the impact factor for traveling cranes and supports. Hence the use of 25% in the analysis for affect on the core shroud repair hardware is conservative as these values provide additional margin above required loads.

Approved by: [signature] 6/20/95
Sharon L. Eldridge
Design Supervisor

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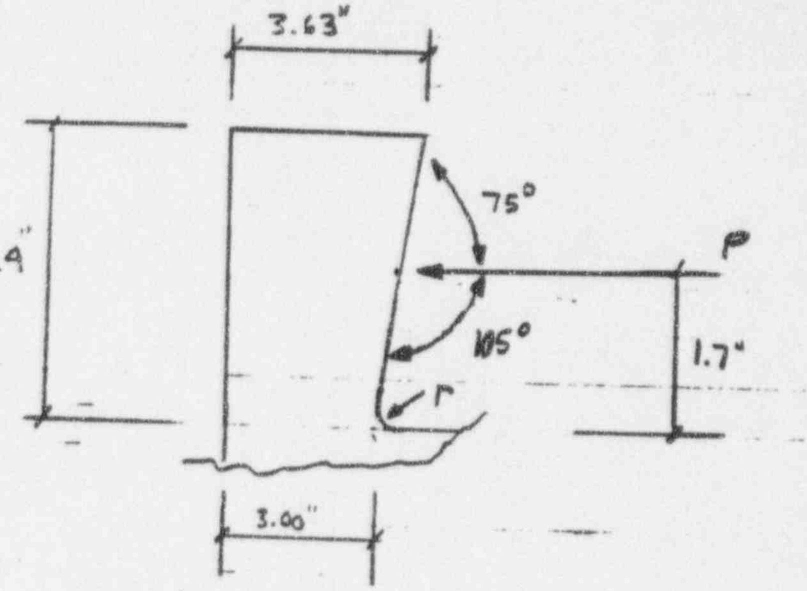
USING REFERENCE, "FORMULAS FOR STRESS AND STRAIN, 5th EDITION, ROARK AND YOUNG", PAGE 187 DETERMINE THE MAXIMUM STRESS AT THE CRITICAL CROSS SECTION USING A DEEP BEAM APPROACH.



$$\begin{bmatrix} e \\ r \\ a \\ b \\ t \end{bmatrix} := \begin{bmatrix} 1.5 \\ 0.375 \\ 1.7 \\ 1.76 \\ 3.5 \end{bmatrix} \cdot in$$

$\beta := 75 \cdot deg$

$W := 81.43 \cdot kip$

$$\sigma := \frac{W}{t} \cdot \left[1 + 0.26 \cdot \left(\frac{e}{r}\right)^{0.7}\right] \cdot \left[\frac{1.5 \cdot a}{e^2} + \frac{\cos(\beta)}{2 \cdot e} + \frac{0.45}{(b \cdot e)^{\frac{1}{2}}}\right]$$

$\sigma\_max := \sigma$

$\sigma\_max = 58.709 \cdot ksi$

A comparison of this stress index (58.709 ksi) without the stress concentration factor of 1.686 (first term of the equation in parenthesis) results in a stress index of 34.82 ksi which is approximately equal to the primary membrane plus primary bending stress value obtained from the finite element analysis (36,695 psi). The results of the FEA are reasonable and within acceptable limits.

Roark & Young
5th Edition

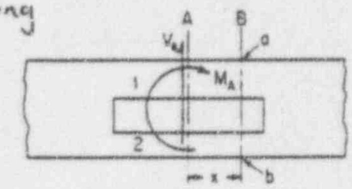


Fig. 7.14

7.9 *Slotted beams*

If the web of a beam is pierced by a hole or slot (Fig. 7.14), the stresses in the extreme fibers a and b at any section B are given by

$$\sigma_a = -\frac{M_A}{I/c} - \frac{V_A x I_1/(I_1 + I_2)}{(I/c)_1} \qquad \text{(compression)}$$

$$\sigma_b = \frac{M_A}{I/c} + \frac{V_A x I_2/(I_1 + I_2)}{(I/c)_2} \qquad \text{(tension)}$$

Here M_A is the bending moment at A (midlength of the slot), V_A is the vertical shear at A; I/c is the section modulus of the net beam section at B; I_1 and I_2 are the moments of inertia, and $(I/c)_1$ and $(I/c)_2$ are the section moduli of the cross sections of parts 1 and 2 about their own central axes. M and V are positive or negative according to the usual convention, and x is positive when measured to the right.

The preceding formulas are derived by replacing all forces acting on the beam to the left of A by an equivalent couple M_A and shear V_A acting at A. The couple produces a bending stress given by the first term of the formula. The shear divides between parts 1 and 2 in proportion to their respective I's and produces in each part an additional bending stress given by the second term of the formula. The stress at any other point in the cross section can be found similarly by adding the stresses due to M_A and those due to this secondary bending caused by the shear. (At the ends of the slot there is a stress concentration at the corners which is not taken into account here.)

The above analysis applies also to a beam with multiple slots of equal length; all that is necessary is to modify the term in brackets so that the numerator is the I of the part in question and the denominator is the sum of the I's of all the parts 1, 2, 3, etc. The formulas can also be used for a rigid frame consisting of beams of equal length joined at their ends by rigid members; thus in Fig. 7.14 parts 1 and 2 might equally well be two separate beams joined at their ends by rigid crosspieces.

7.10 *Beams of relatively great depth*

In beams of small span/depth ratio, the shear stresses are likely to be high and the resulting deflection due to shear may not be negligible. For span/

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depth ratios of 3 or more, the deflection y_s due to shear is found by the method of unit loads to be

$$y_s = F \int \frac{Vv}{AG} dx \tag{19}$$

or by Castigliano's first theorem to be

$$y_s = \frac{\partial U_s}{\partial P} \tag{20}$$

In Eq. 19, V is the vertical shear due to the actual loads, v is the vertical shear due to a load of 1 lb acting at the section where the deflection is desired, A is the area of the section, G is the modulus of rigidity, F is a factor depending on the form of the cross section, and the integration extends over the entire length of the beam, with due regard to the sign of V and v. For a rectangular section, $F = \frac{6}{5}$; for a solid circular section, $F = \frac{10}{9}$; for a thin-walled hollow circular section, $F = 2$; for an I or box section having flanges and web of uniform thickness,

$$F = \left[1 + \frac{3(D_2^2 - D_1^2)D_1}{2D_2^3}\left(\frac{t_2}{t_1} - 1\right)\right]\frac{4D_2^2}{10r^2}$$

where D_1 = distance from neutral axis to the nearest surface of the flange
D_2 = distance from neutral axis to extreme fiber
t_1 = thickness of web (or webs in box beams)
t_2 = width of flange
r = radius of gyration of section with respect to the neutral axis

If the I- or box beam has flanges of nonuniform thickness, it may be replaced by an "equivalent" section whose flanges, of uniform thickness, have the same width and area as those of the actual section (Ref. 19). Approximate results may be obtained for I-beams using $F = 1$ and taking for A the area of the web.

Application of Eq. 19 to several common cases of loading yields the following results:

End support, center load P	$y_s = \frac{1}{4} F \frac{Pl}{AG}$
End support, uniform load W	$y_s = \frac{1}{8} F \frac{Wl}{AG}$
Cantilever, end load P	$y_s = F \frac{Pl}{AG}$
Cantilever, uniform load W	$y_s = \frac{1}{2} F \frac{Wl}{AG}$

In Eq. 20, $U_s = F \int (V^2/2AG)\, dx$, P is a vertical load, real or imaginary,

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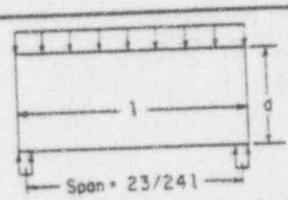
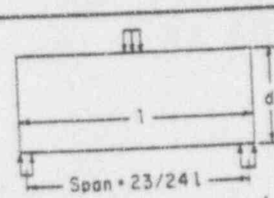
applied at the section where y_s is to be found, and the other terms have the same meaning as in Eq. 19.

The deflection due to shear will usually be negligible in metal beams unless the span/depth ratio is extremely small; in wood beams, because of the small value of G compared with E, deflection due to shear is much more important. In computing deflections it may be allowed for by using for E a value obtained from bending tests (shear deflection ignored) on beams of similar proportions or a value about 10 percent less than that found by testing in direct compression if the span/depth ratio is between 12 and 24. For larger ratios the effect of shear is negligible, and for lower ratios it should be calculated by the preceding method.

For extremely short deep beams, the assumption of linear stress distribution, on which the simple theory of flexure is based, is no longer valid. Equation 1 gives sufficiently accurate results for span/depth ratios down to about 3; for still smaller ratios it was believed formerly that the actual stresses were smaller than the formula indicates (Refs. 1 and 2), but more recent analyses by numerical methods (Refs. 43 and 44) indicate that the contrary is true. These analyses show that at s/d between 1.5 and 1, depending on the manner of loading and support, the stress distribution changes radically and the ratio of maximum stress to Mc/I becomes greater than 1 and increases rapidly as s/d becomes still smaller. In the following table, the influence of s/d on both maximum fiber stress and maximum horizontal shear stress is shown in accordance with the solution given in Ref. 43. Reference 44 gives comparable results, and both strain-gage measurements (Ref. 45) and photoelastic studies (Ref. 46) support the conclusions reached in these analyses.





Ratio l/d	Ratio span/d	Uniform load over entire l			Uniform load over middle $\frac{1}{12}l$		
		$\frac{\max \sigma_t}{Mc/I}$	$\frac{\max \sigma_c}{Mc/I}$	$\frac{\max \tau}{V/A}$	$\frac{\max \sigma_t}{Mc/I}$	$\frac{\max \sigma_c}{Mc/I}$	$\frac{\max \tau}{V/A}$
3	2.875	1.025	1.030	1.58	0.970	1.655	1.57
2.5	2.395	1.046	1.035	1.60	0.960	1.965	1.60
2.0	1.915	1.116	1.022	1.64	0.962	2.525	1.70
1.5	1.4375	1.401	0.879	1.80	1.038	3.585	1.92
1	0.958	2.725	0.600	2.43	1.513	6.140	2.39
0.5	0.479	10.95	2.365	4.53	5.460	15.73	3.78
$\frac{1}{3}$	0.3193	24.70	5.160	6.05	12.35	25.55	7.23

These established facts concerning elastic stresses in short beams seem incompatible with the contrary influence of s/d on modulus of rupture,

discussed in Art. 7.15, unless it is assumed that there is a very radical redistribution of stress as soon as plastic action sets in.

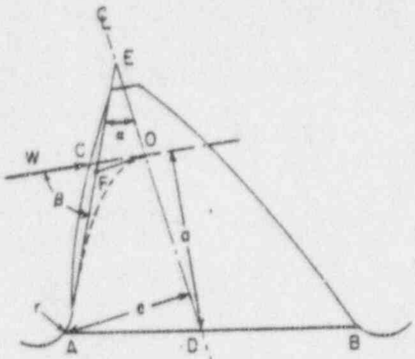


Fig. 7.15

The stress produced by a concentrated load acting on a very short *cantilever* beam or projection (gear tooth, sawtooth, screw thread) can be found by the following formula, due to Heywood (Chap. 2, Ref. 49) and modified by Kelley and Pedersen (Ref. 59). As given here, the formula follows this modification, with some changes in notation. Figure 7.15 represents the profile of the beam, assumed to be of uniform thickness t. ED is the axis or center line of the beam; it bisects the angle between the sides if these are straight; otherwise it is drawn through the centers of two unequal inscribed circles. W represents the load; its line of action, or load line, intersects the beam profile at C and the beam axis at O. The inscribed parabola, with vertex at O, is tangent to the fillet on the tension side of the beam at A, which is the point of maximum tensile stress. (A can be located by making AF equal to FE by trial, F being the intersection of a perpendicular to the axis at O and a trial tangent to the fillet.) B is the corresponding point on the compression side, and D is the intersection of the beam axis with section AB. The dimensions a and e are perpendicular, respectively, to the load line and to the beam axis; r is the fillet radius; and b is the straight-line distance from A to C. The tensile stress at A is given by

$$\sigma = \frac{W}{t}\left[1 + 0.26\left(\frac{e}{r}\right)^{0.7}\right]\left[\frac{1.5a}{e^2} + \frac{\cos\beta}{2e} + \frac{0.45}{(be)^{\frac{1}{2}}}\right]$$

Here the quantity in the first pair of brackets is the factor of stress concentration for the fillet. In the second pair of brackets, the first term represents the bending moment divided by the section modulus; the second term represents the effect of the component of the load along the tangent line, positive when tensile; and the third term represents what Heywood calls the *proximity effect*, which may be regarded as an adjustment for the very small span/depth ratio.

Kelley and Pedersen have suggested a further refinement in locating the point of maximum stress, putting it at an angular distance equal to $25° - \frac{1}{2}\alpha$, positive toward the root of the fillet. Heywood suggests locating this point at 30° from the outer end of the fillet, reducing this to 12° as the ratio of b to e increases; also, Heywood locates the moment of W about a point halfway between A and B instead of about D. For most cases the slightly different procedures seem to give comparable results and agree well with photoelastic analysis. However, more recent experimental studies (1963), including fatigue tests, indicate that actual stresses may considerably exceed those computed by the formula (Ref. 63).

7.11 *Beams of relatively great width*

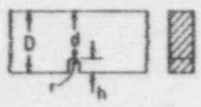
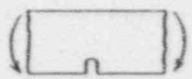
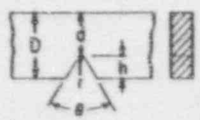
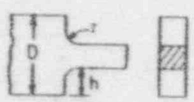
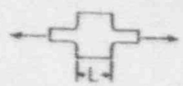
Because of prevention of the lateral deformation that would normally accompany the fiber stresses, wide beams, such as thin metallic strips, are more rigid than the formulas of Art. 7.1 indicate. This stiffening effect is taken into account by using $E/(1 - \nu^2)$ instead of E in the formulas for deflection and curvature (Ref. 21).

In very short wide beams, such as the concrete slabs used as highway-bridge flooring, the deflection and fiber-stress distribution cannot be regarded as uniform across the width. In calculating the strength of such a slab, it is convenient to make use of the concept of *effective width*, i.e., the width of a spanwise strip which, acting as a beam with uniform extreme fiber stress equal to the maximum stress in the slab, develops the same resisting moment as does the slab. The effective width depends on the manner of support, manner of loading, and ratio of breadth to span b/a. It has been determined by Holl (Ref. 22) for a number of assumed conditions, and the results are given in the following table for a slab that is freely supported at each of two opposite edges (Fig. 7.16). Two kinds of loading are considered, viz., uniform load over the entire slab and load uniformly distributed over a central circular area of radius c. The ratio of the effective width e to the span a is given for each of a number of ratios of c to slab thickness h and each of a number of b/a values.

Loading	Values of e/a for				
	$b/a = 1$	$b/a = 1.2$	$b/a = 1.6$	$b/a = 2$	$b/a = \infty$
Uniform	0.960	1.145	1.519	1.900	
Central, $c = 0$	0.568	0.599	0.633	0.648	0.656
Central, $c = 0.125h$	0.581	0.614	0.649	0.665	0.673
Central, $c = 0.250h$	0.599	0.634	0.672	0.689	0.697
Central, $c = 0.500h$	0.652	0.694	0.740	0.761	0.770

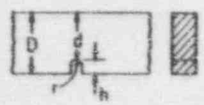
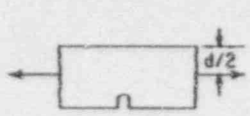
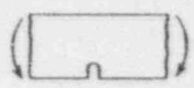
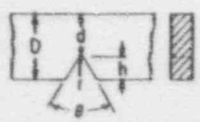
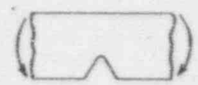
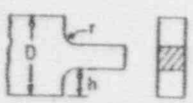
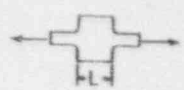
For the same case (a slab that is supported at opposite edges and loaded on a central circular area) Westergaard (Ref. 23) gives $e = 0.58a + 4c$ as an approximate expression for effective width. Morris (Ref. 24) gives $e = \frac{1}{2}e_c + d$

TABLE 37 ***Factors of stress concentration for elastic stress (k)*** **(Cont.)**

Type of form irregularity or stress raiser	Stress condition and manner of loading	Factor of stress concentration k for various dimensions
One U notch in a member of rectangular section 	3a. Elastic stress, axial tension 	$k = K_1 + K_2\left(\frac{h}{D}\right) + K_3\left(\frac{h}{D}\right)^2 + K_4\left(\frac{h}{D}\right)^3$ where for $0.5 \le h/r \le 4.0$ $K_1 = 0.721 + 2.394\sqrt{h/r} - 0.127h/r$ $K_2 = 1.978 - 11.489\sqrt{h/r} + 2.211h/r$ $K_3 = -4.413 + 18.751\sqrt{h/r} - 4.596h/r$ $K_4 = 2.714 - 9.655\sqrt{h/r} + 2.512h/r$ (Refs. 16 and 17) For the semicircular notch ($h/r = 1$) $k = 2.988 - 7.300\left(\frac{h}{D}\right) + 9.742\left(\frac{h}{D}\right)^2 - 4.429\left(\frac{h}{D}\right)^3$
	3b. Elastic stress, in-plane bending 	$k = K_1 + K_2\left(\frac{h}{D}\right) + K_3\left(\frac{h}{D}\right)^2 + K_4\left(\frac{h}{D}\right)^3$ where for $0.5 \le h/r \le 4.0$ $K_1 = 0.721 + 2.394\sqrt{h/r} - 0.127h/r$ $K_2 = -0.426 - 8.827\sqrt{h/r} + 1.518h/r$ $K_3 = 2.161 + 10.968\sqrt{h/r} - 2.455h/r$ $K_4 = -1.456 - 4.535\sqrt{h/r} + 1.064h/r$ (Refs. 17 and 18) For the semicircular notch ($h/r = 1$) $k = 2.988 - 7.735\left(\frac{h}{D}\right) + 10.674\left(\frac{h}{D}\right)^2 - 4.927\left(\frac{h}{D}\right)^3$
4. One V notch in a member of rectangular section 	4b. Elastic stress, in-plane bending 	The stress concentration factor for the V notch, k_θ, is the smaller of the values $k_\theta = k_U$ or $k_\theta = 1.11k_U - \left[0.0275 + 0.1125\left(\frac{\theta}{150}\right)^4\right]k_U^2 \quad$ for $\theta \le 150°$ where k_U is the stress concentration factor for a U notch, case 3b, when the dimensions h, r, and D are the same as for the V notch and θ is the notch angle in degrees. (Ref. 18)
5. Square shoulder with fillet in a member of rectangular section 	5a. Elastic stress, axial tension 	$k = K_1 + K_2\left(\frac{2h}{D}\right) + K_3\left(\frac{2h}{D}\right)^2 + K_4\left(\frac{2h}{D}\right)^3$ where $\frac{L}{D} > \frac{3}{[r/(D-2h)]^{1/4}}$ and where

	$0.1 \le h/r \le 2.0$	$2.0 \le h/r \le 20.0$
K_1	$1.007 + 1.000\sqrt{h/r} - 0.031h/r$	$1.042 + 0.982\sqrt{h/r} - 0.036h/r$
K_2	$-0.114 - 0.585\sqrt{h/r} + 0.314h/r$	$-0.074 - 0.156\sqrt{h/r} - 0.010h/r$
K_3	$0.241 - 0.992\sqrt{h/r} - 0.271h/r$	$-3.418 + 1.220\sqrt{h/r} - 0.005h/r$
K_4	$-0.134 + 0.577\sqrt{h/r} - 0.012h/r$	$3.450 - 2.046\sqrt{h/r} + 0.051h/r$

TABLE 37 ***Factors of stress concentration for elastic stress (k)*** **(Cont.)**

Type of form irregularity or stress raiser	Stress condition and manner of loading	Factor of stress concentration k for various dimensions
3. One U notch in a member of rectangular section 	3a. Elastic stress, axial tension 	$$k = K_1 + K_2\left(\frac{h}{D}\right) + K_3\left(\frac{h}{D}\right)^2 + K_4\left(\frac{h}{D}\right)^3$$ where for $0.5 \le h/r \le 4.0$ $K_1 = 0.721 + 2.394\sqrt{h/r} - 0.127h/r$ $K_2 = 1.978 - 11.489\sqrt{h/r} + 2.211h/r$ $K_3 = -4.413 + 18.751\sqrt{h/r} - 4.596h/r$ $K_4 = 2.714 - 9.655\sqrt{h/r} + 2.512h/r$ (Refs. 16 and 17) For the semicircular notch ($h/r = 1$) $$k = 2.988 - 7.300\left(\frac{h}{D}\right) + 9.742\left(\frac{h}{D}\right)^2 - 4.429\left(\frac{h}{D}\right)^3$$
	3b. Elastic stress, in-plane bending 	$$k = K_1 + K_2\left(\frac{h}{D}\right) + K_3\left(\frac{h}{D}\right)^2 + K_4\left(\frac{h}{D}\right)^3$$ where for $0.5 \le h/r \le 4.0$ $K_1 = 0.721 + 2.394\sqrt{h/r} - 0.127h/r$ $K_2 = -0.426 - 8.827\sqrt{h/r} + 1.518h/r$ $K_3 = 2.161 + 10.968\sqrt{h/r} - 2.455h/r$ $K_4 = -1.456 - 4.535\sqrt{h/r} + 1.064h/r$ (Refs. 17 and 18) For the semicircular notch ($h/r = 1$) $$k = 2.988 - 7.735\left(\frac{h}{D}\right) + 10.674\left(\frac{h}{D}\right)^2 - 4.927\left(\frac{h}{D}\right)^3$$
4. One V notch in a member of rectangular section 	4b. Elastic stress, in-plane bending 	The stress concentration factor for the V notch, k_θ, is the smaller of the values $k_\theta = k_U$ or $k_\theta = 1.11k_U - \left[0.0275 + 0.1125\left(\frac{\theta}{150}\right)^4\right]k_U^2 \quad$ for $\theta \le 150°$ where k_U is the stress concentration factor for a U notch, case 3b, when the dimensions h, r, and D are the same as for the V notch and θ is the notch angle in degrees. (Ref. 18)
5. Square shoulder with fillet in a member of rectangular section 	5a. Elastic stress, axial tension 	$$k = K_1 + K_2\left(\frac{2h}{D}\right) + K_3\left(\frac{2h}{D}\right)^2 + K_4\left(\frac{2h}{D}\right)^3$$ where $\frac{L}{D} > \frac{3}{[r/(D-2h)]^{\frac{1}{4}}}$ and where (see coefficients below)

	$0.1 \le h/r \le 2.0$	$2.0 \le h/r \le 20.0$
K_1	$1.007 + 1.000\sqrt{h/r} - 0.031h/r$	$1.042 + 0.982\sqrt{h/r} - 0.036h/r$
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ENCLOSURE NO. 2 :

CRITERIA USED FOR DETERMINATION

OF 15% IMPACT FACTOR

June 29, 1995

Criteria Used to Determine Impact Factor

References :

1. Whiting Crane Handbook, Whiting Corporation, 1979

2. Response to request for information on the Control of Heavy Loads, Nov. 1981 Rev. 1, Section2.1.7.c no. 13, page 2.1-12. Issued in response to Generic Letter 81-07.

3. Memo from K. Beardsley to S. Eldridge dated June 20, 1995

Reference 1, 2, 3 provide justification for the use of the 1/2% impact for each ft per minute of crane speed with a minimum of 15%. The maximum crane speed for the reactor building 125 ton crane is 5.75 feet per minute (fpm) under full load or 17.25 fpm under no load. This would result in a maximum impact factor of approximately 8.6%. Hence the use of 15% in the analysis contained in calculation no. 9389-64-DQ is conservative and provides additional margin above required loads.

Approved by :
Sharon Eldridge
Design Supervisor

Memorandum

DATE: June 20, 1995

TO: Sharon Eldridge

FROM: Keith F. Beardsley

RE: Unit 2 Reactor Building Crane Speed

CC:

Sharon,

The attached report is contained in the Quad Cities Station, Heavy Load Movement Report, Part 2.

To summarize the report, the Reactor Building cranes main hoist capacity is 125 tons. Precautions / modifications have been implemented to ensure that the maximum speed under a full load condition is 5.75 ft/min.

Our evaluation was based on a maximum speed of 5.0 ft/min. Through discussions with mechanical maintenance it has been determined that at the time the Separator legs impacted the Shroud repair hardware the crane was at "creep" speed . Physical measurement has determined that creep speed equates to approximately 1.1 ft/min.

Therefore, considering a drop rate of 5.0 ft/min in calculating our dynamic impact factor, was a conservative design consideration. As noted in our justification a drop rate of 5.0 ft/min equates to an impact factor of +/- 2.5%. Our design calculations considered a 25% dynamic impact factor.

Therefore the design calculations performed by GE yield conservative results and the maximum possible impact factor is enveloped in the analysis.

Dresden Special Report No. 41

Quad Cities Special Report No. 16

REACTOR BUILDING CRANE

AND

CASK YOKE ASSEMBLY MODIFICATIONS

AEC Dockets

50-237
50-249
50-254
50-265

Commonwealth Edison Company

October, 1974

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1.0 INTRODUCTION

To preclude the possibility of dropping a spent fuel cask during handling operations over the spent fuel pool, modifications will be made to the existing Reactor Building Crane an' Cask Yoke Assembly. Crane modifications shall consist of a new trolley utilizing a dual-load path hoisting system for the main hoist. This system will be available to prevent all postulated credible single-component failures over the entire supporting load path; from the cask supporting system through the redundant cask lifting yoke, the redundant hook, the dual-load path hoisting system to the crane bridge structure.

2.0 REACTOR BUILDING CRANE

2.1 Description of Modifications

The existing reactor building crane is a single trolley, overhead electrical traveling-type, with both a main hoist and auxiliary hoist. The existing trolley will be replaced by a new trolley containing a dual-load path hoist system for the main hoist and a standard arrangement for the auxiliary hoist. Design requirements are as follows:

A. The entire crane trolley and existing bridge girders will be reviewed for the revised trolley weights in conjunction with the lifted load requirements to establish compliance with CMAA #70 permissible stress ranges. Calculations to be performed by Whiting Corporation will also determine the maximum vertical loadings with impact for the bridge girders, as defined in Section 70-3 of CMAA #70. Design values for operation conditions plus seismic will be based on AICS code requirements for OBE and 90% of the minimum yield strength of the material used for DBE. The exact values will be provided by Whiting Corporation with the Component Failure Analysis for this submittal at a later date.

B. The main hoist capacity will be 125 tons and the auxiliary hoist capacity will be 5 tons. Crane stepless variable speeds (maximum) have been established as follows:

Bridge	—	50 fpm at full load
Trolley	—	33 fpm at full load
Main Hoist	—	5.75 fpm at full load
		17.25 fpm at no load
Auxiliary Hoist	—	30 fpm at full load
		90 fpm at no load

The new trolley with its dual load path hoist system weighs 116,000 lbs. which is a 25,000 lbs. increase over the weight of the existing trolley. All calculations and analysis will take this weight increase into account. The existing bridge crane and associated crane runway support structures will be evaluated to determine if any revisions will be required for handling the new trolley with its increased weight. All analyses performed relative to the cask handling procedures will base load values on the details of the National Lead 10/24 Cask. Should larger casks be placed into service, compatibility with the stipulated safety requirements will be established.

C. All crane parts shall equal or exceed design criteria as established by CMAA Specification #70, and shall be compatible with the requirements of the Occupational Safety and Health Act of 1970 and as amended in 1971, as well as ANSI B 30.2.0.

1. Motors — General Electric, open ball bearing, drip proof, solid frame, shunt wound, crane type motors, with Class B non-hydroscopic insulation, rated 30 minutes. Motors will comply with NEMA standards. Auxiliary hoist motor to be gearhead type.
2. Controllers — Existing Maxspeed 320 system for hoists, with existing transfer switch for auxiliary hoist control from main hoist. Existing Maxspeed 100 for trolley and bridge controls.
3. Switchboard — The existing units have been reused.
4. Magnetic Brakes — Two (2) General Electric IC-9528 A-103 16 inch DC magnet operated electric shoe type brakes for main hoist. Two (2) IC-9528 A-102 13 inch DC magnet operated electric shoe type brakes for auxiliary hoist.
5. Trolley Type — Four (4) motor type with welded steel frame; center to center of trolley rails shall be 17'-0".
6. Trolley Drive — Enclosed speed reducer type plus an enclosed Abart speed reducer located between motor and trolley drive.
7. Wheels — 27 inch diameter fabricated from rolled steel rim toughened material.
8. Drum — 58 inch diameter fabricated from steel materials for main hoist. 21 inch diameter fabricated from stainless steel for auxiliary hoist.

9. Hoist Ropes — Main hoist shall consist of 12 parts 1-1/4 inch diameter Monitor AAA type I.W.R.C. Auxiliary hoist shall consist of 1 part 7/8 inch diameter A 304 stainless steel with I.W.R.C. Main hoist ropes attached to a specially damped equalizer assembly with unbalanced condition limit switch cut-offs.
10. Limit Switch — Weight type control circuit switch plus screw type for upper and lower hoist limits and centrifugal overspeed switch for lowering.
11. Load Block — Dual load path type with bronze bushed sheaves for main load block and with forged steel main hook. Stainless steel yoke and hook for auxiliary hoist.
12. Trolley Brakes — One (1) IC-9516-160 and one (1) IC-9516-161 DC solenoid operated electric shoe type brakes.
13. Collectors — Double set of Insul - 8 shoe type.
14. Stops — Four (4) Spring type trolley bumpers.
15. Main Hoist Inching Drive and Controls — AC squirrel cage continuous duty 5HP motor with independent controls.
16. Load Sensing readout with high and low limit cut-offs.

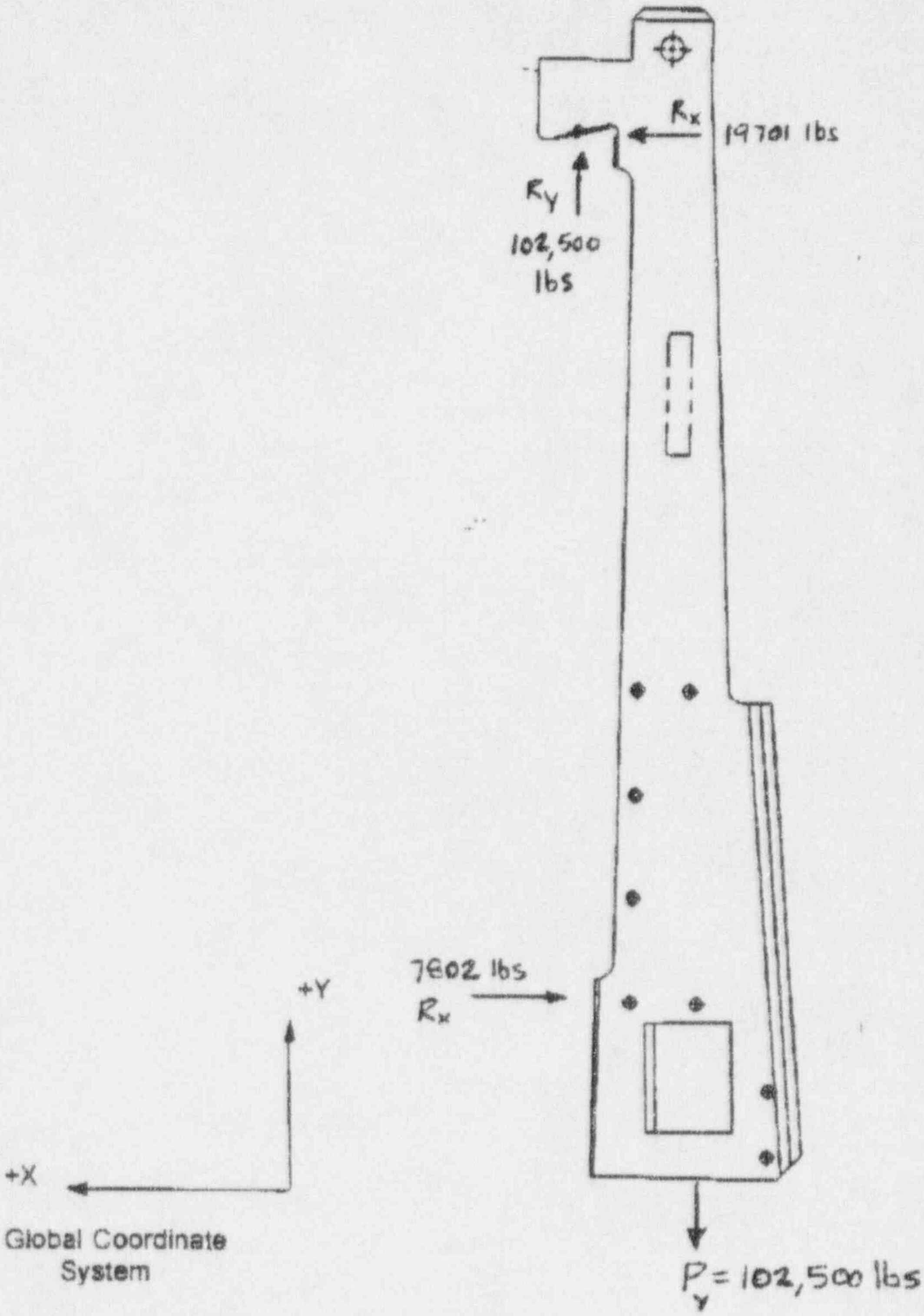
D. Electrical power as presently provided for the existing Reactor Building Crane will be adequate for all operational requirements of the cask handling system.

ATTACHMENT 2

Free Body Diagrams
Reactions and Applied Loads

Original Finite Element Analysis of the Core Shroud Repair Hardware
and Alternative Design Verification

Quad Cities Unit 2 Shroud Head Assembly Contact On Long Upper Support - Free Body Diagram Of Finite Element Analysis Reactions And Applied Loads



Quad Cities Unit 2 Shroud Head Assembly Contact On Long Upper Support - Free Body Diagram Of Finite Element Analysis Reactions And Applied Loads