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25 May 2012

THE MILLSTONE II
STEAM GENERATOR REPLACEMENT PROJECT
WATERFORD, CONNECTICUT

Millstone Nuclear
Power Station

Unit 2 is the tall building just to the right of the stack

DESIGN OF THE LARGE EYE BARS (LINKS)

COMMENTS ON THE CALCULATIONS:

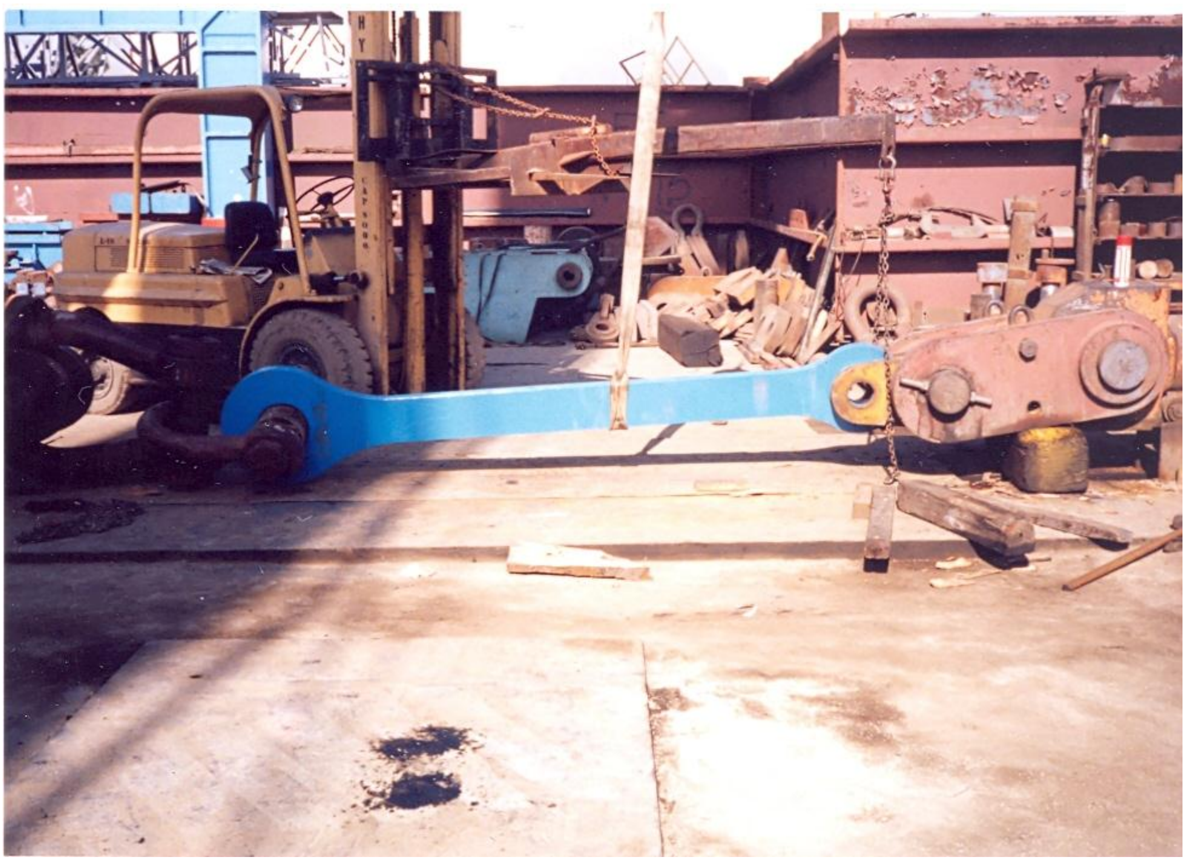
1. The first sheets 1 – 7 are designer's, checker's and reviewer's checklists to make sure that the design conforms to the nuclear codes and standards. They are included just to show the type of information that is required in a nuclear design.
2. The second sheets 1 – 9 are the actual calculations of the eye bars.
3. These design calculations were listed as SC-44 on our design calculation log.
4. Sheet 7 & sheet 8 did not copy well.

   Sheet 7 was a check for the clearance between the Reliance spreader bar and the top hat on the SGLA.

   Sheet 8 was a calculation of the weight of the eye bars.
5. Design references such as the AISC manual have not been included. If anyone wants to have any of the formulas explained, just let me know.

6. As a side note, Babcock & Wilcox (B&W) designed the 10" diameter trunnions and the bands. In our procedure for up/down ending the SGLA, we called out greasing between the eye bars and the trunnions. In reviewing our procedure, B&W marked it up with the words "do not use grease between the trunnions and the eye bars". We contested their comment, but after a series of telex's (emails were not available then) and meeting with the NU engineers, we were told not to grease the eye bars. We put them on notice in writing that it was a bad decision and that there was going to be galling between the trunnions and the eye bars. After we down ended the first old SGLA and removed the eye bars from the trunnions, sure enough there was bad galling on the eye bars and some on the trunnions themselves. Upon learning of this, B&W said to do what every we wanted to do. So we cleaned up the galling on both the eye bars and trunnions as best as the welders could. We then instructed the Boilermaker riggers to be sure and connect the trunnion bands to the SGLA's so that bearing would be on a fresh side and to hookup the eye bars so they would also be in bearing on the opposite side from the galling area. We then placed Teflon between the trunnions and eye bars and didn't have any more problems.

The photo below shows one of the large eye bars being load tested in Wilmington, CA. Coordinated Equipment Company was able to under bid all of the other testing yards in the USA because back in 1975, they bought all of the heavy lifting equipment including many large hydraulic cylinders and the sub-sea grapple or **claw** when the Howard **Hughes Glomar Explorer** was decommissioned. The Glomar Explorer was designed to recover 2,000 ton objects at a 17,000' depth. It was used to recover part of a Soviet submarine in the Pacific Ocean. To see more about this ship, go to http://www.hnsa.org/seashadow/doc/ASME12708.pdf. Down near the bottom of sheet 4, it states that the disposition of the Claw is unknown. Well, we know better. To see part of the Claw as a test device, go to Coordinated's website http://www.ceccwrr.com/testingfacility.asp and click on the test bed labeled "3". The number 3 test bed has been used to break 18" diameter Houser ropes for the Navy. It is ideal for doing this due to the large stroke of the test bed. As a side note, the first time Coordinated broke a 18" Houser rope, the recoil was so great that the rope ends destroyed their control house. Luckily, the test was being run remotely. While you are at the site, be sure and take the testing tour.



FLUOR DANIEL

SHEET NO. 1 OF

STRUCTURAL DIVISION
DESIGNER'S, CHECKER'S AND REVIEWER'S CHECKLIST FOR
DESIGN CALCULATIONS, REPORTS & SPECIFICATIONS (CRS)

PROJECT: MILLSTONE 2 SGRP PROJECT NO: 830100

SYSTEM: SGR CODE: SYMBOL:

~~DWG. NOS:~~ CALC NO. SC-044

ENGINEER(S) TO INDICATE THE INPUT AND REFERENCE DOCUMENTS USED:

	REV. & DATE	COMMENT ATTACH SHEET	REVIEWER APPROVAL YES	NO	INITIA
1. GENERAL PLANT DESIGN BASIS: NA					
2. SYSTEM DEFINITION: SGR					
3. DESIGN INFORMATION PACKAGE FROM RELATED EQUIP. VENDOR: NA					
4. ELECTRICAL DIV. INPUT: NA					
5. MECHANICAL DIV. INPUT: NA					
6. HVAC INPUT: NA					
7. CONTROL SYSTEMS INPUT: NA					
8. CIVIL/HYDRAULICS SECT. INPUT: NA					
9. ARCH. SECT. INPUT: NA					
10. CONFORMED SPECS: NA					
11. CHECKED CALCULATIONS: NA					
12. VENDOR DWGS: E-233-641					
13. DESIGN STANDARDS: NA					
14. CLIENT STANDARDS: NA					
15. SITE CRITERIA: CLIENT/CONSULTANT NA					

ENGINEER SIGNATURE Kent Goodman DATE: 8-2-91

CHECKING PROCEDURE USED: QAB 5.5 REV. & DATE: 3 5-30-89

CHECKER'S SIGNATURE: William Tkaczuk DATE: 8-4-91

REVIEWING PROCEDURE USED: * ______ REV. & DATE: ______

REVIEWER SIGNATURE: * ______ DATE: ______

QA SIGNATURE: * ______ DATE: ______

* REQUIRED FOR NUCLEAR SAFETY RELATED SYSTEMS ONLY.

FORM I - 184DA 2/27/89

FLUOR DANIEL

STRUCTURAL DIVISION
DESIGNER'S, CHECKER'S AND REVIEW CHECKLIST FOR
DESIGN CALCULATIONS, REPORTS & SPECIFICATIONS (CRS)

SC-044

ITEM	YES	NO	N/A	COMMENT NO. ATTACH SHEET
1. DOES THE DESIGN REVIEW PACKAGE CONTAIN THE INPUT AND REFERENCE DOCUMENTS LISTED ON PAGE 1 OF THIS CHECKLIST?	✓			
2. IS THE CRS ADEQUATELY IDENTIFIED BY SUBJECT MATTER AND APPLICABLE FILE NUMBER?				
(A) CLIENT?	✓			
(B) PROJECT?	✓			
(C) STRUCTURE/SYSTEM?	✓			
(D) SUBJECT MATTER?	✓			
(E) FILE NUMBER?	✓			
(F) WORK PACKAGE/WORK ITEM?			✓	
3. IS THE OBJECTIVE OF THE CRS ADEQUATELY IDENTIFIED?	✓			
4. DOES THE CRS HAVE THE PROPER FORMAT?				
(A) ALL PAGES NUMBERED?	✓			
(B) COMPUTER INPUT AND OUTPUT WHEN APPLICABLE?			✓	
(C) SKETCHES?	✓			
(D) REFERENCES?	✓			
(E) APPLICABLE FDI STANDARDS?			✓	

DESIGNER'S, CHECKER'S AND REVIEWER'S CHECKLIST FOR
DESIGN CALCULATIONS, REPORTS & SPECIFICATIONS (CRS)

SC-044

ITEM	YES	NO	N/A	COMMENT NO. ATTACH SHEET
5. IF COMPUTER PROGRAMS WERE USED,				
A. HAVE YOU REVIEWED THE PROGRAM VALIDATION DOCUMENTS FOR THE PRODUCTION VERSION OF THE PROGRAM?			✓	
B. WERE CODES PROPERLY VERIFIED?			✓	
C. WERE THEY APPROPRIATE FOR THE APPLICATION?			✓	
D. WERE THEY CORRECTLY USED?			✓	
E. WAS INPUT DATA CORRECT?			✓	
F. IS THE COMPUTER PROGRAM IDENTIFIED?			✓	
G. IS THE PROGRAM REVISION IDENTIFIED?			✓	
6. ARE APPROVED DESIGN INPUTS USED?	✓			
WERE THEY CORRECTLY SELECTED?	✓			
(A) SYSTEM DEFINITION?	✓			
(B) TECHNICAL MEMO/DATA?	✓			
(C) SUPPORTING CALCULATIONS?	✓			
(D) CODES?	✓			
(E) STANDARDS?	✓			
(F) REGULATORY GUIDES?			✓	
(G) BRANCH TECHNICAL POSITIONS?			✓	
7. ARE QUALITY CONTROL AND QUALITY ASSURANCE REQUIREMENTS SPECIFIED AND INCORPORATED?			✓	
8. ARE THE VARIOUS OPERATING CONDITIONS IDENTIFIED AND CONSIDERED?				
(A) CONSTRUCTION?			✓	
(B) STARTUP?			✓	
(C) NORMAL OPERATION?			✓	
(D) SHUTDOWN?			✓	
(E) EMERGENCY?			✓	
(F) ABNORMAL OR FAULTED?			✓	
(G) SEVERE ENVIROMENTAL?			✓	
(H) EXTREME ENVIRONMENTAL?			✓	

STRUCTURAL DIVSION

FLUOR DANIEL

DESIGNER'S, CHECKER'S AND REVIEWER'S CHECKLIST FOR DESIGN CALCULATIONS, REPORTS & SPECIFICATIONS (CRS)

SC-044

ITEM	YES	NO	N/A	COMMENT NO. ATTACH SHEET
9. ARE FIRE PROTECTION AND CONTROLLED ACCESS REQUIREMENTS SATISFIED IN THE DESIGN?				
(A) PHYSICAL SEPARATION?			✓	
(B) FIRE RATINGS?			✓	
(C) COMBUSTIBILITY OF MATERIALS?			✓	
(D) BARRIERS?			✓	
(E) INTERLOCK SYSTEMS?			✓	
(F) SECURITY?			✓	
10. ARE OTHER FUNCTIONAL REQUIREMENTS IDENTIFIED AND SATISFIED?				
(A) RADIATION?			✓	
(B) SPECIAL SUPPORTING SYSTEMS?			✓	
11. HAVE CONTIGUOUS SYSTEM DESIGN INTERFACE REQUIREMENTS BEEN IDENTIFIED AND INCORPORATED?				
(A) DEFLECTION COMPATIBILITY?			✓	
(B) TRANSFER OF LOADS?			✓	
(C) BOUNDARY CONDITIONS?			✓	
(D) DIFFERENTIAL SETTLEMENTS?			✓	
12. ARE THE ASSUMPTIONS NECESSARY TO PERFORM THE DESIGN ACTIVITY ADEQUATELY DESCRIBED AND REASONABLE?	✓			
13. A) IS THE DESIGN METHOD CONSISTENT WITH THE DESIGN INPUT?	✓			
B) IF ALTERNATIVE METHODS WERE USED, WERE THE RESULTS REASONABLE AND CONSISTENT?			✓	

FORM I - 184DA 2/27/89

SC-044

ITEM	YES	NO	N/A	COMMENT NO. ATTACH SHEET
14. HAVE ALL APPLICABLE LOADING CONDITIONS BEEN CONSIDERED?				
(A) DEAD?	✓			
(B) LIVE?	✓			
(C) CONSTRUCTION?	✓			
(D) WIND?			✓	
(E) SEISMIC?			✓	
(F) HYDROSTATIC?			✓	
(G) FLOOD?			✓	
(H) TORNADO?			✓	
(I) PRESSURE?			✓	
(J) TEMPERATURE?			✓	
(K) EQUIPMENT/PIPE REACTIONS?	-		✓	
(L) VIBRATION?			✓	
(M) EXTREME PRECIPITATION?			✓	
15. IS THE SOURCE OF FORMULAS AND NUMERICAL VALUES FROM CHARTS AND/OR TABLES PROPERLY REFERENCED?	✓			
(A) REFERENCE, PAGE AND TABLE AND/OR CHART NUMBER?	✓			
16. WERE COMPUTER PROGRAMS PROPERLY VALIDATED AND APPROVED?			✓	
17. IS THE STRUCTURE PROPERLY TIED TOGETHER AND IS TRANSFER OF FORCES PROPERLY ACCOMPLISHED?				
(A) CONTINUITY OF VERTICAL ELEMENTS?			✓	
(B) DIAPHRAGM ACTION OF SLABS?			✓	
18. ARE THE ACCEPTANCE CRITERIA IDENTIFIED TO ALLOW VERIFICATION THAT THE DESIGN REQUIREMENTS HAVE BEEN SATISFIED?				
(A) STRESS ALLOWABLES?	✓			
(B) DEFLECTION LIMITS?			✓	

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STRUCTURAL DIVISION
DESIGNER'S, CHECKER'S AND REVIEWER'S CHECKLIST FOR
DESIGN CALCULATIONS, REPORTS & SPECIFICATIONS (CRS)

SC-044

ITEM	YES	NO	N/A	COMMENT NO. ATTACH SHEET
19. ARE THE RESULTS REASONABLE COMPARED TO THE INPUT?	✓			
20. ARE THE SPECIFIED MATERIALS COMPATIBLE WITH EACH OTHER AND WITH THE ENVIRONMENTAL CONDITIONS TO WHICH THE MATERIAL WILL BE EXPOSED?				
(A) TEMPERATURE?			✓	
(B) PRESSURE?			✓	
(C) RADIATION?			✓	
(D) FATIGUE?			✓	
(E) CORROSION?			✓	
(F) EROSION?			✓	
(G) TRANSPORT AND STORAGE?			✓	
(H) HYDROGEN GENERATION?			✓	
(I) FIRE?			✓	
(J) CATHODIC PROTECTION?			✓	
(K) CHEMICAL REACTION?			✓	
21. ARE THE STRUCTURAL ELEMENTS SUITABLE FOR THE REQUIRED APPLICATION AND ARE THEY CONSTRUCTABLE?				
(A) CONNECTION DETAILS?	✓			
(B) EMBEDMENTS?			✓	
(C) ATTACHMENTS?	✓			
(D) FASTENERS (BOLTS)?	✓			
(E) WELDING PROCESSES?	✓			
(F) LAMELLAR TEARING?	✓			
(G) CONCRETE DELAMINATION?			✓	
22. HAS ADEQUATE ACCESSIBILITY BEEN PROVIDED FOR:				
(A) INSERVICE INSPECTION?			✓	
(B) TESTING?			✓	
(C) MAINTENANCE AND REPAIR?			✓	

SC-044

ITEM	YES	NO	N/A	COMMENT NO. ATTACH SHEET
23. HAVE THE FURNISHING AND INSTALLING OF ALL STRUCTURAL MATERIALS BEEN ADEQUATELY IDENTIFIED?	✓			
24. HAS APPLICABLE CONSTRUCTION AND OPERATING EXPERIENCE BEEN CONSIDERED?	✓			
25. IF THE VERIFICATION OF THE DESIGN IS BY A QUALIFICATION TEST:				
(A) IS THE TESTING IDENTIFIED AND DOCUMENTED?			✓	
(B) DOES THE TEST DEMONSTRATE THE ADEQUACY OF PERFORMANCE UNDER THE MOST ADVERSE DESIGN CONDITIONS?			✓	
(C) WAS THE TEST PERFORMED IN ACCORDANCE WITH WRITTEN PROCEDURES?			✓	
26. WERE THE REQUIREMENTS OF THE PROCEDURES MET?	✓			
27. IF STANDARD DESIGN OR DETAILS WERE USED, WAS THE APPLICATION APPROPRIATE?	✓			

1. PURPOSE & SCOPE:

The purpose of this set of calculations is to design & specify the lifting attachments required for handling the steam generator lower assembly in the vertical position.

2. REFERENCES & DESIGN INPUT:

A. ANSI/ASME N45.2.15 - 1981 NUCLEAR RIGGING
B. AISC MANUAL FOR STEEL CONSTRUCTION 9th. Edition
C. CE DWG E-233-641(6)

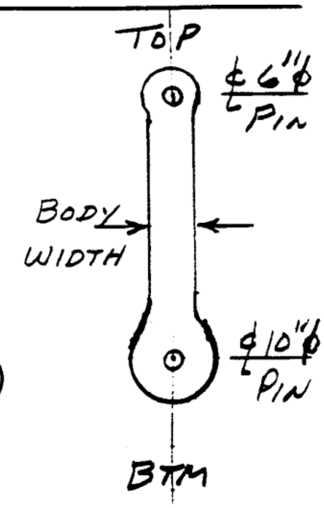
3. SUMMARY OF RESULTS & CONCLUSIONS:

The old steam generator's lower assembly can be safely removed and the new one safely installed using links designed per these calculations.

4. CRITERIA & ASSUMPTIONS:

A. Per Fluor Rigging Dept. & AISC, Use 25% Impact.
B. USE .5 F_y for bearing (No impact)
C. USE Hole Dia. $\frac{1}{8}$" over pin Dia.

LINKS FOR LIFTING LOWER ASSY



LOAD = 450 TON
LOAD/LINK = 450 K

TRUNION φ = 10" $^{+0}_{-.013}$"

TRY 2½ T-1 (A514 GRADE 100)
Fy = 100 KSI MIN

TOP END W/6"φ PIN $^{+.0}_{-.01}$"

BEARING = $\frac{450k}{6"\phi \times 2\frac{1}{2}"}$ = 30.0ksi < .5Fy (50ksi)

END AREA REQ = $\frac{.67 \times 450k \times 1.25}{45\ KSI}$ = 8.38 in² (45 KSI ← .45Fy)

PER AISC D3.3 MAX BODY WIDTH = 6"φPIN/7/8 = 6.86", USE 7"

MIN EYEBAR RAD. = $\frac{8.38 in^2}{2.50"} + \frac{6\frac{1}{8}"\phi}{2}$ = 6.41"

MIN EDGE DIST = 2/3 × 7" = 4.67"
MAX. EDGE DIST = 3/4 × 7" = 5.25"
∴ USE EYEBAR RAD = 6 1/8"φ/2 + 4.94" = 8"

FOR 100ksi MAT'L : 2.50" ℞ × 5 = 12.50" > 6 1/8"φ O.K.

TRANSITION RADIUS = 16"

LINKS CONT.

BOTTOM END W/10" φ PIN

BEARING = $\frac{450\text{ k}}{10'' * 2\frac{1}{2}''}$ = 18.0 KSI < 50KSI

END AREA REQ = 8.38 in² (FROM PREVIOUS PAGE)

MIN EYEBAR HEAD RADIUS = $\frac{8.38\text{ in}^2}{2.5''}$ + 5 in = 8.35"

MAX. BODY WIDTH = 10" φ PIN / 7/8 = 11.43" USE 7"
MIN EDGE DIST. = 2/3 * 7" = 4.67"
MAX. EDGE DIST = 3/4 * 7" = 5.25"

∴ USE EYEBAR RAD = 10" φ PIN/2 + 5.25" = 10.25" USE 11"

7.0 * 7/8 = 6.13" < 10" O.K.

FOR F_y = 100

2½" R * 5 = 12.5 > 10⅛" φ HOLE

∴ USE A 2½" x 7.0" BODY

CHECK STRESS IN THE BODY

f_T = $\frac{450\text{ k} * 1.25}{2\frac{1}{2}'' * 7''}$ = 32.14 KSI < .6F_y = 60k

FLUOR DANIEL

CALCULATIONS and SKETCHES

DATE 21 MAR 91
CONT. NO. 830100
BY K E GOODMAN CHK'D [illegible]
SHEET NO. 4

MW		gals/mol
16	C_1	6.40
30	C_2	9.07
44	C_3	10.44
58	iC_4	12.40
58	C_4	11.94
72	iC_5	13.86
72	C_5	13.74
86	iC_6	15.5
86	C_6	15.59
100	iC_7	17.[illegible]
100	C_7	17.46
114	C_8	19.41
28	$C_2^=$	9.64
42	$C_3^=$	9.67

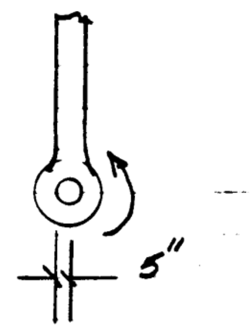
ASSUME A MOMENT IN THE EYEBAR DUE TO THE FRICTION AT THE TRUNION.

$\mu = .2$ GREASED — CONSERATIVE

$F = 450k * \mu = 90k$

$M_{TRUNNION} = 5'' * 90k$

$= 450\ k\text{-}in$



$S = \frac{bd^2}{6} = \frac{2\frac{1}{2}'' * 7^2 in^2}{6}$

$= 20.42\ in^3$

$f_b = \frac{450.0k\text{-}in * 1.25}{20.42\ in^3} = 27.55\ ksi$

$f_a = \frac{P}{A} = \frac{450k}{2\frac{1}{2}'' * 7''} = 25.71\ ksi$

$F_b = .6 * F_y = 60\ ksi$

$F_t = .6 * F_y = 60\ ksi$

MISC

MW		gals/mol
44	CO_2	6.47
34	H_2S	5.18
28	N_2	4.16
2	H_2	3.38

AISC H2 : COMBINED STRESS

$\frac{f_a}{F_t} + \frac{f_{bx}}{F_{bx}} = \leq 1$

$\frac{25.71}{60.00} + \frac{27.55}{60.00} = \leq 1$

$.43 + .46 = .89 < 1.0$ CLOSE

FORM E-050 REV. 6/88
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NOTE:
AS THE .2 FOR μ IS ONLY A GUESS & COULD BE HIGHER, I RECOMMEND THAT THE FINAL DIMENSIONS OF THE EYEBAR BE:

TOP HEAD RADIUS = 9"

BODY WIDTH = 9"

BOTTOM HEAD RADIUS = 12"

MAT'L THICKNESS = 2½"

HOLE ϕ'S = 1/8" OVER PIN ϕ

THE ABOVE INCREASES WILL PROVIDE A LARGER SECTION TO RESIST THE MOMENT DUE TO THE LINKS ROTATING ON THE PINS OR TRUNNIONS. <u>THE 1/8" OVER PIN ϕ WILL HELP US WITH BETTER CLEARANCES WHEN WE ARE INSTALLING THE LINKS OVER THE TRUNNIONS.</u>

<u>THE RATIONAL</u> FOR THE ABOVE DEVIATION FROM AISC D3.3 ARE:

1. THE EYEBAR WAS DESIGNED PER AISC D3.3 USING A 900K LOAD. THE INCREASED DIMENSIONS WILL STILL BE FOR A 900K LOAD BUT WILL NOW PROVIDE ADDITIONAL SAFETY FACTOR FOR COMBINED STRESS.
2. FLUOR'S RIGGING DEPARTMENTS HAVE ALWAYS USED A PIN HOLE SIZE 1/8" LARGER THAN PIN ϕ. TO JUSTIFY THIS, THE ALLOW. BEARING STRESS IS REDUCED FROM .9 TO .5 F

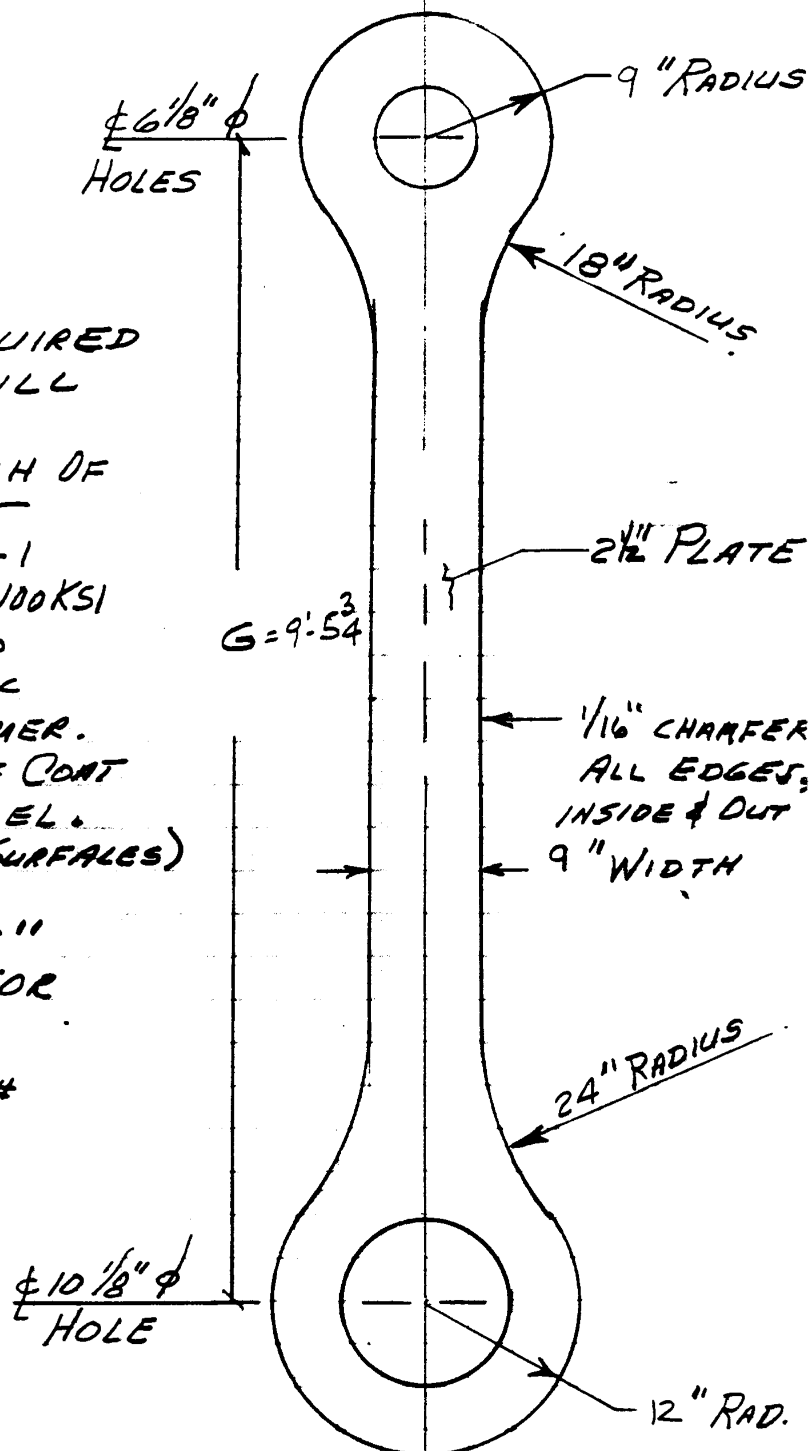
FLUOR DANIEL
CALCULATIONS and SKETCHES

DATE 21 MAR 91
CONT. NO. 830100
BY K E GOODMAN CHK'D [illegible]
SHEET NO. 6

NOTES
1. 2 LINKS REQUIRED
2. BORE OR DRILL HOLES
3. INSIDE FINISH OF HOLES IS 250√
4. MATL IS T-1 (A514), Fy = 100KSI
5. PRIME W/ TWO COATS OF ZINC CHROMATE PRIMER. FINISH W/ONE COAT YELLOW ENAMEL. (NOT ON BEARING SURFACES)

G = 11.3.75"
(SEE SH 7 FOR CALC'S)

EST. WT 1050 #
SEE SH 8
FOR CALC'S



FORM E-050 REV. 6/88
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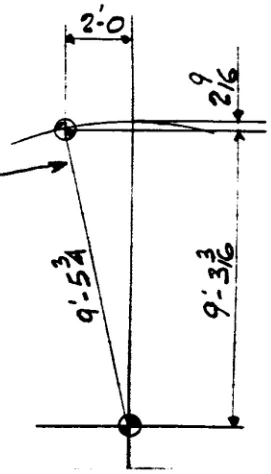
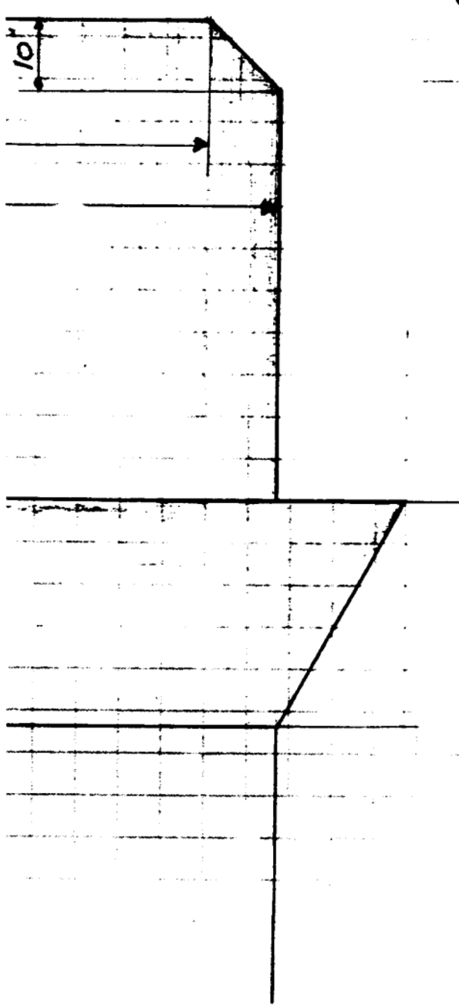
ANIEL
ONS and SKETCHES

DATE 7-30-91
CONT. NO. 830100
BY W.T CHK'D KEG
SHEET NO. 7

When Links are 2'-0 out of plumb Clearence = 5"



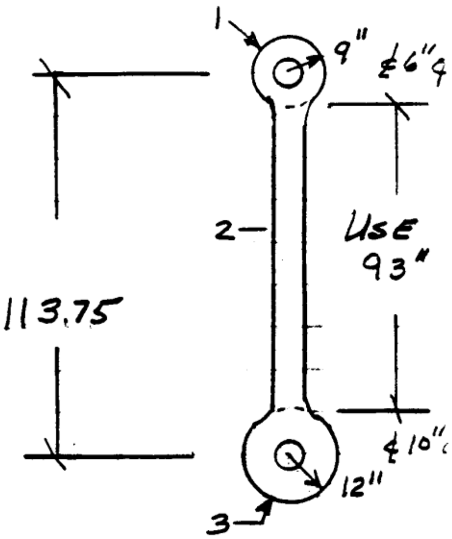


FLUOR DANIEL
CALCULATIONS and SKETCHES

DATE 24 APR 91
CONT. NO. 830100
BY KE GOODMAN CHK'D
SHEET NO. 8

REF TAYLOR FORGE Pg 189

(EYE BARS)



5 * 8 lb.

lbs.

$ft^3 * 500^{\#} / ft^3$

.

2.5 * 22.25 lb

lb

For 1 LINK = 1031 lb

2 LINKS = 2061 lb

USE 2100 lb

5 16 17 18 19 20 21 22 23 24 25 26 27 28 29 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29

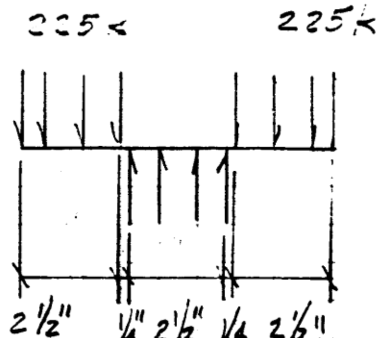
FLUOR DANIEL

CALCULATIONS and SKETCHES

DATE 29 APR 91
CONT. NO. 830100
BY K.E. GOODMAN CHK'D WO
SHEET NO. 9

6" φ PIN CHECK

YOKES TO LINK CONN.
(2½" THICK) (2½" THICK)



$M = 225^k \left(\frac{2.5''}{2} + .25'' + \frac{2.5''}{2} \right)$

$- 225^k * \frac{2.5''}{4}$

$= 478.13$ K-in

$S_{6'' \phi PIN} = .098175 (6)^3 = 21.21 \text{ in}^3$

$f_b = \frac{478.13 \text{ k-in} * 1.25}{21.21 \text{ in}^3} = 28.18 \text{ ksi} < 50 \text{ ksi}$ OK

$F_y = .5 * 100 = 50 \text{ ksi}$

FORM E-050 REV. 6/88
PRINTED IN U.S.A.

THE END