

QA Record

DNE CALCULATIONS

VA 10697 (DNE-6-86)

Sheet 1 of 69 73 SAL 4-12-91

TITLE : <i>Example Calculation for Qualification of Thermally Restrained Structures</i>	Plant/Unit <i>WBNP / UNIT 1</i>
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REPARING ORGANIZATION <i>NE, Ebasco Services Inc.</i>	KEY NOUNS (Consult RIMS DESCRIPTORS LIST)
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BRANCH/PROJECT IDENTIFIERS <i>WCG-1-771</i>	Each time these calculations are issued, preparers must ensure that the original (RO) RIMS accession number is filled in. Rev (for RIMS' use)	RIMS accession number
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	RO	B18 910415 251
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APPLICABLE DESIGN DOCUMENT(S) <i>WB-DC-20-21</i>	R	
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SAR SECTION(S) <i>NA SAL 41291</i>	UNID SYSTEM(S) <i>NA SAL 41291</i>	R	
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Revision 0	R1	R2	R3	Safety-related? Yes <input checked="" type="checkbox"/> No <input type="checkbox"/>
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ECN NO. (or indicate Not Applicable) <i>NA SAL 41291</i>	Statement of Problem.			
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Prepared: <i>SING-GEE A. LIN</i>				<p><i>Prepare example calculation for the qualification of the thermally restrained structures of Category I structural and miscellaneous steel population.</i></p> <p>ORIGINAL</p>
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Checked/Verified: <i>CHENG-TH WU</i> <i>Cheng-Th Wu</i>			
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Reviewed: <i>R. Larkhan</i>			
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Approved: <i>H. Totunogly</i>			
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Date <i>4/10/91</i>			
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JSE FORM	List all pages added by this revision			
TVA 10534				
IF MORE SPACE REQUIRED	List all pages deleted by this revision			
	List all pages changed by this revision			

Abstract: These calculations contain an unverified assumption(s) that must be verified later. Yes No

Rev 0 demonstrates the methodology of the qualification of the thermally restrained structures. Energy balance method and non-linear acceptance criteria are considered in this example calculation.

LEGIBILITY EVALUATED and ACCEPTED for issue.

H. Totunogly 4/10/91
Signature Date

<input type="checkbox"/> Microfilm and store calculations in RIMS Service Center	Microfilm and destroy. <input type="checkbox"/>
<input checked="" type="checkbox"/> Microfilm and return calculations to: Calculations Library	Address: WBN N QA BLDG.
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EXAMPLE CALCULATION FOR QUALIFICATION OF
TITLE: THERMALLY RESTRAINED STRUCTURES

PREP. BY: SING-GEE ALAN LIN / ~~Cheng-Hu Wu~~ DATE: 4-9-91

CHECKED BY: CHENG-HU WU / Cheng-Hu Wu DATE: 4-10-91

REVISION LOG

Revision No.	DESCRIPTION OF REVISION	Date Approved
0	ORIGINAL ISSUE	4/10/91

BRANCH/PROJECT ID: WCG-1-771

BY: SAL DATE: 4-8-91

DEPT NO.: -

CHECKED BY: C Wa DATE: 4-10-91

OFS NO.: -

CLIENT: TVA

PROJECT: WBNP/UNIT - 1

SUBJECT: Example Calculation for Qualification of Thermally Restrained Structures

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TOTAL PAGES 70

THIS CALCULATION PACKAGE CONTAINS 70 TOTAL PAGES.

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CHKD. BY C Wu DATE 4-10-91

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PROJECT WBNP-Unit

SUBJECT _____

5. PURPOSE:

THE PURPOSE OF THIS CALCULATION IS TO PRESENT EXAMPLES FOR THE QUALIFICATION OF THE THERMALLY RESTRAINED STRUCTURES OF CATEGORY I STRUCTURAL AND MISCELLANEOUS STEEL POPULATION.

6. APPLICABLE CRITERIA (MARKED "X"):

- _____ 1. DS-C1.7.1 R4 General Anchorage To Concrete
- _____ 2. DS-C1.7.3 R0 Application of Baseplate II
- _____ 3. DS-C1.8.1 R3 Standard Calculation for Evaluating Type II Embedded Plates
- _____ 4. WB-DC-20-1 R6 Concrete Structures-General
- _____ 5. WB-DC-20-2 R6 Reactor Building Concrete Structures
- X 6. WB-DC-20-21 R6 Misc. Steel Component for Category I Structures
- _____ 7. WB-DC-40-31.53 R4 Design Criteria for Pipe Whip Restraints, Jet Deflectors and Sleeves
- _____ 8. QIR-CEB-WBN-89-361 R0 Auxiliary Control and Reactor Buildings Acceleration & Response Spectra
- _____ 9. WCG-1-370 R0 Generation of OBE 4% Damping ARS for Unit 1 ICS, SCV, and SB
- _____ 10. WCG-1-377 R0 Aux. Control Building 4% Damping Curves and Seismic Forces
- _____ 11. (Specify):

7. APPLICABLE CODES AND STANDARDS (MARKED "X"):

- X 1. AISC Manual of Steel Construction, 7th Edition
- _____ 2. AWS D.1.1-83, 1983, Structural Welding Code
- X 3. ACI 318-77 Building Code Requirements for Reinforced Concrete
- _____ 4. (Specify):

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8. ASSUMPTIONS, LITERATURE SEARCHES AND OTHER APPLICABLE BACKGROUND DATA:

NONE

9. APPLICABLE REFERENCES (MARKED "X"):

- 1. Design of Welded Structures by O.W. Blodgett 1966
- 2. Formulas for Stress and Strain by R.J. Roark & W.C. Young, 5th Edition
- 3. WCG-1-580 R0 Selection and Grouping of Embedded Plates for Evaluation
- 4. WCG-1-256 R0 Concrete Quality Evaluation
- 5. N3-PA-34 R0 Non-linear Transient Dynamic Analysis of FW Lines-Piping Analysis Calculation No. N3-PA-34
- 6. QIR-CEB-WBN 90757 R0 Active List of Pipe Whip Restraints/Protective Devices (PD's)
- 7. (Specify):

- (1) WCG-1-769, R0 Platform Elevation 730'-10 1/2"
- (2) WCG-1-811, R0 Test Correlation Study for Thermal Use of Ductility Ratio
- (3) WCG-1-343, R0 Seismic SSI Analysis for ICS+NSSS System

10. APPLICABLE DESIGN INPUT DATA:

See Section 11.3

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11. Calculations

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11.1 Objective

The objective of this calculation is to present examples for the qualification of the thermally restrained structures of Category I structural and miscellaneous steel population.

11.2 Scope

Two (2) example calculations are presented for the qualification of the thermally restrained structures:

Example #1

Qualification for an axially restrained member (W14x30), including connections and concrete anchorage; The qualification of member considers both the Energy Balance Method and the Nonlinear Acceptance Criteria.

Example #2

Qualification for the axially restrained member (M4x13) identified in Problem #2 of WCG-1-811 (Test Correlation Study for Thermal Use of Ductility Ratio) with the Energy Balance Method.

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11.3 Methodology

Geometric Configuration

A W14x30 member in the RB Instrument Room, platform elevation 730'-10.5", as shown in Figure 11.3.1 (for detail, see Drawing 48W902), is considered for Example #1. The geometry of this member is presented in Figure 11.3.2.

The geometric configuration of the member M4x13 used in Example #2 is shown in Figure 11.3.3.

Loading Condition

According to A8.1.2 of WB-DC-20-21, thermal effects and loads during normal operating condition (T_o) can be ignored since the operating temperature of this member does not exceed 120°F; Therefore, only loading combination (8a) in Appendix A of WB-DC-20-21 is selected for evaluation. Dead Load, Live Load, SSE Load as well as Thermal Load are considered in this loading combination.

All loading data are obtained from the calculation WCG-1-769 and the G-values for SSE loadings are obtained from the ARS results in WCG-1-343. 1.5 is used for the MMF (Multi-Mode Magnification Factor) for Floor SSE loads and 1.2 is used for the MMF for Conduit SSE loads. A unit weight of 0.786 pci is considered for Dead Load and 100.0 psf is used for Live Load. Unfactored conduit load and the pipe foot-print load are directly obtained from the GTSTRUDL input file used in WCG-1-769.

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Mathematical Model

ANSYS computer program is used for both example calculations. The ANSYS STIF4 element, a three dimensional beam element, is used to construct the model for the linear analysis. The ANSYS STIF24 element, the three dimensional thin-wall plastic beam element, is used in the model for nonlinear analysis. Both models used for linear and nonlinear analysis for Example #1 consist of 13 elements and 12 nodes, as shown in Figure 11.3.4. ANSYS model for Example #2 is shown in Figure 11.3.5.

For the nonlinear analysis utilizing ANSYS STIF24 element, the cross-section of the member is represented by twelve (12) rectangular segments defined by fifteen (15) stress points as shown in Figure 11.3.6. A bilinear stress-strain property, as shown in Figure 11.3.7, is used to simulate the elastic-plastic material property in the nonlinear analysis. 29×10^3 ksi is used as the Young's Modulus (E) and 1,500 ksi is used as the Tangent Modulus (Et). 0.05 is considered as the factor of (E/Et) as recommended in ANSYS User's Manual, Section 2.27. The ANSYS large deflection solution method is used in the nonlinear analysis so that the stiffness matrix characterizes the deformed structure in the iterative solution process. 36 ksi is used as the Yield Strength and 6.5×10^{-6} in/in-°F is considered as the Coefficient of Thermal Expansion. Incremental temperature steps are utilized to represent the temperature change.

Qualification of Members- Linear Acceptance Criteria (Energy Balance Method)

The Energy Balance Method provided in DG-C1.6.12, R0 is used for the qualification of the member. The allowable ductility ratio is determined per WB-DC-20-21. The P-

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delta effect, resulting from the thermally induced axial force and lateral deflections of the member due to non-thermal load, is taken into account to calculate maximum combined stress. The energy balance method is not applicable if the calculated combined stress exceeds the ultimate strength ($F_u=58$ ksi).

Qualification of Members- Non-linear Acceptance Criteria

The displacement based ductility ratio requirement is considered for the qualification as presented in Section 11.4.2. The allowable ductility ratio is determined in accordance with WB-DC-20-21.

Qualification of Connections

The weld connections at both end of the member W14x30 are qualified based on an allowable stress level of two thirds of the nominal tensile strength of the weld per DG-C1.6.12, R0. The forces and moments at both ends of the member obtained from the ANSYS nonlinear analysis results are considered.

Qualification of Anchorage

Same forces used to qualify connections are considered for the Anchorage. The baseplates are evaluated using the BASEPLATE II computer program. The maximum plate principal stresses and bolt tension loads are evaluated. The CONAN mathematical

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model is used to evaluate the concrete capacity. The model incorporates the critical case of having two free edges on both side of the plate. Maximum tensile loads are used. The concrete free edges and punching shear are evaluated by hand calculations. Shear loads on the bolts as well as "pullwout" created by tensile loads on the anchor head are grouped together due to extreme ^{SAL 4/10/91} overlapping.

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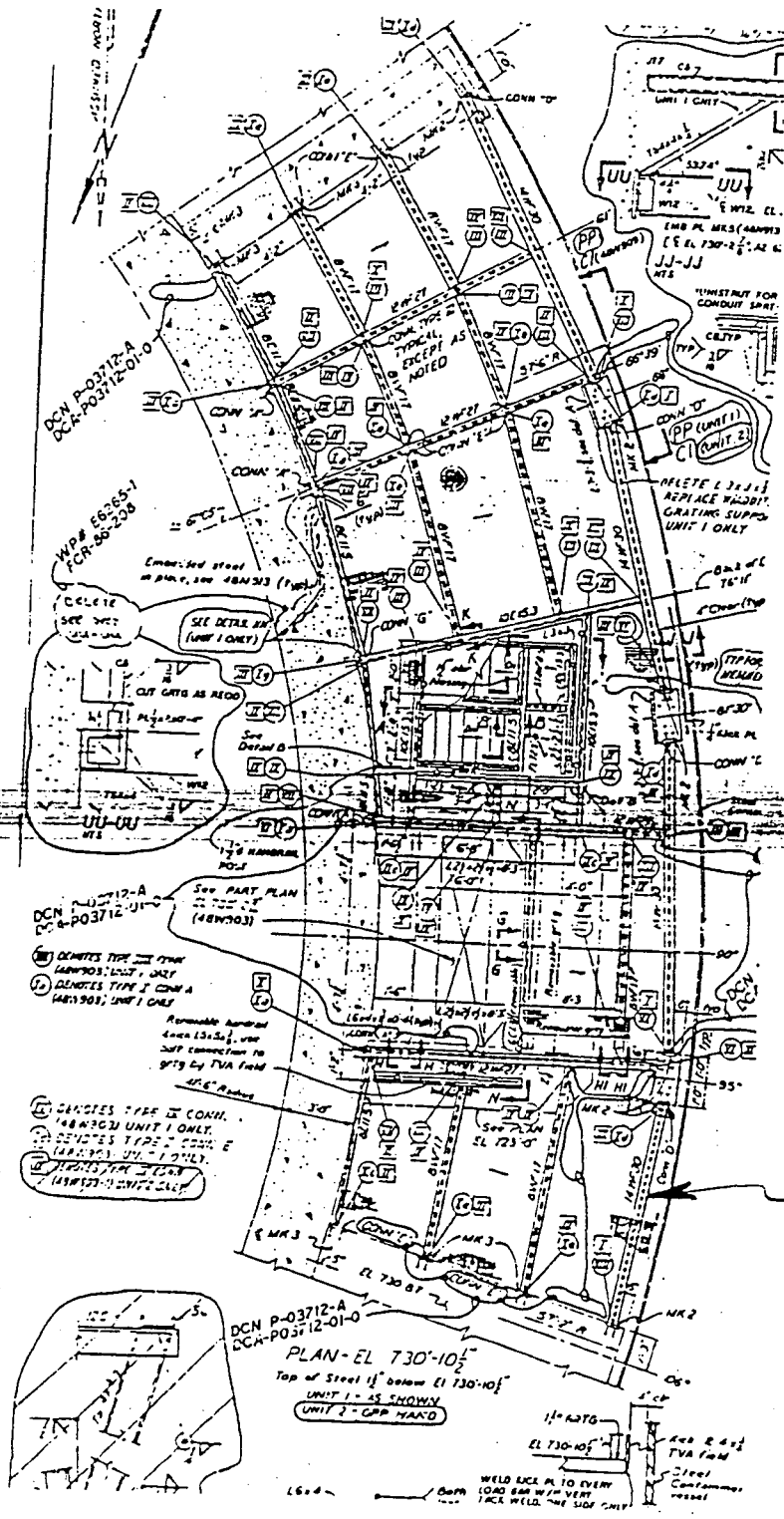
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Figure 11.3.1 Member Considered in Example #1



Drawing # :
48W902

Member Considered in
Example #1

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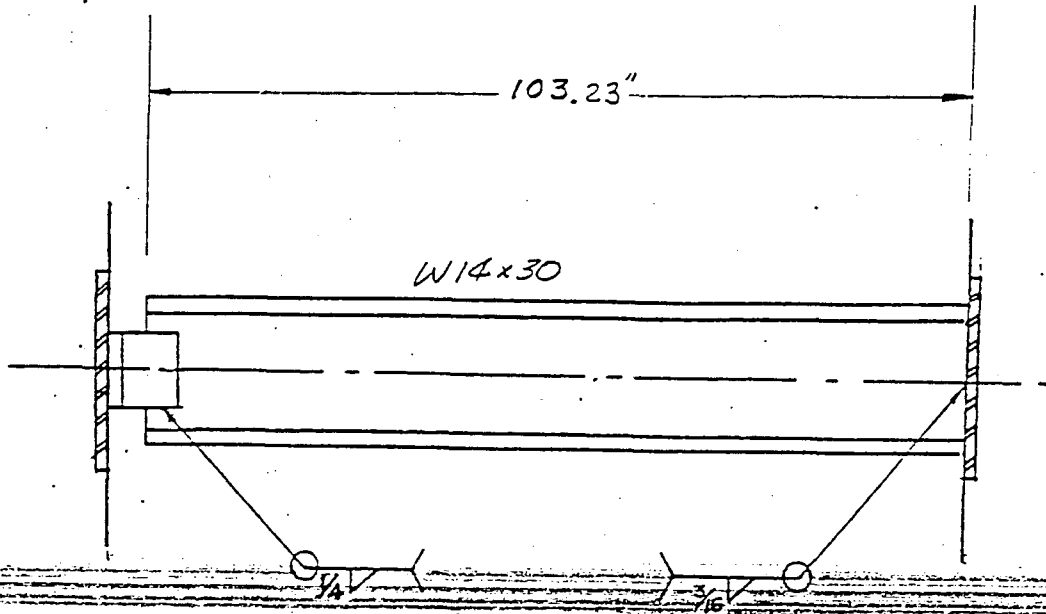
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Figure 11.3.2 Geometric Configuration of Member W14x30 for Example #1



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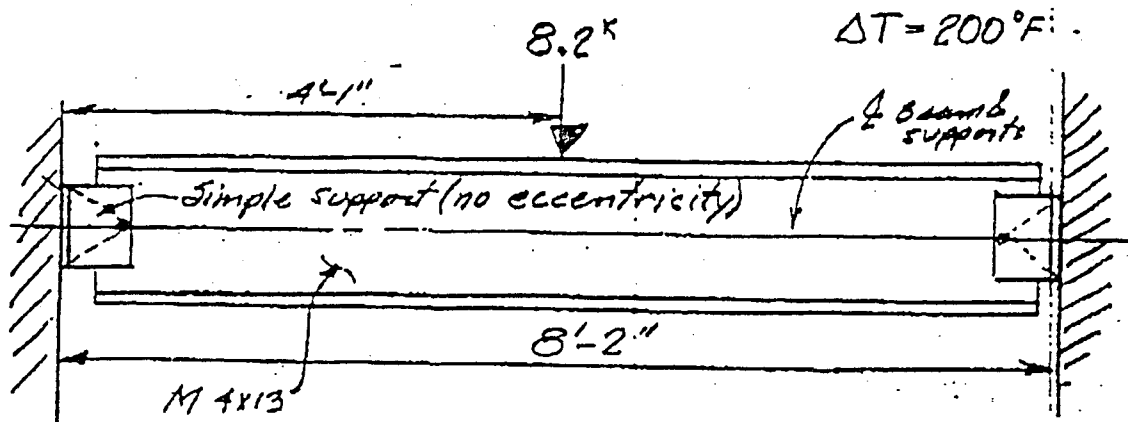
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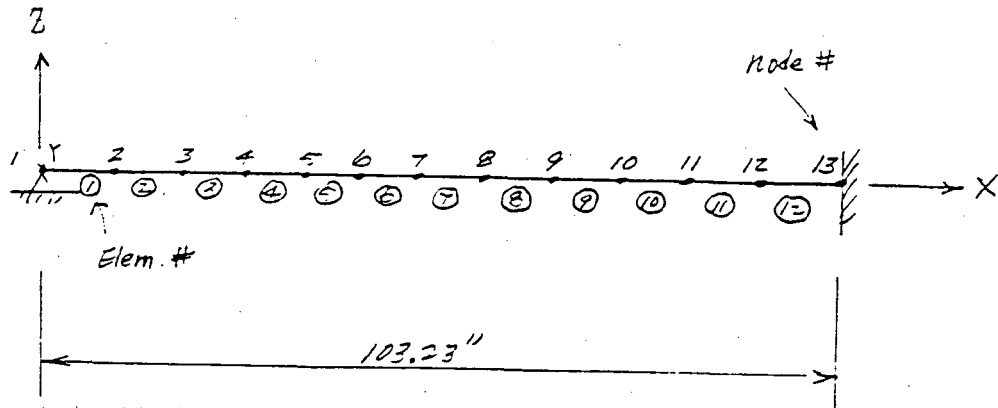
Figure 11.3.3 Geometric Configuration of Member M4x13 for Example #2



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Figure 11.3.4 ANSYS Model of Member W14x30 for Example #1

Temperature = 70°F \rightarrow 255°F



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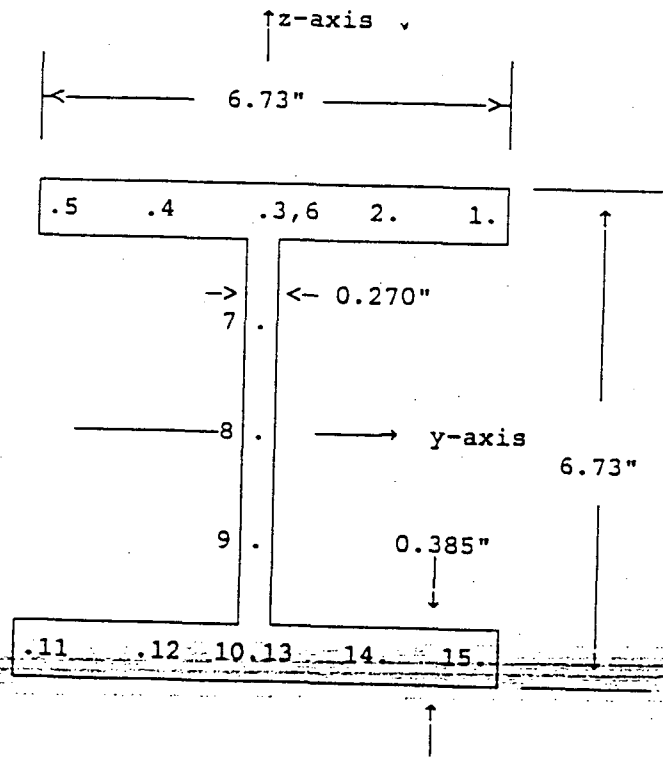
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Figure 11.3.6 Stress Point Definition for ANSYS STIF24 Element



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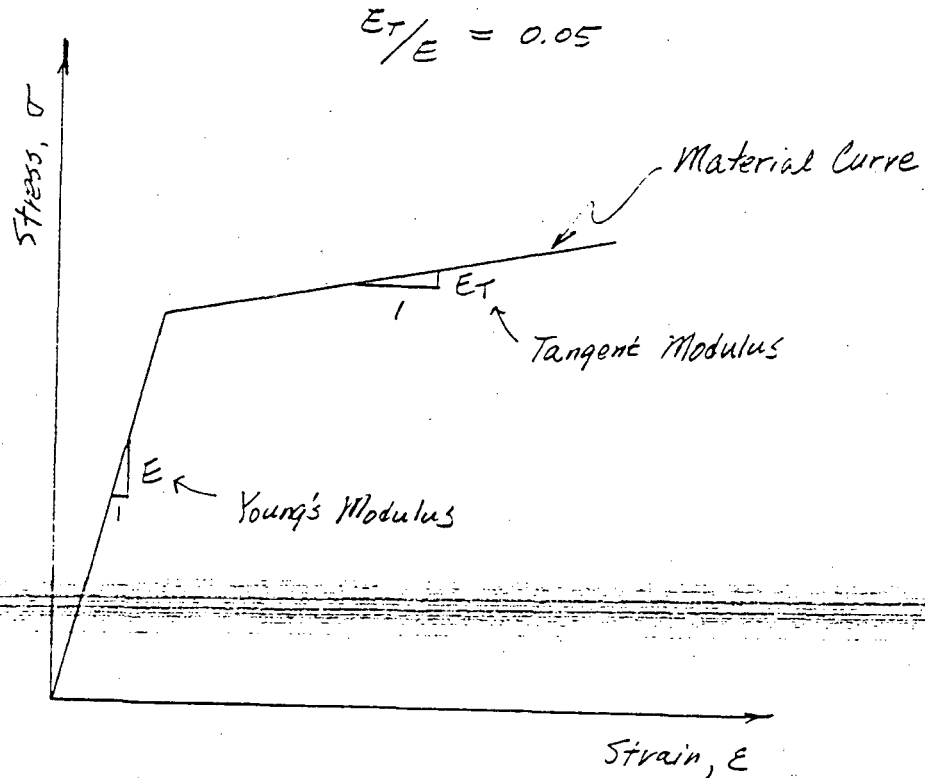
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Figure 11.3.7 Material Properties Used in ANSYS Nonlinear Analysis



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11.4 Qualification of Member W14x30 (Example #1)

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11.4.1 Member Qualification - Linear Acceptance Criteria (Energy Balance Method)

Two (2) linear analyses are performed using ANSYS program. The first analysis considers a loading combination of DL, LL, and SSE loads in Z (vertical) and Y (horizontal) directions (coordinate system used in ANSYS model) with an uniform temperature increase from 70°F to 255°F. The second analysis considers a loading combination of DL, LL and SSE loads in Z (vertical) and X (horizontal) directions with an uniform temperature increase from 70°F to 255°F. The input files of these runs are provided in Section 11.6.1. The analysis results indicate that the first loading combination is most critical, therefore, the results from the first loading combination are used for the qualification of the member.

W14x30 Properties

$$A = 8.85 \text{ in}^2$$

$$d = 13.84 \text{ in}; \quad b_f = 6.730 \text{ in}$$

$$t_w = 0.270 \text{ in}; \quad t_f = 0.385 \text{ in}$$

$$I_x = 291.0 \text{ in}^4; \quad S_x = 42.0 \text{ in}^3; \quad r_x = 5.73 \text{ in}$$

$$I_y = 19.6 \text{ in}^4; \quad S_y = 5.82 \text{ in}^3; \quad r_y = 1.49 \text{ in}$$

Equivalent Properties using coordinate system in ANSYS analysis:

$$I_y = 291.0 \text{ in}^4; \quad S_y = 42.0 \text{ in}^3$$

$$I_z = 19.6 \text{ in}^4; \quad S_z = 5.82 \text{ in}^3$$

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Table 11.4.1.1 documents the calculated nodal displacements from ANSYS analysis. Table 11.4.1.2 documents the calculated nodal stresses and forces. Table 11.4.1.3 documents the reaction forces at both ends of the member. See Figure 11.3.4 for locations of the nodes and elements.

Maximum combined stress = 40.93 ksi (see Table 11.4.1.2, node 13)

(From Linear Analysis Results)

Account for the P-delta effect of the member due to thermally induced axial load and deflections resulting from non-thermal loads.

$$M_y = P * u_z = 310.5 * 0.0047 = 1.46 \text{ k-in}$$

$$M_z = P * u_y = 301.5 * 0.021 = 6.52 \text{ k-in}$$

where $P = \text{Max. Axial Force}$

$u_z = \text{Max. deflection in z direction (node 5)}$

$u_y = \text{Max. deflection in y direction (node 5)}$

$$\begin{aligned} \text{Maximum Combined Stress} &= 40.93 + (M_y/S_y) + (M_z/S_z) \\ &= 40.93 + (1.46/42) + (6.52/5.82) \\ &= 42.08 \text{ ksi} \end{aligned}$$

42.08 ksi < $F_u = 58 \text{ ksi} \implies$ Energy Balance Method Applicable

42.08 > $F_y = 36 \text{ ksi} \implies$ Eq. 7 of DG-C.1.6.12 is used

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$$\begin{aligned}\mu &= 0.5 [(Pr/Py)^2 + 1] \\ &= 0.5 [(42.08/36)^2 + 1] \\ &= 1.18 < \mu_{allow} = 1.5 \quad \text{O.K.}\end{aligned}$$

The member is qualified per WB-DC-20-21.

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Table 11.4.1.1 Nodal Displacements for Example #1 (Linear Analysis)

EX1YZ - THERMAL EVALUATION FOR A BEAM WITH AXIAL RESTRAINT (SSE-YZ)

14.3914 APR 7, 1991 CP= 1.285

***** DISPLACEMENT SOLUTION *****						
NOOE	UX	UY	UZ	ROTX	ROTY	CUM. ITER.= ROTZ
1	0.00000	0.00000	0.00000	0.00000	.174391E-03	- .814476E-03
2	.144679E-04	-.566902E-02	-.121519E-02	.866207E-02	.166915E-03	-.776869E-03
3	.328444E-04	-.121016E-01	-.260567E-02	.163036E-01	.140161E-03	-.642862E-03
4	.553956E-04	-.179239E-01	-.389655E-02	.215569E-01	.923843E-04	-.405676E-03
5	.839017E-04	-.211911E-01	-.469791E-02	.281974E-01	.214614E-04	-.584569E-04
6	.114720E-03	-.192301E-01	-.442885E-02	.342153E-01	-.561426E-04	.311426E-03
7	.122762E-03	-.178382E-01	-.417191E-02	.343150E-01	-.742679E-04	.394962E-03
8	.139113E-03	-.141244E-01	-.345295E-02	.344217E-01	-.103977E-03	.525121E-03
9	.161644E-03	-.788810E-02	-.218042E-02	.304485E-01	-.121767E-03	.578527E-03
10	.165777E-03	-.672837E-02	-.193464E-02	.297195E-01	-.121377E-03	.568647E-03
11	.158317E-03	-.617135E-02	-.181263E-02	.284243E-01	-.122553E-03	.545417E-03
12	.763233E-04	-.157348E-02	-.547189E-03	.141903E-01	-.952846E-04	.290592E-03
13	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
MAXIMUMS						
NOOE	10	5	5	8	1	1
VALUE	.165777E-03	-.211911E-01	-.469791E-02	.344217E-01	.174391E-03	-.814476E-03

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Table 11.4.1.3 Reaction Forces for Example #1 (Linear Analysis)

EX1YZ - THERMAL EVALUATION FOR A BEAM WITH AXIAL RESTRAINT (SSE-YZ)

14.3914 APR 7, 1991 CP=

1.334

***** REACTION FORCES ***** TIME = 0.0000 LOAD STEP= 3 ITERATION= 1 CUM. ITER.= 3

NOTE - REACTION FORCES ARE IN THE NODAL COORDINATE SYSTEM

NODE	FX	FY	FZ	HX	HY	HZ
1	308.096	.882029	2.60124	-5.19291		
13	-310.536	.612943	5.82450	-5.87929	107.825	-19.0832
TOTAL	-2.44000	1.49497	8.42574	-11.0722	107.825	-19.0832

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11.4.2 Member Qualification - Nonlinear Acceptance Criteria

ANSYS computer program is used to perform nonlinear analysis for the same member W14x30 in section 11.4.1.

The nonlinear analysis considers the same loading condition used in Section 11.4.1 for linear analysis. The worst load combination including seismic horizontal and vertical SSE accelerations is selected for ANSYS nonlinear analysis. Uniform temperature is applied on the model incrementally from 70°F to 255°F (5 degrees per increment).

The first plastic deformation occurs at 240°F at nodes 3, 4 and 5 (See Figure 11.3.4 for locations of nodes). At temperature of 255°F, the region of plastic deformation is expanded to node 1 through 7. The stresses and strains at stress points 1, 8 and 15 at member cross-section for the 2nd (J) node of each element are presented in Tables 11.4.1 and 11.4.2 for temperatures 240°F and 255°F respectively. The locations of stress points on member cross-section are defined in Figure 11.3.6. The nodal displacements are presented in Tables 11.4.3 and 11.4.4 for temperatures 240°F and 255°F respectively. The reaction forces are listed in Tables 11.4.5 and 11.4.6 for temperatures 240°F and 255°F, respectively.

Primary member is accepted on the basis of the displacement based ductility ratio:

$$\mu_d = \sqrt{(U_x^2 + U_y^2 + U_z^2)} / \sqrt{(U_{xy}^2 + U_{yy}^2 + U_{zy}^2)}$$

where

μ_d = the displacement based ductility ratio

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U_x, U_y, U_z = Actual displacements in x, y, and z directions.

U_{xy}, U_{yy}, U_{zy} = Displacements at yield condition.

The maximum displacement occurs at Node 5, as shown in Table 11.4.4. The ductility ratios for Node 5 at 240°F and 255°F are computed as follows:

Displacements and Ductility Ratio at Node 5 for T = 240°F and 255°F

TEMP	UX	UY	UZ	SRSS	RATIO, μ_d
240°F	0.00010	0.0307	0.00617	0.0313	1.0
255°F	0.00029	0.0653	0.01093	0.0662	2.1

(Note that the yield condition occurs at temperature = 240°F)

The ductility ratio for the member at temperature 255°F:

$$\mu_d = 2.1 < 3.0$$

Therefore, this member is qualified based on the nonlinear acceptance criteria.

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Table 11.4.1 Stresses and Strains at 240°F for Example #1 (Nonlinear Analysis)

ELEM	TMPO	SX01	SX08	SX15	EE01	EE08	EE15	EP01	EP08	EP15
1	240.00	-33.690	-31.956	-32.868	-.11617E-02	-.10949E-02	0.0000	0.0000	0.0000	0.0000
2	240.00	-35.254	-31.956	-33.751	-.12157E-02	-.10890E-02	0.0000	0.0000	0.0000	0.0000
3	240.00	-36.013	-31.964	-34.364	-.12418E-02	-.10860E-02	0.0000	-.81167E-05	0.0000	0.0000
4	240.00	-36.042	-31.982	-34.691	-.12428E-02	-.10846E-02	0.0000	-.26312E-04	0.0000	0.0000
5	240.00	-36.000	-31.956	-34.165	-.12414E-02	-.10861E-02	0.0000	-.10250E-07	0.0000	0.0000
6	240.00	-35.472	-31.956	-33.858	-.12232E-02	-.10880E-02	0.0000	0.0000	0.0000	0.0000
7	240.00	-34.135	-31.956	-33.051	-.11771E-02	-.10926E-02	0.0000	0.0000	0.0000	0.0000
8	240.00	-31.362	-31.956	-31.468	-.10814E-02	-.11029E-02	0.0000	0.0000	0.0000	0.0000
9	240.00	-30.820	-31.956	-31.166	-.10628E-02	-.11049E-02	0.0000	0.0000	0.0000	0.0000
10	240.00	-29.764	-32.233	-29.563	-.10263E-02	-.11098E-02	0.0000	0.0000	0.0000	0.0000
11	240.00	-27.647	-32.263	-30.255	-.95336E-03	-.11350E-02	0.0000	0.0000	0.0000	0.0000
12	240.00	-24.243	-32.533	-30.337	-.83596E-03	-.11744E-02	0.0000	0.0000	0.0000	0.0000

Notes: 1. Stresses and strains are listed for stress points 1,8,15. (See Figure 11.3.6 for stress point locations)

2. TMPO = Temperature, in °F

SX01, SX08, SX15 = Axial stresses at points 1, 8 and 15

EE01, EE08, EE15 = Elastic strains at stress points 1, 8 and 15

EP01, EP08, EP15 = Plastic strains at stress points 1, 8 and 15.

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Table 11.4.2 Stresses and Strains at 255°F for Example #1 (Nonlinear Analysis)

ELEM	TMPO	SX01	SX08	SX15	EE01	EE08	EE15	EP01	EP08	EP15
1	255.00	-35.890	-34.108	-35.418	-.12376E-02	-.11683E-02	0.0000	-.14853E-04	0.0000	0.0000
2	255.00	-36.209	-34.421	-36.099	-.12486E-02	-.11686E-02	0.0000	-.13221E-03	0.0000	0.0000
3	255.00	-36.393	-34.903	-36.240	-.12549E-02	-.11780E-02	0.0000	-.24869E-03	0.0000	0.0000
4	255.00	-36.496	-35.236	-36.312	-.12585E-02	-.11844E-02	0.0000	-.31346E-03	0.0000	0.0000
5	255.00	-36.339	-34.729	-36.185	-.12531E-02	-.11718E-02	0.0000	-.21431E-03	0.0000	0.0000
6	255.00	-36.249	-34.496	-36.118	-.12499E-02	-.11678E-02	0.0000	-.15711E-03	0.0000	0.0000
7	255.00	-36.063	-34.145	-35.745	-.12436E-02	-.11647E-02	0.0000	-.39990E-04	0.0000	0.0000
8	255.00	-33.531	-34.092	-33.369	-.11562E-02	-.11742E-02	0.0000	0.0000	0.0000	0.0000
9	255.00	-32.879	-34.092	-32.953	-.11338E-02	-.11762E-02	0.0000	0.0000	0.0000	0.0000
10	255.00	-31.164	-34.626	-30.516	-.10746E-02	-.11884E-02	0.0000	0.0000	0.0000	0.0000
11	255.00	-26.753	-35.331	-30.461	-.92253E-03	-.12413E-02	0.0000	0.0000	-.89894E-05	0.0000
12	255.00	-20.392	-36.121	-32.456	-.70318E-03	-.12509E-02	0.0000	0.0000	-.17539E-03	0.0000

Notes: 1. Stresses and strains are listed for stress points 1,8,15. (See Figure 11.3.6 for stress point locations)

2. TMPO = Temperature, in °F

SX01, SX08, SX15 = Axial stresses at points 1, 8 and 15

EE01, EE08, EE15 = Elastic strains at stress points 1, 8 and 15

EP01, EP08, EP15 = Plastic strains at stress points 1, 8 and 15.

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Table 11.4.3 Nodal Displacements at 240°F For Example #1 (Nonlinear Analysis)

THE FOLLOWING X,Y,Z DISPLACEMENTS ARE IN NODAL COORDINATES

NODE	UX	UY	UZ	ROTX	ROTY	ROTZ
1	0.0000000	0.0000000	0.0000000	0.0000000	.23146293E-03	-.11591664E-02
2	.16834828E-04	-.80841805E-02	-.15987532E-02	.96436043E-02	.21280621E-03	-.11128371E-02
3	.39340228E-04	-.17346285E-01	-.34148982E-02	.18179326E-01	.17467756E-03	-.93443283E-03
4	.68198366E-04	-.25865304E-01	-.51116211E-02	.24080694E-01	.11488081E-03	-.59945416E-03
5	.10152021E-03	-.30713311E-01	-.61730703E-02	.31483927E-01	.25847661E-04	-.86559044E-04
6	.14005331E-03	-.27780500E-01	-.57717072E-02	.38122038E-01	-.69016112E-04	.45289996E-03
7	.15153823E-03	-.25770733E-01	-.54186656E-02	.38219144E-01	-.90837113E-04	.57021764E-03
8	.17414901E-03	-.20464869E-01	-.44452393E-02	.38300880E-01	-.12539672E-03	.74779921E-03
9	.20421133E-03	-.11694171E-01	-.27609749E-02	.33858446E-01	-.14537445E-03	.81010470E-03
10	.20971897E-03	-.10077222E-01	-.24413667E-02	.33043399E-01	-.14433119E-03	.79448016E-03
11	.20291625E-03	-.92982804E-02	-.22839930E-02	.31605040E-01	-.14541574E-03	.76822069E-03
12	.12378125E-03	-.25897495E-02	-.70460561E-03	.15800081E-01	-.11349698E-03	.43759177E-03
13	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
MAXIMUMS						
NODE	10	5	5	8	1	1
VALUE	.20971897E-03	-.30713311E-01	-.61730703E-02	.38300880E-01	.23146293E-03	-.11591664E-02

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Table 11.4.4 Nodal Displacements at 255°F For Example #1 (Nonlinear Analysis)

THE FOLLOWING X,Y,Z DISPLACEMENTS ARE IN NODAL COORDINATES

NODE	UX	UY	UZ	ROTX	ROTY	ROTZ
1	0.000000	0.000000	0.000000	0.000000	.39133739E-03	-.23344520E-02
2	.16891783E-03	-.16364845E-01	-.27080379E-02	.97438699E-02	.36046453E-03	-.22737670E-02
3	.33541515E-03	-.35804021E-01	-.58637903E-02	.18404900E-01	.30286922E-03	-.19837627E-02
4	.39723055E-03	-.54517121E-01	-.89192849E-02	.24439734E-01	.20621254E-03	-.13152893E-02
5	.29214325E-03	-.65353300E-01	-.10928293E-01	.31938521E-01	.51298973E-04	-.17941603E-03
6	.22386096E-03	-.58293182E-01	-.10233465E-01	.38558689E-01	-.11443097E-03	.98296795E-03
7	.25578057E-03	-.53953476E-01	-.96247243E-02	.38635325E-01	-.15097324E-03	.12122517E-02
8	.39988237E-03	-.42811912E-01	-.79571669E-02	.38664289E-01	-.20375115E-03	.15136822E-02
9	.67208489E-03	-.25323399E-01	-.51593106E-02	.34142059E-01	-.23786335E-03	.16087128E-02
10	.72381029E-03	-.22099773E-01	-.46237298E-02	.33312301E-01	-.23877225E-03	.15896761E-02
11	.73161798E-03	-.20532902E-01	-.43579701E-02	.31863045E-01	-.24187524E-03	.15516110E-02
12	.68067237E-03	-.61176815E-02	-.15219759E-02	.15944359E-01	-.20515473E-03	.95746966E-03
13	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

MAXIMUMS
NODE
VALUE

11	5	5	8	1	1
.73161798E-03	-.65353300E-01	-.10928293E-01	.38664289E-01	.39133739E-03	-.23344520E-02

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Table 11.4.5 Reaction Forces at 240°F for Example #1 (Nonlinear Analysis)

THE FOLLOWING X,Y,Z FORCES ARE IN NODAL COORDINATES

NCDE	FX	FY	FZ	MX	MY	MZ
1	281.69441	.79775046	2.5596255	-5.2384619		
13	-284.13439	.61191188	5.8943068	-5.9561054	113.47454	-23.566164
TOTAL	-2.4399790	1.4096623	8.4539323	-11.194567	113.47454	-23.566164

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Table 11.4.6 Reaction Forces at 255°F for Example #1 (Nonlinear Analysis)

THE FOLLOWING X,Y,Z FORCES ARE IN NODAL COORDINATES

NODE	FX	FY	FZ	MX	MY	MZ
1	300.52198	.73287175	2.6228412	-5.2929467		
13	-302.96193	.67581947	5.8313954	-6.0386113	106.89684	-30.008045
TOTAL	-2.4399475	1.4086912	8.4542366	-11.331558	106.89684	-30.008045

BY Y. Chen DATE 4-7-91
 CHKD. BY C Wu DATE 4-10-91
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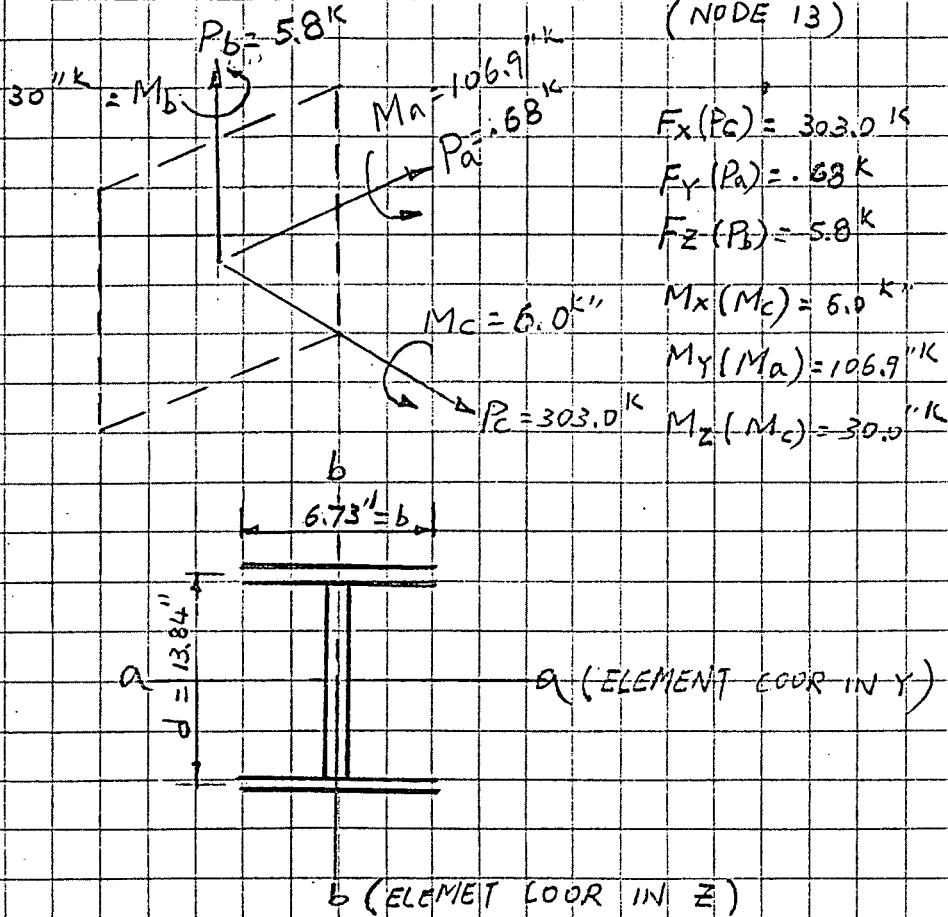
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SUBJECT EXAMPLE CALCULATION FOR QUALIFICATION OF THERMALLY RESTRAINED STRUCTURES

REF

11.4.3 CONNECTION QUALIFICATION

11.4.3.1 WELD CONNECTION CHECK AT FIXED END



$F_x(P_c) = 303.0 \text{ k}$

$F_y(P_a) = .68 \text{ k}$

$F_z(P_b) = 5.8 \text{ k}$

$M_x(M_c) = 6.0 \text{ k-in}$

$M_y(M_a) = 106.9 \text{ k-in}$

$M_z(-M_c) = 30.0 \text{ k-in}$

48W902 R2.1
 48W903 R.16

$I_c = A = 6.73 \times 4 + 13.84 \times 2 = 54.60$

$I_a = A_a = 6.73 \times 4 = 26.92$

$I_b = A_b = 13.84 \times 2 = 27.68$

$PMI = J = \frac{2b^3 + 6bd^2 + d^3}{6} = 1832.54$

$SM_a = S_a = 2bd + \frac{d^2}{3} = 250.1$

$SM_b = S_b = 4 \frac{b^2}{3} = 60.4$

BY Y. Chen DATE 4-7-71

CHKD. BY C. Wu DATE 4-10-71

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SUBJECT EXAMPLE CALCULATION FOR QUALIFICATION OF THERMALLY RESTRAINED STRUCTURES

<p>1143.1. WELD CALCULATION SHEET (CONT'D)</p> <p>WELD MAP LETTER _____</p>		<p>REFERENCES WBN-PSDM VOL. 1 Properties calculated or from tables in Section 9.5-6 Table A or B</p>
<p>NOMENCLATURE:</p> <p>Pa, Pb, Pc, Ma, Mb, and Mc - Applied forces and moments (kips and in-kips)</p> <p>La, Lb, Lc, S_{Ma}, S_{Mb}, P_{MI}, Ca, and Cb - Weld group properties</p>		<p>MEMBER _____</p> <p>JOINT _____</p> <p><input type="checkbox"/> GLOBAL</p> <p><input type="checkbox"/> LOCAL</p>
<p>Any weld configuration C - Axis always perpendicular to plane of weld group</p>	<p>Sketch weld group being sized:</p>	
$f_a = \left(\frac{P_a}{L_a}\right) + \left(\frac{M_c C_b}{P_{MI}}\right) = \left(\frac{0.7}{26.92}\right) + \left(\frac{6.0 \times 6.92}{1832.54}\right) = \underline{0.049} \text{ k/in.}$ $f_b = \left(\frac{P_b}{L_b}\right) + \left(\frac{M_c C_a}{P_{MI}}\right) = \left(\frac{58}{27.68}\right) + \left(\frac{6.0 \times 3.37}{1832.54}\right) = \underline{0.221} \text{ k/in.}$ $f_c = \left(\frac{P_c}{L_c}\right) + \left(\frac{M_a}{S_{Ma}}\right) + \left(\frac{M_b}{S_{Mb}}\right)$ $f_c = \left(\frac{303.0}{54.6}\right) + \left(\frac{106.9}{250.1}\right) + \left(\frac{30.0}{60.4}\right) = \underline{6.47} \text{ k/in.}$ $f_r = \sqrt{f_a^2 + f_b^2 + f_c^2} = \sqrt{0.049^2 + 0.221^2 + 6.47^2} = \underline{6.47} \text{ k/in.}$		
<p>ALLOWABLE STRESS: $38.67 \text{ KSI} = \frac{2}{3} \times 58$</p>		
<p>Required Size = $\frac{f_r}{\text{Allowable Stress}} = \frac{6.47}{38.67} = \underline{0.167} \text{ in.}$</p>		
<p>∴ Use <u>3/16</u> inch <input checked="" type="checkbox"/> Fillet } Weld D.K</p> <p style="margin-left: 100px;"><input type="checkbox"/> Groove } <input type="checkbox"/> Other }</p>		
<p>BASED ON:</p> <p><input type="checkbox"/> REQUIRED SIZE</p> <p><input type="checkbox"/> BASE PLATE THICKNESS*</p> <p><input type="checkbox"/> ATTACHMENT THICKNESS.*</p> <p>* MINIMUM WELD REQUIRED</p>		

BY Y. Chen DATE 4-7-91 BRANCH/PROJECT ID: WCA-1-711

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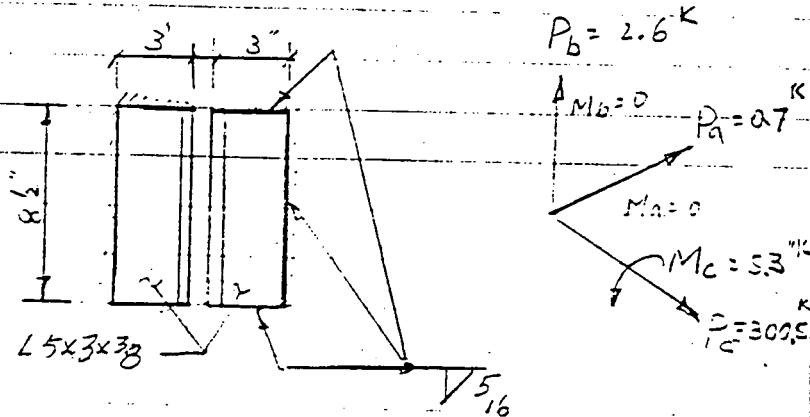
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PROJECT WBNP - UNIT 1

SUBJECT EXAMPLE CALCULATION FOR QUALIFICATION OF THERMALLY RESTRAINED STRUCTURE

REF

11.4.3.2 WELD CONNECTION CHECK AT NODE 1



48W902 R21
48W903 R16
TYPE I

$$L_c = A = 2 \times 8.5 + 4 \times 3 = 29$$

$$L_a = A_a = 4 \times 3 = 12$$

$$L_b = A_b = 8.5 \times 2 = 17$$

$$J = \frac{8.5^3 + 3(8.5)(6.26)^2}{6} + \frac{(6.26)^3 + 3(6.26)(8.5)^2}{6} - \frac{(2.6)^3 + (2.6)(3)(8.5)^2}{6}$$

$$= 526.5$$

$$f_a = \frac{0.7}{12} + \frac{5.3 \times 4.25}{526.5} = 0.101 \text{ K/IN}$$

$$f_b = \frac{2.6}{17} + \frac{5.3 \times 2}{526.5} = 0.183 \text{ K/IN}$$

$$\frac{f}{J_c} = \frac{300.5}{29} = 10.36 \text{ K/IN}$$

$$f_y = \sqrt{f_a^2 + f_b^2 + f_c^2} = 10.36 \text{ K/IN}$$

$$\text{REQUIRED SIZE} = \frac{10.36}{58 \times \frac{3}{8}} = 0.26 \text{ IN}$$

$\frac{3}{8}$ WELD USED, O.K.

BY Y Chen DATE 4-10-91 BRANCH/PROJECT ID : WCG-1-771

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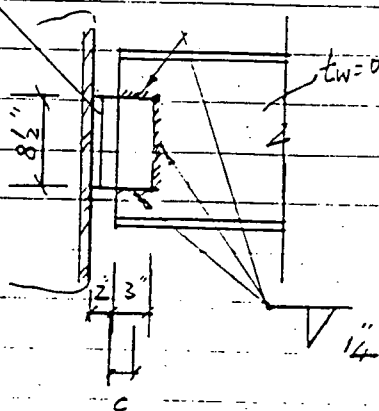
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SUBJECT EXAMPLE CALCULATION FOR QUALIFICATION OF THERMALLY RESTRICTED STRUCTURE

REF

11.4.3.2 WELD CONNECTION CHECK AT NODE 1 (CONTD)

2- L5x3x3/8



THREE 3/4" Ø BOLT

48 W 902 R 21
48 W 902 R 16

W14x30

$t_w = 0.27$

$d_w = 13.86$

$P_b = 2.6^k$
 $M_b = 0$

$P_a = 300.5^k$
 $M_a = 5.3$

$P_c = 0.7$

CONSIDER $L_a = L_b = L_c = 2 \times 2 \times 3 + 2 \times 8.5 = 29$

$$S_a = \frac{(3)(8.5) + 8.5^2/6}{2} = 37.542$$

$$J_c = \frac{(0.27 + 0.25)^3 + 3(0.52)(8.5)^2}{6} = 18.82$$

$$S_b = \frac{3^2(2(8.5) + 3)}{3(8.5 + 3)} = 5.217$$

$$x = \frac{b^2}{2b + d} = \frac{3^2}{2(3) + 8.5} = 0.62"$$

$$c = b - x = 3 - 0.62 = 2.38"$$

$$M'_c = P_b(2" + c) = 2.6(2 + 2.38) = 11.39 \text{ ''-k}$$

$$M'_b = P_c(2" + c) = 0.7(2 + 2.38) = 3.07 \text{ ''-k}$$

$$f_a = \frac{300.5}{29} + \frac{11.39(8.5/2)}{18.82(2)} = 11.65$$

$$f_b = \frac{2.6}{29} + \frac{11.39(2.38)}{18.82(2)} = 0.81$$

$$f_c = \frac{0.7}{29} + \frac{5.3}{(2)37.542} + \frac{3.07}{(2)5.217} = 0.359$$

$$f_r = \sqrt{f_a^2 + f_b^2 + f_c^2} = 11.68 \text{ ksi}$$

$$\text{REQUIRED SIZE} = \frac{11.68}{50 \times 3/4} = 0.30 > 1/4 \text{ N.G.}$$

Will require modification as noted on page 68

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CLIENT TVAPROJECT WBNP - UNIT 1SUBJECT EXAMPLE CALCULATION FOR QUALIFICATION OF THERMALLY RESTRAINED STRUCTURECHECK SHEAR IN ANGLE LEG TO WEB

$$v_b = 2.6 / [8.5(3/8)]^2 = 0.408$$

$$v_c = 0.7 / [8.5(3/8)]^2 = 0.110$$

$$v = (v_b^2 + v_c^2)^{1/2} = (.408^2 + .110^2)^{1/2} = .422 \text{ KSI} < .4F_y = 14.4 \text{ KSI OK}$$

CHECK SHEAR IN WEB

$$v_b = 2.6 / [(27)(13.86)] = 0.695$$

$$v_c = 0.7 / [(27)(13.86)] = 0.187$$

$$v = (v_b^2 + v_c^2)^{1/2} = (.695^2 + .187^2)^{1/2} = 0.720 \text{ KSI} < .4F_y = 14.4 \text{ KSI OK}$$

BY R. DAGLI DATE 4-7-91

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OFS NO.

DEPT.
NO.

CLIENT TVA

PROJECT WBNP UNIT #1

SUBJECT EXAMPLE CALCULATION FOR QUALIFICATION OF THERMALLY RESTRAINED STRUCTURE

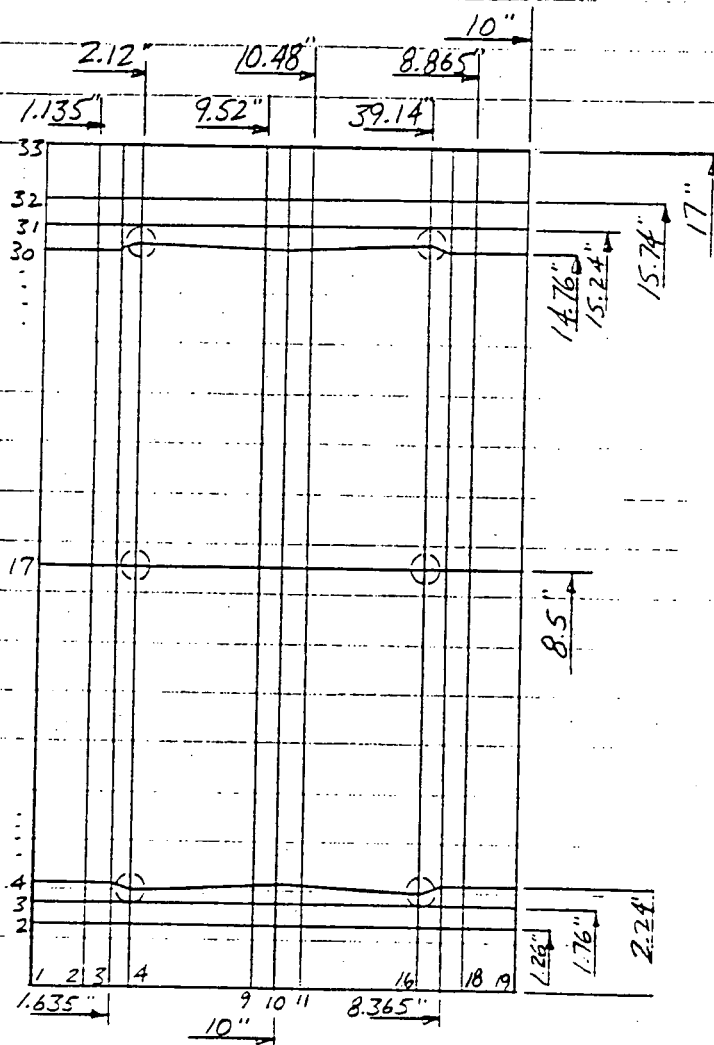
11.4.4. ANCHORAGE QUALIFICATION

REFERENCES

11.4.4.1 BASEPLATE II MATH MODEL

EMBEDDED PLATE

APPLICABLE TO NODE 1 AND 13 OF ANSYS MODEL



MK2 PLATE SIZE $1'5" \times 10" \times \frac{1}{2}"$ THK

ATTACHMENT W14 x 30

$d = 13.86" \quad t_w = 0.27$

$b_f = 6.73" \quad t_f = 0.38$

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CLIENT TVA

PROJECT WBNP UNIT #1

SUBJECT EXAMPLE CALCULATION FOR QUALIFICATION OF THERMALLY RESTRAINED STRUCTURES

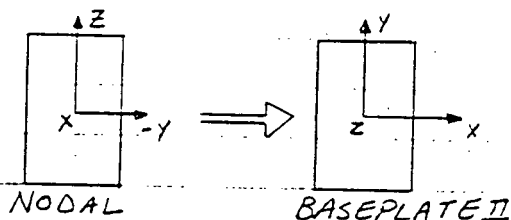
REFERENCES

11.4.4.2 APPLIED LOADS

THE FOLLOWING LOADS ARE BASED ON ANSYS OUTPUT FOR NODES 1 AND 13

THE FOLLOWING X, Y, Z FORCES ARE IN NODAL COORDINATES

NODE	FX	FY	FZ	MX	MY	MZ
1	300.52198	.73287175	2.6228412	-5.2929467		
13	-302.96193	.57581947	5.8313954	-6.0386113	106.89624	-30.008045
TOTAL	-2.4399475	1.4086912	8.4542366	-11.331558	106.89624	-30.008045



NODAL COORDINATES ARE CONVERTED TO BASEPLATE II COORDINATES

NODE	F_x (lb)	F_y (lb)	T (lb)	M_x (in-lb)	M_y (in-lb)	M_z (in-lb)
1	-750	-2700	0	0	0	5300
13	680	-5850	0	107000	30100	-6100

ANCHOR STIFFNESS

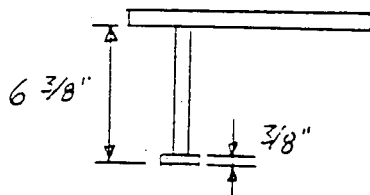
ANCHOR SIZE $5/8" \phi \times 6 3/8$ ASTM 108

AREA = 0.307 IN²

$T_0 = 0.55 F_y A$

$T_0 = (0.55)(44)(0.307)$

$T_0 = 7.429 K$



$$K_c = \frac{1}{\frac{0.015}{T_0} + \frac{L}{AE}} = \frac{1}{\frac{0.015}{7.429} + \frac{6}{(0.307)(29000)}} = 371 \frac{K}{IN}$$

$K_s = 1000 \frac{K}{IN}$

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SUBJECT EXAMPLE CALCULATION FOR QUALIFICATION OF THERMALLY RESTRAINED STRUCTURE

11.4.4.3 BASEPLATE II INPUT

 *
 * PREPROCESSOR INPUT DATA CARDS *
 *

CARD	1	2	3	4	5	6	7
NO	12345678901234567890123456789012345678901234567890123456789012						
1	3 EMBEDDED PLATE MK2 SPECIAL; I=MK2SP						
2	OUT , , , -1,000/						
3	CON , , , ,3000,1.7,1.7/						
4	PLA 19,33, ,10,17,0.5,29/						
5	APR 28,14,1,13.48,6.73,0.27,0.38,12,90/						
6	BPR , ,1,3.713E5,1.0E6,7429,7429/						
7	BOL 4,4,1,2,2/						
8	BOL 4,17,1,2,8.5/						
9	BOL 4,30,1,2,15/						
10	BOL 16,4,1,8,2/						
11	BOL 16,17,1,8,8.5/						
12	BOL 16,30,1,8,15/						
13	CON 2,2, ,1.135,1.26/						
14	CON 18,32, ,8.865,15.74/						
15	END /						
16	WFI 10,17,1,5,8.5/						
17	END /						
18	POI 10,17/						
19	LOA , ,1, -750, -2700, , , ,5300/						
20	POI 10,17/						
21	LOA , ,2,680, -5850, ,107000,30100, -6100/						
22	END /						
23	END OF JOB						

END OF INPUT DATA

BY R-DAGLI DATE 4-7-91 BRANCH/PROJECT ID: WCG-1-771

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SUBJECT EXAMPLE CALCULATION FOR QUALIFICATION OF THERMALLY RESTRAINED STRUCTURE

N. A. 4.4 SUMMARY OF BASEPLATE OUTPUT

REFERENCES

MAXIMUM PRINCIPAL STRESS

NODE 1 1554 < 27000

NODE 13 18263 < 27000

MAXIMUM BOLT TENSION

NODE 1 150 < 7429 K

NODE 13 5039 < 7429 K

MAXIMUM INTERACTION RATIO

NODE 1 0.014 < 1

NODE 13 0.547 < 1

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OFS NO.

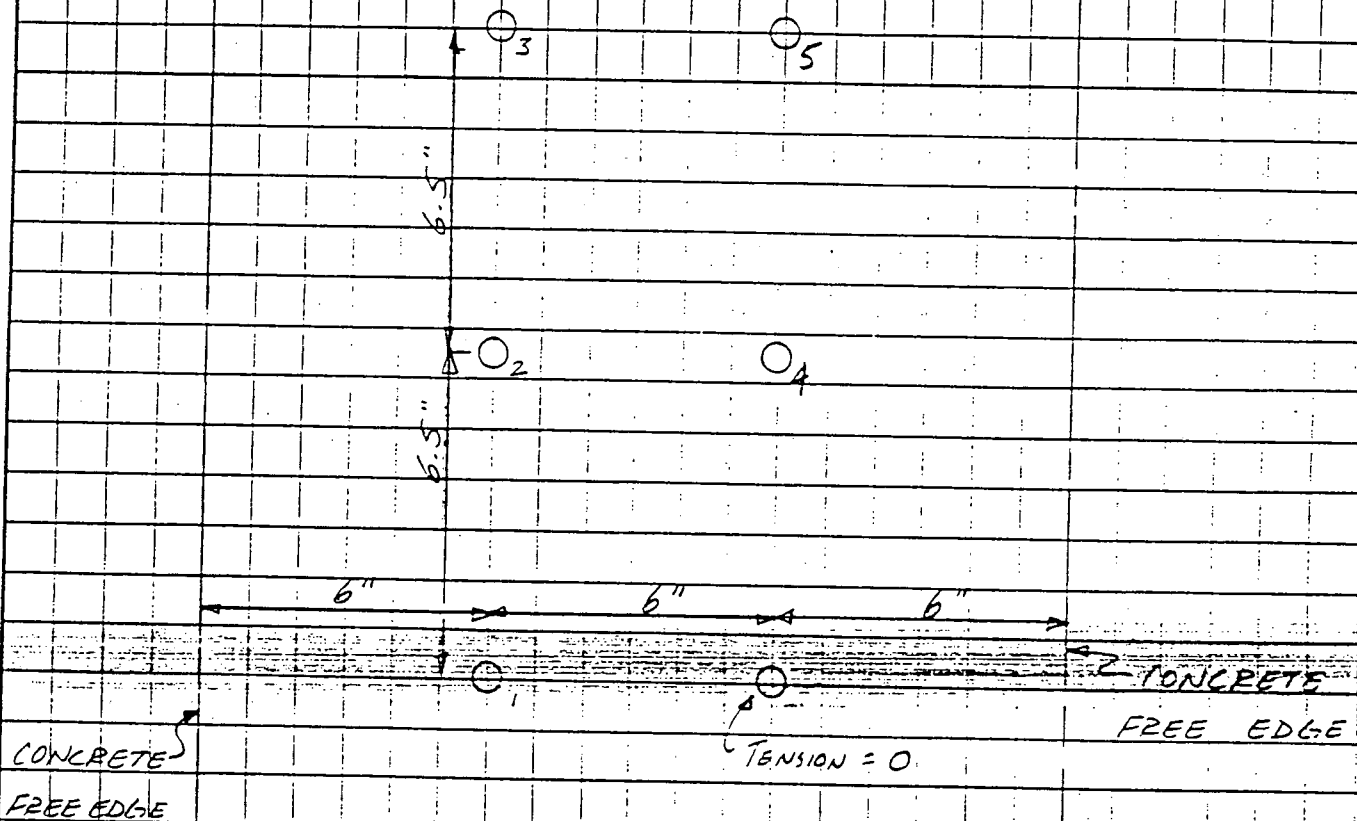
DEPT. NO.

CLIENT TVA

PROJECT WBNP UNIT 1

SUBJECT EXAMPLE CALCULATION FOR QUALIFICATION OF THERMALLY RESTRAINED STRUCTURE

11.4.4.5 CONAN MODEL



THE MODEL FOR BASEPLATE AT NODE 13 IS MOST CONSERVATIVE, THEREFORE IT WILL GOVERN BOTH PLATES. THE TENSILE LOADS ON THE BOLTS IS HIGHEST FOR NODE 13.

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SUBJECT EXAMPLE CALCULATION FOR QUALIFICATION OF THERMALLY RESTRAINED STRUCTURE

11.4.4.6 CONAN INPUT

CONCRETE CAPACITY FOR JT. 13

BPROP

1,WS,0.625,,6.375,A

9DATA

0,0,1,.19,U

0,6.5,1,.96,U

0,13,1,5.04,U

6,6.5,1,.66,U

6,13,1,2.32,U

FEDATA

-6,-2,-6,15,-

12,-2,12,15,+

CONAN OUTPUT

CONAN OUTPUT REPORT

FOR CONCRETE CAPACITY FOR JT. 13

LOAD CASE NO. 1

BOLT	MAX ALLOW TEN LOAD	ALLOWABLE LOAD	APPLIED LOAD	ALLOW/APPLIED LOAD	PULLOUT AREA
1	6.07	3.52(A)	.19	18.54	75.65
2	6.07	3.65(A)	.96	3.80	78.39
3	6.07	5.54(A)	5.04	<u>1.10</u>	119.09
4	6.07	1.90(A)	.66	2.88	40.88
5	6.07	3.50(A)	2.32	1.51	75.17

1.10 > 1 O.K.

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OFS NO. DEPT. NO.

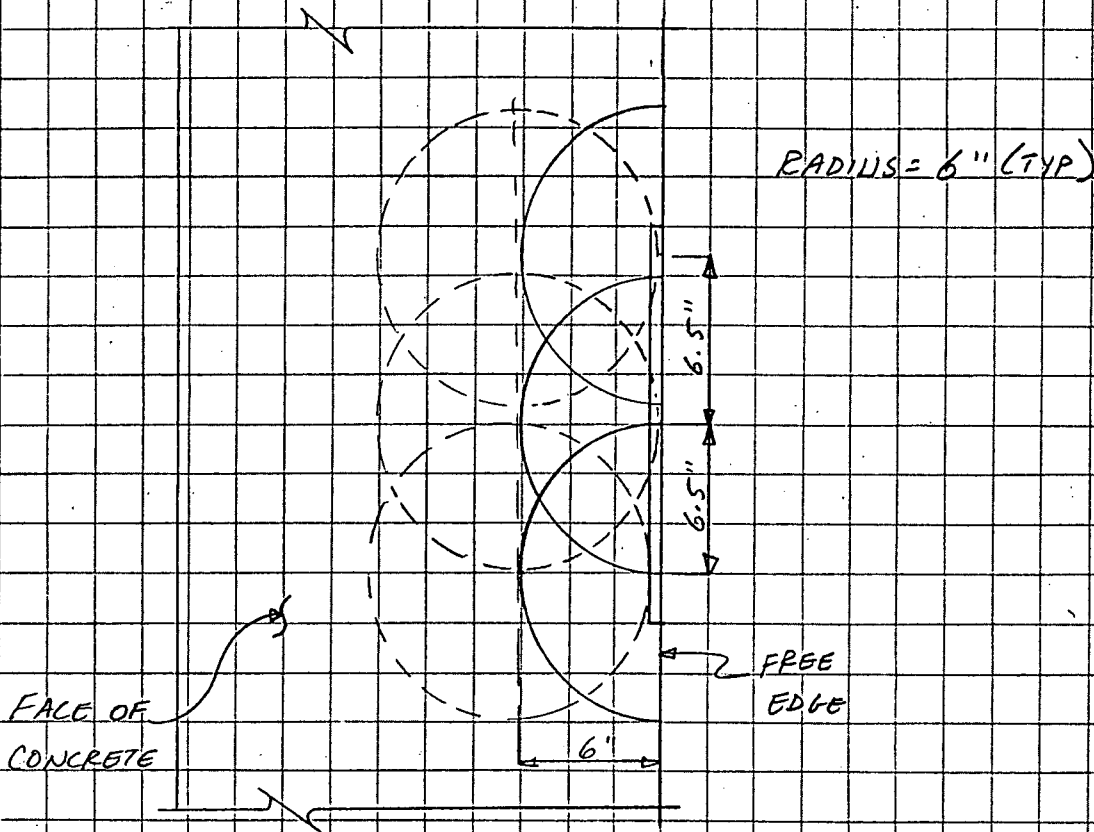
CLIENT TVA

PROJECT WBNP UNIT #1

SUBJECT EXAMPLE CALCULATION FOR QUALIFICATION OF THERMALLY RESTRAINED STRUCTURES

REFERENCES

11.4.4.7 CONCRETE EVALUATION AT FREE EDGE



DOTTED LINED CIRCLES REPRESENT BLOWOUT WHICH IS EQUIVALENT TO $0.2 T$, WHERE T IS TENSILE LOAD OF BOLT. SOLID LINED CIRCLES ARE AREAS DUE TO SHEAR LOADING.

$$\text{GROUP LOAD} = 3 \text{ HIGHEST SHEAR LOAD} + 0.2 (3 \text{ MAX TENSION})$$

$$= 360 + 250 + 109 + 0.2 (5039 + 960 + 2139)$$

$$= 23476$$

$$\text{ULTIMATE} = 3.4 \sqrt{5000} 2 \pi R^2 \text{ (CONSERVATIVE)}$$

$$= 5438016$$

$$f.s. = \frac{54380}{2347} = 23 > 4 \text{ O.K.}$$

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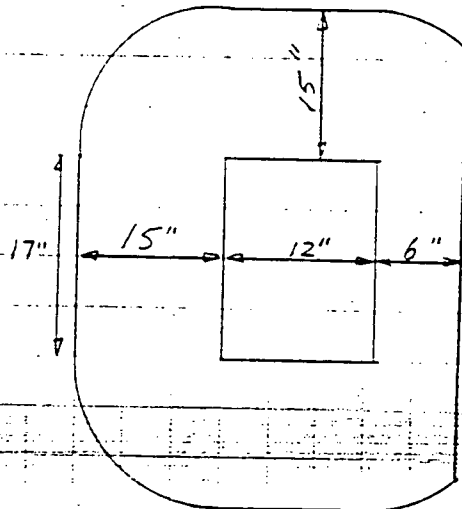
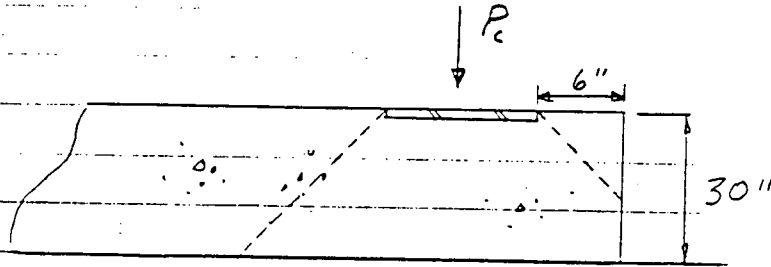
CLIENT TVA

PROJECT WBNP UNIT 1

SUBJECT EXAMPLE CALCULATION FOR QUALIFICATION OF THERMALLY RESTRAINED STRUCTURES

11.4.4.8 PUNCHING SHEAR OF CONCRETE

NODE 13 of ANSYS model



$$A = ((17 + 2(15)) + (12 + 15)(2))30$$

$$A = 3030 \text{ IN}^2$$

$$P_c = 303000 \text{ lb}$$

Ref: ACI-318-77

$$\text{ULTIMATE CAPACITY} = 0.85 \sqrt{5000} A = 728461 \text{ lb}$$

$$F.S. = \frac{728461 \text{ lb}}{303000 \text{ lb}} = 2.40$$

O.K.

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PROJECT WRNP UNIT #1

SUBJECT Example Calculation for Qualification of Thermally Restrained Structures

11.4.4.9 CONCRETE BEARING

REFERENCES

AREA OF PLATE = $12" \times 17" = 204 \text{ IN}^2$

MAX COMPRESSION = 303000 lb

$$f_{cb} = \frac{303000}{204} = 1485 \text{ psi} < 3000 \text{ psi}$$

O.K.

By SAL Date 6/8/91

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Chkd. by C. Wu Date 6/10/91

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11.5 Qualification of Member M4x13 (Example #2)

EBASCO SERVICES INCORPORATED

BY Y. Chen DATE 4-8-91 BRANCH/PROJECT ID: WCG-1-771

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CHKD. BY C. Wu DATE 4-10-91

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PROJECT WBNP - UNIT 1

SUBJECT EXAMPLE CALCULATION FOR QUALIFICATION OF THERMALLY RESTRAINED STRUCTURES

11.5 QUALIFICATION OF M4X13 BY LINEAR ACCEPTANCE CRITERIA

COMPUTER MODEL AND ANALYSIS METHODOLOGY ARE DISCUSSED IN SECTION 11.2

ANSYS COMPUTER INPUT IS LISTED IN SECTION 11.5.1. SECTIONS 11.5.2 AND SECTION 11.5.3 ARE THE CALCULATION FOR COMBINED STRESS CHECK BASED ON LINEAR CONCEPT OF DUCTILITY RATIO.

11.5.1 ANSYS COMPUTER INPUT

INPUT IS LISTED IN THE FOLLOWING SECTION 11.6.3 SHEET 67.

EBASCO SERVICES INCORPORATED

BY JChen DATE 4-10-91 Branch/project ID = WLG-1-711

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CHKD. BY CWu DATE 4-10-91

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PROJECT WBNP - UNIT 1

SUBJECT EXAMPLE CALCULATION FOR QUALIFICATION OF THERMALLY RESTRAINED STRUCTURES

REF.

11.5 QUALIFICATION OF M 4x13 BY LINEAR METHOD
(CONTINUED)

11.5.2 M 4x13 PROPERTIES : $E = 29,000 \text{ ksi}$
 $F_y = 55.3 \text{ ksi}$

AISC 8TH EDITION

$A = 3.81 \text{ in}^2$

$d = 4.0 \text{ in}$ $t_w = 0.254 \text{ in}$

$b_f = 3.94 \text{ in}$ $t_f = 0.371 \text{ in}$

$I_x = 10.5 \text{ in}^4$ $S_x = 5.24 \text{ in}^3$, $r_x = 1.66 \text{ in}$

$I_y = 3.36 \text{ in}^4$ $S_y = 1.71 \text{ in}^3$ $r_y = 0.939 \text{ in}$

$Z_y = 2.74 \text{ in}^3$

$l = 98 \text{ in}$

BY J. Ch... DATE 4-10-91

BRANCH/PROJECT ID: WCG-1-771

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CHKD. BY C.W.M. DATE 4-10-91

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PROJECT WBNP - UNIT 1

SUBJECT EXAMPLE CALCULATION FOR QUALIFICATION OF THERMAL RESTRAINED STRUCTURES

11.5.3 EVALUATION OF MEMBER BASED ON DUCTILITY RATIO

THE MAXIMUM COMBINED LINEAR STRESS IS

$$f_r = 76.0 \text{ KSI} > F_u = 58 \text{ KSI}$$

(From ANSYS analysis results)

Out of the applicable range of
the Energy Balance Method.

(f_r does include the stress due to P- Δ effect)

N.G.

⇒ Nonlinear Analysis is required

REF.

ANSYS OUTPUT

'JOCWZLI'

APPENDIX B

EBASCO SERVICES INCORPORATED

BRANCH/PROJECT ID: WCG-1-771

By SM Date 4-10-91

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11.6 Input Files for ANSYS Runs

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11.6.1 Input Files for ANSYS Linear Analysis of Member W14x30 for Example #1

***** ANSYS INPUT DATA LISTING (FILE18) *****

```

1 /PREP7
2 /TITLE, EX1YZ - THERMAL EVALUATION FOR A BEAM WITH AXIAL RESTRAINT (SSE-YZ)
3 /COM
4 /COM EXAMPLE PROBLEM FOR WORST CASE EVALUATION
5 /COM
6 /COM SSE - Y & Z; LINEAR ANALYSIS
7 /COM
8 /COM DWG 48W902, EL 730'-10.5"
9 /COM
10 /COM LATEST REVISION BY SAL 4/3/91
11 ET,1,4,,,,,1
12 EX,1,29000
13 ALPX,1,6.5E-6
14 R,1,8.85,19.6,291,13.84,6.73, * W14X30
15 RMORE,,0.38
16 TREF,70
17 /COM
18 N,1 SN,2,7.07 SN,3,16.05 SN,4,27.07 SN,5,41 SN,6,56.06
19 N,7,59.99 SN,8,67.98 SN,9,78.99 SN,10,81.01
20 N,11,82.01 SN,12,93. SN,13,103.23
21 /COM
22 E,1,2
23 EGEN,12,1,1,2
24 D,1,UX,,,,,UY,UZ,ROTX
25 D,13,ALL
26 /COM
27 NND=13 * NO. OF NODES
28 LEN=103.23 * MEMBER LENGTH
29 AREA=8.83
30 DL=AREA*.786 * DL = DEAD LOAD
31 DL=DL/1000
32 LL=(18.15)/1000. * LL = LIVE LOAD
33 /COM
34 /COM SEISMIC LOADS (SSE)
35 /COM
36 GZ=0.73 * G FOR FLOOR DL (Z)
37 GY=1.09 * G FOR FLOOR DL (Y)
38 GX=0.79 * G FOR FLOOR DL (X)
39 MMF=1.5 * MAGNIFICATION FACTOR
40 MGZ=MMF*GZ
41 MGY=MMF*GY
42 MGX=MMF*GX
43 SGZ=DL*MGZ
44 SGZ=DL+SGZ
45 SGY=DL*MGY
46 SGX=DL*MGX
47 SGXF=SGX*LEN * EQUIVALENT NODAL FORCE
48 SGXF=SGXF/NND * FACTORS FOR CONDUIT LOAD
49 /COM
50 CZ=(1)*1.87
51 CY=1.31
52 CX=0.95
53 /COM
54 /COM SSE Z & Y *****
55 /COM
56 /COM DL+LL+ FLOOR SSE (Z)
57 /COM
58 QZ=LL+SGZ
59 EP,1,1,QZ,,12,1
60 /COM

```

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11.6.1 Input Files for ANSYS Linear Analysis of Member W14x30 for Example #1 (Cont'd)

***** ANSYS INPUT DATA LISTING (FILE18) *****

```

61 /COM CONDUIT SSE (Z)
62 /COM
63 F,2,FZ,(-.2044*CY),,3
64 F,6,FZ,(-.2044*CY),,8,2
65 F,5,FZ,(-.0265*CY)
66 F,7,FZ,(-.0132*CY)
67 F,12,FZ,(-.0316*CY)
68 F,2,MX,(1.1465*CY),,3
69 F,5,MX,(.106*CY)
70 F,6,MX,(1.3125*CY),,8,2
71 F,12,MX,(.1264*CY)
72 /COM
73 /COM FLOOR SSE (Y)
74 /COM
75 EP,ALL,2,SGY
76 /COM
77 /COM CONDUIT SSE (Y)
78 /COM
79 PY1=-.2044*CY
80 MX1=1.5862*CY
81 F,2,FY,PY1,,3
82 F,2,MX,MX1,,3
83 F,6,FY,PY1,,8,2
84 F,6,MX,MX1,,8,2
85 F,5,FY,(-.0265*CY)
86 F,5,MX,(.2495*CY)
87 F,7,FY,(-.0132*CY)
88 F,7,MX,(.0388*CY)
89 F,12,FY,(-0.316*CY)
90 F,12,MX,(.2975*CY)
91 /COM
92 /COM SSE ENVELOP FPL PIPE SUPPORT 47A915-8-9
93 /COM
94 F,10,FY,-.96
95 F,10,FZ,-2.5
96 F,10,FX,2.44
97 F,10,MY,16.58
98 F,10,MZ,9.54
99 F,10,MX,3.96
100 *STAT
101 RLIST,ALL
102 FLIST,ALL
103 /SHOW
104 /PNUM,NODE,1
105 /PNUM,ELEM,1
106 EPLO
107 ITER,1,1
108 *CREAT,MAC
109 TUNIF,ARG1
110 LWRITE
111 *END
112 *USE,MAC,70
113 *USE,MAC,235
114 *USE,MAC,255
115 AFWRITE,,1
116 FINISH
117 /INPUT,27
118 FINISH

```

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11.6.1 Input Files for ANSYS Linear Analysis of Member W14x30 for Example #1 (Cont'd)

***** ANSYS INPUT DATA LISTING (FILE18) *****

```

1 /PREP7
2 /TITLE, EX1XZ - THERMAL EVALUATION FOR A BEAM WITH AXIAL RESTRAINT (SSE-XZ)
3 /COM
4 /COM EXAMPLE PROBLEM FOR WORST CASE EVALUATION
5 /COM
6 /COM SSE - X & Z; LINEAR ANALYSIS
7 /COM
8 /COM DWG 48W902, EL 730'-10.5"
9 /COM
10 /COM LATEST REVISION BY SAL 4/3/91
11 KAN,0
12 TREF,70
13 ET,1,4,,,,,,,,1
14 EX,1,29000
15 ALPX,1,6.5E-6
16 R,1,8.85,19.6,291,13.84,6.73, * W14X30
17 RMORE,0,0.376
18 /COM
19 N,1 SN,2,7.07 SN,3,16.05 SN,4,27.07 SN,5,41 SN,6,56.06
20 N,7,59.99 SN,8,67.98 SN,9,78.99 SN,10,81.01
21 N,11,82.01 SN,12,93. SN,13,103.23
22 /COM
23 E,1,2
24 EGEN,12,1,1,2
25 D,1,UX,,,,,UY,UZ,ROTX
26 D,13,ALL
27 /COM
28 NND=13 * NO. OF NODES
29 LEN=103.23 * MEMBER LENGTH
30 AREA=8.83
31 DL=AREA*.786 * DL = DEAD LOAD
32 DL=DL/1000
33 LL=(18.15)/1000. * LL = LIVE LOAD
34 /COM
35 /COM SEISMIC LOADS (SSE)
36 /COM
37 GZ=0.73 * G FOR FLOOR DL (Z)
38 GY=1.09 * G FOR FLOOR DL (Y)
39 GX=0.79 * G FOR FLOOR DL (X)
40 MMF=1.5 * MAGNIFICATION FACTOR
41 MGZ=MMF*GZ
42 MGY=MMF*GY
43 MGX=MMF*GX
44 SGZ=DL*MGZ
45 SGZ=DL+SGZ
46 SGY=DL*MGY
47 SGX=DL*MGX
48 SGXF=SGX*LEN * EQUIVALENT NODAL FORCE
49 SGXF=SGXF/NND

```

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11.6.1 Input Files for ANSYS Linear Analysis of Member W14x30 for Example #1 (Cont'd)

```

50 /COM          * FACTORS FOR CONDUIT LOAD
51 CZ=(1)+1.87
52 CY=1.31
53 CX=0.95
54 /COM
55 /COM  SSE Z & X *****
56 /COM
57 /COM  DL+LL+ FLOOR SSE (Z)
58 /COM
59 QZ=LL+SGZ
60 EP,ALL,1,QZ
61 /COM
62 /COM  CONDUIT SSE (Z)
63 /COM
64 F,2,FZ,(-.2044*CZ),,3
65 F,6,FZ,(-.2044*CZ),,8,2
66 F,5,FZ,(-.0265*CZ)
67 F,7,FZ,(-.0132*CZ)
68 F,12,FZ,(-.0316*CZ)
69 F,2,MX,(1.1465*CZ),,3
70 F,5,MX,(.106*CZ)
71 F,6,MX,(1.3125*CZ),,8,2
72 F,12,MX,(.1264*CZ)
73 /COM
74 /COM  FLOOR SSE (X)
75 /COM
76 F,ALL,FX,SGXF
77 /COM
78 /COM  CONDUIT SSE (X)
79 /COM
80 PX1=.2044*CX
81 MY1=-1.5862*CX
82 MZ1=1.146*CX
83 MZ2=1.1312*CX
84 F,2,FX,PX1,,3
85 F,2,MY,MY1,,3
86 F,2,MZ,MZ1,,3
87 F,6,FX,PX1,,8,2
88 F,6,MY,MY1,,8,2
89 F,6,MZ,MZ2,,8,2
90 F,5,FX,(-.0265*CX)
91 F,5,MY,(-.2495*CX)
92 F,5,MZ,(.106*CX)
93 F,7,FX,(.0152*CX)
94 F,7,MY,(-.0388*CX)
95 F,12,FX,(0.316*CX)
96 F,12,MY,(-.2975*CX)
97 F,12,MZ,(.126*CX)

```

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 Client TVA
 Project WBNP Unit 1
 Subject Example Calculation for Qualification of Thermally Restrained Structures

11.6.1 Input Files for ANSYS Linear Analysis of Member W14x30 for Example #1
 (Cont'd)

```

98 /COM
99 /COM SSE ENVELOP FPL PIPE SUPPORT 47A915-8-9
100 /COM
101 F,10,FY,-.96
102 F,10,FZ,-2.5
103 F,10,FX,(SGXF+2.44)
104 F,10,MY,16.58
105 F,10,MZ,9.54
106 F,10,MX,3.96
107 *STAT
108 RLIST,ALL
109 FLIST,ALL
110 /SHOW
111 /PNUM,NCOE,1
112 /PNUM,ELEM,1
113 EPLO
114 /COM
115 ITER,-1,1
116 TREF,70
117 *CREAT,MAC
118 TUNIF,ARG1
119 LWRITE
120 *END
121 *USE,MAC,70
122 *USE,MAC,235
123 *USE,MAC,255
124 AFWRITE,,1
125 FINISH
126 /INPUT,27
127 FINISH

```

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11.6.2 Input Files for ANSYS Nonlinear Analysis of Member W14x30 for Example #1

1

***** ANSYS INPUT DATA LISTING (FILE18) *****

```

1 /PREP7
2 /TITLE, EXYZ - THERMAL EVALUATION FOR A BEAM WITH AXIAL RESTRAINT (SSE-YZ)
3 /COM
4 /COM EXAMPLE PROBLEM FOR WORST CASE EVALUATION
5 /COM
6 /COM SSE - Y & Z; NONLINEAR ANALYSIS
7 /COM
8 /COM DWG 48W902, EL 730'-10.5"
9 /COM
10 /COM LATEST REVISION BY SAL 4/6/91
11 KAN,0
12 KAY,6,1
13 KNL,1
14 TREF,70
15 ET,1,24,.....1
16 EX,1,29000
17 ALPX,1,6.5E-6
18 C*** NONLINEAR MATERIAL CONSTANT
19 NL,1,13,10
20 NL,1,19,70,470
21 NL,1,25,36,36
22 NL,1,31,1500,1500
23 C*** CROSS SECTIONAL DIMENSION
24 BF=6.73
25 TP=0.385
26 D=13.84
27 TW=0.27
28 AREA=8.83
29 C***
30 AA=BF/2
31 BB=(D-TP)/2
32 QA=AA/2
33 QB=BB/2
34 *STAT
35 R,1,AA,BB,0,QA,BB,TF
36 RMORE,0,BB,TF,-QA,BB,TF
37 RMORE,-AA,BB,TF,0,BB,0
38 RMORE,0,QB,TW,0,0,TW
39 RMORE,0,QB,TW,0,-BB,TW
40 RMORE,-AA,-BB,0,-QA,-BB,TF
41 RMORE,0,-BB,TF,QA,-BB,TF
42 RMORE,AA,-BB,TF
43 C*** LINEAR PROPERTIES:
44 C*** R,1,8.85,19.6,291,13.84,6.73 * W14X30 FOR LINEAR ANALYSIS ONLY
45 /COM
46 N,1 SN,2,7.07 SN,3,16.05 SN,4,27.07 SN,5,41 SN,6,56.06
47 N,7,59.99 SN,8,67.98 SN,9,78.99 SN,10,81.01
48 N,11,82.01 SN,12,93 SN,13,103.23
49 N,100,....10
50 /COM
51 E,1,2,100
52 RP12,1,1,0
53 D,1,UX,.....,UY,UZ,ROTX
54 D,13,ALL
55 /COM
56 NND=13 * NO. OF NODES
57 LEN=103.23 * MEMBER LENGTH
58 AREA=8.83
59 DL=AREA*.786 * DL = DEAD LOAD
60 DL=DL/1000

```

By SAL Date 4/8/91Sheet 65 of 69Chkd. by C WLL Date 4-10-91OFS No. - Dept. No. -Client TVAProject WBNP Unit 1Subject Example Calculation for Qualification of Thermally Restrained Structures

11.6.2 Input Files for ANSYS Nonlinear Analysis of Member W14x30 for Example #1

(Cont'd)

1

***** ANSYS INPUT DATA LISTING (FILE18) *****

```

61 LL=(18.15)/1000. * LL = LIVE LOAD
62 /COM
63 /COM SEISMIC LOADS (SSE)
64 /COM
65 GZ=0.73 * G FOR FLOOR DL (Z)
66 GY=1.09 * G FOR FLOOR DL (Y)
67 GX=0.79 * G FOR FLOOR DL (X)
68 MMF=1.5 * MAGNIFICATION FACTOR
69 MGZ=MMF*GZ
70 MGY=MMF*GY
71 MGX=MMF*GX
72 SGZ=DL*MGZ
73 SGZ=DL+SGZ
74 SGY=DL*MGY
75 SGX=DL*MGX
76 SGXF=SGX*LEN * EQUIVALENT NODAL FORCE
77 SGXF=SGXF/NNND
78 /COM * FACTORS FOR CONDUIT LOAD
79 CZ=(1)+1.87
80 CY=1.31
81 CX=0.95
82 /COM
83 /COM SSE Z & Y *****
84 /COM
85 /COM DL+LL+ FLOOR SSE (Z)
86 /COM
87 QZ=LL+SGZ
88 EP,1,1,QZ,,12,1
89 /COM
90 /COM CONDUIT SSE (Z)
91 /COM
92 P,2,FZ,(-.2044*CZ),,3
93 P,6,FZ,(-.2044*CZ),,3,2
94 P,5,FZ,(-.0265*CZ)
95 P,7,FZ,(-.0132*CZ)
96 P,12,FZ,(-.0316*CZ)
97 P,2,MX,(1.1465*CZ),,3
98 P,5,MX,(1.106*CZ)
99 P,6,MX,(1.3125*CZ),,3,2
100 P,12,MX,(1.1264*CZ)
101 /COM
102 /COM FLOOR SSE (Y)
103 /COM
104 EP,ALL,2,SGY
105 /COM
106 /COM CONDUIT SSE (Y)
107 /COM
108 PY1=-.2044*CY
109 MX1=1.5862*CY
110 P,2,FY,PY1,,3
111 P,2,MX,MX1,,3
112 P,6,FY,PY1,,3,2
113 P,6,MX,MX1,,3,2
114 P,5,FY,(-.0265*CY)
115 P,5,MX,(.2495*CY)
116 P,7,FY,(-.0132*CY)
117 P,7,MX,(.0388*CY)
118 P,12,FY,(-0.316*CY)
119 P,12,MX,(.2975*CY)
120 /COM

```

By SAL Date 4/9/91Sheet 66 of 69Chkd. by C-WU Date 4-10-91OFS No. - Dept. No. -Client TVAProject WBNP Unit 1Subject Example Calculation for Qualification of Thermally Restrained Structures

11.6.2 Input Files for ANSYS Nonlinear Analysis of Member W14x30 for Example #1
(Cont'd)

1

***** ANSYS INPUT DATA LISTING (FILE18) *****

```
121 /COM SSE ENVELOP FPL PIPE SUPPORT 47A915-8-9
122 /COM
123 F,10,FY,.96
124 F,10,FZ,-2.5
125 F,10,FX,2.44
126 F,10,MY,16.58
127 F,10,MZ,9.54
128 F,10,MX,3.96
129 *STAT
130 FLIST,ALL
131 /SHOW
132 /PNUM,NODE,1
133 /PNUM,ELEM,1
134 EPLO
135 ITER,-20,20
136 POSTR,,1,5
137 *CREAT,TMP
138 TUNIP,ARG1
139 LWRITE
140 *END
141 *USE,TMP,70
142 RP61,,5
143 APWRITE,,1
144 FINISH
145 /INPUT,27
146 FINISH
```

By SAL Date 4/8/91Sheet 67 of 69Chkd. by C. Wu Date 4-10-91OFS No. - Dept. No. -Client TVAProject WBNP Unit 1Subject Example Calculation for Qualification of Thermally Restrained Structures

11.6.3 Input Files for ANSYS Linear Analysis of Member M4x13 for Example #2

***** ANSYS INPUT DATA LISTING (FILE18) *****

```

1 /PREP7
2 /PMCOE
3 /SHOW
4 /TITLE, HOWLAND-NEWMARK MODEL, FZ=-8.2KIPS, DT=0,400 F, SIGY=55.3KSI
5 /COM
6 /COM HOWLAND - NEWMARK MODEL
7 /COM REF. NEWMARK LOAD TESTS
8 /COM SPECIMEN 415 S 4X13.0
9 /COM E=29E3 KSI, FY=55.3 KSI
10 /COM
11 /COM INPUT: JOHN2L1
12 /COM OUTPUT: JOCW2L1
13 /COM LINEAR ANALYSIS
14 /COM PLOT FILE: SEE WCG-1-811
15 /COM
16 /COM
17 KAN,0
18 ET,1,4,.....,1
19 TREF,70
20 EX,1,29E3
21 ALPX,1,6.5E-6
22 C***
23 R,1,3.81,3.36,10.5,4.0,3.94
24 C***
25 L=98
26 C***
27 NUM=31
28 MID=(NUM+1)/2
29 ND=5
30 AL=L/4
31 N,1
32 N,ND+1,AL
33 FILL
34 N,NUM-ND,L-AL
35 FILL
36 N,NUM,L
37 FILL
38 N,NUM+1,L/2,0,5
39 E,1,2,NUM+1
40 RP30,1,1,0 * RPNN, NNN=NUM-1
41 C***
42 ITER,-1,1
43 C*** BOUNDARY CONDITIONS:
44 0,1,UX,0,,,UY,UZ,ROTX
45 0,NUM,UX,0,,,UY,UZ,ROTX
46 C*** DEFINE REPEATING LOADINGS AS MACRO
47 F,MID,FZ,-8.2
48 *CREAT,TMP
49 TUNIF,ARG1
50 LWRITE
51 *END
52 *USE,TMP,270
53 AFWRITE,,1
54 FINISH
55 /INPUT,27
56 FINISH

```

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BRANCH/PROJECT ID: WCG-1-771

By SAC Date 4-10-91Sheet 68 of 69Chkd. by id/p-cil Date 4-10-91OFS No. - Dept. No. -Client TVAProject WBNP Unit 1Subject Example Calculation for Qualification of Thermally Restrained Structures

12.0 Summary of Results

The member in Example #1 is qualified with both the Energy Balance Method (ductility ratio = $1.18 < 1.5$) and the Non-linear Acceptance Criteria (Displacement based Ductility Ratio = $2.1 < 3$). The connections and anchorages are evaluated using the results obtained from the nonlinear analysis. One of the weld connections is qualified and the other requires modification. The anchorage is also qualified.

The member in Example #2 is not qualified with the Energy Balance Method (Combined stress = 76 ksi, out of the applicable range of Energy Balance Method) while it is qualified with Nonlinear Acceptance Criteria (Displacement based Ductility Ratio = $1.9 < 3$) as documented in Calculation WCG-1-811.

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BRANCH/PROJECT ID: WCG-1-771

By SAL Date 4-10-91

Sheet 69 of 69

Chkd. by H. J. C. W. Date 4/10/91

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Subject Example Calculation for Qualification of Thermally Restrained Structures

13.0 Conclusion

The linear acceptance criteria using Energy Balance Method, with a limitation of applicability, is conservative. Energy Balance Method is not applicable for members with calculated combined stress exceeding the ultimate strength of steel ($F_u = 58$ ksi). It is expected that rigorous nonlinear analysis will be used as required for the qualification of thermally restrained structures.

BY SAL DATE 4/9/91
CHKD. BY C Wu DATE 4-10-91

CLIENT TVA

PROJECT WBNP - Unit

SUBJECT EXAMPLE CALCULATION FOR QUALIFICATION OF THERMALLY RESTRAINED STRUCTURES

14. ATTACHMENTS

TABLE OF CONTENTS

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Attachment "B" - MICROFICHE	1

TOTAL NO. OF PAGES 3

ATTACHMENT A
VERIFICATION WORKSHEET
FOR CALCULATIONS AND DRAWINGS

Task No. PWL = CA

Title: Example Calculation for Qualification of Thermally Restrained Structures

Document No. WCG-1-771

Revision 0

QUESTIONS TO BE ADDRESSED

1	Were the inputs correctly selected at the correct revision level, and incorporated into the design?
2	Are the assumptions necessary to perform the design activity adequately described and reasonable? Where necessary, are assumptions identified for subsequent reverification after the detailed design activities are completed?
3a	Are the appropriate quality requirements specified?
3b	Are the appropriate quality assurance requirements specified?
4	Are the applicable codes, standards, and regulatory requirements including issue and addenda properly identified, and are their requirements for design met?
5	Have applicable construction and operating experience been considered?
6	Have the design interface requirements been satisfied?
7	Was an appropriate design method used?
8	Is the output reasonable compared to inputs?
9	Are the specified parts, equipment, and processes suitable for the required application? Are all applicable construction specifications referenced on the drawing(s)?
10	Are the specified materials compatible with each other and with the design environmental conditions to which the materials will be exposed?
11	Have adequate maintenance features and requirements been specified?
12	Are accessibility and other design provisions adequate for performing needed maintenance and repair?
13	Has adequate accessibility been provided to perform the inservice inspection expected to be required during the plantlife?
14	Has the design properly considered radiation exposure to the public and plant personnel?
15	Is the acceptance criteria incorporated in the design document sufficient to allow verification that design requirements have been satisfactorily accomplished?
16	Have adequate preoperational and subsequent periodic test requirements been appropriately specified?
17	Are adequate handling, storage, cleaning and shipping requirements specified?
18	Are adequate identification requirements specified?
19	Are requirements for record preparation review, approval, retention, etc., adequately specified?

For Calculations, only questions 1, 2, 4, 6, 7, 8 and 15 are considered applicable.

Independent Verifier CHENG-1H WU / C Wu
Print/Sign

4-10-91
Date

EBASCO SERVICES INCORPORATED

BRANCH/PROJECT ID: WCG-1-771

ATTACHMENT "B"

By SAL Date 4-11-91

Sheet 1 of 1

Chkd. by C Wu Date 4-11-91

OFS No. - Dept. No. -

Client TVA

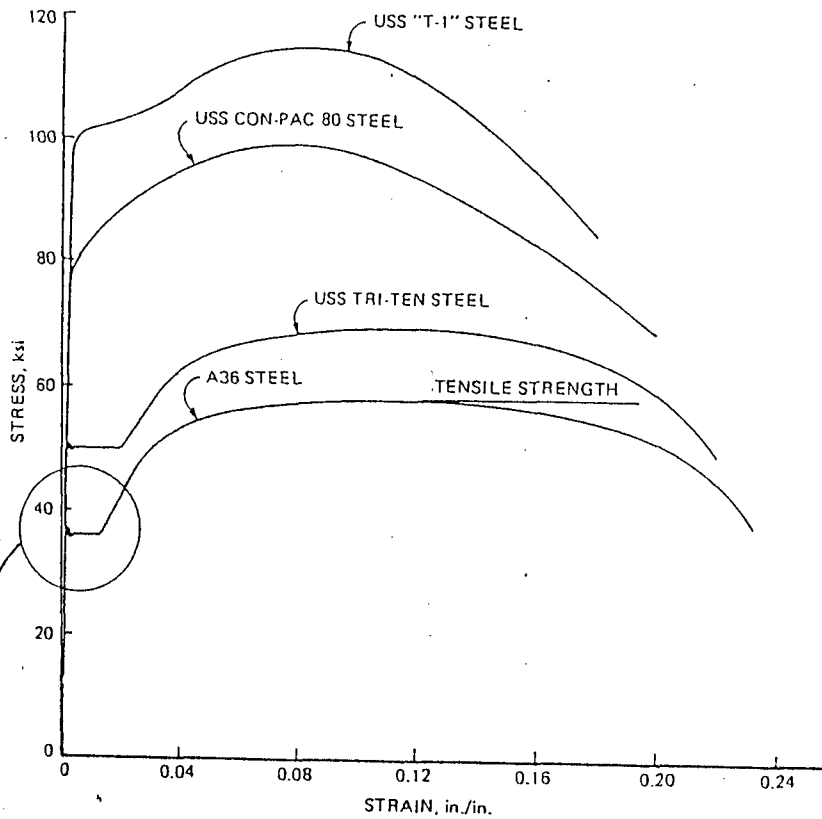
Project WBNP Unit 1

Subject Example Calculation for Qualification of Thermally Restrained Structures

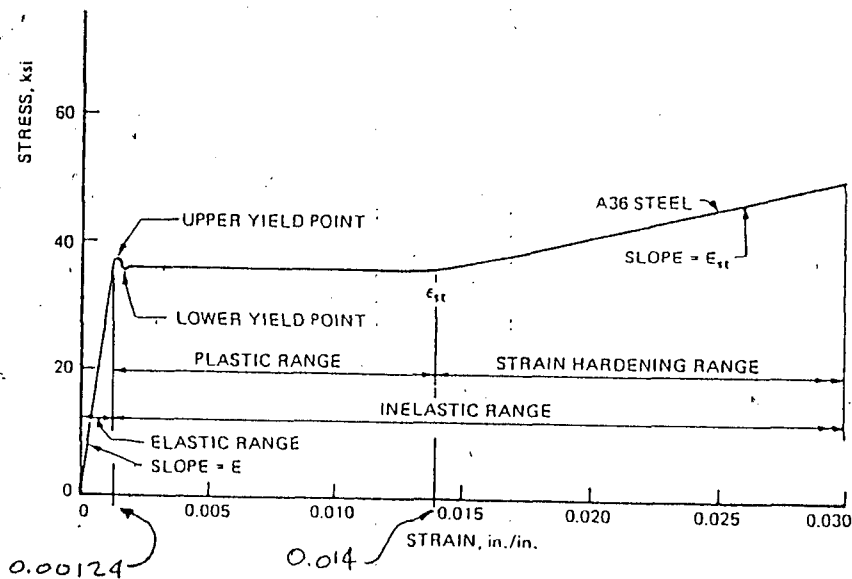
ATTACHMENT B: MICROFICHE LISTING

Description	Outputfile	Microfiche ID
LINEAR XZ	EX1XZR	TVA-F-G098484
LINEAR YZ	EX1YZR	TVA-F-G098486
NONLINEAR YZ	EX2YZR	TVA-F-G098488
LINEAR PROB#2	JOCW2L1	TVA-F-G098490

NRC REQUEST FOR ADDITIONAL INFORMATION ON THERMAL DESIGN METHODS



TYPICAL STRESS-STRAIN CURVES FOR STRUCTURAL STEELS



TYPICAL INITIAL STRESS-STRAIN CURVES

TAKEN FROM STEEL DESIGN MANUAL
 BY UNITED STATES STEEL CORPORATION

ATTACHMENT 3

NRC REQUEST FOR ADDITIONAL INFORMATION

ON THERMAL DESIGN METHODS

SHEET 1 OF 2

TAKEN FROM

EBASCO SERVICES INCORPORATED
 BRANCH/PROJECT ID: WCG-1-811

By IC Wa Date 2-3-91 Sheet 42 of 55
 Chkd. by Y Chen Date 4-4-91 OFS No. - Dept. No. -
 Client TVA
 Project WBNP Unit 1
 Subject Test Correlation Study for Thermal Use of Ductility Ratio

11.6.2 (Continued)

Figure 11.6.2A

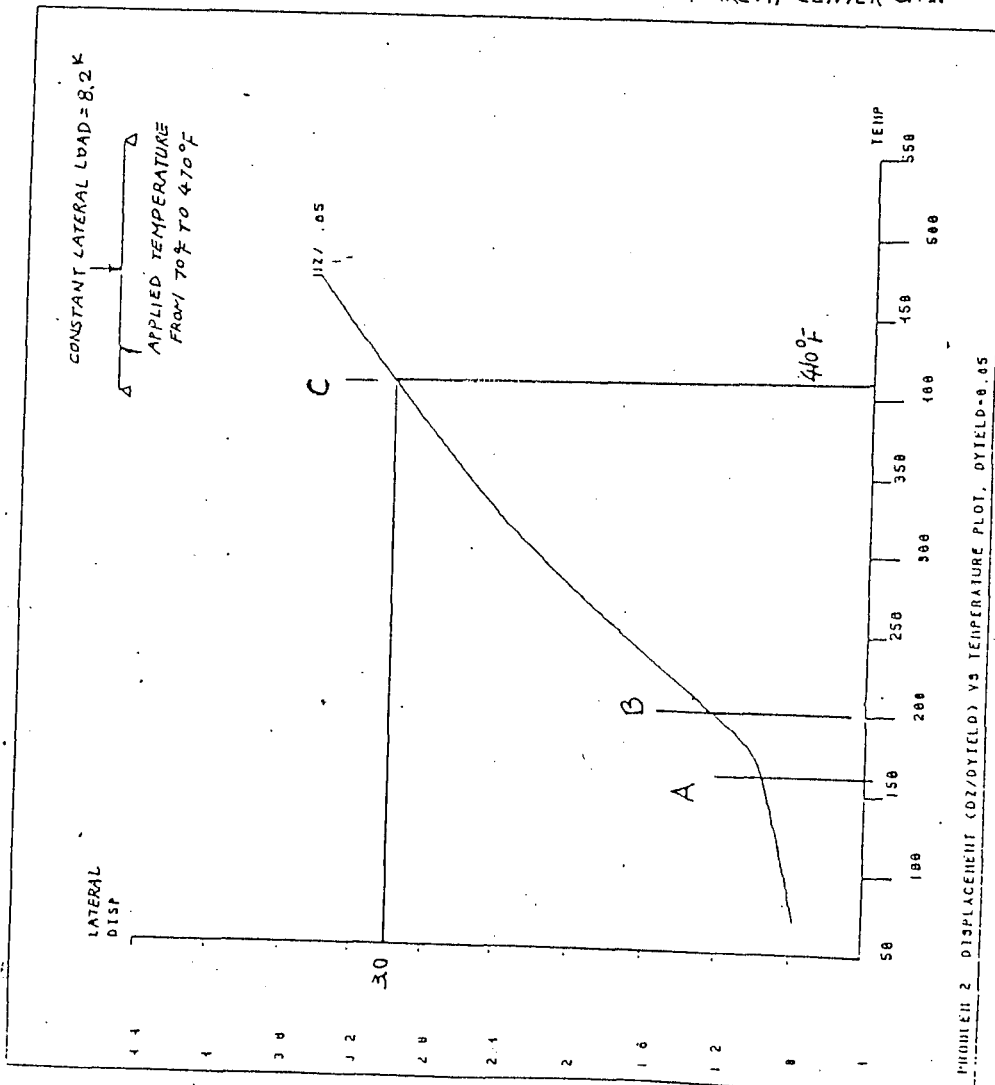
DISPLACEMENT RATIO VS TEMPERATURE - HOWLAND NEWMARK THERMAL MODEL

APPLIED CONSTANT LATERAL LOAD ($F_2 = 8.2^k$)

$$\text{DISP. RATIO} = \frac{\text{ACTUAL LATERAL DISP}}{\text{LATERAL DISP. @ YIELD}}$$

ALL DISPLACEMENTS ARE AT CENTER SPAN

ANSYS 1.5A
 MAR 28 1991
 14 18 33
 PLOT NO.
 POSI20
 ZV = 1
 DIST = .0000
 XF = .5
 YF = .5
 ZF = .5



ATTACHMENT 3

NRC REQUEST FOR ADDITIONAL INFORMATION

ON THERMAL DESIGN METHODS

SHEET 2 OF 2

EBASCO SERVICES INCORPORATED

BRANCH/PROJECT ID: WCG-1-811

By C Wu Date 4-3-91

Chkd. by M Chen Date 4-4-91

Client TVA

OFS No. - Dept. No. -

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Project WBNP Unit 1

Subject Test Correlation Study for Thermal Use of Ductility Ratio

11.6.2 (Continued)

Figure 11.6.2C

AXIAL FORCE VS TEMPERATURE - HOWLAND NEWMARK THERMAL MODEL

APPLIED CONSTANT LATERAL LOAD = 8.2K

