Submittal Documents

Seismic Analysis of the Boiler model EVG 220

November 16, 2019

For:
WEIL-McLAIN

Prepared By:
Sam Salissen, ME,PE, Ph.D.

CAE Piping ● 14271 Jeffrey Rd., Irvine, CA 92620 ● Tel: (800) 948-1460

Summary

The scope of this report is the seismic qualification, based on the structural analysis, of the boiler model EVG 220, under the seismic loads for the seismic zone 4 in the United States. The analyses are limited to the load path from the COG of the assembly to the floor and the interior parts of the boiler are not within the scope of this work.

The qualification is in accordance with the seismic design requirements of IBC 2015, ASCE 7-10 and AISC 14th edition for the seismic zone 4, for non-structural components and based on the seismic parameters used in this report.

The structural analyses carried out on the base frame assembly and based on the safety factors reported in section **5.4**, the design requirements of ASCE is met in all the analyses performed in this report.

It is concluded that the design of the main frame and seismic stands meets the design requirements of IBC 2015, ASCE 7-10 and ASME BPVC and AISC standards. This conclusion is contingence to the accuracy of the SolidWorks model and other input data provided by WEIL-McLAIN (WM) and used to build the FE models and set up the analyses (material, COG,...) appended in Appendix 1.

Revision History

Rev	Date	Scope of the revision	Created by
A	11/17/2019	First Issue	Sam Salissen

Table of Contents

APPENDICES

APPENDIX 1- Drawing with COG markup

APPENDIX 2- Anchor Bolt Calculation Report

1 Introduction

1.1 Scope

The scope of this report is the seismic qualification, based on the structural analysis, of the boiler, model EVG 220, under the seismic loads for the seismic zone 4 in the states. The analyses are limited to the load path from the COG of the assembly to the floor and the interior parts of the boiler are not within the scope of this work. The qualification is in accordance with the design requirements of IBC 2015, ASCE 7-10 and AISC.

2 Assumptions and open issues

In this chapter, assumptions and open issues are presented in two categories. The definition of each is presented below.

Open issues- Is defined as issues that must be solved, otherwise the analysis cannot be completed.

Key assumption- Is defined as assumptions that may have noticeable impact on the analysis results.

2.1 Open Issues

- No open issues exist.

2.2 Key Assumptions

No fabrication drawing of the parts and assembly were provided and the analyses are based on the SolidWorks model that is provided by WM and no responsibility of the accuracy of the model with respect to the actual assembly will be taken by the author of this report.

- The weight and the location of the center of the gravity of the boiler assembly are estimated and provided by WM, Appendix 1.
- It is assumed that the material of the base frame and the top plate are S235JR.
- It is assumed that the welds have at least the same strength as the base material (Weld strength FEXX=70ksi>54ksi for base material) based on ASME allowable stress in welds under shear and tension is 0.3 *tensile strength =21000psi. In this case it is lower than the allowable stress of the in the members (AISC). So, no weld analysis will be performed in this work.

4 *Analyses' model*

4.1 The extent of the model

The FE model is built based on the SoildWorks model of the boiler, provided by WM. However, just the (seismic) loads bearing parts are used to build the FE- model. Flexible joint (same stiffness as the base materials) and contact elements are used to join the parts, simulating the bolts and welds, see Fig. 2.

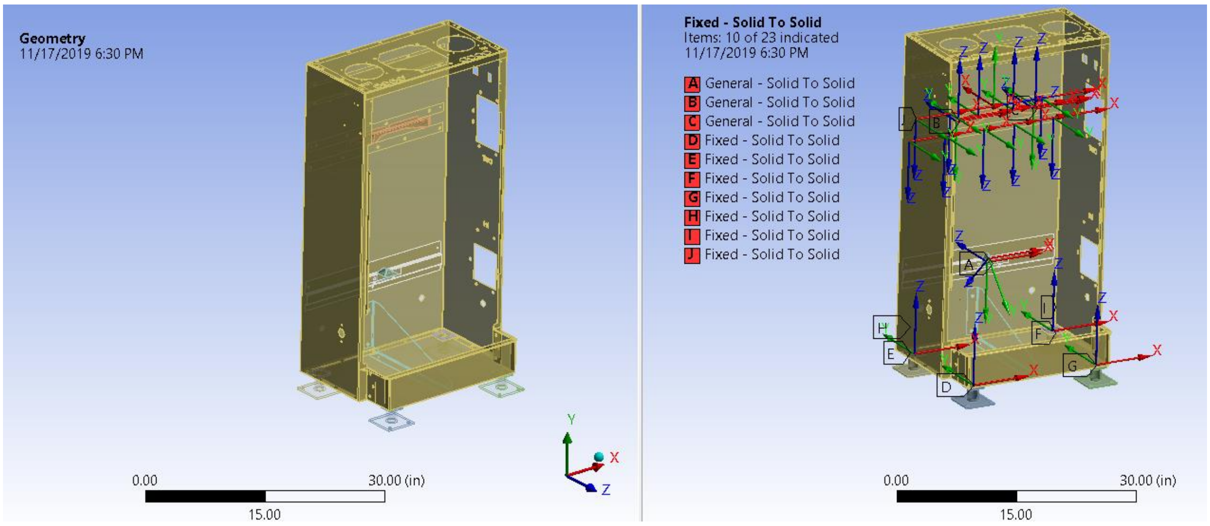


Figure **2-** FE model of the boiler and joint/contact definitions

4.2 Material data

The material used in the construction of the boiler is governed under the internationally recognized ANSI, ASTM standards for solid shapes and the AWS standards for welding wire. The specific alloys of steel bar, tube, plate, round and channel used in the construction include **S235JR** Carbon Steel and listed below.

S235JR Carbon Steel: E=2.9E+7 psi, S_Y=34,000 psi

5.4 *Results Evaluation*

Minimum required strength specified in ASCE (LRFD design approach) is obtained in the analyses of the assembly carried out in sections 5.1 to 5.4, (minimum safety factor of 1 for LRFD load). The stresses reported in section 5 are the local stresses and the average stress through the thickness of the members are much lower and that can be shown by stress linearization through the thickness. However, since even the maximum local peak stresses don't exceed the allowable values, the stress linearization work is skipped here.

6 *Conclusion*

Seismic analysis of the boiler, model EVG 220, is carried out in this report and based on the safety factors reported in section **5.4**, minimum required strength factor is obtained in all the analyses performed in this report.

It is concluded that the design of the structure of the boiler EVG 220 meets the design requirements of AISC, ASCE7-10 and IBC 2012 standards.

7 References

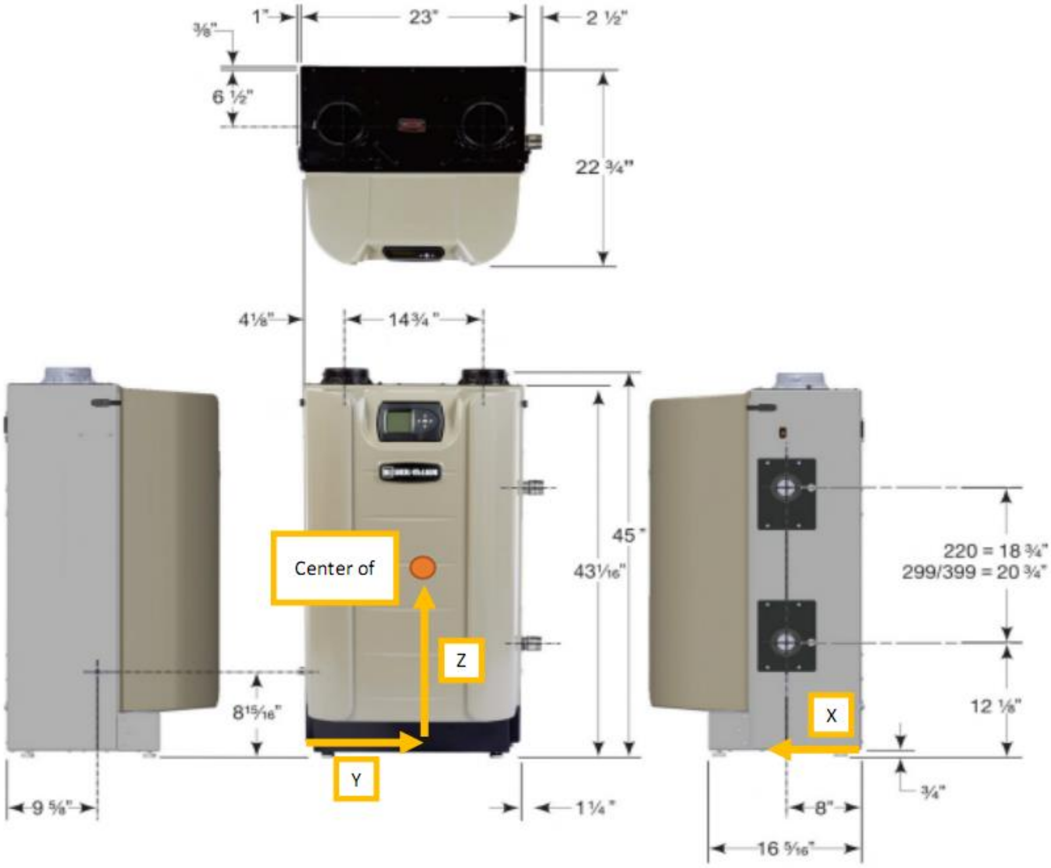
[1]- IBC 2012.

[2]- AISC 14^{th} Edition.

[3]- ASCE 7-10.

APPENDIX ***1-*** Drawing with COG markup

EVG	Operating Weight (lbs.)	Dry Weight (lbs.)	Center of Mass (Dry Weight) X (inches)	Center of Mass (Dry Weight) Y (inches)	Center of Mass (Dry Weight) Z (inches)
220	190	153	7.6	12.1	23.1
299/300	255	199	8.0	12.3	21.8
399	255	201	7.5	12.3	22.0



Appendix ***2-*** Anchor Bolt Calculation

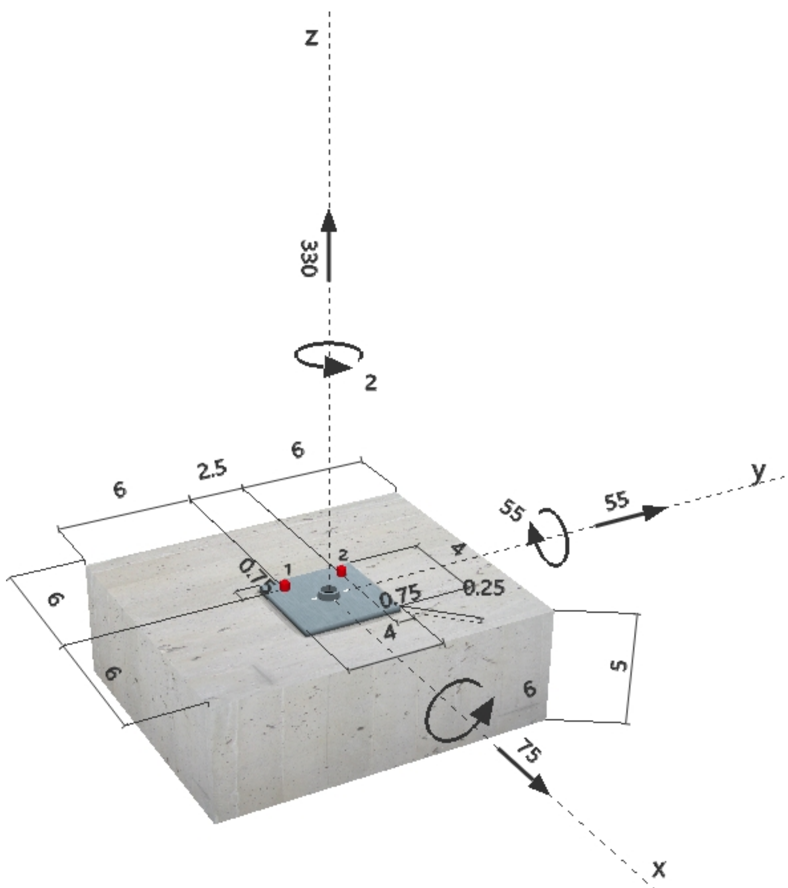
Company:	CAE PIPING INC.	Page:	1
Specifier:	SAM SALISSEN	Project:	ANCHOR EVG 220
Address:		Sub-Project I Pos. No.:	FOR WEIL-McLAIN
Phone I Fax:	|	Date:	11/17/2019
E-Mail:	SSALISSEN@CAEPIPING.COM		

Specifier's comments:

1 Input data

Anchor type and diameter:	**Kwik Bolt TZ - CS 3/8 (2 3/4)**
Effective embedment depth:	$h_{ef,act}$ = 2.750 in., h_{nom} = 3.063 in.
Material:	Carbon Steel
Evaluation Service Report:	ESR-1917
Issued I Valid:	6/1/2016 | 5/1/2017
Proof:	Design method ACI 318-14 / Mech.
Stand-off installation:	e_b = 0.000 in. (no stand-off); t = 0.250 in.
Anchor plate:	l_x x l_y x t = 4.000 in. x 4.000 in. x 0.250 in.; (Recommended plate thickness: not calculated
Profile:	Round HSS, Steel pipe (AISC); (L x W x T) = 0.840 in. x 0.840 in. x 0.109 in.
Base material:	cracked concrete, 2500, f_c' = 2500 psi; h = 5.000 in.
Installation:	**hammer drilled hole, Installation condition: Dry**
Reinforcement:	tension: condition B, shear: condition B; no supplemental splitting reinforcement present edge reinforcement: none or < No. 4 bar
Seismic loads (cat. C, D, E, or F)	Tension load: yes (17.2.3.4.3 (d)) Shear load: yes (17.2.3.5.3 (c))

Geometry [in.] & Loading [lb, ft.lb]



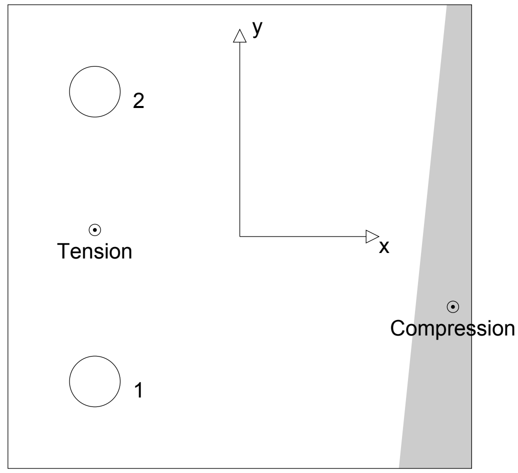
2 Load case/Resulting anchor forces

Load case: Design loads

Anchor reactions [lb]
Tension force: (+Tension, -Compression)

Anchor	Tension force	Shear force	Shear force x	Shear force y
1	196	80	75	27
2	214	28	0	27

max. concrete compressive strain: 0.03 [‰]
max. concrete compressive stress: 131 [psi]
resulting tension force in (x/y)=(-1.250/0.057): 410 [lb]
resulting compression force in (x/y)=(1.839/-0.606): 80 [lb]



3 Tension load

	Load N_{ua} [lb]	Capacity ϕN_n [lb]	Utilization $\beta_N = N_{ua}/\phi N_n$	Status
Steel Strength*	214	4875	5	OK
Pullout Strength*	214	1538	14	OK
Concrete Breakout Strength**	410	2429	17	OK

* anchor having the highest loading **anchor group (anchors in tension)

3.1 Steel Strength

N_{sa} = ESR value refer to ICC-ES ESR-1917
$\phi N_{sa} \geq N_{ua}$ ACI 318-14 Table 17.3.1.1

Variables

$A_{se,N}$ [in.^{2}]	f_{uta} [psi]
0.05	125000

Calculations

N_{sa} [lb]
6500

Results

N_{sa} [lb]	ϕ_{steel}	$\phi_{nonductile}$	ϕN_{sa} [lb]	N_{ua} [lb]
6500	0.750	1.000	4875	214

Company:	CAE PIPING INC.	Page:	3
Specifier:	SAM SALISSEN	Project:	ANCHOR EVG 220
Address:		Sub-Project I Pos. No.:	FOR WEIL-McLAIN
Phone I Fax:	|	Date:	11/17/2019
E-Mail:	SSALISSEN@CAEPIPING.COM		

3.2 Pullout Strength

$N_{pn,f'_c} = N_{p,2500}\ \lambda_a \sqrt{\frac{f'_c}{2500}}$ refer to ICC-ES ESR-1917

$\phi\ N_{pn,f'_c} \geq N_{ua}$ ACI 318-14 Table 17.3.1.1

Variables

f'_c [psi]	λ_a	$N_{p,2500}$ [lb]
2500	1.000	3155

Calculations

$\sqrt{\frac{f'_c}{2500}}$
1.000

Results

N_{pn,f'_c} [lb]	$\phi_{concrete}$	$\phi_{seismic}$	$\phi_{nonductile}$	$\phi\ N_{pn,f'_c}$ [lb]	N_{ua} [lb]
3155	0.650	0.750	1.000	1538	214

3.3 Concrete Breakout Strength

$N_{cbg} = \left(\frac{A_{Nc}}{A_{Nc0}}\right) \psi_{ec,N}\ \psi_{ed,N}\ \psi_{c,N}\ \psi_{cp,N}\ N_b$ ACI 318-14 Eq. (17.4.2.1b)

$\phi\ N_{cbg} \geq N_{ua}$ ACI 318-14 Table 17.3.1.1

A_{Nc} see ACI 318-14, Section 17.4.2.1, Fig. R 17.4.2.1(b)

$A_{Nc0} = 9\ h_{ef}^2$ ACI 318-14 Eq. (17.4.2.1c)

$\psi_{ec,N} = \left(\frac{1}{1 + \frac{2\ e'_N}{3\ h_{ef}}}\right) \leq 1.0$ ACI 318-14 Eq. (17.4.2.4)

$\psi_{ed,N} = 0.7 + 0.3\left(\frac{c_{a,min}}{1.5 h_{ef}}\right) \leq 1.0$ ACI 318-14 Eq. (17.4.2.5b)

$\psi_{cp,N} = \text{MAX}\left(\frac{c_{a,min}}{c_{ac}}, \frac{1.5 h_{ef}}{c_{ac}}\right) \leq 1.0$ ACI 318-14 Eq. (17.4.2.7b)

$N_b = k_c\ \lambda_a \sqrt{f'_c}\ h_{ef}^{1.5}$ ACI 318-14 Eq. (17.4.2.2a)

Variables

h_{ef} [in.]	$e_{c1,N}$ [in.]	$e_{c2,N}$ [in.]	$c_{a,min}$ [in.]	$\psi_{c,N}$
2.750	0.000	0.057	6.000	1.000

c_{ac} [in.]	k_c	λ_a	f'_c [psi]
4.125	17	1.000	2500

Calculations

A_{Nc} [in.^{2}]	A_{Nc0} [in.^{2}]	$\psi_{ec1,N}$	$\psi_{ec2,N}$	$\psi_{ed,N}$	$\psi_{cp,N}$	N_b [lb]
88.69	68.06	1.000	0.986	1.000	1.000	3876

Results

N_{cbg} [lb]	$\phi_{concrete}$	$\phi_{seismic}$	$\phi_{nonductile}$	$\phi\ N_{cbg}$ [lb]	N_{ua} [lb]
4982	0.650	0.750	1.000	2429	410

4 Shear load

	Load V_{ua} [lb]	Capacity ϕV_n [lb]	Utilization $\beta_V = V_{ua}/\phi V_n$	Status
Steel Strength*	80	1466	6	OK
Steel failure (with lever arm)*	N/A	N/A	N/A	N/A
Pryout Strength*	80	3536	3	OK
Concrete edge failure in direction y+**	93	1632	6	OK

* anchor having the highest loading **anchor group (relevant anchors)

4.1 Steel Strength

$V_{sa,eq}$ = ESR value refer to ICC-ES ESR-1917

$\phi V_{steel} \geq V_{ua}$ ACI 318-14 Table 17.3.1.1

Variables

$A_{se,V}$ [in.^{2}]	f_{uta} [psi]
0.05	125000

Calculations

$V_{sa,eq}$ [lb]
2255

Results

$V_{sa,eq}$ [lb]	ϕ_{steel}	$\phi_{nonductile}$	ϕV_{sa} [lb]	V_{ua} [lb]
2255	0.650	1.000	1466	80

4.2 Pryout Strength

$V_{cp} = k_{cp} \left[\left(\frac{A_{Nc}}{A_{Nc0}} \right) \psi_{ed,N} \, \psi_{c,N} \, \psi_{cp,N} \, N_b \right]$ ACI 318-14 Eq. (17.5.3.1a)

$\phi V_{cp} \geq V_{ua}$ ACI 318-14 Table 17.3.1.1

A_{Nc} see ACI 318-14, Section 17.4.2.1, Fig. R 17.4.2.1(b)

$A_{Nc0} = 9 \, h_{ef}^2$ ACI 318-14 Eq. (17.4.2.1c)

$\psi_{ec,N} = \left(\frac{1}{1 + \frac{2 \, e'_N}{3 \, h_{ef}}} \right) \leq 1.0$ ACI 318-14 Eq. (17.4.2.4)

$\psi_{ed,N} = 0.7 + 0.3 \left(\frac{c_{a,min}}{1.5 h_{ef}} \right) \leq 1.0$ ACI 318-14 Eq. (17.4.2.5b)

$\psi_{cp,N} = \text{MAX}\left(\frac{c_{a,min}}{c_{ac}}, \frac{1.5 h_{ef}}{c_{ac}} \right) \leq 1.0$ ACI 318-14 Eq. (17.4.2.7b)

$N_b = k_c \, \lambda_a \sqrt{f'_c} \, h_{ef}^{1.5}$ ACI 318-14 Eq. (17.4.2.2a)

Variables

k_{cp}	h_{ef} [in.]	$e_{c1,N}$ [in.]	$e_{c2,N}$ [in.]	$c_{a,min}$ [in.]
2	2.750	0.000	0.000	6.000

$\psi_{c,N}$	c_{ac} [in.]	k_c	λ_a	f'_c [psi]
1.000	4.125	17	1.000	2500

Calculations

A_{Nc} [in.^{2}]	A_{Nc0} [in.^{2}]	$\psi_{ec1,N}$	$\psi_{ec2,N}$	$\psi_{ed,N}$	$\psi_{cp,N}$	N_b [lb]
44.34	68.06	1.000	1.000	1.000	1.000	3876

Results

V_{cp} [lb]	$\phi_{concrete}$	$\phi_{seismic}$	$\phi_{nonductile}$	ϕV_{cp} [lb]	V_{ua} [lb]
5051	0.700	1.000	1.000	3536	80

Company:	CAE PIPING INC.	Page:	5
Specifier:	SAM SALISSEN	Project:	ANCHOR EVG 220
Address:		Sub-Project I Pos. No.:	FOR WEIL-McLAIN
Phone I Fax:	|	Date:	11/17/2019
E-Mail:	SSALISSEN@CAEPIPING.COM		

4.3 Concrete edge failure in direction y+

$V_{cbg} = \left(\frac{A_{Vc}}{A_{Vc0}}\right) \psi_{ec,V}\ \psi_{ed,V}\ \psi_{c,V}\ \psi_{h,V}\ \psi_{parallel,V}\ V_b$ ACI 318-14 Eq. (17.5.2.1b)

$\phi\ V_{cbg} \geq V_{ua}$ ACI 318-14 Table 17.3.1.1

A_{Vc} see ACI 318-14, Section 17.5.2.1, Fig. R 17.5.2.1(b)

$A_{Vc0} = 4.5\ c_{a1}^2$ ACI 318-14 Eq. (17.5.2.1c)

$\psi_{ec,V} = \left(\frac{1}{1 + \frac{2e_V'}{3c_{a1}}}\right) \leq 1.0$ ACI 318-14 Eq. (17.5.2.5)

$\psi_{ed,V} = 0.7 + 0.3\left(\frac{c_{a2}}{1.5c_{a1}}\right) \leq 1.0$ ACI 318-14 Eq. (17.5.2.6b)

$\psi_{h,V} = \sqrt{\frac{1.5c_{a1}}{h_a}} \geq 1.0$ ACI 318-14 Eq. (17.5.2.8)

$V_b = \left(7\left(\frac{l_e}{d_a}\right)^{0.2} \sqrt{d_a}\right) \lambda_a \sqrt{f_c'}\ c_{a1}^{1.5}$ ACI 318-14 Eq. (17.5.2.2a)

Variables

c_{a1} [in.]	c_{a2} [in.]	e_{cV} [in.]	$\psi_{c,V}$	h_a [in.]
4.000	6.000	0.000	1.000	5.000

l_e [in.]	λ_a	d_a [in.]	f_c' [psi]	$\psi_{parallel,V}$
2.750	1.000	0.375	2500	1.000

Calculations

A_{Vc} [in.^{2}]	A_{Vc0} [in.^{2}]	$\psi_{ec,V}$	$\psi_{ed,V}$	$\psi_{h,V}$	V_b [lb]
60.00	72.00	1.000	1.000	1.095	2554

Results

V_{cbg} [lb]	$\phi_{concrete}$	$\phi_{seismic}$	$\phi_{nonductile}$	$\phi\ V_{cbg}$ [lb]	V_{ua} [lb]
2332	0.700	1.000	1.000	1632	93

5 Combined tension and shear loads

β_N	β_V	ζ	Utilization $\beta_{N,V}$ [%]	Status
0.169	0.057	5/3	7	OK

$\beta_{NV} = \beta_N^{\zeta} + \beta_V^{\zeta} <= 1$

6 Warnings

- Load re-distributions on the anchors due to elastic deformations of the anchor plate are not considered. The anchor plate is assumed to be sufficiently stiff, in order not to be deformed when subjected to the loading! Input data and results must be checked for agreement with the existing conditions and for plausibility!
- Condition A applies when supplementary reinforcement is used. The Φ factor is increased for non-steel Design Strengths except Pullout Strength and Pryout strength. Condition B applies when supplementary reinforcement is not used and for Pullout Strength and Pryout Strength. Refer to your local standard.
- Refer to the manufacturer's product literature for cleaning and installation instructions.
- Checking the transfer of loads into the base material and the shear resistance are required in accordance with ACI 318 or the relevant standard!
- An anchor design approach for structures assigned to Seismic Design Category C, D, E or F is given in ACI 318-14, Chapter 17, Section 17.2.3.4.3 (a) that requires the governing design strength of an anchor or group of anchors be limited by ductile steel failure. If this is NOT the case, the connection design (tension) shall satisfy the provisions of Section 17.2.3.4.3 (b), Section 17.2.3.4.3 (c), or Section 17.2.3.4.3 (d). The connection design (shear) shall satisfy the provisions of Section 17.2.3.5.3 (a), Section 17.2.3.5.3 (b), or Section 17.2.3.5.3 (c).
-
- Hilti post-installed anchors shall be installed in accordance with the Hilti Manufacturer's Printed Installation Instructions (MPII). Reference ACI 318-14, Section 17.8.1.

Company:	CAE PIPING INC.	Page:	6
Specifier:	SAM SALISSEN	Project:	ANCHOR EVG 220
Address:		Sub-Project I Pos. No.:	FOR WEIL-McLAIN
Phone I Fax:	|	Date:	11/17/2019
E-Mail:	SSALISSEN@CAEPIPING.COM		

Fastening meets the design criteria!

Company:	CAE PIPING INC.	Page:	7
Specifier:	SAM SALISSEN	Project:	ANCHOR EVG 220
Address:		Sub-Project I Pos. No.:	FOR WEIL-McLAIN
Phone I Fax:	|	Date:	11/17/2019
E-Mail:	SSALISSEN@CAEPIPING.COM		

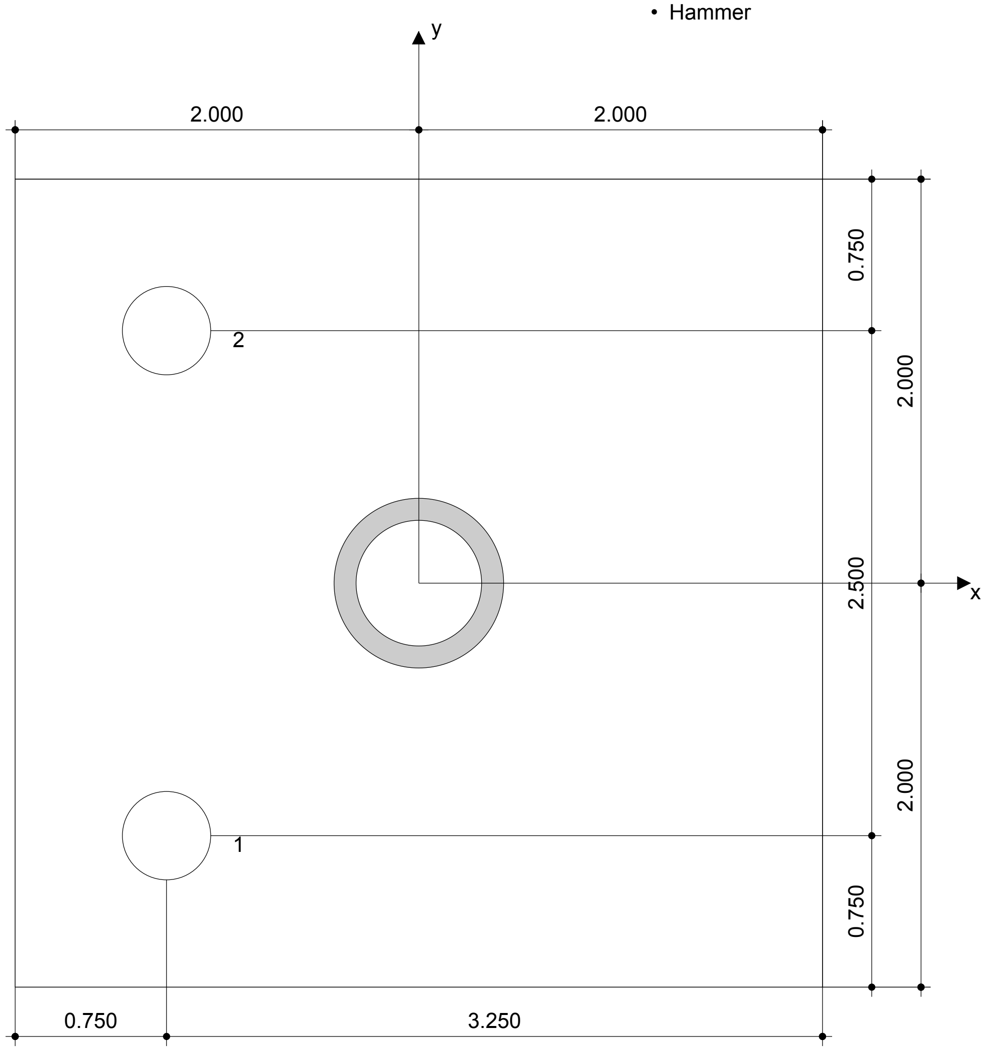
7 Installation data

Anchor plate, steel: -
Profile: Round HSS, Steel pipe (AISC); 0.840 x 0.840 x 0.109 in.
Hole diameter in the fixture: d_f = 0.438 in.
Plate thickness (input): 0.250 in.
Recommended plate thickness: not calculated
Drilling method: Hammer drilled
Cleaning: Manual cleaning of the drilled hole according to instructions for use is required.

Anchor type and diameter: Kwik Bolt TZ - CS 3/8 (2 3/4)
Installation torque: 25.000 ft.lb
Hole diameter in the base material: 0.375 in.
Hole depth in the base material: 3.375 in.
Minimum thickness of the base material: 5.000 in.

7.1 Recommended accessories

Drilling	Cleaning	Setting
• Suitable Rotary Hammer	• Manual blow-out pump	• Torque wrench
• Properly sized drill bit		• Hammer



Coordinates Anchor in.

Anchor	x	y	c_{-x}	c_{+x}	c_{-y}	c_{+y}
1	-1.250	-1.250	6.000	6.000	6.000	8.500
2	-1.250	1.250	6.000	6.000	8.500	6.000

Company:	CAE PIPING INC.	Page:	8
Specifier:	SAM SALISSEN	Project:	ANCHOR EVG 220
Address:		Sub-Project I Pos. No.:	FOR WEIL-McLAIN
Phone I Fax:	|	Date:	11/17/2019
E-Mail:	SSALISSEN@CAEPIPING.COM		

8 Remarks; Your Cooperation Duties

- Any and all information and data contained in the Software concern solely the use of Hilti products and are based on the principles, formulas and security regulations in accordance with Hilti's technical directions and operating, mounting and assembly instructions, etc., that must be strictly complied with by the user. All figures contained therein are average figures, and therefore use-specific tests are to be conducted prior to using the relevant Hilti product. The results of the calculations carried out by means of the Software are based essentially on the data you put in. Therefore, you bear the sole responsibility for the absence of errors, the completeness and the relevance of the data to be put in by you. Moreover, you bear sole responsibility for having the results of the calculation checked and cleared by an expert, particularly with regard to compliance with applicable norms and permits, prior to using them for your specific facility. The Software serves only as an aid to interpret norms and permits without any guarantee as to the absence of errors, the correctness and the relevance of the results or suitability for a specific application.
- You must take all necessary and reasonable steps to prevent or limit damage caused by the Software. In particular, you must arrange for the regular backup of programs and data and, if applicable, carry out the updates of the Software offered by Hilti on a regular basis. If you do not use the AutoUpdate function of the Software, you must ensure that you are using the current and thus up-to-date version of the Software in each case by carrying out manual updates via the Hilti Website. Hilti will not be liable for consequences, such as the recovery of lost or damaged data or programs, arising from a culpable breach of duty by you.