Pacific Gas and Electric Company®

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March 28, 2014

PG&E Letter DCL-14-027

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555-0001

10 CFR 50.55a

Docket No. 50-275, OL-DPR-80
Diablo Canyon Power Plant (DCPP) Unit 1
Request for Relief from the Requirements of Appendix IX of ASME Section XI, 2001 Edition with 2003 Addendum

Dear Commissioners and Staff:

Pursuant to 10 CFR 50.55a(a)(3)(ii), Pacific Gas and Electric Company (PG&E) hereby requests NRC approval for relief from the requirements of Appendix IX, "*Mechanical Clamping Devices for Class 2 and 3 Piping Pressure Boundary*," of ASME Section XI, 2001 Edition with 2003 Addendum. Paragraph (c)(2) of Article IX-1000 of Appendix IX prohibits the use of clamping devices on "portions of a piping system that forms the containment boundary." PG&E requests approval to use a clamping device on piping that forms part of the containment boundary. Paragraph (a) of Article IX-6000 contains monitoring requirements including that "the area immediately adjacent to the clamping device shall be examined using a volumetric method." PG&E requests approval to use increased visual monitoring of the clamping device in lieu of the volumetric method. This request, contained in Enclosure 1, applies to Diablo Canyon Power Plant (DCPP), Unit 1. PG&E has also provided additional background information regarding the repair and monitoring plans in Enclosure 1.

The NRC staff previously approved similar requests to use a clamping device on piping that forms part of the containment boundary for Turkey Point Nuclear Power Plant, Unit 4 (TAC No. MC7338) and for Waterford Steam Electric Station, Unit 3 (TAC No. MC8542), for relief from the requirements of paragraph 1.0(a) of ASME Section XI, Code Case N-523-2, "*Mechanical Clamping Devices for Class 2 and 3 Piping*," when it was unconditionally approved by the NRC in Regulatory Guide 1.147, Revision 13, prior to Code Case N-523-2 being incorporated into Appendix IX of ASME Section XI Code.

PG&E requests authorization of this relief request no later than March 31, 2014, to allow DCPP to remain in Mode 1 and prevent additional dose received by personnel and unnecessary cycles to plant systems and components that would result from a unit shutdown and subsequent restart.

PG&E makes regulatory commitments (as defined by NEI 99-04) in this letter. The commitments are contained in Enclosure 2.

If you have any questions regarding the information enclosed, or other inservice inspection program activities, please contact Mr. Tom Baldwin at (805) 545-4720.

Sincerely,

Barry S. Allen

Barry S. Allen
Site Vice President

kjse/4328/SAPN 50619608
Enclosures
cc: Diablo Distribution
cc/enc: Peter J. Bamford, NRR Project Manager
Marc L. Dapas, NRC Region IV Administrator
Thomas R. Hipschman, NRC Senior Resident Inspector
State of California, Pressure Vessel Unit

ASME Code Section XI Inservice Inspection Program
Request for Relief from the Requirements of
Appendix IX of ASME Section XI, 2001 Edition with 2003 Addendum

**10 CFR 50.55a Request for Proposed Alternative
in Accordance with 10 CFR 50.55a(a)(3)(ii)**

**Hardship or Unusual Difficulty without Compensating Increase
in Level of Quality and Safety**

1. ASME Code Component(s) Affected

The American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section XI, Class 2, Diablo Canyon Power Plant (DCPP) Unit 1, 3/4-inch vent valve line off Main Steam System Line 1066. The leak is located in a socket weld:

Code Cat/Item	Description	Size
C-H C7.10	Socket weld for vent valve off Main Steam System Line 1066	3/4-inch carbon steel

2. Applicable Code Edition and Addenda

The ASME Boiler and Pressure Vessel Code (Code) of record is Section XI, 2001 Edition including Addenda through 2003, for the current 10-year inservice inspection (ISI) interval and the Repair/Replacement Program.

3. Applicable Code Requirements

The applicable ASME Code requirements are ASME Section XI, 2001 Edition with 2003 Addendum, Article IX-1000 of Appendix IX, "*Mechanical Clamping Devices for Class 2 and 3 Piping Pressure Boundary.*"

Paragraph (c) of Article IX-1000 states in part "Clamping devices shall not be used on the following: (1) Class 1 piping; (2) portions of a piping system that forms the containment boundary; ..."

4. Impracticality of Compliance

Pursuant to 10 CFR 50.55a(a)(3)(ii), an alternative from the requirements of Appendix IX of ASME Section XI, 2001 Edition with 2003 Addendum, is requested. DCPP Unit 1 is currently in Mode 1 and PG&E has determined that a permanent ASME Code Section XI repair is not possible during Mode 1 or 2 operation as the leak is unisolable and subject to full steam generator (SG) pressure. PG&E intends to implement a code repair in accordance with Appendix IX of ASME Section XI, however, relief is required to allow application of a mechanical clamping device to piping that forms the containment boundary and to utilize increased visual monitoring in lieu of volumetric method monitoring.

Background

On March 26, 2014, during main steam system ISI pressure test walkdowns, a nonradioactive steam pin-hole leak was identified at the socket weld interface of the 3/4-inch Vent Valve MS-1-908. This vent line is downsteam of the relief valves in Main Steam Line 1066. This vent valve line is an ASME Class 2 line located outside the reactor containment and upstream of the main steam isolation valve on Main Steam Lead 1-4. The piping for the vent valve line is 3/4-inch, Schedule 80 (0.154-inch nominal wall thickness), seamless carbon steel pipe, A106 Grade B piping. The design and operating conditions for vent valve line are as follows:

Design conditions: 1085 PSIG and 600°F
Operating conditions (full power): 790 PSIG and 519°F
Operating conditions (Startup): 1005 PSIG and 547°F

The leak is located in the socket weld for the riser to Vent Valve MS-1-908. Since the time of discovery, the leak has been monitored and has remained stable. Based on visual examination of the defect area using a ten times magnification instrument, the leak source was determined to be a triangular shape with approximately 0.050-inch diameter in the largest dimension and volumetric in nature.

An extent of condition has been completed on DCPP Unit 1 through piping walkdowns and no other similar steam leaks have been identified.

The through-wall pinhole defect appears to be the result of a welding abnormality that has corroded through the wall. Based on the location of the leak (45 degrees off the extrados point of the elbow above) and the orientation and shape of the defect in relation to the cantilever load, the defect was not caused by fatigue. An ultrasonic (UT) examination demonstrated that the base material in the pipe stub next to the pinhole defect is approximately 0.18 inches and complies with minimum wall requirements and is of sufficient thickness to install a mechanical clamp device. A radiographic examination of the weld was

performed on March 28, 2014, using a 58 curie iridium source and computed radiography phosphor film. Multiple exposures with varying angles were taken to assure that the flaw was properly characterized to the extent possible. The temperature of the piping (approximately 500°F) and the active steam leak limited the accessibility of the area of investigation. The images were interpreted by a PG&E Level III radiographer and the flaw appears to initiate on the root of the fillet weld, and propagate radially along the lower fusion line of the weld, adjacent to the coupling. At this location, the fitting was scaled to be 0.191 inches thick and the pipe is 0.133 inches thick. There is visible pullback between the pipe and the fitting, as the pipe is not bottomed out in the socket. This is an appropriate engagement for this type of coupling. By interpreting the different radiographic views, it was determined that the flaw has volumetric aspects which are not commonly found with fatigue cracks. The radiographic density of the flaw is much greater than is expected to be found in a fatigue crack, and the direction of flaw propagation appears to follow the fusion zone without any other orientation. These attributes, when considered with no measurable vibration on the pipe and the off-axis location of the flaw, do not indicate a fatigue-type crack.

On March 28, 2014, a vibration inspection survey was performed to determine if steam line vibration exists in the vicinity of Vent Valve MS-1-908. The inspection was performed using a SKF Microloganalyzer over a frequency span of 2 to 10 Hertz at locations above the leak, on the body of the elbow, and below the leak on the larger transition member that is attached to the main steam pipe. The survey was performed at a radial azimuth directly above and below the leak, and at angles 45 degrees both left and right of the leak. The observed vibration amplitudes were very low and the spectral content showed random broadly distributed energy across the entire frequency span and no dominant peaks. The inspection did not identify any dominant specific frequencies of vibration within the frequency span of 2 to 10 Hertz.

A calculation for the allowable flaw size at the fillet weld of the main steam vent line was performed using a linear elastic fracture mechanics method using guidance in IWB-3612 of Section XI of ASME Boiler & Pressure Vessel Code. It was conservatively assumed the weld was a flux weld and that the flaw is in the circumferential direction. The loadings considered include design pressure, deadweight, and seismic events. The allowable flaw length for the normal/upset condition is 1.16 inches. All seismic loads were included regardless of whether they are for normal/upset or emergency/faulted conditions. The allowable flaw size of 1.16 inches significantly exceeds the existing flaw size of 0.050 inches in the largest dimension. Therefore, the existing flaw is bounded by the allowable flaw length of 1.16 inches and structural integrity of the vent line is confirmed.

Subsequent crack growth is not expected to be significant. For the location of Vent Valve MS-1-908, the mechanism considered for crack growth would be fatigue. For fatigue crack growth to occur, cyclic loading is required. The leak location is subjected to cyclic pressure from plant startup-shutdown events,

which are very limited in number. Thermal stress cycling is expected to be insignificant because of the vent line configuration. The only other cyclic load would be from vibration. Based on the vibration inspection of Vent Valve MS-1-908 performed on March 28, 2014, there are no dominant specific frequencies of vibration within the frequency span of 2 to 10 Hertz in the vicinity of the Vent Valve MS-1-908. In addition, based on the location of the leak and the orientation and shape of the defect in relation to the load on the pipe, the cause of the defect is not due to fatigue. Therefore due to the lack of cyclic events and cyclic stress, crack growth is not expected to be significant through the end of the operating cycle.

The mechanical clamping device has been designed to encapsulate the 3/4-inch vent line pipe and conform to the geometry of the pipe configuration. Therefore, even in the unlikely event that flaw growth caused failure of the vent line pipe, the clamp will provide the needed restraint to maintain the piping configuration and prevent it from separating.

PG&E performed an operability determination to address the impact of the steam leak located on Main Steam Line 1066 on containment integrity and the requirements of Technical Specification (TS) 3.6.1, Containment. This determination considered dose consequences due to secondary steam leakage from the steam system during a postulated accident. The accident considered limiting is the Steam Generator Tube Rupture (SGTR) accident. PG&E has an administrative procedure for controlling and evaluating plant leakage. The Administrate Procedure AD4.ID2, "Plant Leakage Evaluation," contains a limit of 0.5 lbm/sec for un-isolable leakage from secondary side systems within the containment isolation boundary outside containment. Calculations demonstrate that the leak on Main Steam Line 1066 at the current leak rate (0.015 lbm/sec) are well within the administrative limit of 0.5 lbm/sec for secondary side systems within the containment isolation boundary outside containment and do not adversely effect the consequence results of the dose analyses. Therefore, the primary containment remains operable and applicable 10 CFR 100 consequences limits continue to be met.

PG&E has determined that a permanent ASME Code Section XI repair is not possible during power operation since the leak is unisolable and subject to full SG pressure. Therefore, PG&E intends to implement a code repair in accordance with Appendix IX of ASME Section XI. However, relief is required from Paragraph (c) of Article IX-1000 of Appendix IX and Paragraph (a) of Article IX-6000 of Appendix IX as described below.

5. <u>Proposed Alternative and Basis for Use</u>

According to Paragraph (c) of Article IX-1000 of Appendix IX of ASME Section XI, 2001 Edition with 2003 Addendum, clamping devices shall not be used on portions of a piping system that forms the containment boundary. Also,

Paragraph (a) of Article IX-6000 contains monitoring requirements including that "the area immediately adjacent to the clamping device shall be examined using a volumetric method."

Pursuant to 10 CFR 50.55a(a)(3)(ii), PG&E requests relief from the containment boundary restriction of Paragraph (c) of Article IX-1000 of Appendix IX of ASME Section XI and relief from the volumetric method monitoring requirements of Paragraph (a) of Article IX-6000, so that repair may be performed on the vent valve line using a mechanical clamping device that meets the remaining provisions of Article IX-1000 of Appendix IX of ASME Section XI.

As required by Paragraph (a) of Article IX-1000 of Appendix IX of ASME Section XI, the proposed clamping device will not remain in service beyond the next scheduled DCPP Unit 1 refueling in Fall of 2015, at which time the defect will be repaired or piping replaced.

A permanent ASME Code repair is not possible during plant operation in Modes 1 or 2 as the affected piping cannot be isolated. Although a mechanical clamping device would provide an acceptable repair to control leakage and ensure continued structural integrity of the vent valve line, Paragraph (c) of Article IX-1000 of Appendix IX of ASME Section XI prohibits its' use in a containment boundary. Under these conditions, it would be necessary for DCPP, Unit 1, to shutdown from Mode 1 to Mode 5 in order to perform a permanent ASME Code repair. When the plant is shutdown from Mode 1 to Mode 5 and then returned to Mode 1, plant inspections and TS surveillances need to be performed which results in total radiological dose to personnel exceeding 150 mrem. In addition, a shutdown and subsequent restart unnecessarily cycles plant systems and components. The additional dose received by plant personnel and unnecessary cycling of plant systems and components represents a hardship without compensating increase in plant quality and safety.

PG&E plans to use a mechanical clamping device to control the leak and to ensure structural integrity of the piping. The proposed mechanical clamping device is to be designed to comply with the design requirements of Article IX-3000 of Appendix IX and the material requirements of Article IX-4000 of Appendix IX. These requirements meet or exceed the design rating of the piping. The clamping device enclosure material is carbon steel (SA 516 GR 70). Therefore, the clamping device is suitable for the intended application and capable of performing its specified design function. A drawing of the clamping device is contained in Enclosure 3 to this letter. The design for the clamping device including stress calculations is contained in Enclosure 4. A sealant will be used within the clamping device to eliminate the leak path. The sealant temperature rating is 600°F which is within the design rating of the piping. The degradation temperature of the sealant is 1200°F. PG&E has performed an evaluation of the weight (76 pounds) of the clamping device on Main Steam Line 1066, including consideration of seismic loads during a design basis seismic

event, on the piping stress analysis and concluded the piping will be acceptable and perform its design function. Main Steam Line 1066 is well supported with a bilateral restraint adjacent to the vent line.

Mandatory Appendix IX Article IX-1000 Paragraph (d) requires a Repair/Replacement plan shall be developed in accordance with IWA-4150, and shall identify the defect characterization method, design requirements, and monitoring requirements. PG&E is developing a Repair/Replacement plan in accordance with IWA-4150 for the steam leak on Main Steam Line 1066.

Paragraph (c) of Article IX 1000

PG&E understands that the basis for the limitation in Paragraph (c) of Article IX-1000 for use of a clamping device in piping that forms the containment boundary is concerns that temporary clamp devices may not be able to prevent interactions between the affected line and the containment atmosphere during accident conditions.

The main steam system containment isolation design utilizes a closed system inside containment and isolation valves outside containment. The mechanical clamping device will be located on a small 3/4-inch pipe outside containment, and the closed system will continue to provide a passive containment isolation barrier. The normal operating pressure at the location of the mechanical clamping device is in the range of 790 - 1005 psig. The clamping device is located in an area that is readily accessible for inspection. As such, positive verification of the leak-tight integrity of the mechanical clamping device will be accomplished by visual observations. The clamping device will be visually monitored for leakage once per day (24 hours). This significantly exceeds the requirements of paragraph (c) of Article IX-6000 of Appendix IX, which states "The clamping device shall be monitored for leakage at least weekly. Any leakage at any time shall be dispositioned."

The use of a mechanical clamping device on a portion of a system which is considered containment boundary is acceptable based on the system being continuously pressurized at pressures significantly greater than containment post-accident conditions as well as ambient atmospheric pressure. Because this is the case, leakage during operation would be readily detected by visual observation. In addition, since the clamping device is suitable for the intended application, capable of performing its specified design function, and not directly exposed to containment atmosphere during an accident conditions, the main steam vent line will continue to perform its containment boundary safety function.

Any observed leakage during operation will be evaluated according to the current administrate procedure requirements that limit unisolable leakage from secondary side systems within the containment isolation boundary outside

containment to less than 0.5 lbm/sec to ensure there is no adverse effect on the consequence results of the dose analyses.

Paragraph (a) of Article IX-6000

Paragraph (a) of Article IX-6000 contains monitoring requirements associated with use of a clamping device. Paragraph (a) states: "Except as permitted by (b) below, or where precluded by the clamping device configuration, the area immediately adjacent to the clamping device shall be examined using a volumetric method. The examination frequency shall not exceed three months, and shall be specified in the Repair/Replacement Plan. When the examination reveals defect growth to a size that exceeds the projected size determined by IX-3100(b), the defect shall be removed or reduced to an acceptable size." PG&E requests relief from the volumetric method monitoring requirements of paragraph (a) of Article IX-6000. In order to ensure structural integrity of the main steam vent line containing the defect, the clamping device being installed on the main steam vent line will entirely encapsulate the vent line piping section containing the flaw (see drawing in Enclosure 3). This configuration will prevent access to perform a volumetric method inspection of the piping immediately adjacent to the clamping device.

Paragraph (c) of Article IX-6000 of Appendix IX of ASME Section XI states: "The clamping device shall be monitored for leakage at least weekly. Any leakage at any time shall be dispositioned." The clamping device will be visually monitored for leakage once per day (24 hours). This significantly exceeds the requirements of Paragraph (c) of Article IX-6000 and provides equivalent assurance that any leakage will be promptly identified without the performance of volumetric method inspections. In addition, Paragraph (a) of Article IX-6000 allows an exception to performing examinations of the area immediately adjacent to the clamping device using a volumetric method, when it is precluded by the clamping device configuration.

Therefore, the use of the proposed alternative will continue to provide an acceptable level of quality and safety.

6. Duration of Proposed Alternative

The proposed relief will apply until the next DCPP, Unit 1, refueling outage in fall of 2015 (Refueling Outage 19).

7. Precedents

Similar requests to use a clamping device on piping that forms part of the containment boundary have been previously approved for relief from the requirements of Paragraph 1.0(a) of ASME Section XI, Code Case N-523-2, "*Mechanical Clamping Devices for Class 2 and 3 Piping*," when it was

unconditionally approved by the NRC in Regulatory Guide 1.147, Revision 13, prior to Code Case N-523-2 being incorporated into Appendix IX of ASME Section XI Code:

1. Waterford Steam Electric Station, Unit 3 (TAC No. MC8542) dated February 9, 2006 (ADAMS Accession No. ML060460590).

2. Turkey Point Nuclear Power Plant, Unit 4 (TAC No. MC7338)

8. References

1. Article IX-1000 of Appendix IX, "*Mechanical Clamping Devices for Class 2 and 3 Piping Pressure Boundary*," of ASME Section XI, 2001 Edition with 2003 Addendum.

Regulatory Commitments

Regulatory Commitments

Commitment 1

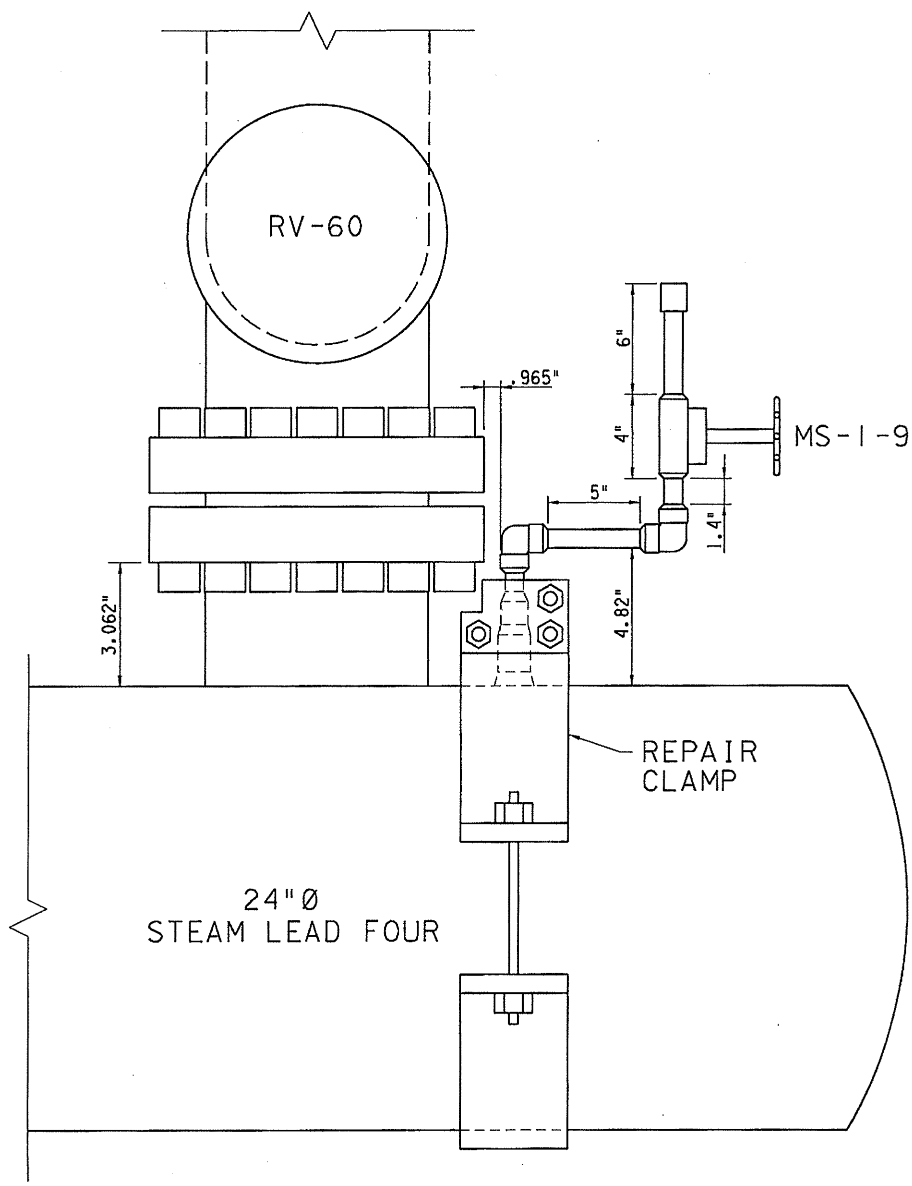
The clamping device will be visually monitored for leakage once per day (24 hours).

Commitment 2

As required by Paragraph (a) of Article IX-1000 of Appendix IX of ASME Section XI, the proposed clamping device will not remain in service beyond the next scheduled DCPP, Unit 1, refueling in fall 2015, at which time the defect will be repaired or piping replaced.

Clamping Device Drawing

Clamping Device Drawing



Clamp Design Calculation

(18 pages)

TEAM® Industrial Services

Registration# F-003143

Engineering Department. Tel: (281) 388-5695 Fax: (281) 388-5690

ROUTING SLIP & COVER SHEET FOR NUCLEAR SAFETY RELATED JOBS

Branch Work Order #: 212-00359	Status: Priority	Caller: Eddie Rivera
Customer: PG& E Diablo Canyon	Safety Review #: 288166	Engr Order #: 288166EM

	Name:	Signature:	Date:	Time:
Data Taken By:	Matthew Yasensky	[signature]	3/26/2014	11:10pm
Designed By:	Matthew Yasensky	[signature]	3/27/2014	6:00pm
Verified By:	Adam Gutierrez	[signature]	3/27/2014	10:45pm
Shop Received By:				
QC Received By:				

Specifications:			
Design Pressure:	1085 psi	Design Temperature:	600 °F
Service:	Steam	Torque Value:	1/4" studs: 7.63 ft*lbs 5/8" studs: 125.21 ft*lbs
Total Weight:	75.76 lb	Void:	7.56 in^3 BC 11.35 in^3 AC
Sealant Type:	2X	Notification Number:	50619608
Maximum Injection Pressur	1627.5 PSI + STATIC		
Equipment Number:	MS-1-908		

QC FINAL INSPECTION REQUIRED

Nuclear - Safety Related
CMTRs and COCs Required
PMI Required

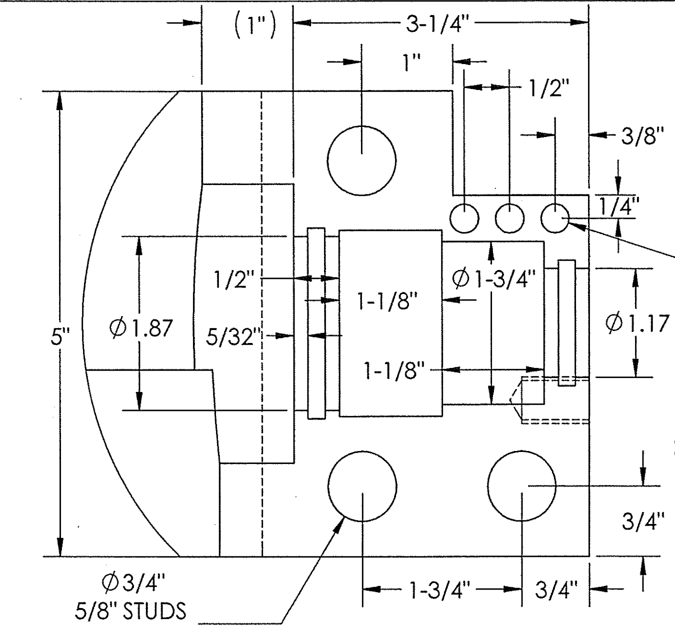
STATE OF TEXAS
CHRISTIAN G. LARSEN
93539
LICENSED
PROFESSIONAL ENGINEER

[signature]

3/28/14

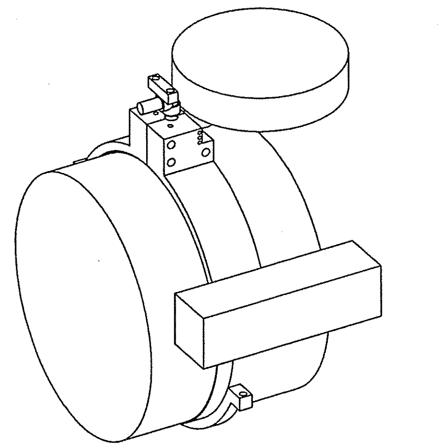
Rev. 3/3/2010

Safety First
In Everything We Do



DETAIL A
SCALE 2 : 3

CLAMP



ASSEMBLY
SCALE 1 : 12

STATE OF TEXAS
CHRISTIAN G. LARSEN
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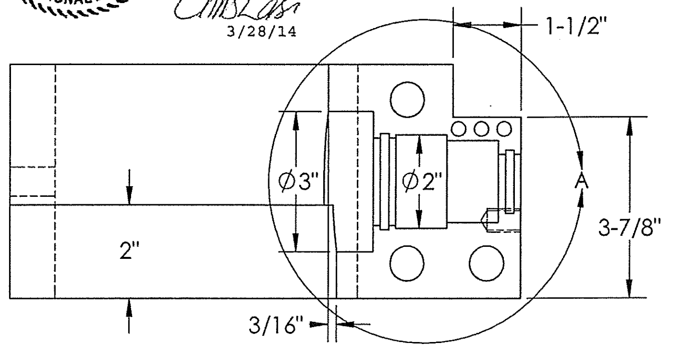
LICENSED
PROFESSIONAL ENGINEER

Chris Larsen
3/28/14



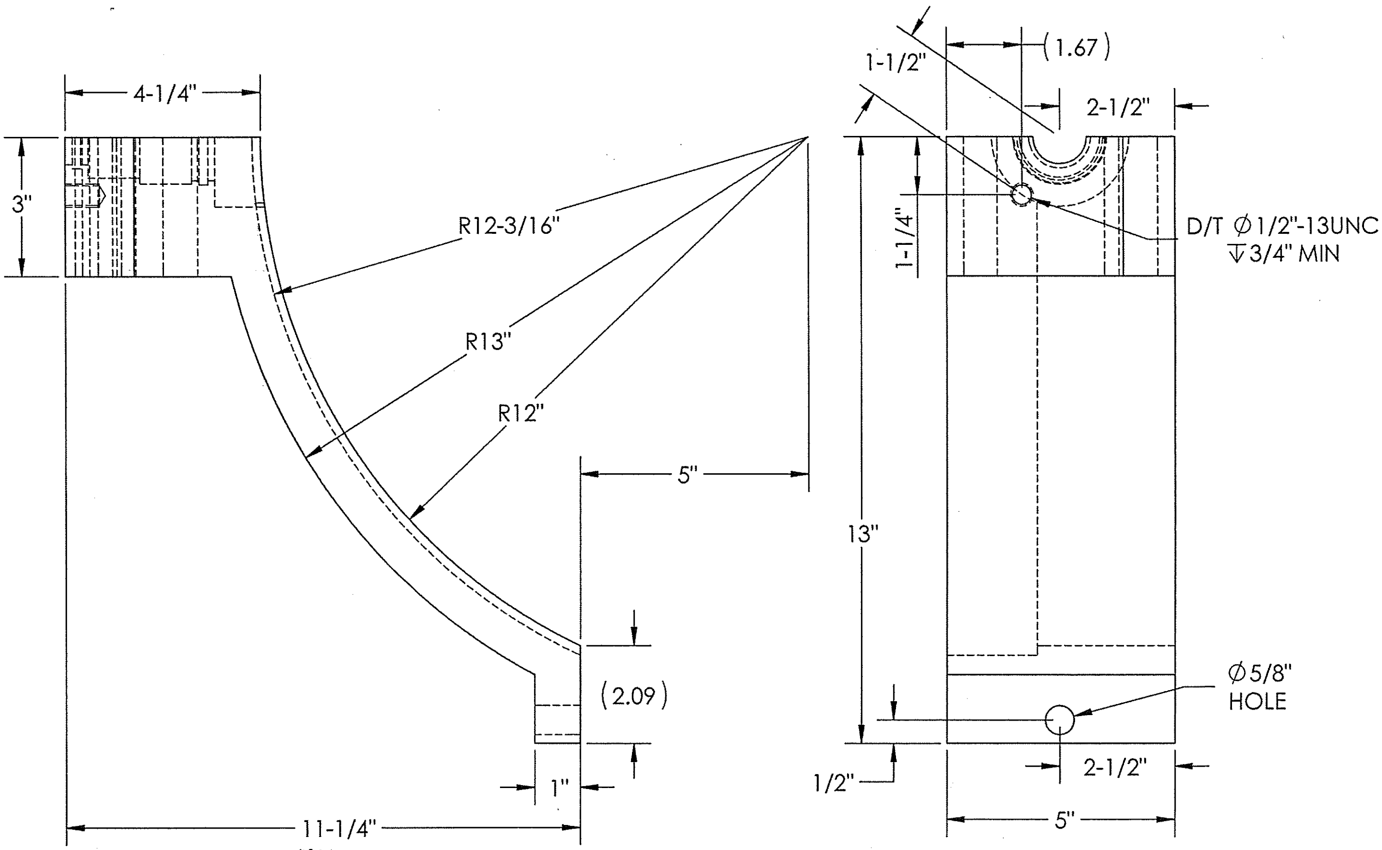
EQUIPMENT#: MS-1-908
NOTIFICATION #:50619608

***VOID:
VOID BC: 7.63 IN^3
VOID AC: 11.35 IN^3

1. APPROVED TO MANUFACTURE
2. 3/16 X 0.09 TUBING GROOVES IN BORES
3. INSTALL COPPER TUBING
4. COMMERCIAL GRADE DEDICATION REQUIRED
5. PMI REQUIRED
6. STAMP ORDER NUMBER ON ALL PIECES OF CLAMP
7. D/T (4) 1/4-NPT INJ PORTS IN CAVITY (VENT, FILL)
8. (2) HALVES REQ.
9. NUCLEAR SAFETY RELATED
10. DO NOT PAINT
11. NO WELDED ALLOWED
12. MAXIMUM INJECTION PRESSURE: 1627.5 PSI + STATIC
13. ALL DIM TYP UNLESS NOTED

TEAM® Industrial Services, Inc.

ENGINEERING ORDER# 288166EM		UNLESS OTHERWISE SPECIFIED:	REGISTRATION # F-003143 PERIMETER VOL IN^3 BC WT. 75.76 LBS VOL *** IN^3 BC
DRAWING # N/A		ALL DIMENSIONS TYPICAL:	PG&E DIABLO CANYON
TECO PART # N/A		MACHINED SURFACES: ∇	BAR CLAMP
WPS: N/A		BREAK SHARP CORNERS: 0.005"	
DRAWN BY: MWY	3/27/14	TOLERANCES: FRACTIONAL ±1/32 ANGULAR ±1/2° TWO PLACE DECIMAL ±0.01 THREE PLACE DECIMAL ±0.005	
CHECKED BY: AG	3/27/14		SIZE A REV 0
APPROVED BY:		ALL DIMENSIONS IN INCHES	SCALE: 1:3 SHEET 1 OF 17



STATE OF TEXAS
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ChrisLarsen
3/28/14

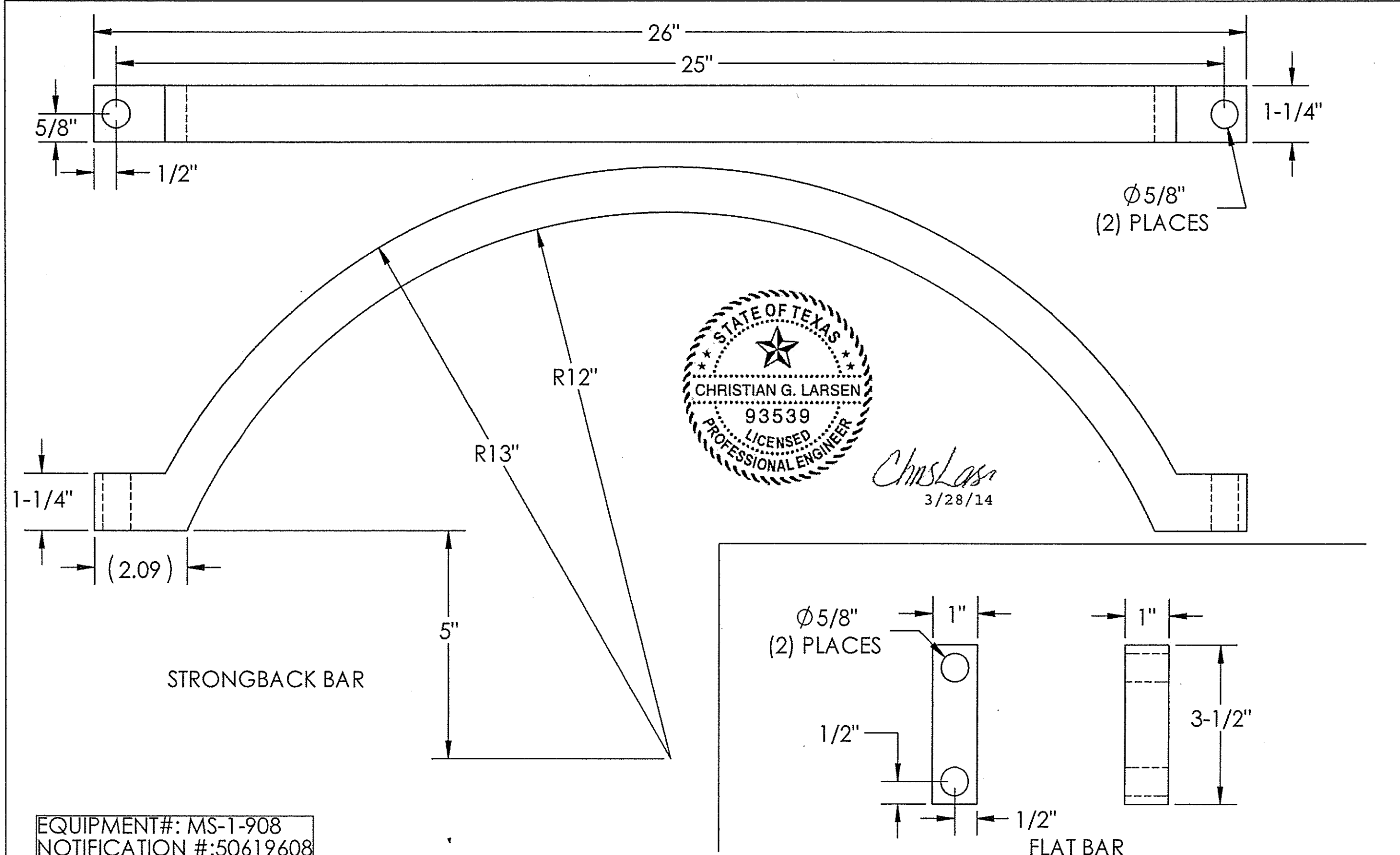
EQUIPMENT#: MS-1-908
NOTIFICATION #:50619608

TEAM® Industrial Services, Inc.

REGISTRATION # F-003143

ENGINEERING ORDER# 288166EM		UNLESS OTHERWISE SPECIFIED: ALL DIMENSIONS TYPICAL: MACHINED SURFACES: ▽ BREAK SHARP CORNERS: 0.005" TOLERANCES: FRACTIONAL ±1/32 ANGULAR ±1/2° TWO PLACE DECIMAL ±0.01 THREE PLACE DECIMAL ±0.005 ALL DIMENSIONS IN INCHES	PERIMETER VOL IN^3 BC / WT. LBS VOL IN^3 BC
DRAWING # N/A			PG&E DIABLO CANYON BAR CLAMP
TECO PART # N/A			
WPS: N/A			
DRAWN BY: MWY	3/27/14		
CHECKED BY: AG	3/27/14		SIZE A / REV 0
APPROVED BY:			SCALE: 1:3 / SHEET 2 OF 17

"SAFETY FIRST - QUALITY ALWAYS"



EQUIPMENT#: MS-1-908
NOTIFICATION #:50619608

1. (1) STRONGBACK BAR REQUIRED
2. (1) FLAT BAR REQUIRED
3. SEND (2) 1/2 X 13-UNC X 18" LONG ALLTHREADS
4. SEND (2) 1/2 X 13-UNC X 8" LONG ALLTHREADS
5. SEND (6) 1/2 HEAVY HEX NUTS
6. HAND TIGHTEN STRONGBACK NUTS
7. ALL DIM TYP UNLESS NOTED

TEAM® Industrial Services, Inc.

REGISTRATION # F-003143

ENGINEERING ORDER# 288166EM		UNLESS OTHERWISE SPECIFIED:	PERIMETER VOL IN^3 BC
DRAWING # N/A		ALL DIMENSIONS TYPICAL:	WT. LBS VOL IN^3 BC
TECO PART # N/A		MACHINED SURFACES: ∇	PG&E DIABLO CANYON
WPS: N/A		BREAK SHARP CORNERS: 0.005"	BAR CLAMP
DRAWN BY: MWY	3/27/14	TOLERANCES: FRACTIONAL ±1/32; ANGULAR ±1/2°; TWO PLACE DECIMAL ±0.01; THREE PLACE DECIMAL ±0.005	
CHECKED BY: AG	3/27/14		SIZE A REV 0
APPROVED BY:		ALL DIMENSIONS IN INCHES	SCALE: 1:3 SHEET 3 OF 17

TEAM® Industrial Services, Inc.
Registration # F-003143

EQUIPMENT #:
MS-1-908
NOTIFICATION #:
50619608

MATERIAL SPECIFICATIONS

☐ Non-Critical/Nuclear ☒ Critical/Nuclear

Drawn By: MWY Date: 3/27/14

Checked By: AG Date: 3/27/14

Engineering Order No.:
288166EM

Enclosures	Material Specification	MTR	COC	NR
PIPE				
FITTING				
ROLLED PLATE				
BLOCK / PLATE / SIDEBARS	**SA 516 GR 70**	X	X	
ENDPLATES				
STRONGBACK BARS	**SA 516 GR 70**	X	X	
S.B. EARS/FINGERS				
Fasteners				
STUDS ENCLOSURE	**SA 193 GR B7**	X	X	
STUDS STRONGBACK	**SA 193 GR B7**	X	X	
NUTS ENCLOSURE	**SA 194 GR 2H**	X	X	
NUTS STRONGBACK	**SA 194 GR 2H**	X	X	
SET SCREWS				
HTS				
FLANGE				
TEE				
RUN (if fabricated)				
BRANCH (if fabricated)				
FITTING				
WELD-O-LET				
VALVE				
FES				
Miscellaneous				
TUBING	**COPPER**		X	

STATE OF TEXAS
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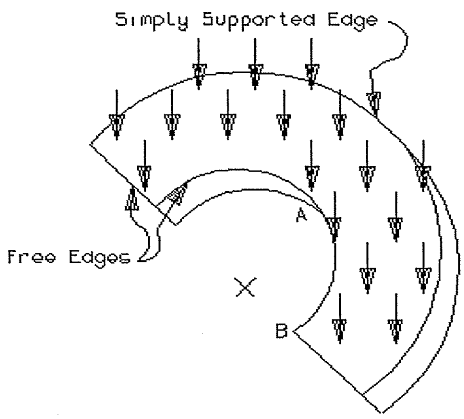
Chris Larsen
3/28/14

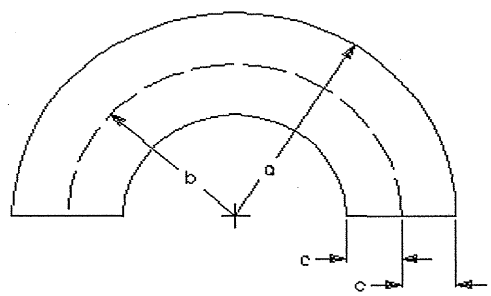
Split Circular Endplate Analysis

EQUIPMENT #: MS-1-908
NOTIFICATION #: 50619608

References: ASME Boiler and Pressure Vessel Code, Section II, Part D, (Table for Maximum Allowable Stresses, 2013

Formulas for Stress and Strain by Roark and Young, Fifth Edition, Table 24, Case 31





Data:

Design Pressure	$P := 1085 \cdot psi$	Modulus of Elasticity	$E := 0.265 \cdot 10^{8} \cdot psi$
Design Temperature	$T := 600 \cdot deg$	Poisson's Ratio	$\nu := 0.30$
Split Endplate OD	$OD := 6.0 \cdot in$	Maximum Allowable Deflection	$y_{max} := 0.05 \cdot in$
Cover Wall Thickness	$t_{wall} := 2.0 \cdot in$	Joint Efficiency	$JE := 1$
Split Endplate Thickness	$t_{endpl} := 0.5 \cdot in$	External Corrosion Allowance	$ExtCA := 0 \cdot in$
Opening Hole Diameter	$HD := 0 \cdot in$ (consv)	Internal Corrosion Allowance	$IntCA := 0 \cdot in$
Maximum Allowable Stress	$S_{allow} := 19400 \cdot psi$	$OD := OD - 2 \cdot ExtCA$	$OD = 6 \cdot in$
		$t_{wall} := t_{wall} - ExtCA - IntCA$	$t_{wall} = 2 \cdot in$
Inside Radius	$IR := \frac{[OD - 2(t_{wall})]}{2}$	$t_{endpl} := t_{endpl} - ExtCA - IntCA$	$t_{endpl} = 0.5 \cdot in$

Analysis:

Solving for Modulus of Rigidity

$$G := \frac{E}{2 \cdot (1 + \nu)} \qquad G = 10192307.6923 \cdot psi$$

Solving for variables

$$a := \frac{OD - 2 \cdot t_{wall}}{2} \qquad a = 1 \cdot in \qquad c := \frac{a - \frac{HD}{2}}{2} \qquad c = 0.5 \cdot in$$

$$b := a - c \qquad b = 0.5 \cdot in$$

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Solving for Constants

$$K := 0.42338\cdot\left(\frac{b-c}{b+c}\right)^4 - 1.58614\cdot\left(\frac{b-c}{b+c}\right)^3 + 2.85046\cdot\left(\frac{b-c}{b+c}\right)^2 - 3.17277\cdot\left(\frac{b-c}{b+c}\right) + 2.48483$$

$$K = 2.4848$$

$$\gamma := \sqrt{\frac{2\cdot b}{c} + 4\cdot\left(1 - \frac{.625\cdot t_{endpl}}{2\cdot c}\right)\cdot\frac{G}{E}\cdot\left(1 + \frac{b}{c}\right)^2} \qquad \gamma = 2.4962$$

$$\gamma_1 := \frac{\gamma}{\sqrt{2}}\cdot\sqrt{1 + \sqrt{1 - \frac{4\cdot b^2}{c^2\cdot\gamma^4}}} \qquad \gamma_1 = 2.4629$$

$$\gamma_2 := \frac{\gamma}{\sqrt{2}}\cdot\sqrt{1 - \sqrt{1 - \frac{4\cdot b^2}{c^2\cdot\gamma^4}}} \qquad \gamma_2 = 0.406$$

$$\lambda_1 := 4\cdot\left(1 - \frac{.625\cdot t_{endpl}}{2\cdot c}\right)\cdot\frac{G}{E}\cdot\left(1 + \frac{b}{c}\right)^2 \qquad \lambda_1 = 4.2308$$

$$\lambda := \frac{\gamma_1\cdot\left(\frac{b}{c} - \gamma_1^2 + \lambda_1\right)\cdot\left(\frac{b}{c} - \gamma_2^2\right)\cdot\tanh\left(\frac{\gamma_1\cdot\pi}{2}\right)}{\gamma_2\cdot\left(\frac{b}{c} - \gamma_2^2 + \lambda_1\right)\cdot\left(\frac{b}{c} - \gamma_1^2\right)\cdot\tanh\left(\frac{\gamma_2\cdot\pi}{2}\right)} \qquad \lambda = 0.2924$$

$$c_1 := \frac{1}{\left(\frac{b}{c} - \gamma_1^2\right)\cdot(\lambda - 1)\cdot\cosh\left(\frac{\gamma_1\cdot\pi}{2}\right)} \qquad c_1 = 0.0116$$

$$c_2 := \frac{1}{\left(\frac{b}{c} - \gamma_2^2\right)\cdot\left(\frac{1}{\lambda} - 1\right)\cdot\cosh\left(\frac{\gamma_2\cdot\pi}{2}\right)} \qquad c_2 = 0.4087$$

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<u>Stress at A (maximum)</u>

$$\sigma_t := \frac{6\cdot P\cdot c\cdot b}{t_{endpl}^2}\cdot\left(\frac{b}{c} - \frac{1}{3}\right)\cdot\left[c_1\cdot\left(1 - \gamma_1^2\cdot\frac{c}{b}\right) + c_2\cdot\left(1 - \gamma_2^2\cdot\frac{c}{b}\right) + \frac{c}{b}\right]\cdot K \qquad \sigma_t = 13828.95\cdot psi \quad < \quad S_{allow} = 19400\cdot psi$$

<u>Deflection at B (maximum)</u>

$$y := \frac{24\cdot P\cdot c^2\cdot b^2}{E\cdot t_{endpl}^3}\cdot\left(\frac{b}{c} - \frac{1}{3}\right)\cdot\left(c_1\cdot\cosh\left(\frac{\gamma_1\cdot\pi}{2}\right) + c_2\cdot\cosh\left(\frac{\gamma_2\cdot\pi}{2}\right) + \frac{c}{b}\right) \qquad y = 0.0006\cdot in \quad < \quad y_{max} = 0.05\cdot in$$

<u>Minimum Cover Wall Thickness</u>

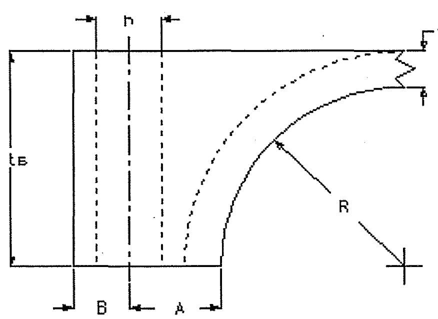
$$t_{reqd} := \frac{P\cdot IR}{(JE\cdot S_{allow}) - (0.6\cdot P)} \qquad t_{reqd} = 0.05787\cdot in \quad < \quad t_{wall} = 2\cdot in$$

Line Enclosure Analysis

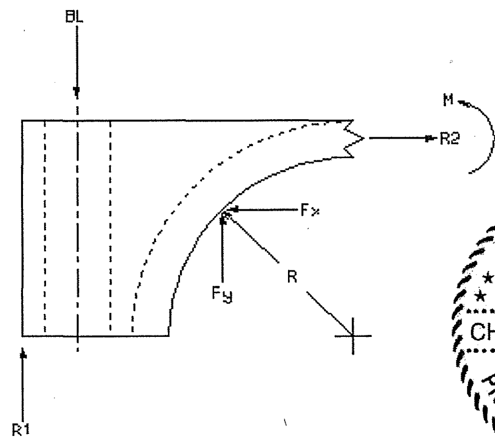
EQUIPMENT #: MS-1-908
NOTIFICATION #: 50619608

Purpose:
This analysis will calculate the internal stresses and bolt load of a line enclosure.

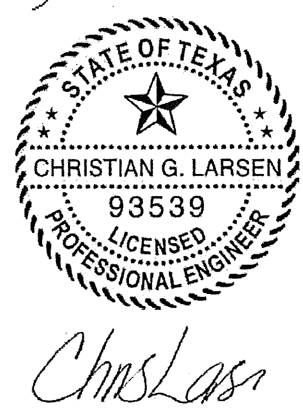
References:
ASME Boiler and Pressure Vessel Code, Section II, Part D, (Table for Maximum Allowable Stresses),2013
Team Industrial Services, Teco Manufacturing, Engineering Department, ISO-9001 Quality Manual, EP8.7



Dimensions



Free Body Diagram



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Data:

Design Pressure		$P = 1085 \cdot psi$	Length Between Centerline of Seals	$LS := 1.25 \cdot in$
Design Temperature		$T = 600 \cdot deg$	Sidebar Length (at Centerline)	$LB := 1.5 \cdot in$
Inside Radius	$R := IR - IntCA$	$R = 1 \cdot in$	# of Studs per Half	$NS2 := 3$
Cover Thickness	$t := t_{wall} + IntCA$	$t = 2 \cdot in$	Hole Size	$h := 0.3125 \cdot in$
Cavity to Stud CL		$A := 0.25 \cdot in$	Stud Tensile Area	$TA := 0.0318 \cdot in^2$
End of Sidebar to Stud CL		$B := 0.25 \cdot in$	Stud Allowable Stress	$S_S := 25000 \cdot psi$
Sidebar Thickness		$ts := 3.0 \cdot in$	Enclosure Allowable Stress	$S_{allow} = 19400 \cdot psi$

External Corrosion Allowance	$ExtCA = 0 \cdot in$
Internal Corrosion Allowance	$IntCA = 0 \cdot in$

$R := R + IntCA$	$R = 1 \cdot in$	$B := B - ExtCA$	$B = 0.25 \cdot in$
$t := t - ExtCA - IntCA$	$t = 2 \cdot in$	$LB := LB - 2 \cdot ExtCA$	$LB = 1.5 \cdot in$
$A := A - IntCA$	$A = 0.25 \cdot in$	$ts := ts - ExtCA$	$ts = 3 \cdot in$

EQUIPMENT #: MS-1-908
NOTIFICATION #: 50619608

Analysis:

Solving for forces and moments

$F := P \cdot R \cdot LS$ $\quad F_x := F$ $\quad F_y := F$

$F = 1356.25 \cdot lbf$ $\quad F_x = 1356.25 \cdot lbf$ $\quad F_y = 1356.25 \cdot lbf$

Setting forces in x direction equal to 0

$R_2 := F_x$ $\quad R_2 = 1356.25 \cdot lbf$

Setting moments around centerpoint of cavity equal to 0

$$BL := F \cdot \frac{A + B - \frac{t}{2}}{B} \qquad BL = -2712.5 \cdot lbf \qquad BL := if(BL < F, F, BL) \qquad BL = 1356.25 \cdot lbf$$

Allowable Bolt Load

$BL_a := TA \cdot S_S \cdot NS2$ $\quad BL_a = 2385 \cdot lbf$

<u>Stresses in Shell</u> (thin walled enclosure)

$$\sigma := P \cdot \frac{R}{t} \qquad \sigma = 542.5 \cdot psi$$

<u>Sidebar Stress</u> (at Bolt Centerline)

$R_1 := BL - F$ $\quad R_1 = 0 \cdot lbf$

$$\sigma_{b2} := \frac{R_1 \cdot B \cdot \frac{ts}{2}}{\frac{1}{12} \cdot (LB - NS2 \cdot h) \cdot ts^3} \qquad \sigma_{b2} = 0 \cdot psi$$

$$\tau_s := \frac{3}{2} \cdot \frac{F}{(LB - NS2 \cdot h) \cdot ts} \qquad \tau_s = 1205.5556 \cdot psi$$

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Results:

Bolt Load	**Less Than**	Allowable
$BL = 1356.25 \cdot lbf$		$BL_a = 2385 \cdot lbf$
Stresses in Shell (thin walled enclosure)		
$\sigma = 542.5 \cdot psi$		$S_{allow} = 19400 \cdot psi$
Sidebar Stresses (@ bolt centerline)		
$\sigma_{b2} = 0 \cdot psi$		$S_{allow} = 19400 \cdot psi$
Shear Stresses in Sidebar		
$\tau_s = 1205.56 \cdot psi$		$0.8 \cdot S_{allow} = 15520 \cdot psi$

Torque Analysis:

An Introduction To The Design And Behavior Of The Bolted Joint by Bickford, Second Edition, Page 133.

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Stud Tensile Area		$TA := 0.0318 \cdot in^2$
Stud Allowable Stress		$SS := 25000 \cdot psi$
Allowable Strength of Stud	$Fp := TA \cdot SS$	$Fp = 795 \cdot lbf$
Torque Application Factor		$A := 2.1$
Pitch of Threads		$Pitch := 0.05 \cdot in$
Coefficient of Friction Nut/Stud		$\mu t := 0.15$
Effective Contact Radius of Threads		$rt := 0.1082 \cdot in$
Half Angle of Threads		$\beta := 30 \cdot deg$
Coefficient of Friction Nut/Joint		$\mu n := 0.15$
Effective Contact Radius Nut/Joint		$rn := 0.1875 \cdot in$

Analysis:

$$Torque := Fp \cdot A \cdot \left(\frac{Pitch}{2 \cdot \pi} + \frac{\mu t \cdot rt}{\cos(\beta)} + \mu n \cdot rn \right)$$

$Torque = 7.63 \cdot ft \cdot lbf$ OR $Torque = 91.5279 \cdot in \cdot lbf$

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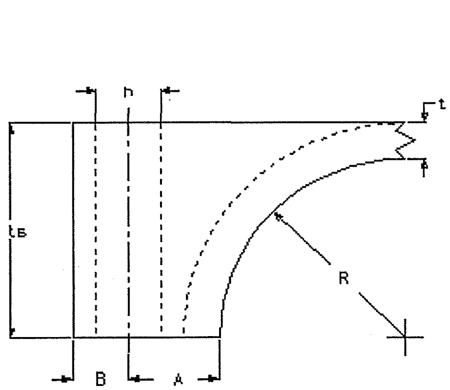
Line Enclosure Analysis-Worst Case

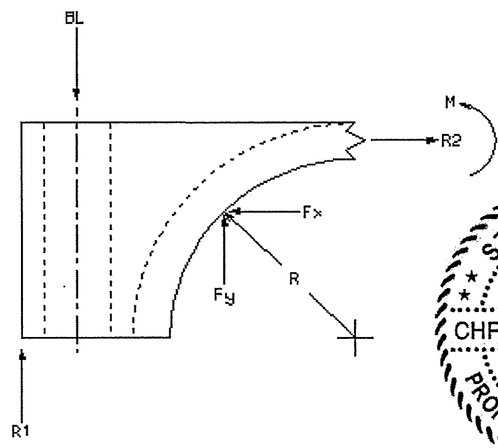
EQUIPMENT #: MS-1-908
NOTIFICATION #: 50619608

Purpose:
This analysis will calculate the internal stresses and bolt load of a line enclosure.

References:
ASME Boiler and Pressure Vessel Code, Section II, Part D, (Table for Maximum Allowable Stresses),2013
Team Industrial Services, Teco Manufacturing, Engineering Department, ISO-9001 Quality Manual, EP8.7



Dimensions



Free Body Diagram

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Data:

Design Pressure		$P = 1085 \cdot psi$	Length Between Centerline of Seals	$LS := 1.5 \cdot in$
Design Temperature		$T = 600 \cdot deg$	Sidebar Length (at Centerline)	$LB := 1.75 \cdot in$
Inside Radius	$R := IR - IntCA$	$R = 1 \cdot in$	# of Studs per Half	$NS2 := 1$
Cover Thickness	$t := t_{wall} + IntCA$	$t = 2 \cdot in$	Hole Size	$h := 0.75 \cdot in$
Cavity to Stud CL		$A := 0.75 \cdot in$	Stud Tensile Area	$TA := 0.226 \cdot in^2$
End of Sidebar to Stud CL		$B := 0.75 \cdot in$	Stud Allowable Stress	$S_S := 25000 \cdot psi$
Sidebar Thickness		$ts := 3.0 \cdot in$	Enclosure Allowable Stress	$S_{allow} = 19400 \cdot psi$

External Corrosion Allowance $ExtCA = 0 \cdot in$

Internal Corrosion Allowance $IntCA = 0 \cdot in$

$R := R + IntCA$	$R = 1 \cdot in$	$B := B - ExtCA$	$B = 0.75 \cdot in$
$t := t - ExtCA - IntCA$	$t = 2 \cdot in$	$LB := LB - 2 \cdot ExtCA$	$LB = 1.75 \cdot in$
$A := A - IntCA$	$A = 0.75 \cdot in$	$ts := ts - ExtCA$	$ts = 3 \cdot in$

Analysis:

EQUIPMENT #: MS-1-908
NOTIFICATION #: 50619608

Solving for forces and moments

$F := P \cdot R \cdot LS$ $\quad F_x := F$ $\quad F_y := F$

$F = 1627.5 \cdot lbf$ $\quad F_x = 1627.5 \cdot lbf$ $\quad F_y = 1627.5 \cdot lbf$

Setting forces in x direction equal to 0

$R_2 := F_x$ $\quad R_2 = 1627.5 \cdot lbf$

Setting moments around centerpoint of cavity equal to 0

$BL := F \cdot \frac{A + B - \frac{t}{2}}{B}$ $\quad BL = 1085 \cdot lbf$ $\quad BL := if(BL < F, F, BL)$ $\quad BL = 1627.5 \cdot lbf$

Allowable Bolt Load

$BL_a := TA \cdot S_S \cdot NS2$ $\quad BL_a = 5650 \cdot lbf$

Stresses in Shell (thin walled enclosure)

$\sigma := P \cdot \frac{R}{t}$ $\quad \sigma = 542.5 \cdot psi$

Sidebar Stress (at Bolt Centerline)

$R_1 := BL - F$ $\quad R_1 = 0 \cdot lbf$

$$\sigma_{b2} := \frac{R_1 \cdot B \cdot \frac{ts}{2}}{\frac{1}{12} \cdot (LB - NS2 \cdot h) \cdot ts^3} \qquad \sigma_{b2} = 0 \cdot psi$$

$$\tau_s := \frac{3}{2} \cdot \frac{F}{(LB - NS2 \cdot h) \cdot ts} \qquad \tau_s = 813.75 \cdot psi$$

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Results:

Bolt Load	Less Than	Allowable
$BL = 1627.5 \cdot lbf$		$BL_a = 5650 \cdot lbf$
Stresses in Shell (thin walled enclosure)		
$\sigma = 542.5 \cdot psi$		$S_{allow} = 19400 \cdot psi$
Sidebar Stresses (@ bolt centerline)		
$\sigma_{b2} = 0 \cdot psi$		$S_{allow} = 19400 \cdot psi$
Shear Stresses in Sidebar		
$\tau_s = 813.75 \cdot psi$		$0.8 \cdot S_{allow} = 15520 \cdot psi$

Torque Analysis:

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NOTIFICATION #: 50619608

An Introduction To The Design And Behavior Of The Bolted Joint by Bickford, Second Edition, Page 133.

Stud Tensile Area		$TA := 0.226 \cdot in^2$
Stud Allowable Stress		$SS := 25000 \cdot psi$
Allowable Strength of Stud	$Fp := TA \cdot SS$	$Fp = 5650 \cdot lbf$
Torque Application Factor		$A := 2.1$
Pitch of Threads		$Pitch := 0.0909 \cdot in$
Coefficient of Friction Nut/Stud		$\mu t := 0.15$
Effective Contact Radius of Threads		$rt := 0.2822 \cdot in$
Half Angle of Threads		$\beta := 30 \cdot deg$
Coefficient of Friction Nut/Joint		$\mu n := 0.15$
Effective Contact Radius Nut/Joint		$rn := 0.4219 \cdot in$

Analysis:

$$Torque := Fp \cdot A \cdot \left(\frac{Pitch}{2 \cdot \pi} + \frac{\mu t \cdot rt}{\cos(\beta)} + \mu n \cdot rn \right)$$

$Torque = 125.21 \cdot ft \cdot lbf$ OR $Torque = 1502.4728 \cdot in \cdot lbf$

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Thrust Calculation Due to Unequal Bores

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Larger Diameter $D := 1.75 \cdot in$

Smaller Diameter $d := 1.05 \cdot in$

Number of Studs $NS := 2$

Size of Studs 1/2" x 13UNC

Injection Pressure $IP := 1627.5 \cdot psi$

Design Pressure $P = 1085 \cdot psi$

Tensile Area of Studs $A_t := 0.1418 \cdot in^2$

Stud Allowable Stress $SS := S_S$ $SS = 25000 \cdot psi$

Allowable Load of Studs $H := A_t \cdot SS$

$H = 3545 \cdot lbf$

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Thrust Produced

$$Thrust := \left(D^2 - d^2\right) \cdot \frac{\pi}{4} \cdot IP + \left(d^2\right) \cdot \frac{\pi}{4} \cdot P$$ $Thrust = 3444.845 \cdot lbf$

Number of Studs Required

$$ND := \frac{Thrust}{H}$$ $ND = 0.9717$ < $NS = 2$

Force per Stud

$$F := \frac{Thrust}{NS}$$ $F = 1722.422 \cdot lbf$

Thrust and Bending Calculation: Clamp Ear

Thrust Produced $Thrust = 3444.845 \cdot lbf$

Moment Arm $X := 1.5913 \cdot in$

Total Width $B := 5 \cdot in$

Number of Studs per Half $N := 1$

Allowable Stress $S_{allow} = 19400 \cdot psi$

Thickness Provided $tp := 1.0 \cdot in$

Joint Efficiency $E := 1$

Force per Ear

$$Fs := \frac{Thrust}{N}$$ $Fs = 3444.845 \cdot lbf$

Thickness Required

$$tr := \sqrt{\frac{6 \cdot Fs \cdot X}{B \cdot E \cdot S_{allow}}}$$ $tr = 0.582 \cdot in$ < $tp = 1 \cdot in$

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Thrust and Bending Calculation: Radius Bar Ear

Thrust Produced	$Thrust = 3444.845 \cdot lbf$
Moment Arm	$X = 1.5913 \cdot in$
Total Width	$B := 1.25 \cdot in$
Number of Studs per Half	$N := 1$
Allowable Stress	$S_{allow} = 19400 \cdot psi$
Thickness Provided	$tp := 1.25 \cdot in$
Joint Efficiency	$E := 1$

Force per Ear

$Fs := \frac{Thrust}{N}$ $\quad$ $Fs = 3444.845 \cdot lbf$

Thickness Required

$tr := \sqrt{\frac{6 \cdot Fs \cdot X}{B \cdot E \cdot S_{allow}}}$ $\quad$ $tr = 1.165 \cdot in$ $\quad < \quad$ $tp = 1.25 \cdot in$

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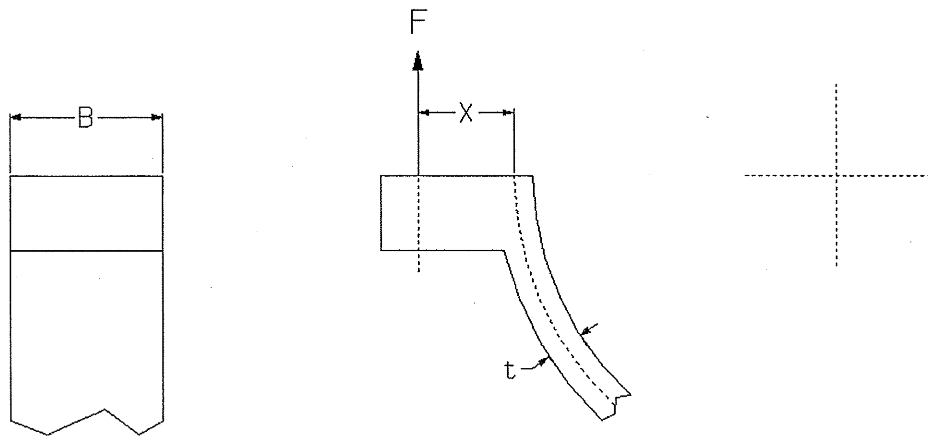
Strap Thickness: Radius Bar

REFERENCE: Practical Stress Analysis in Engineering Design, Alexander Blake, 2nd Ed., pages 29-30.



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DATA:

Number of Bolts	$N := 1$	
Thrust per Bolt	$F = 1722.422 \cdot lbf$	
Ear Width	$B := 1.25 \cdot in$	
Maximum Allowable Stress	$S_{allow} = 19400 \cdot psi$	
Joint Efficiency	$E := 1$	
Strap ID	$ID := 24 \cdot in$	
Strap OD	$OD := 26 \cdot in$	
Bolt Circle	$BC := 25 \cdot in$	
Bar thickness(furnished)	$t := \frac{OD - ID}{2}$	$t = 1 \cdot in$
Moment Arm	$X := \frac{BC - \frac{OD + ID}{2}}{2}$	$X = 0 \cdot in$ $X := 1.5913 \cdot in$

Thickness Equation derivation:

Where, $P2 := N \cdot F$ $M := P2 \cdot X$; C = t/2 ; I = (1/12)B(t_{reqd})^3

S = (M*C)/I ; S = (P2*X*(t/2))/(1/12)*B*t^3

Bar thickness(required):

$$t_{reqd} := \sqrt{\frac{6 \cdot M}{B \cdot S_{allow} \cdot E}}$$

$t_{reqd} = 0.82 \cdot in$ < $t = 1 \cdot in$

Stress on Ear

$$Stress := \frac{6 \cdot M}{t^2 \cdot B \cdot E}$$

$Stress = 13156.28 \cdot psi$ < $S_{allow} = 19400 \cdot psi$

Thrust Calculation Due to Separation (Flat Bar)

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Separation Diameter — $d = 1.05 \cdot in$

Thrust Produced

$$Thrust := \left(d^2\right) \cdot \frac{\pi}{4} \cdot P \qquad Thrust = 939.503 \cdot lbf$$

Moment Arm — $X := 1.25in$

Total Width — $B := 1 \cdot in$

Number of Studs per Half — $N := 1$

Allowable Stress — $S_{allow} = 19400 \cdot psi$

Thickness Provided — $tp := 1 \cdot in$

Joint Efficiency — $E := 1$

Force per Ear

$$Fs := \frac{Thrust}{N} \qquad Fs = 939.503 \cdot lbf$$

Thickness Required

$$tr := \sqrt{\frac{6 \cdot Fs \cdot X}{B \cdot E \cdot S_{allow}}} \qquad tr = 0.603 \cdot in \quad < \quad tp = 1 \cdot in$$

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Weight and Void

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Void

Number of Injection Valves

$NIV := 4$

$Cavity := (2\cdot in)^2\cdot\frac{\pi}{4}\cdot(1.125\cdot in) + (1.75\cdot in)^2\cdot\frac{\pi}{4}\cdot(1.125\cdot in)$ $\qquad Cavity = 6.2402\cdot in^3$

$InjVlv := NIV\cdot 0.19\cdot in^3$ $\qquad InjVlv = 0.76\cdot in^3$

$Line := (1.75\cdot in)^2\cdot\frac{\pi}{4}\cdot(0.375\cdot in) + (1.05\cdot in)^2\cdot\frac{\pi}{4}\cdot(1.14\cdot in) + (1.05\cdot in)^2\cdot\frac{\pi}{4}\cdot(0.735\cdot in)$ $\qquad Line = 2.5255\cdot in^3$

$Hose := (0.375\cdot in)^2\cdot\frac{\pi}{4}\cdot 28in$

$Void := Cavity - Line + InjVlv + Hose$

$Void = 7.5672\cdot in^3$ B.C.

$Voidac := Void\cdot 1.5$

$Voidac = 11.3508\cdot in^3$ A.C

Weight (Clamp & Strongback from SolidWorks Models)

$Clamp := 29.91\cdot lb\cdot 2$ $\qquad Clamp = 59.82\cdot lb$

$allthread := 2\cdot 0.056\frac{lb}{in}\cdot 8\cdot in + 2\cdot 0.056\frac{lb}{in}\cdot 18\cdot in + 6\cdot 0.066\cdot lb$ $\qquad allthread = 3.308\cdot lb$

$Studs := 3\cdot 0.087\frac{lb}{in}\cdot 8\cdot in + 6\cdot 0.11\cdot lb + \left(3\cdot 0.014\frac{lb}{in}\cdot 6\cdot in + 3\cdot 0.012\cdot lb\right)$ $\qquad Studs = 3.036\cdot lb$

$Sealant := Void\cdot 1.5\cdot 0.051\cdot\frac{lb}{in^3}$ $\qquad Sealant = 0.5789\cdot lb$

$InjValves := NIV\cdot 0.46\cdot lb$ $\qquad InjValves = 1.84\cdot lb$

$Strongback := 6.37\cdot lb + 0.81\cdot lb$ $\qquad Strongback = 7.18\cdot lb$

$Weight := Clamp + allthread + Sealant + InjValves + Strongback + Studs$

$Weight = 75.7629\cdot lb$

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3/28/14