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Unlisted Component Evaluation

Project Number:	TM-1
Project Name:	Tube-Mac piping Technologies Ltd.
Date:	03/05/2017
Description:	B31.1, B31.3, B31.4 and B31.8 Compliance
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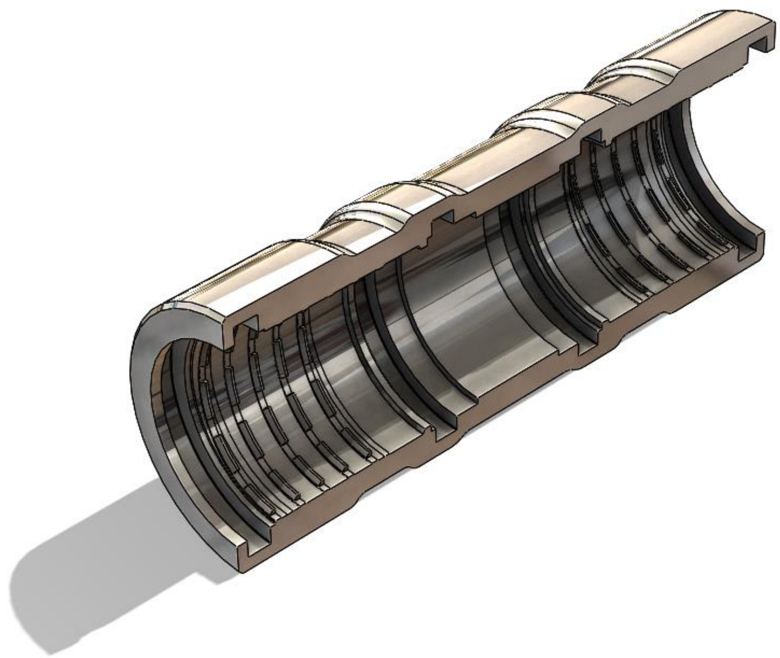

P.Eng Stamp	**Executive Summary**
LICENSED PROFESSIONAL ENGINEER E.H.H. DE RUBEIS 100090347 PROVINCE OF ONTARIO 01/06/2022	• PYPLOK fittings were evaluated for code compliance for B31.1, B31.3, B31.4 and B31.8 • Fittings meet code requirements with the ratings outlined.

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1 Introduction

Globally, the American Society of Mechanical Engineers (ASME) B31 Pressure Pipe Codes are recognized and generally accepted as good engineering practise for piping design. Various sections of the code exist for different applications, Tube-Mac's Pyplok product lines mainly fall under the scope of section B31.1 – Power Piping, B31.3 – Process Piping, B31.4 – Pipeline Transportation Systems for Liquids and Slurries, and B31.8 – Gas Transmission and Distribution Piping Systems.

All of these codes have requirements regarding the use of fittings in piping systems designed in accordance with these standards. B31.1 Table 126.1, B31.3 Table 326.1, B31.4 Table 423.1-1, and B31.8 Chapter 3 list specifications and standards for fittings that have an established temperature and pressure ratings. Fittings that are manufactured in accordance with these referenced specifications and standards maybe used in piping systems designed to the applicable B31 code. Note that these fittings shall not be modified and shall be used within the temperature and pressure rating basis provided in the referenced specification or standard. Fittings that are not listed in the referenced specifications and standards are considered unlisted components and the pressure design of the component must meet the requirements set out in section 104.7.2 in B31.1, 304.7.2 in B31.3, 404.10 in B31.4 and 831.3.6 in B31.8. Below are the quoted texts from these standards

ASME B31.3
304.7.2 Unlisted Components.
Pressure design of unlisted components to which the rules elsewhere in para. 304 do not apply shall be based on the pressure design criteria of this Code. The designer shall ensure that the pressure design has been substantiated through one or more of the means stated in subparas. (a) through (d) below. Note that designs are also required to be checked for adequacy of mechanical strength as described in para. 302.5. Documentation showing compliance with this paragraph shall be available for the owner's approval.

a) extensive, successful service experience under comparable conditions with similarly proportioned components of the same or like material.
b) experimental stress analysis, such as described in the BPV Code, Section VIII, Division 2, Annex 5.F.
c) proof test in accordance with ASME B16.9, MSS SP-97, or Section VIII, Division 1, UG-101.
d) detailed stress analysis (e.g., finite element method) with results evaluated as described in Section VIII, Division 2, Part 5. The basic allowable stress from Table A-1 shall be used in place of the allowable stress, S, in Division 2 where applicable. At design temperatures in the creep range, additional considerations beyond the scope of Division 2 may be necessary.

ASME B31.1
104.7.2 Specially Designed Components.
The pressure design of components not covered by the standards listed in Table 126.1 or for which design formulas and procedures are not given in this Code shall be based on calculations consistent with the design criteria of this Code. These calculations shall be substantiated by one or more of the means stated in (A), (B), (C), and (D) below.

a) extensive, successful service experience under comparable conditions with similarly proportioned components of the same or similar material
b) experimental stress analysis, such as described in the ASME Boiler and Pressure Vessel Code, Section VIII, Division 2, Annex 5-F
c) proof test in accordance with either ASME B16.9; MSS SP-97; or the ASME Boiler and Pressure Vessel Code, Section I, A-22
d) detailed stress analysis, such as finite element method, in accordance with the ASME Boiler and Pressure Vessel Code, Section VIII, Division 2, Part 5, except that the basic material allowable stress from the Allowable Stress Tables of Mandatory Appendix A shall be used in place of Sm

For any of (A) through (D) above, it is permissible to interpolate between sizes, wall thicknesses, and pressure classes and to determine analogies among

e) For any of the above, the designer may interpolate between sizes, wall thicknesses, and pressure classes, and may determine analogies among related materials.	related materials. Calculations and documentation showing compliance with this paragraph shall be available for the owner's approval, and, for boiler external piping, they shall be available for the Authorized Inspector's review.
ASME B31.4	ASME B31.8
404.10 Other Pressure-Containing Components Pressure-containing components that are not covered by the standards listed in Table 423.1-1 or Table 426.1-1 and for which design equations or procedures are not given herein may be used where the design of similarly shaped, proportioned, and sized components has been proven satisfactory by successful performance under comparable service conditions. (Interpolation may be made between similarly shaped proved components with small differences in size or proportion.) In the absence of such service experience, the pressure design shall be based on an analysis consistent with the general design philosophy embodied in this Code, and substantiated by at least one of the following: a) proof tests (as described in UG-101 of Section VIII, Division 1, of the ASME Boiler and Pressure Vessel Code) b) experimental stress analysis (as described in Annex 5-F of Section VIII, Division 2, of the ASME Boiler and Pressure Vessel Code) c) engineering calculations	831.3.6 Pressure Design of Other Pressure-Containing Components. Pressure-containing components that are not covered by the standards listed in Mandatory Appendix A and for which design equations or procedures are not given herein may be used where the design of similarly shaped, proportioned, and sized components has been proven satisfactory by successful performance under comparable service conditions. (Interpolation may be made between similarly shaped components with small differences in size or proportion.) In the absence of such service experience, the pressure design shall be based on an analysis consistent with the general design philosophy embodied in this Code and substantiated by at least one of the following: a) proof tests, as described in UG-101 of Section VIII, Division 1 of the BPV Code b) experimental stress analysis, as described in Annex 5.F of Section VIII, Division 2 of the BPV Code c) engineering calculations

This document will evaluate Pyplok fittings to demonstrate compliance with both of these code requirements.

2 Design Codes

ASME B31.3, 2014 edition
ASME B31.1, 2014 edition
ASME B31.4, 2016 edition
ASME B31.8, 2016 edition
ASME Section VIII Division 2, 2015 edition
ASME Section VIII Division 1, 2015 edition
ASME Section I, 2015 edition

3 Pressure Design

As specified in the first paragraph in 104.7.2 in B31.1, 304.7.2 in B31.3, 404.10 in B31.4 and 831.3.6 in B31.8 the pressure design of the unlisted component shall be based on the pressure design criteria of this Code. Below are sample calculations for the pressure design of each component for each code.

ASME B31.3 304.1.2

$$t = \frac{PD}{2(SEW + PY)}$$

t = pressure design thickness, as calculated in accordance with para. 304.1.2 for internal pressure or as determined in accordance with para. 304.1.3 for external pressure
P = internal design gage pressure
D = outside diameter of pipe (tube) as listed in tables of standards or specifications or as measured
S = stress value for material from Table A-1
E = quality factor from Table A-IA or A-IB
W = weld joint strength reduction factor in accordance with para. 302.3.5(e)
Y = coefficient from Table 304.1.1, valid for t < D/6 and for materials shown. The value of Y may be interpolated for intermediate temperatures. For t ≥ D/6,

$$Y = \frac{d + 2c}{D + d + 2c}$$

d = inside diameter of pipe (tube). For pressure design calculation, the inside diameter of the pipe (tube) is the maximum value allowable under the purchase specification.
c = sum of the mechanical allowances (thread or groove depth) plus corrosion and erosion allowances. For threaded components, the nominal thread depth (dimension h of ASME B1.20.1, or equivalent) shall apply. For machined surfaces or grooves where the tolerance is not specified, the tolerance shall be assumed to be 0.5 mm (0.02 in.) in addition to the specified depth of the cut.

ASME B31.1 104.1.2

$$t_m = \frac{PD_o}{2(SE + Py)} + A$$

t_m = minimum required wall thickness
P = internal design gage pressure
D = outside diameter of pipe (tube) as listed in tables of standards or specifications or as measured
SE = stress value for material from Appendix A, these values include the weld joint efficiency E.
y = coefficient from Table 104.1.2(A), valid for materials shown. The value of y may be interpolated for intermediate temperatures. For $t_m < D_o/6$ and less than 900°F,

$$Y = \frac{d}{D_o + d}$$

d = inside diameter of pipe (tube). For pressure design calculation, the inside diameter of the pipe (tube) is the maximum value allowable under the purchase specification.
A = Additional thickness for threading, grooving, corrosion, and erosion.

Sample Calculation for 1” NPS fitting

P = 4000 psi
D = 1.731 in
S = 20500 psi @ 400F (pg. 166 ASTM A350 LF2)
E = 1 (seamless product)
W = 1
Y = 0.4
c = 0
d = 1.336 in

$$t = \frac{PD}{2(SEW + PY)}$$

$$t = \frac{(4000)(1.731)}{2((20500)(1)(1) + (4000)(.4))}$$

$$t = 0.1567''$$

Thickness available 0.1975” therefore acceptable

Sample Calculation for 1” NPS fitting

P = 4000 psi
D_o = 1.731 in
S = 20000 psi @ 400F (pg. 123 ASTM A350 LF2)
E = 1 (seamless product)
Y = 0.4
A = 0
d = 1.336 in

$$t_m = \frac{PD_o}{2(SE + Py)} + A$$

$$t = \frac{(4000)(1.731)}{2((20000)(1) + (4000)(.4))} + 0$$

$$t = 0.1603''$$

Thickness available 0.1975” therefore acceptable

ASME B31.4 A402.3.5 (offshore)	ASME B31.8 A842.2 (offshore)
$$t = \frac{(P_i - P_e)D}{\left[2(F_1 S) + (P_i - P_e)\right]}$$ t = minimum required wall thickness P_i = internal design gage pressure P_e = external design gage pressure D = outside diameter of pipe (tube) as listed in tables of standards or specifications or as measured S = Specified minimum yield strength F_1 = Hoop stress factor	$$t = \frac{(P_i - P_e)D}{\left[2(F_1 ST) + (P_i - P_e)\right]}$$ t = minimum required wall thickness P_i = internal design gage pressure P_e = external design gage pressure D = outside diameter of pipe (tube) as listed in tables of standards or specifications or as measured S = Specified minimum yield strength F_1 = Hoop stress factor T = Temperature derating factor from Table 841.1.8-1
Sample Calculation for 2" NPS fitting	Sample Calculation for 2" NPS fitting
P_i = 1500 psi P_e = 0 psi D = 2.9 in S_y = 30800 psi @ 400F (ASME Section VIII part IID ASME SA350 LF2) F_1 = 0.6 (platform piping) $$t = \frac{(P_i - P_e)D}{\left[2(F_1 S) + (P_i - P_e)\right]}$$ $$t = \frac{(1500 - 0)2.9}{\left[2(.6)(30800) + (1500 - 0)\right]}$$ $$t = 0.11''$$ Thickness available 0.3" therefore acceptable	P = 1500 psi D_o = 2.9 in S = 36000 psi @ 100F (from material specification) F_1 = 0.5 (platform piping) T = 0.9 (for 400F) $$t = \frac{(P_i - P_e)D}{\left[2(F_1 ST) + (P_i - P_e)\right]}$$ $$t = \frac{(1500 - 0)2.9}{\left[2(.5)(36000)(.9) + (1500 - 0)\right]}$$ $$t = 0.13''$$ Thickness available 0.3" therefore acceptable

Table 1 below contains a summary of completed calculations for the remaining PYPLOK fittings to demonstrate compliance with the code's pressure design criteria at 400°F. Calculated thicknesses in white represent a design pressure of 4000psi, green is 3000psi, blue is 2500psi and yellow is 1500psi.

PYPLOK Designation	Nominal Pipe Size	Outside Diameter (in)	Minimum Fabricated thickness (in)	ASTM A350 LF2				ASTM A479 316			
				Required thickness for B31.1 (in)	Required thickness for B31.3 (in)	Required thickness for B31.4 (in)	Required thickness for B31.8 (in)	Required thickness for B31.3 (in)	Required thickness for B31.1 (in)	Required thickness for B31.4 (in)	Required thickness for B31.8 (in)
DM20001#04	1/4" NPS	0.75	0.09	0.07	0.07	0.07	0.08	0.07	0.07	0.08	0.07
DM20001#06	3/8" NPS	0.93	0.11	0.09	0.08	0.09	0.10	0.09	0.09	0.10	0.09
DM20001#08	1/2" NPS	1.14	0.14	0.11	0.10	0.11	0.12	0.11	0.11	0.12	0.11
DM20001#12	3/4" NPS	1.40	0.16	0.13	0.13	0.14	0.15	0.13	0.13	0.15	0.14
DM20001#16	1" NPS	1.73	0.20	0.16	0.16	0.07	0.08	0.17	0.17	0.10	0.09
DM20001#20	1-1/4" NPS	2.16	0.24	0.20	0.20	0.08	0.10	0.21	0.21	0.12	0.11
DM20001#24	1-1/2" NPS	2.47	0.27	0.23	0.22	0.10	0.11	0.24	0.24	0.14	0.13
DM20001#32	2" NPS	2.90	0.35	0.27	0.26	0.11	0.13	0.28	0.28	0.16	0.15
DM20001#48	3" NPS	4.27	0.36	0.25	0.25	0.17	0.19	0.26	0.26	0.24	0.22
DP40N100#48	3" NPS	3.98	0.19	0.24	0.23	0.16	0.18	0.25	0.25	0.22	0.21
DP40N100#64	4" NPS	5.19	0.32	0.31	0.30	0.20	0.23	0.32	0.32	0.29	0.27
DP40N100#40	2.5" NPS	3.33	0.21	0.20	0.19	0.13	0.15	0.20	0.20	0.18	0.18

TABLE 1 - B31.1, B31.3, B31.4, AND B31.8 PRESSURE DESIGN CALCULATIONS

**The # symbol can be replaced with "G" for ASTM A350 LF2 or "K" for ASTM A479 316.

4 Service Experience

The PYPLOK technology was developed in 1968 for the aerospace industry. The industrial version was introduced in 1979. Since that time PYPLOK has been used extensively in the marine, navy ship, offshore, industrial, oil and gas sectors in a variety of applications including but not limited to: hydraulics, compressed gas, steam and fuel. A substantial list of actual applications is listed in Appendix A.

5 Experimental Stress Analysis

Experimental stress analyses as described in ASME Section VIII Division 2 Annex 5.F has not been performed. However supplemental analyses have been conducted for vibration loads, impulse loads, fire testing, and gas leakage. A summary of these tests are included in Appendix B.

6 Proof Tests

Proof test requirements in ASME Section VIII Division 1 UG-101 and ASME Section I A-22 are identical. ASME Section VIII Division 1 UG-101(m) bursting test procedure was followed with the allowable stress values taken from the appropriate code. Appendix C contains the results of the testing.

7 Detailed Stress Analysis

Finite element models were created for PYPLOK fittings and were evaluated to ASME Section VIII Division 2 Part 5 requirements. Appendix D contains the results of these analyses.

8 Summary

PYPLOK fittings, manufactured by Tube-Mac Piping Technologies, meets the criteria established in ASME B31.3 section 304.7.2, ASME B31.1 section 104.7.2, 404.10 in B31.4 and 831.3.6 in B31.8.

PYPLOK fittings have undergone successful service experience, supplemental testing, proof testing, and detailed stress analysis using finite element methods.

Appendix E summarizes the PYPLOK fitting maximum allowable working pressure (MAWP) in psig as required for B31.1, B31.3, B31.4, and B31.8 code of construction.

APPENDIX A – SERVICE EXPERIENCE

Customer/End User	Location	Application	Piping Material	Pyplok Size	First Install Date
Exxon Chemical	USA Baton Rouge, LA	Low Pressure Steam	CS	1" Couplings	1984
Dow Chemical	USA Freeport, TX	Nitrogen Lines and Low Temp Steam	CS	1" and 2" NPS Couplings	1984
Caltex Refining	Austrailia (NSW)	Hot Boiler Feed Water	SS	25mm Couplings and 90° Elbows	1985
Exxon Mobil	USA Beaumont, Texas	Lube Oil	CS	1 1/2" and 2" Couplings and 90° Elbows	1985
Shell Refinery	USA Norco, LA	Low Pressure Steam	SS	1" NPS couplings and Elbows	1985
Exxon Co.	USA Jackville, Texas Baytown, Texas	Glycol	CS	1/2" and 1" Couplings	1992
Philadelphia Electric Co.	USA (Philadelphia)	CO2 Purge Line	SS	1" and 1 1/2" NPS	1990's
General Ship	USA (Boston)	Halon System	SS, CS, CuNi 70/30	1/2" thru 1" NPS	1990's
Philadelphia Naval Shipyard	USA (Philadelphia)	Halon and Hydraulic Systems	SS, CuNi 70/30	1/2" thru 1 1/2" NPS	1990's
Newport News Shipbuilding	USA (Virginia)	Halon, HP Air and Hydraulics	SS, CuNi 70/30	1/2" thru 1 1/2" NPS	1990's
Norshipco	USA (Virginia)	Halon and Control Systems	SS, CuNi 70/30	1/2" thru 1 1/2" NPS	1990's
Norfolk Naval Shipyard	USA (Virginia)	Halon	SS, CuNi 70/30	1/2" thru 1 1/2" NPS	1990's
Metro Machine	USA (Virginia)	Halon	SS, CuNi 70/30	1/2" thru 1 1/2" NPS	1990's
Charleston Naval Shipyard	USA (South Carolina)	Halon, HP Air, Fuel Oil and Hydraulics	SS, CuNi 70/30	1/2" thru 1 1/2" NPS	1990's
Hiller Systmes	USA (Alabama)	Halon	SS, CuNi 70/30	1/2" thru 1 1/2" NPS	1990's

NASSCO	USA (California)	Halon, HP Air, Fuel Oil and Hydraulics	SS, CuNi 70/30	1/2" thru 1 1/2" NPS	1990's
Southwest Marine	USA (California)	Hydraulic, Halon and Fuel Lines	SS, CuNi 70/30	1/2" thru 1 1/2" NPS	1990's
Long Beach Naval Shipyard	USA (California)	Hydraulic, Halon, Ballast and Fuel Lines	SS, CuNi 70/30	1/2" thru 1 1/2" NPS	1990's
Puget Sound Naval Shipyard	USA (Washington)	Halon, HP Air, Fuel Oil and Hydraulics	SS, CuNi 70/30	1/2" thru 1 1/2" NPS	1990's
Mobil Oil	USA (Texas)	Oil and Gas Lines	CS	2" NPS	1990's
Marathon Oil	USA (Louisiana)	Oil and Gas Lines	CS	1" thru 2" NPS	1990's
Vista Chemical	USA (Louisiana)	Nitrogen	CS	1" NPS	1990's
Goodyear Chemical	USA (Texas)	Robine	CS	2" NPS	1990's
Southwestern Refining Co.	USA (Texas)	Hydraflouric Acid, Oil and LP Steam	CS	1" and 2" NSP	1990's
Bethleham Steel	USA (Texas)	Hydraulics and Pneumatics	CS & SS	1/4" thru 1 1/2" NPS	1990's
Occidental Chemical Corp.	USA (Texas)	Header Wash System	CS	1 1/2" NPS	1990's
ANZAC	Australia & New Zealand	Navy Frigates?	SS	6mm thru 42mm	1990's
Bath Iron Works	Bath, Maine	Hydraulic and Other High Pressure lines	SS CuNi 70/30	1/2" and 1/4" NPS	Since 1990
Marine Hydraulics	USA (Virginia)	Halon and Hydraulic Systems	SS, CuNi 70/30	1/2" thru 1 1/2" NPS	since 1990's
Baltimore Gas and Electirc	Northeast USA	Natural Gas Ball Valve replacement and line upgrades	CS	1" and 1 1/2"	Since 1992
Arcelor Mital (Dofasco)	Canada (Ontario)	Hydraulic Maintaince Repair	SS & CS	1/2" thru 2" NPS	since 1995
Taurus Engineering Inc.	USA (California)	Dow Hole Chemical Injection	SS	1/4" OD	since 1997
ESSO/EXXON Austrailia	Bass Strait Austrailia	Deluge System Repair, Process Piping, Methanol Piping Repair	CuNi 70/30 SS CS	1/2" thru 2" NPS 44.5mm and 57mm	1999 to present
Sarawak Shell Bhd.	Sarawak, Malaysia	Wellhead Instrument Air (South Furious Platform)	Stainless Steel	1/2" thru 1"	1994

Exxon Offshore Inc.	Lafayette, LA	Water Sprinkler System	SS	1" and 1 1/2" Couplings	1995
Chevron Australia	Australia Barrow Island	Oil Stringer Lines	Carbon Steel	3" NPS	Since 2000
US Steel Stelco	Canada (Hamilton)	Hydraulic Pipe Repair	CS	1/2" thru 1 1/2" NPS	since 2000
US Corps. of Engineers	USA (New York)	Black Rock Canal Lock Hydraulic Upgrade	SS	3/4", 1" and 1 1/4" NPS Couplings	2000
Woodside Energy / Transfield Worley	Western Austrailia	Process piping Re-pair/Upgrades and Deluge Install	SS, CS, CuNi 70/30	1/2" thuru 3" NPS and 44.5 and 57mm CuNi	2000
Shell Sydney	Australia	Steam Lines	Stainless Steel	3/4" and 1"	2001
ATCO GAS	Alberta, CANADA	Natural Gas Distribution	CS	3/4" NPS	2002
BP Brisbane	Australia	Process Lines	Carbon Steel	1/2" thry 2"	2002
Shell Eastern Petroleum	Singapore	Steam Lines	Carbon Steel	1/2" NPS	2003
Wynn Casino- Le Reve Show	USA (Las Vegas, Navada)	Underwater Hydraulic Piping	SS	1/2" thru 2" NPS	2004
Boeing - SBX Platform	USA (Alaska)	Hydraulics- interconnect of old piping to new piping	SS	2" Couplings	2006
Great Lakes Dredge	Virgina, U.S.A	Dredger Hydraulics	SS	1 1/4"NPS	2006
ATCO GAS	Canada (Alberta)	Gas Transmission	CS	3/4" NPS	2007
Severstal Columbus	USA (Mississippi)	Steel Mill Hydraulics	SS & CS	1/2" thru 2" NPS	2007
Arcelor Mittal E.S. Fox	Canada (Ontario)	Castor Hydraulics - Dofasco	SS	1/2" and 1" NPS	2007
Versitech	Canada (Ontario)	Steel Mill Glycol Lines	CS	1" and 1 1/2" NPS	2007
Prime Metals	USA (Pennsylvania)	Hydraulics	SS	1/2" and 3/4" OD Straights, Tees and 90°	2007
Wagg's Petroleum	Canada (Quebec)	Diesel Disruibtion System	CS	1" and 1 1/2" Carbon NPC	2008
Moog	Philipines	Hydraulic - Aerospace Testing Lab	SS & CS	1/2" NPS thru 1 1/4" NPS	2008
Montco Offshore	USA (Alabama)	Lift Cylinder Hydraulics L/B Caitlan & L/B Paul	CS & SS	1/2" thur 1 1/2" NPS Reducer Tees	2008

Rowan Offshore / Keppel AmFels	Brownsville, Texas	Derrick and BOP Hydraulic Piping Systems	SS	1/2" NPS thru 2" NPS Tees x SAE Ports	2008
National Oilwell Varco	Houston, TX	Derrick Piping -HP Compressed Air	SS	16mm-30mm Couplings and Shapes	2008
Maersk	Australia	FPSO Piping Repair	CS	1" thru 1 1/2" NPS	2008
TTS Energy	Canada (Alberta)	Stabilizer Lines	SS	3/8" OD	2008
Advanced Piping Systems	Canada (Alberta)	Land Based Drilling Rig Hydrauilics	SS	3/8" OD Tube x JIC End connector	2008
Atlas Copco	USA (Texas)	Hydraulics for "Predator" Drilling System Rig	SS	2" Sch.160 NPS	2008
Conoco Philips - Humber Refinery	Engalnd	Steam Trace Lines	CS	1/2" OD Carbon	2008
Ragan Mechanical - SSAB Iowa	USA (Iowa)	Steel Mill Hydraulics	SS	1/2" and 3/4" NPS	2008
North American Stainless	USA (Kentucky)	Hydraulic Pipe/Ball Valve Upgrades	CS	1" thur 2" NPS	2008
Worldwide Oilfield Machine	USA (Houston)	Subsea B.O.P. Hydraulics	SS	1" and 1 1/4" Straights, 90° and Pyplok x SAE Flange c/w subsea insert	2008
Holland America Lines M/S Vandeem	Bahamas	Fuel heating line Repair Low Temp Steam (120°)	CuNi 70/30	44.5mm Couplings	2009
Helix Energy Solutions Group	Gulf of Mexico	Ball Valve Upgrade (Rig: Q4000)	CS	25mm Couplings and 90° Elbows	2009
Factoria Naval de Marin Shipyard	Marin, Spain	Ultra Fog Fire Suppression System Y102 Haul and Y0104 Haul (60m and 45m long Super Yachts)	SS	12mm thru 30mm Straights, BSSP End connection and special distribution blocks	2009
Austal (Hawaii Supper Ferry)	Mobile, Alabama	Ramp Hydraulics for the Vessel Huakai	SS	3/8" thru 1" OD Tube and 1/2" thru 1 1/4" NPS	2009
Subsea 7	Port Isabel, Texas	Pipe Handling/ Spool Base Equipment Hydraulics	CS & SS	1/2" thru 1 1/4" NPS	2009

Transocean	Canada (Newfoundland)	Replace BOP (Cameron) accumulator piping system	CS	3/4" through 1 1/2"	2009
Transocean	Canada (Newfoundland)	Install high pressure filter manifold into compensator active heave	SS	1 1/2" NPS	2009
Transocean	Canada (Newfoundland)	Drill Derrick Hydraulic System	SS	3/4" through 2" NPS	2009
Suncor Energy (Transocean)	Canada (Newfoundland)	High pressure air line for ROV Cursor system	SS	1 1/2" NPS	2009
TotalFina Elf	Brunei	Oil and Gas Lines	Stainless Steel	1/2" thru 2"	2009
Alta Steel (OneSteel)	Canada (Alberta)	Tundish Car Hydraulics	CS	1" thru 1 1/2" NPS	2009
US Corps. of Engineers	USA (Washington)	John Day Dam Turbine Lube Piping	CS	1/2" thru 1" OD	2009
Navantia	Cartagena, Spain	Shock test	SS & CUNI	3/8" thru 1 1/2" NPS	2009
Astilleros Gondán, S.A.	Castropol, Spain	Hydraulic piping system for tugboat	SS	12 mm	2009
General Motors Orion Plant	USA (Michigan)	Brake Fluid, Transmission Fluid, Sealer and Cleaner Line	CS & SS	1" OD and 1" thru 2" NPS	2010
Cargill	USA (Ohio)	Steam Condenstat Line	CS	3" NPS	2010
Madrid City Council	Madrid, Spain	Fogtec Fire System Piping	SS	16mm 42mm	2010
Mataró City Council / Protecnia	Spain (Mataró)	Fogtec Fire System Piping	SS	16mm thru 38mm	2010
Acis/LLC “Ecomed Munhen Haus”	Ukraine (Kiev)	Fogtec water mist system for Genetics Laboratory	SS	12mm thru 22mm	2010
Acis/TT2 Tyne Tunnel	England (Tyne Tunnel)	Fogtec water mist system for Motorway Tunnel	SS	20mm thru 60mm	2010
Acis/BKV	Hungary (Budapest)	Fogtec water mist system for Underground Depot	SS	12mm	2010
Acis Complex / LLC “Ecomed Munhen Haus”	Ukraine (Kiev)	Fogtec Fire System Piping	SS	12 mm, 3/8" & 1/2" NPS	2010
Acis Complex / BKV	Hungary	Fogtec Fire System Piping	SS	12 mm	2010

Airbus - Telson	Getafe, Spain	Tail Wing Test Fixture	CS	12 mm thru 25 mm with EPDM Seals	2010
Dalian Shipbuilding Industry Offshore Co.,LTD (DSIC)	China	Hydraulic Lines for Aircraft Carrier	SS	10mm and 30mm	2010
Armon Shipyard / Remolques Gijoneses	Navia, Spain	Hydraulic Piping for Tug Boat Equipment	SS & CS	20 mm thru 42mm	2010
Barreras Shipyard / Naviera ARMAS	Vigo, Spain	Piping for Danfoss Water Mist System for Ro-Pax Ferry	SS	1" thru 2" NPS	2010
Transocean	USA (Gulf of Mexico)	Hydraulic System Upgrades	SS	1/2" thru 2" NPS	2010
Meyer Werft	Papenburg, Germany	Piping for High Pressure Fire System	SS	30mm and 38mm	2010
Weatherford	Canada (Alberta)	Hydraulic Down Hole Motors	CS	1-1/2" NPS	2010
Syncrude Canada Ltd. (EXXON)	Canada (Alberta)	Nitrogen Line	CS	3/4" NPS	2010
Severstal Warren	USA (Ohio)	Hydraulic Lines	SS	3/4" OS	2010
ThyssenKrupp Steel USA	USA (Alabama)	Hydraulic, Air and Glycol Lines	CS & SS	20mm thru 60mm	2010
Ford Dearborn Plant	USA (Michigan)	Paint Line	SS	2" NPS	2011
Adelaide Aqua- South Australia Gov't.	Australia (Adelaide)	Desalination Plant Instrumenation Lines	Super Duplex	1/2" and 1" NPS	2011
US Corps. of Engineers	USA (Michigan)	Oil, High Pressure Air & Grease Lines	CS	1/2" thru 1 NPS	2011
Bombardier	Ireland	Cycom Liquid Apoxy Resin Vacuum and Injection Lines	CS	3/8" and 1/2" OD	2011
Messier-Dowty Services	Singapore	Aerospace Acuator Testing Equipment	SS	38mm with EPDM Seals	2011
Mataró City Council / Protecnia	Mataró, Spain	Fogtec Fire System Piping	SS	1/2" tru 1" NPS	2011
Pierre / Museo Egizio	Italy (Torino)	Fogtec Fire System Piping	SS	12 mm, 22 mm & 28 mm	2011

Niscayah / Loomis	Spain (Madrid)	Fogtec Fire System Piping	SS	12 mm, 20 mm and 25 mm	2011
TŰZŐR Tervező és Fővállalkozó kft	Hungary (Mosonmagyaróvár)	Danfoss Semco Water Mist piping	SS	12 mm, 3/8", 1/2", 3/4" and 1" NPS	2011
NASA	USA (Virginia)	Wallops Island Flight Station Rocket Launcher Hydraulics - High Pressure Nitrogen and Hyd. Oil	SS	1/2" thru 2" NPS	2011
Vaagland Båtbyggeri	Vaagland Norway	Tank cleaning system, Well Boat	SS	22mm,28mm and 60mm Elbows, Couplings, Tees, SAE flanges, BSP maled, DIN2353 female	2011
Vinje Industri BP Norge	Norway (North Sea)	Instrument Air System	CS	1”thru 3” PYPLOK x SAE Flange and NPT Connectors	2011
Armon Shipyard / L' Enterprise Port. D' Oran	Navia, Spain	Hydraulic Piping for Tug Boat Equipment	SS &CS	20mm thru 42mm	2011
Armon Shipyard/ Adria Tow SRL	Navia, Spain	Hydraulic Piping for Tug Boat Equipment	SS & CS	20mm thru 38mm	2011
Clearwater Seafoods	Canada (Newfoundland)	Pressure and Return manifolds on HPU	CS	1" & 1 1/2" NPS	2011
DTE Energy	USA (Michingan)	Natural Gas Line	CS	1" NPS	2011
Ensign Energy Group	Canada (Alberta)	Accumulator Systems	CS	1" NPS End connectors and Couplings	2011
Gasco Inc.	USA (California)	Dow Hole Chemical Injection	SS	1/4" OD	2011
Columbia Industries	USA (Oregon)	Rig Walking System Hydraulics	CS	1" thru 1 1/2" NPS	2011
Titan Chemicals Corp. Sdn. Bhd.	Malaysia	Propylene and Butane Lines	CS & SS	1/2" and 2" NPS	2011

PTT Chemical	Thailand	Wates Gas Line Repair	CS	2" Couplings (EPDM Seals)	2011
Thai Oleochemicals Ltd	Thailand	Sodium Methylate Line Repair	CS	1" NPS (EPDM Seals)	2011
Thai Oleochemicals Ltd	Thailand	Glycerine Residue Line	CS	1" NPS	2011
Solvay Chemicals	Italy	Steam Trap Replacment	CS	1/2" Couplings (EPDM Seals)	2011
Glow Energy (GDF Suez)	Thailand	Diesel Line Repair	CS	3/4" NPS	2011
Senoko Power Station	Singapore	Natural Gas Line Repair	SS	2" NPS	2011
Severstal Dearborn	USA (Michigan)	On Board Equipment Hydraulics	CS	16mm thru 30mm	2011
Marl Technologies	Canada (Alberta)	Subsea Coring	SS	1/4" thru 3/4" OD End Connectors, Tees & Straights	2011
Rio Tinto	Western Austrailia	Hydraulic Piping on Jetty Mooring System (Cavotec)	SS	1" thru 2" NPS	2011
Siemens VAI / Thyssen Krupp	Bruckhausen, Germany	Hot Strip Mill Hydraulics for Workroll Latches	SS	16mm and 20mm	2011
Astilleros Gondán, S.A.	Castropol, Spain	Hydraulic piping system for OSV	SS	12 mm thru 42 mm	2011
Ford Oakville	Oakville, Canada	Fuel Leveler Line	CS	1/2" NPS	2012
Nissan Motors	China (Guangzhou)	Car Testing Equipment - 270 bar Hydraulics	CS	16mm thru 30mm	2012
TŰZŐR Tervező és Fővállalkozó kft	Hungary (Budapest)	Danfoss Semco Water Mist piping	SS	12 mm, 3/8", 1/2", 3/4" and 1" NPS	2012
Inima	Algeria (Mostaganem)	Fogtec Fire System Piping	SS	16 mm thru 30 mm	2012
Inima	Algeria (Cap d'Jinet)	Fogtec Fire System Piping	SS	16 mm thru 30 mm	2012
ECOPETROL	Colombia	Pipeline to Exhaust Valve System for Gas Compressor	CS	3" NPS	2012

Kennecot (Rio Tinto)	USA (Utah)	Copper Processing Equipemt (Hydraulics)	Super Duplex & SS	1/2" thru 1"NPS	2012
COSL (Yanti Raffles Yard)	Yantai, China	Hydraulic Piping on Winch System	SS	20mm and 25mm	2012
Dolphin Offshore A/S	Norway	BOP Accumalator Piping	SS	1" thru 2" NPS	2012
MacGregor Cargotec	Norway	Hydraulic Piping for Link Span Loading System	SS	16mm thru 38mm	2012
US Shippings Lines	New Jersey, USA	3000 PSI Hydraulic Line Repair	SS	1 1/2" NPS	2012
Cosco Fire Protection	Sacremento, California	Hi-Fog Fire Mist System for Stanley Mosk State Library	SS	38mm Couplings and Tees	2012
Rio Tinto Australia	Western Austrailia	Dampier Fuel Wharf Hydraulics	SS	1 1/4" thru 2"	2012
Tűzőr Tervező és Fővállalkozó Kft.	Budapest, Hungary	Danfoss Semco Water Mist piping	SS	12 mm thru 1 1/4" NPS	2013
Tűzőr Tervező és Fővállalkozó Kft.	Budapest, Hungary	Danfoss Semco Water Mist piping	SS	12 mm thru 1" NPS	2013
Tűzőr Tervező és Fővállalkozó Kft.	Budapest, Hungary	Danfoss Semco Water Mist piping	SS	12 mm thru 1" NPS	2013
Tűzőr Tervező és Fővállalkozó Kft.	Pécs, Hungary	Danfoss Semco Water Mist piping	SS	12 mm thru 1" NPS	2013
Astilleros de Murueta	Erandio, Spain	Hydraulic piping system for sand carrier	CS & SS	12 mm thru 50 mm	2013
Astilleros de Murueta	Erandio, Spain	Hydraulic piping system for dredger	CS & SS	8 mm thru 60 mm	2013
MTS Systems GmbH	Castelo Branco, Portugal	Aircraft Testing Equipment	CS	20 mm thru 38 mm	2013
ArcelorMittal España	Avilés, Spain	Hydraulic piping for steel mill	SS	12 mm thru 20 mm	2013
Böhler Bleche	Hönigsberg, Austria	Steel Mill Hydraulics	CS	12 mm up to 60 mm	2013

Siemens VAI / Thyssen Krupp	Bruckhausen, Germany	Finishing mill	SS	16 mm up to 30 mm	2013
Trützschler, Germany	Chemnitz, Germany	HP-Aqua Jet	SS	50 mm	2013
Xingang Shipayard/ MTM Ship Management	Xingang, China	Hatch Cover Hydraulics	CS	25mm thru 42mm	2013
Guangzhou Huangpu Shipyard	Guangzhou, China	PSV Deck Machinery Hydraulics	CS	12mm thru 30mm	2013
Fincantieri Bay Shipbuilding / Canada Steamship Line	Sturgeon Bay, USA	Fuel and Lube Piping for Engine Upgrades	CS	2" NPS	2013
Kuwait Oil Company	Al-Ahmadi Refinery	Fire Line Repair	CS	1 1/2" NPS	2013
Rolls Royce Training Center	Ålesund, Norway	Rolls Royce Training Center Hydraulics	SS	18mm thru 38mm	2013
BCM /BHP	Australia	Fuel and Lubrication Piping	CS	2" and 2 1/2" NPS	2013
Dragados	Madrid, Spain	Fogtec Fire System Piping	SS	12 mm thru 38 mm	2014
Astilleros Gondán, S.A.	Castropol, Spain	Ultra Fog Fire Suppression System	SS	12 mm thru 42 mm	2014
AMAG,	Ranshofen, Austria	casting and rolling	CS+SS	16, 20, 25 30 + 38 mm	2014
VÖEST Stahl	Linz, Austria	roll change	Duplex	11/2" NPS + 60 mm	2014
Trützschler, Germany	Portugal	HP-Aqua Jet	Duplex/SS	11/2" NPS	2014
Trützschler, Germany	Polen	HP-Aqua Jet	SS	38 + 60 mm	2014
Bosch Rexroth Germany	Panama Canal	HPU and gate cylinders	316 SS	1-1/4", 1-1/2" and 2"	2014
Astilleros de Santander, S.A.	El Astillero, Spain	Conversion Atlantic Leader	CS & SS	12 mm up to 2 1/2"	2014

NOAA	GMD Shipayrd, New York	Fuel Drain Line Repair	CS	2" NPS	2014
PetroBras	Cacimbas Gas Plant	Compressed Air System Upgrade	CS	2" NPS	2014
Arglye Diamond Mine	Western Austrailia	Underground Workshop Fuel and Lube Piping	SS	1" thru 2" NPS	2014
Astilleros Gondán, S.A.	Castropol, Spain	Hydraulic piping system for OSV	CS & SS	12 mm thru 2 1/2"	2015
Astilleros de Murueta	Erandio, Spain	Hydraulic piping system for tuna fishing vessel	CS & SS	8 mm thru 60 mm	2015
Astilleros de Santander, S.A.	El Astillero, Spain	Conversion Belle Carnelle	CS & SS	12 mm up to 2"	2015
Astilleros de Santander, S.A.	El Astillero, Spain	Refurbishment of different lines on Ro-Ro (Brittany Ferries)	CS & SS	8 mm up to 10 mm	2015
Astilleros de Santander, S.A.	Spain	Refurbishment of hydraulic lines on Atlantic Guardian	CS & SS	12 mm up to 25 mm	2015
Astilleros Canarios	Spain	Conversion Arctic Endurance - Hydraulic lines	CS & SS	12 mm up to 42 mm	2015
Vane Brothers / Vane Double Skin 509A Barge	USA	Thermal Fluid Trace Line Repair	SS	1" NPS	2015
PetroBras	Cherne 1 Platform	Compressed Air System Repair	CS	2" NPS	2015
Bassdrill /PetroBras	P61 Platform	Hydraulic Line Repair	SS	2" NPS	2015
Sarawak Shell Bhd.	Sarawak, South China Sea	Potable Water, Compressed and other process line repairs	CS & SS	1" thru 3"	2015
GE Oil and Gas	Houston, TX	Test Stand Hydraulics	SS	1" thru 2" NPS	2015
Rio Tinto / Decmil	West Angelas Mine Western Austrailia	Lube and Fuel Piping	SS	2"	2015
Astilleros Gondán, S.A.	Castropol, Spain	Hydraulic piping system for oceanographic vessel	CS & SS	12 mm thru 2 1/2"	2016

Astilleros de Murueta	Erandio, Spain	Hydraulic piping system for tuna fishing vessel	CS & SS	8 mm thru 60 mm	2016
Astilleros de Santander, S.A.	Spain	Refurbishment of different lines on Ferry (Brittany Ferries)	CS & SS	12 mm up to 30 mm	2016
Harley Marine	USA	Hydraulic Line Repair	CS	3/4" NPS	2016
Rolls Royce Sterring Gear	Ålesund, Norway	Sterring Gear Test Stand Hydraulics	SS	20mm thru 60mm	2016
Acis Complex / TT2	UK (Wallsend)	Fogtec Fire System Piping	SS	1/2", 3/4", 1 1/4", 1 1/2" & 2"NPS	2009-2011
First Steel	Canada (Alberta)	Steel Mill Hydraulics	CS	3/4" NPS Straights & Tees	2010-2011
ST Marine / Swire Pacific Offshore	Singapore	High Pressure Fire System for (6) AHTS Vessels - Swire Pacific Offshore	SS	16mm thru 35mm	2012/2013
COSCO Guangdong/ Vroom Shipping	Guangdong, China	High Pressure Wash System for Cow Carrier	SS	16mm thru 38mm	2012-2015
Yantai Raffles Shipyard /COSL	Yanti, China	High Pressure Water Mist System Piping for Semi Submersible	SS	12mm thru 60mm	2012-2015
Yantai Raffles Shipyard /GM4D	Yanti, China	High Pressure Water Mist System Piping for Semi Submersible	SS	12mm thru 42mm	2012-2015
TMK IPSCO - Koppel	USA (Pennsylvania)	Steel Mill Hydraulics	CS	1/2" thru 2" NPS	since 2005
Astilleros Armon / URS	Navia, Spain	(20) Tug Boat Hydraulics (Winch, Thruster and Crane Lines)	CS & SS	38mm and 42mm Couplings	Since 2008
Weatherford	Canada USA	Cylinder Hydraulics for Oil Pumping Unit	CS	1 1/2" NPS Pyplok x JIC and Pypllok x NPT End connection	Since 2008

Millar Western Forest Product Ltd.	Canada (Alberta)	Saw Mill Hydraulics	CS	1/2" thru 2" NPS	since 2009
Whitby Co-Generation	Canada (Ontario)	Rolls Royce Turbine Hydraulics & Glycol Cooling Lines	SS	2" NPS Couplings, 90° Elbows and special connectors	Since 2009
Environmental Fluid Solutions	Canada (Alberta)	Lube Lines	SS	3/8" OD	Since 2009
SASOL Synfules	South Afrcia	Steam Trace Lines & Steam Distribution	Carbon Steel Stainless Steel	1/2" thru 1" (EPDM Seals)	Since 2009
Brunei Shell Petroleum (Domestic Gas Reticulation Station)	Brunei	Domestic Gas	SS	1" 90°& 45° Elbow, SAE 150# Flange	since 2009
Brunei Shell Petroleum (Seria Crude Oil Terminal)	Brunei	Air Instrument Line and Process Drain Line.	SS	1/2", 1" and 2" 90°& 45° Elbow, SAE 150# Flange, NPS Coupling.	since 2009
Brunei Shell Petroleum (In Take Station)	Brunei	Process Drain Line	SS	2" 90°& 45° Elbow, SAE 150# Flange, NPS Coupling.	since 2009
Brunei Shell Petroleum (BLNG)	Brunei	Air Instrument Line	SS	1" 90°& 45° Elbow, SAE 150# Flange, NPS Coupling.	since 2009
Brunei Shell Petroleum (Natural Gas Compressor Plant)	Brunei	Air Instrument Line and Process Drain Line.	SS	1/2", 1" and 2" 90°& 45° Elbow, SAE 150# Flange, NPS Coupling.	since 2009
Suncor Energy Inc.	Canada (Alberta)	Steam Trace	SS	1/2" and 3/4" OD 1/2" and 3/4" NPS (EPDM Seals)	since 2010
Chevron Cape Town	South Africa	Steam Lines	Carbon Steel	1/2" NPS	Since 2010
Shell Bokum	Singapore	Steam and other Process/Hydro Carbon Line Reparis	CS	1/2" thru 3"	since 2010
ASC	Australia	Navy Vessel	CuNi 70/30	1/2" thru 1 1/2" NPS	Since 2011

APPENDIX B – SUPPLEMENTAL TESTING

P2.11.5.5 Methods of tests

.1 Tightness test

In order to ensure correct assembly and tightness of the joints, all mechanical joints are to be subjected to a tightness test, as follows.

a) Mechanical joint assembly test specimen is to be connected to the pipe or tubing in accordance with the requirements of P2.11.5.3 and the manufacturers instructions, filled with test fluid and de-aerated.

   Mechanical joints assemblies intended for use in rigid connections of pipe lengths, are not to be longitudinally restrained.

   Pressure inside the joint assembly is to be slowly increased to 1.5 times of design pressure. This test pressure is to be retained for a minimum period of 5 minutes.

   In the event where there is a drop in pressure or there is visual indication of leakage, the test (including fire test) shall be repeated for two test pieces.

   If during the repeat test one test piece fails, the testing is regarded as having failed.

   Other alternative tightness test procedure, such as pneumatic test, may be accepted.

b) For compression couplings a static gas pressure test is to be carried out to demonstrate the integrity of the mechanical joints assembly for tightness under the influence of gaseous media. The pressure is to be raised to maximum pressure or 70 bar whichever is less.

c) Where the tightness test is carried out using gaseous media as permitted in (a) above, then the static pressure test mentioned in (b) above need not be carried out.

.2 Vibration (fatigue) test

In order to establish the capability of the mechanical joint assembly to withstand fatigue, which is likely to occur due to vibrations under service conditions, mechanical joints assembly is to be subject to the following vibration test.

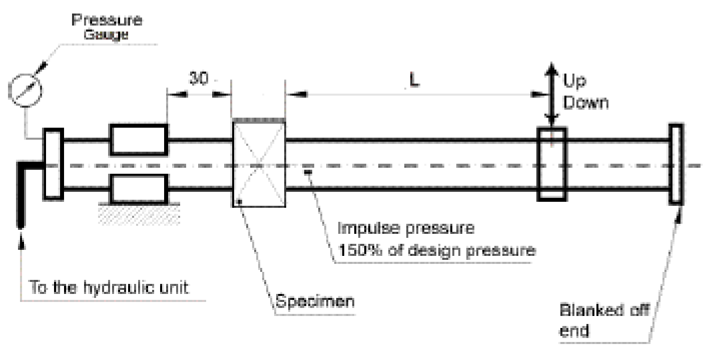
Conclusions of the vibration tests should show no leakage or damage, which could subsequently lead to a failure.

a) Testing of compression couplings and pipe unions

Compression couplings, pipe unions or other similar joints intended for use in rigid connections of pipe are to be tested in accordance with this method described as follows. Rigid connections are joints, connecting pipe length without free angular or axial movement.

Two lengths of pipe are to be connected by means of the joint to be tested. One end of the pipe is to be rigidly fixed while the other end is to be fitted to the vibration rig. The test rig and the joint assembly specimen being tested are to be arranged as shown in Fig.1.

Fig. 1



The joint assembly is to be filled with test fluid, de-aerated and pressurised to the design pressure of the joint.

P2
(cont)

Pressure during the test is to be monitored. In the event of drop in the pressure and visual signs of leakage the test is to be repeated as described in P2.11.5.4.

Visual examination of the joint assembly is to be carried out for signs of damage which may eventually lead to joint leakage.

Re-tightening may be accepted once during the first 1000 cycles.

Vibration amplitude is to be within 5% of the value calculated from the following formula:

$$A = \frac{2 \times S \times L^2}{3 \times E \times D}$$

where:

A	-	single amplitude, mm
L	-	length of the pipe, mm
S	-	allowable bending stress in N/mm^2 based on 0.25 of the yield stress
E	-	modulus of elasticity of tube material (for mild steel, E = 210 kN/mm^2)
D	-	outside diameter of tube, mm.

Test specimen is to withstand not less than 10^7 cycles with frequency 20 - 50 Hz without leakage or damage.

.3 Pressure pulsation test

In order to determine capability of mechanical joint assembly to withstand pressure pulsation likely to occur during working conditions, joint assemblies intended for use in rigid connections of pipe lengths, are to be tested in accordance with the following method.

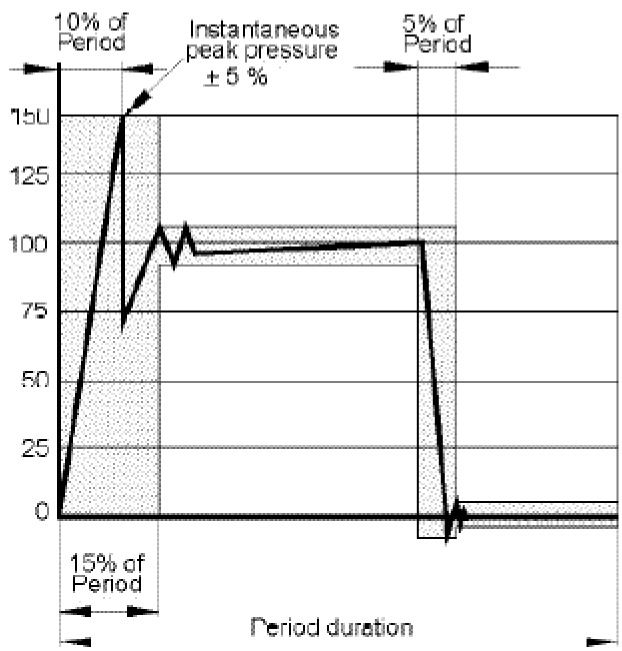
The mechanical joint test specimen for carrying out this test may be the same as that used in the test in P2.11.5.5.1 (a) provided it passed that test.

The vibration test in P2.11.5.5.2 and the pressure pulsation test are to be carried out simultaneously for compression couplings and pipe unions.

The mechanical joint test specimen is to be connected to a pressure source capable of generating pressure pulses of magnitude as shown in Fig 3.

P2
(cont)

Fig.3 Impulse pressure diagram



Impulse pressure is to be raised from 0 to 1.5 times the design pressure of the joint with a frequency equal to 30-100 cycles per minute. The number of cycles is not to be less than 5 x 10^5.

The mechanical joint is to be examined visually for sign of leakage or damage during the test.

.6 Fire endurance test

In order to establish capability of the mechanical joints to withstand effects of fire which may be encountered in service, mechanical joints are to be subjected to a fire endurance test. The fire endurance test is to be conducted on the selected test specimens as per the following standards.

(a) ISO 19921: 2005(E): Ships and marine technology – Fire resistance of metallic pipe components with resilient and elastomeric seals – Test methods

(b) ISO 19922: 2005(E): Ships and marine technology – Fire resistance of metallic pipe components with resilient and elastomeric seals – Requirements imposed on the test bench.

Clarifications to the standard requirements:

1. If the fire test is conducted with circulating water at a pressure different from the design pressure of the joint (however of at least 5 bar) the subsequent pressure test is to be carried out to twice the design pressure.

2. A selection of representative nominal bores may be tested in order to evaluate the fire resistance of a series or range of mechanical joints of the same design. When a mechanical joint of a given nominal bore (D_n) is so tested then other mechanical joints falling in the range D_n to $2xD_n$ (both inclusive) are considered accepted.

APPENDIX C – PROOF TEST DATA

TUBE-MAC PIPING TECHNOLOGIES www.tube-mac.com

TUBE-MAC® PIPING TECHNOLOGIES LTD.
853 Arvin Avenue, Stoney Creek
Ontario, L8E 5N8 CANADA
TEL: (905) 643-8823
FAX: (905) 643-0643
TOLL FREE 1-877-643-8823

TEST REPORT ______

Date: ______ **Distributor:** ______ **Customer:** ______

TEST DATE	Mar 23, 2016	TECHNICIAN		AMBIENT TEMP (deg C)
		Name (Print)	MIKE BELL	23 C
		Name (Signature)	Mike Bell	
TEST	Test Fluid:	Dexron III / Mercon Automatic Transmission Fluid (ATF)		
	Test Procedure:	ASME Section VIII, Division 1, Section UG-101(*m*) *Burst Test Procedure*		
TEST EQUIPMENT	Pressure Intensifier:	Model 67-6VVBS300	SN: 0796181	
	Digital Readout Gauge:	Honeywell JHW30KGZ	SN: 77-0152504	
	Pressure Transducer:	Honeywell A-105	SN: 1505870	
TEST SPECIMEN MATERIAL	Material Specification:	ASTM A350 LF2 CARBON STEEL	Material Size:	Φ 1/4" NPS
	Avg. OD before test:	.549/A .544/B	Max. OD after test:	.549/A .546/B
	PYPLOK Identification:	DM20001G04 - cplg 06-16 A1G	/DM20085G04 - caps	50-15 A1G
PROCEDURE	Increase pressure gradually to 150% anticipated MAWP. Hold for approximately 5 minutes. Increase pressure gradually to rupture point of test specimen.			
TEST RESULT	Failure Location (pipe/fitting)	END CAP	Pressure - Peak @ Failure	20100 psig
	Failure Mode (rupture/slip)	slip	Pressure - 1st visual observation of slip	NA

Report Written: Thursday February 25, 2016

Test Witnessed by: Adam Li (TSSA) on. 965

[signature] Mar. 23, 2016

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TUBE-MAC® PIPING TECHNOLOGIES www.tube-mac.com

TEST REPORT ______

Date: ______ **Distributor:** ______ **Customer:** ______

TEST DATE	Mar 23, 2016	TECHNICIAN		AMBIENT TEMP (deg C)
		Name (Print)	MIKE BELL	~~70F~~ 23 C
		Name (Signature)	Mike Bell	
TEST	Test Fluid:	Dexron III / Mercon Automatic Transmission Fluid (ATF)		
	Test Procedure:	ASME Section VIII, Division 1, Section UG-101(*m*) *Burst Test Procedure*		
TEST EQUIPMENT	Pressure Intensifier:	Model 67-6VVBS300	SN: 0796181	
	Digital Readout Gauge:	Honeywell JHW30KGZ	SN: 77-0152504	
	Pressure Transducer:	Honeywell A-105	SN: 1505870	
TEST SPECIMEN MATERIAL	Material Specification:	316SS ASTM A276	Material Size:	ϕ 1/4" NPS
	Avg. OD before test:	.536 A / .536 B	Max. OD after test:	.608/A .632/B
	PYPLOK Identification:	DM20001K04 - cplg 06-16 A3H / DM20085K04 - caps 50-15 A0T		
PROCEDURE	Increase pressure gradually to 150% anticipated MAWP. Hold for approximately 5 minutes. Increase pressure gradually to rupture point of test specimen.			
TEST RESULT	Failure Location (pipe/fitting)	pipe, side B	Pressure - Peak @ Failure	28460 psig
	Failure Mode (rupture/slip)	rupture	Pressure - 1st visual observation of slip	NA

Report Written: Thursday February 25, 2016

Test Witnessed by: Adam Li ON.965 (TSSA)

Mar. 23. 2016

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TEST REPORT ______

Date: ______ **Distributor:** ______ **Customer:** ______

TEST DATE	Wed Mar 23, 2016	TECHNICIAN		AMBIENT TEMP (deg C)
		Name (Print)	MIKE BELL	23 C
		Name (Signature)	Mike Bell	
TEST	Test Fluid:	Dexron III / Mercon Automatic Transmission Fluid (ATF)		
	Test Procedure:	ASME Section VIII, Division 1, Section UG-101(*m*) *Burst Test Procedure*		
TEST EQUIPMENT	Pressure Intensifier:	Model 67-6VVBS300	SN: 0796181	
	Digital Readout Gauge:	Honeywell JHW30KGZ	SN: 77-0152504	
	Pressure Transducer:	Honeywell A-105	SN: 1505870	
TEST SPECIMEN MATERIAL	Material Specification:	ASTM A350 LF2 CARBON STEEL	Material Size:	Ø 1/2" NPS
	Avg. OD before test:	.844/A .842/B	Max. OD after test:	.844/A .845/B
	PYPLOK Identification:	DM20001G08 – cplg 06-16 AIG / DM20085G08 – caps 28-14 XTØ		
PROCEDURE	Increase pressure gradually to 150% anticipated MAWP. Hold for approximately 5 minutes. Increase pressure gradually to rupture point of test specimen.			
TEST RESULT	Failure Location (pipe/fitting)	fitting, inboard of thin crimp band.	Pressure - Peak @ Failure	20860 psig
	Failure Mode (rupture/slip)	rupture	Pressure - 1st visual observation of slip	NA

Report Written: Thursday February 25, 2016

Test Witnessed by: Adam Li (TSSA). ON.965

Mar. 23. 2016

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TEST REPORT ______

Date: ______ **Distributor:** ______ **Customer:** ______

TEST DATE	Wed Mar 23, 2016	TECHNICIAN		AMBIENT TEMP (deg C)
		Name (Print)	MIKE BELL	23 C
		Name (Signature)	Mike Bell	
TEST	Test Fluid:	Dexron III / Mercon Automatic Transmission Fluid (ATF)		
	Test Procedure:	ASME Section VIII, Division 1, Section UG-101(*m*) *Burst Test Procedure*		
TEST EQUIPMENT	Pressure Intensifier:	Model 67-6VVBS300	SN: 0796181	
	Digital Readout Gauge:	Honeywell JHW30KGZ	SN: 77-0152504	
	Pressure Transducer:	Honeywell A-105	SN: 1505870	
TEST SPECIMEN MATERIAL	Material Specification:	316SS ASTM A276	Material Size:	ϕ ½" NPS
	Avg. OD before test:	.832/A .832/B	Max. OD after test:	.833/A .832/B
	PYPLOK Identification:	DM20001 K08 - cplg 03-16 B1C / DM20085 K08 - caps 28-14 XT2		
PROCEDURE	Increase pressure gradually to 150% anticipated MAWP. Hold for approximately 5 minutes. Increase pressure gradually to rupture point of test specimen.			
TEST RESULT	Failure Location (pipe/fitting)	fitting - center	Pressure - Peak @ Failure	26 240 psig
	Failure Mode (rupture/slip)	rupture	Pressure - 1st visual observation of slip	- NA -

Report Written: Thursday February 25, 2016

Test Witnessed by: Adam Li (TSSA) on.965

Mar. 23. 2016

TUBE-MAC® PIPING TECHNOLOGIES LTD.
853 Arvin Avenue, Stoney Creek
Ontario, L8E 5N8 CANADA
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TOLL FREE 1-877-643-8823

TEST REPORT ______

Date: ________ **Distributor:** ____________ **Customer:** ____________

TEST DATE	Mar 23, 2016	TECHNICIAN		AMBIENT TEMP (deg C)
		Name (Print)	MIKE BELL	23
		Name (Signature)	Mike Bell	
TEST	Test Fluid:	Dexron III / Mercon Automatic Transmission Fluid (ATF)		
	Test Procedure:	ASME Section VIII, Division 1, Section UG-101(*m*) *Burst Test Procedure*		
TEST EQUIPMENT	Pressure Intensifier:	Model 67-6VVBS300	SN: 0796181	
	Digital Readout Gauge:	Honeywell JHW30KGZ	SN: 77-0152504	
	Pressure Transducer:	Honeywell A-105	SN: 1505870	
TEST SPECIMEN MATERIAL	Material Specification:	ASTM A350 LF2 CARBON STEEL	Material Size:	ϕ1" NPS
	Avg. OD before test:	1.323/A 1.319/B	Max. OD after test:	1.373/A 1.373/B
	PYPLOK Identification:	DM20001 G16-cplg 05-16 A2S	DM20 085 G16-caps 14-14 XE1	
PROCEDURE	Increase pressure gradually to 150% anticipated MAWP. Hold for approximately 5 minutes. Increase pressure gradually to rupture point of test specimen.			
TEST RESULT	Failure Location (pipe/fitting)	fitting/pipe interface	Pressure - Peak @ Failure	19020 psig
	Failure Mode (rupture/slip)	slip	Pressure - 1st visual observation of slip	19 020 psig

Report Written: Thursday February 25, 2016

Test Witnessed by: Adam Li (TSSA) ON.965

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TEST REPORT ______

Date: ________ **Distributor:** ____________ **Customer:** ____________

TEST DATE	Wed Mar 23, 2016	TECHNICIAN		AMBIENT TEMP (deg C)
		Name (Print)	MIKE BELL	23C
		Name (Signature)	Mike Bell	
TEST	Test Fluid:	Dexron III / Mercon Automatic Transmission Fluid (ATF)		
	Test Procedure:	ASME Section VIII, Division 1, Section UG-101(*m*) *Burst Test Procedure*		
TEST EQUIPMENT	Pressure Intensifier:	Model 67-6VVBS300	SN: 0796181	
	Digital Readout Gauge:	Honeywell JHW30KGZ	SN: 77-0152504	
	Pressure Transducer:	Honeywell A-105	SN: 1505870	
TEST SPECIMEN MATERIAL	Material Specification:	316 SS ASTM A276	Material Size:	Ø 1" NPS
	Avg. OD before test:	1.307/A 1.305/B	Max. OD after test:	1.513/A 1.422/B
	PYPLOK Identification:	DM20001K16 - cplg 05-16 A1B / DM20085K16 - caps 25-14 XR1		
PROCEDURE	Increase pressure gradually to 150% anticipated MAWP. Hold for approximately 5 minutes. Increase pressure gradually to rupture point of test specimen.			
TEST RESULT	Failure Location (pipe/fitting)	pipe	Pressure - Peak @ Failure	23140.
	Failure Mode (rupture/slip)	rupture	Pressure - 1st visual observation of slip	~NA~

Report Written: Thursday February 25, 2016

Test witnessed by: Adam Li (TSSA) on. 965
[signature] Mar. 23. 2016

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TEST REPORT ______

Date: ______ **Distributor:** ______ **Customer:** ______

TEST DATE	Wed Mar 23, 2016	TECHNICIAN		AMBIENT TEMP (deg C)
		Name (Print)	MIKE BELL	23 C
		Name (Signature)	Mike Bell	
TEST	Test Fluid:	Dexron III / Mercon Automatic Transmission Fluid (ATF)		
	Test Procedure:	ASME Section VIII, Division 1, Section UG-101(*m*) *Burst Test Procedure*		
TEST EQUIPMENT	Pressure Intensifier:	Model 67-6VVBS300	SN: 0796181	
	Digital Readout Gauge:	Honeywell JHW30KGZ	SN: 77-0152504	
	Pressure Transducer:	Honeywell A-105	SN: 1505870	
TEST SPECIMEN MATERIAL	Material Specification:	ASTM A350 LF2 CARBON STEEL	Material Size:	ϕ2" NPS
	Avg. OD before test: ϕ2.934 fitting	2.374/A 2.372/B	Max. OD after test:	ϕ3.066" (fitting)
	PYPLOK Identification:	DM20001G32 - cplg 04-16 YP3 / DM20085G32 - caps 43-14 YN6		
PROCEDURE	Increase pressure gradually to 150% anticipated MAWP. Hold for approximately 5 minutes. Increase pressure gradually to rupture point of test specimen.			
TEST RESULT	Failure Location (pipe/fitting)	fitting	Pressure - Peak @ Failure	15,400 psi
	Failure Mode (rupture/slip)	slip.	Pressure - 1st visual observation of slip	12,000 psi

Report Written: Thursday February 25, 2016

Test Witnessed by: Adam Li (TSSA) ON.965
Mar. 23, 2016

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TOLL FREE 1-877-643-8823

TEST REPORT ______

Date: ______ **Distributor:** ______ **Customer:** ______

TEST DATE	Wed Mar 23/2016	TECHNICIAN		AMBIENT TEMP (deg C)
		Name (Print)	MIKE BELL	23
		Name (Signature)	Mike Bell	
TEST	Test Fluid:	Dexron III / Mercon Automatic Transmission Fluid (ATF)		
	Test Procedure:	ASME Section VIII, Division 1, Section UG-101(*m*) *Burst Test Procedure*		
TEST EQUIPMENT	Pressure Intensifier:	Model 67-6VVBS300	SN: 0796181	
	Digital Readout Gauge:	Honeywell JHW30KGZ	SN: 77-0152504	
	Pressure Transducer:	Honeywell A-105	SN: 1505870	
TEST SPECIMEN MATERIAL	Material Specification:	316SS ASTM A276	Material Size:	Ø2" NPS
	Avg. OD before test: Ø2.934 fitting	2.373/A 2.373/B	Max. OD after test:	3.186 (fitting)
	PYPLOK Identification:	DM20001K32 - cplg 04-16 B1A / DM20085K32 - caps 04-14 WX8		
PROCEDURE	Increase pressure gradually to 150% anticipated MAWP. Hold for approximately 5 minutes. Increase pressure gradually to rupture point of test specimen.			
TEST RESULT	Failure Location (pipe/fitting)	fitting	Pressure - Peak @ Failure	17160 psig
	Failure Mode (rupture/slip)	- NA - orings on ports and adapter.	Pressure - 1st visual observation of slip	>15,000 psig

Report Written: Thursday February 25, 2016

Test Witnessed by: Adam Li (TSSA) on. 865

Mar. 23. 2016

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TOLL FREE 1-877-643-8823

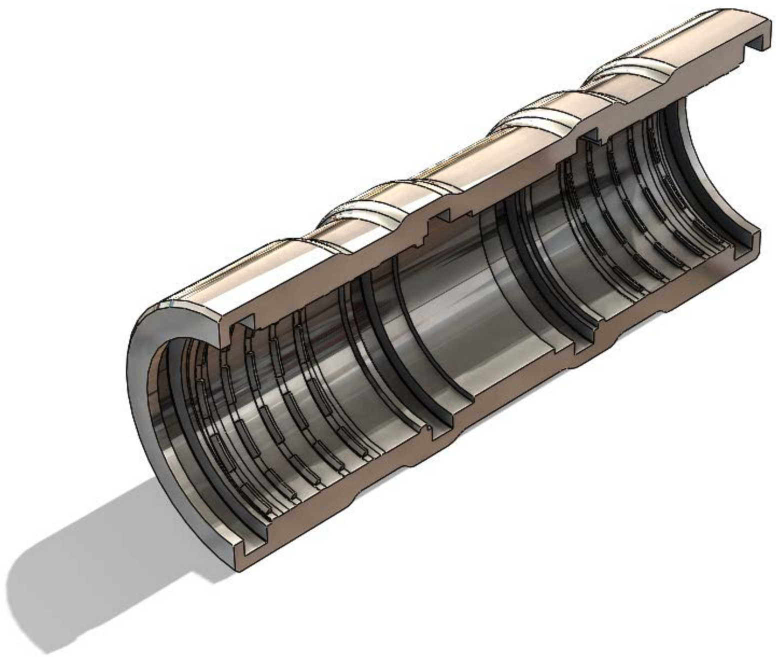
TEST REPORT ID NO. 2018-04-13

TEST DATE	Friday April 13, 2018 9:30am – 11:00am	TECHNICIAN		AMBIENT TEMP (deg C)
		Name (Print)	Mike Bell	22 deg C
		Name (Signature)	Mike Bell	
TEST	Test Fluid:	Water in test specimen / Oil in hydraulic power unit		
	Test Procedure:	ASME Section VIII, Division 1, Section UG-101		
TEST EQUIPMENT	Pressure Intensifier:	Model 67-6VVBS300	SN: 0796181	
	Digital Readout Gauge:	Honeywell JHW30KGZ	SN: 77-0152504	
	Pressure Transducer:	Honeywell A-105	SN: 1505870	
TEST SPECIMEN MATERIAL	Material Specification:	ASTM A350 LF2	Material Size:	5.56" OD x 0.625" wall (G758932)
	Avg. OD before test:	NA	Max. OD after test:	NA
	PYPLOK Identification:	PYPLOK DP40N100G64 CSP-628 CANADA 39-17		
TEST PRESSURE SET-POINT	Design Pressure = 508 psig (35 bar) Increase pressure gradually to 1.5X design 800 psig (Hydrostatic Test). Hold for approximately 5 minute. Increase pressure gradually to 4X design 2300 psig (Burst Test). Hold for approximately 5 minutes. Increase pressure gradually to rupture point of test specimen. Part slipped at 4300 psig			
TEST RESULT	Rupture (pipe/fitting)	No Fitting/Pipe Rupture	Pressure - Peak @ Failure	4300 psig
	Failure Mode (rupture/slip)	Slip – both ends	Pressure - 1st visual observation slip	4300 psig

Witnessed by: Jean ON.965
TSSA Apr. 13. 2018

Report Written: Friday April 13, 2018

APPENDIX D – DETAILED STRESS ANALYSIS



Pyplok 1/2" Finite Element Analysis Report – ASTM A350 LF2

Performed for: TubeMac Piping Technologies Ltd.

Prepared by: Edward De Rubeis

Date: 30/11/2015

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2 EXECUTIVE SUMMARY

A 1/2” pyplok fitting was analyzed using finite element analysis (FEA). The part was created in Solidworks 2015 using drawing DM20001G08 revision 1 and DS267-08 revision 4. The part was analyzed using Solidworks Simulation; a linear elastic modelling software package. A detailed stress analysis of the simulation results were analyzed to ASME section VIII division 2 Part 5, elastic stress analysis method using allowable stress values from B31.3 Appendix A-1. The materials analyzed were ASTM A-350 LF2 Cl. 2 and ASTM A-105. The conclusion of the analysis is that the part is acceptable for use for B31.3 systems in accordance with the requirements of B31.3 304.7.2(d).

3 INTRODUCTION

It is assumed that the applicable code section for the Pyplok fittings is B31.3 - Part 4: Fluid service requirements for piping joints; specifically section 318 Special Joints. The analysis outlined in 304.7.2(d) will only apply to pressure design of the Pyplok fitting as indicated in B31.3-318.1.2 and not to the sealing mechanism or integrity of the joint. B31.3-318.2 requirements are outside of the current scope of work. Also it is assumed this fitting will be used in normal fluid service applications.

The scope of the FEA analysis will consist of the pressure design of the fitting while considering internal pressure and end load reactions only. The effect of crimping the ends will not be included in the analysis. Furthermore interaction between the fitting, pipe and o-rings will not be included in the analysis. This simplification will permit the use of a static linear elastic FEA analysis with small displacements of the fitting. Since the area of interest in this analysis is mainly the mid-section of the fitting, these simplifications will not have an adverse effect of the analysis results.

4 DESIGN CODES

ASME B31.-3, 2014 edition

ASME Section VIII Division 2, 2013 edition

5 MATERIAL PROPERTIES

The material types and corresponding mechanical properties at 400F (the fitting’s maximum allowable operating temperature) are listed in Table 1 - Material Properties.

Specification	Allowable Stress at Temperature	Yield Strength at Temperature	Elastic Modulus at Temperature	Poison’s Ratio
ASTM A-350 LF2 Cl. 2	20500psi	31800psi	27900000psi	0.3
ASTM A-105	20500psi	31800psi	27900000psi	0.3

TABLE 1 - MATERIAL PROPERTIES

Since both materials used to manufacture this fitting have the same mechanical properties only one analysis will be done.

The allowable stress values as prescribed by ASME Section VIII Division 2 Part 5 are shown in the table below.

Stress Type	Allowable Stress (psi)
Sm (General Primary membrane Stress)	20500
PL (Local Primary Membrane Stress	30750
PL + Pb (Local Primary + Primary Bending Stress)	30750
PL + Pb + Q (Local Primary + secondary stress intesity)	63600

TABLE 2 - ALLOWABLE STRESS VALUES

6 MODEL DESCRIPTION

A three dimensional model was created using drawing DM20001G08 revision 1 and DS267-08 revision 4. The model was verified to dimensionally match the drawing.

The small manufacturing details in the part model required a more refined mesh. In order to reduce the analysis time only a quarter of the model was analyzed. Part symmetry was used to reduce the model size, free memory requirements, and allow for a more refined mesh in the area of interest for the analysis.

Below is a summary of the mesh type and elements used. A mesh control was applied to the inside surface where the element size was set at 0.05in and ratio of 1.

TABLE 3 - MESH PARAMETERS

Mesh type	Solid Mesh
Mesher Used:	Curvature based mesh
Jacobian points	4 Points
Maximum element size	0.06 in
Minimum element size	0.012 in
Mesh Quality	High
Total Nodes	143323
Total Elements	92252
Maximum Aspect Ratio	266.04
% of elements with Aspect Ratio < 3	91.7
% of elements with Aspect Ratio > 10	1
% of distorted elements(Jacobian)	0

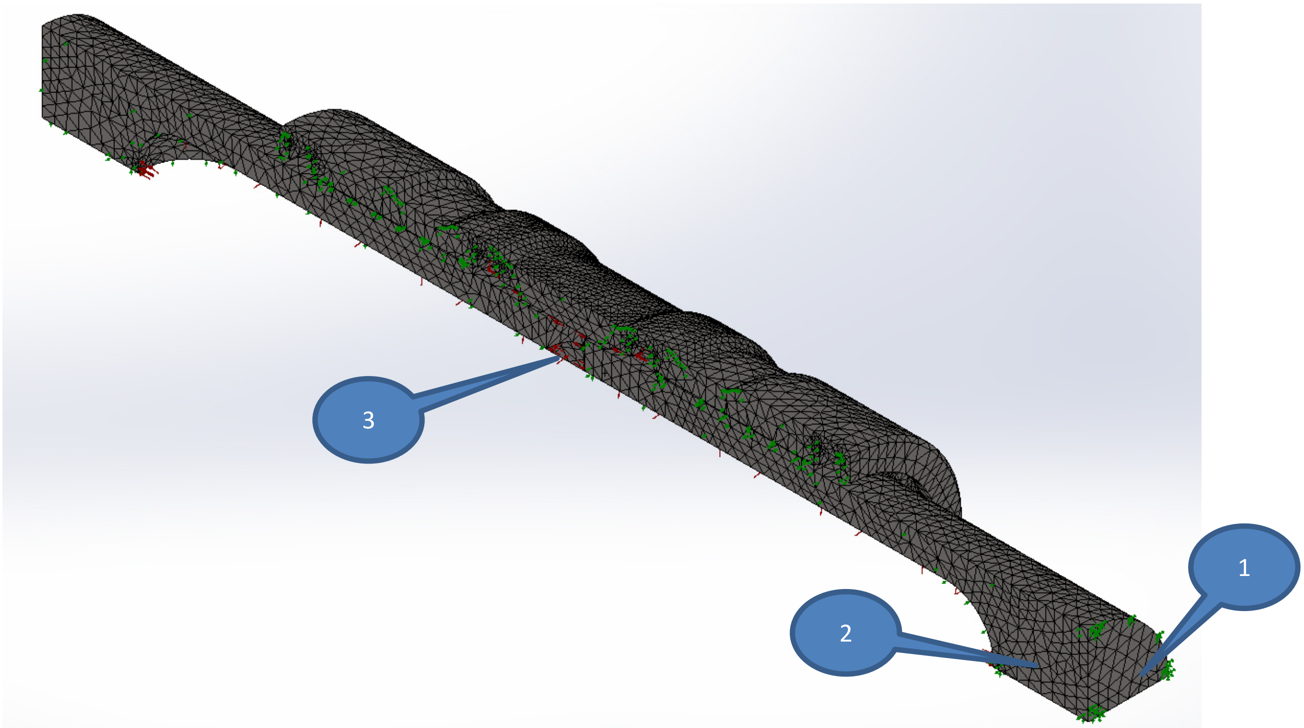


FIGURE 1- MODEL MESHED

Load / boundary Conditions	Value applied	Location Marker (Blue and White)
Fixed edge support	-	1
Symmetry end condition	-	2
Internal Pressure	4000psi	3

The following load and boundary conditions were applied to the model see, Figure 1- Model Meshed.

The internal pressure was applied up until the inner o-ring on each side of the fitting's centerline. This would represent the o-ring being pressurized up against the opposite face sealing the unit.

The pressure thrust reaction loads were modelled by introducing a 1/2" NPS Sch. 80 pipe section in the model. Evaluating the 6 rows of barb pieces and the crimping action interacting with the pipe was beyond the capabilities of the software tool being used and beyond the scope of the analysis. Therefore a simplification was made, the barb pieces were removed and the pipe was connected to the fitting in those regions. Since the analysis was not concerned about those regions from a pressure design perspective, this simplification will not have an effect on the results. The end load reaction due to pressurization was evaluated by capping off the pipe sections and applying pressure.

7 Simulation Plot Results

The following figures and tables are the results of the simulation.

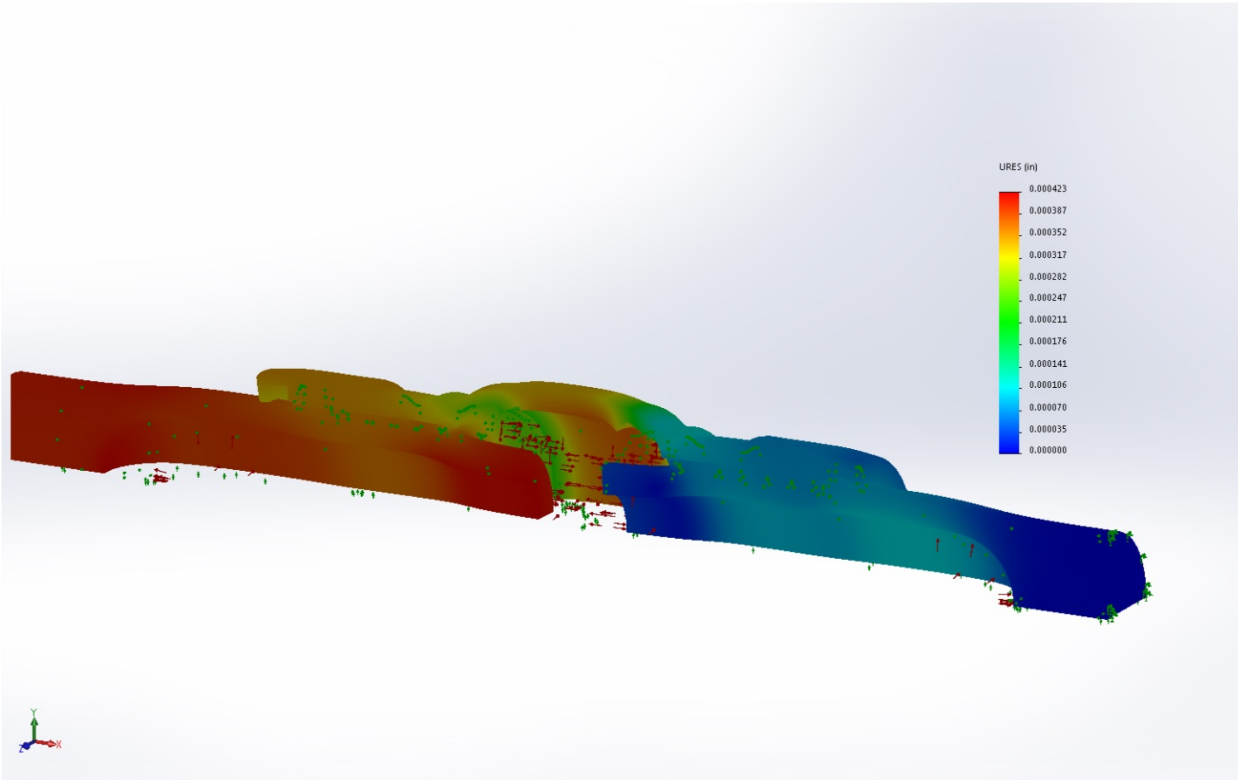


FIGURE 2 - DISPLACEMENT PLOT

The deformed shaped in Figure 2 - Displacement Plot is scaled by a factor of 600 in order actually see the deformation. The maximum resultant displacement is only 0.0004in.

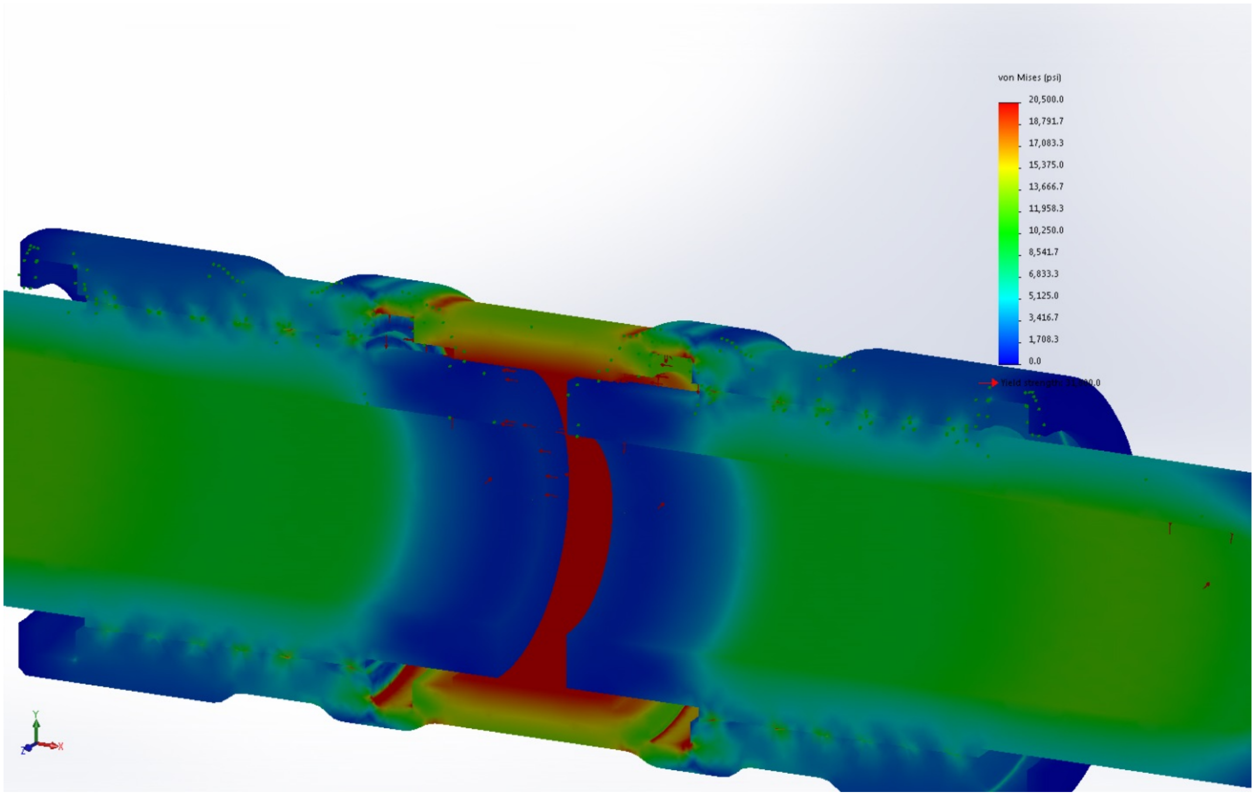


FIGURE 3- VON MISES STRESS PLOT

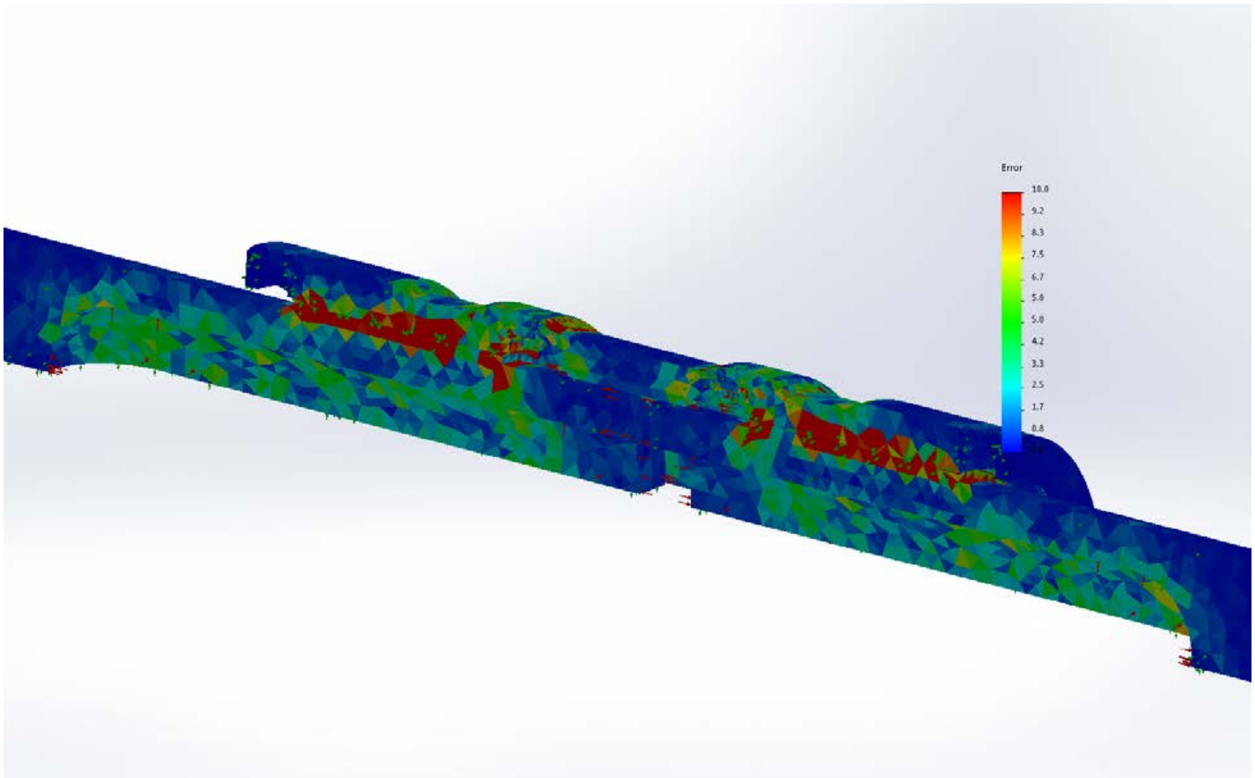


FIGURE 4 - ERROR PLOT

7.1 Resultant Forces

7.1.1 Reaction forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	lbf	0.52308	-5002	5001.6	7073.7

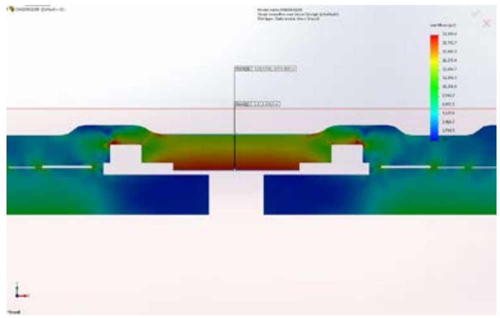
7.1.2 Reaction Moments

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	lbf.in	0	0	0	0

8 Discussion of Results

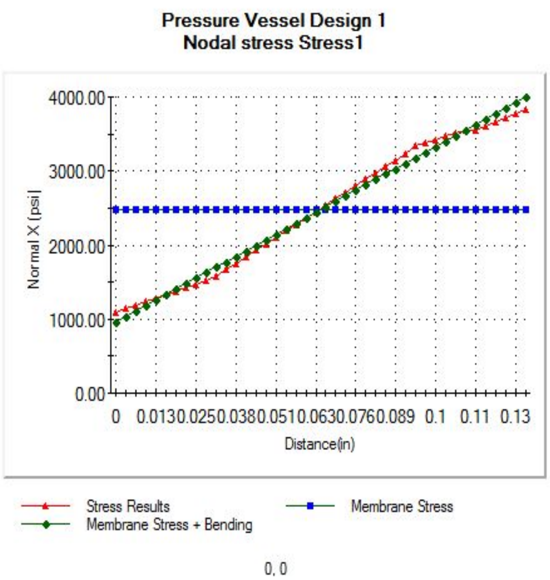
As shown in Figure 3- Von Mises Stress Plot the main point of interest from a high stress standpoint is in the middle section of the pyplok fitting. Using the assessment procedure outlined in ASME Section VIII Division 2, a stress classification line (SCL) was selected through the highest stress region to evaluate its stress state to code values.

Plot : Stress1
Point(1): -1.63, 0.439, 0 in
Point(2) : -1.63, 0.568, -4.97e-028 in
Units : psi

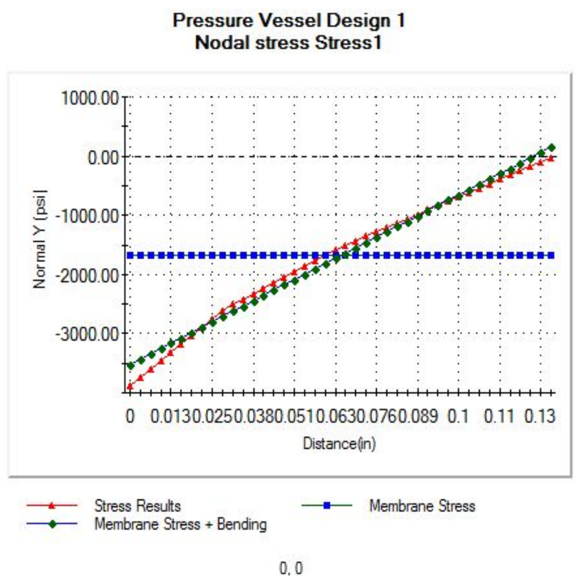


Components	Normal X	Normal Y	Normal Z	Shear XY	Shear XZ	Shear YZ	von Mises	Stress intensity (P1-P3)
Membrane Stress	2.48E+003	-1.69E+003	1.64E+004	-45.3	-6.43	9.16	1.64E+004	1.81E+004
Bending (Point 1)	-1.52E+003	-1.83E+003	2.06E+003	-11.9	6.13	18.3	3.75E+003	3.9E+003
Membrane Stress + Bending (Point 1)	960	-3.52E+003	1.84E+004	-57.2	-0.302	27.4	2.01E+004	2.19E+004
Bending (Point 2)	1.52E+003	1.83E+003	-2.06E+003	11.9	-6.13	-18.3	3.75E+003	3.9E+003
Membrane Stress + Bending (Point 2)	3.99E+003	148	1.43E+004	-33.4	-12.6	-9.1	1.27E+004	1.42E+004
Peak (Point 1)	139	-357	281	-9.01	13.1	19.5	582	641
Peak (Point 2)	-168	-180	201	30.3	4.67	-4.99	379	407

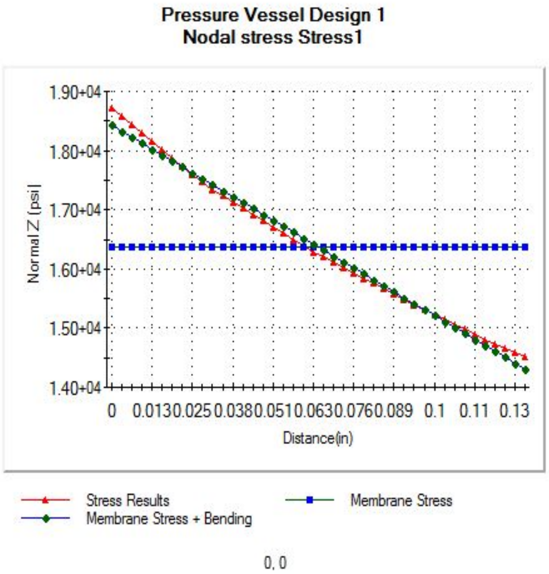
Curve Data:



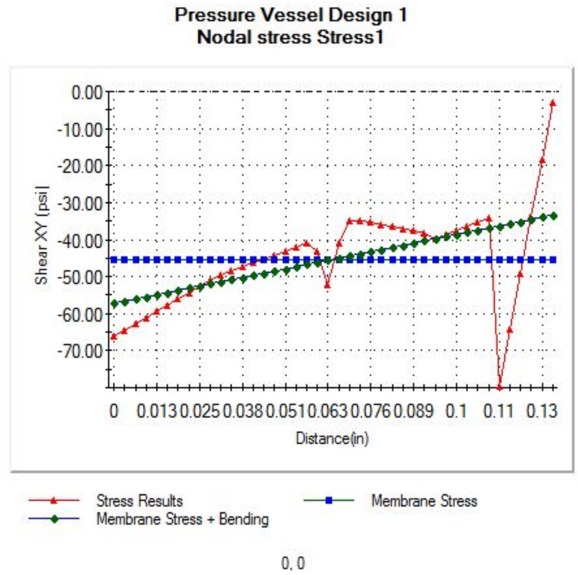
Normal X (psi)



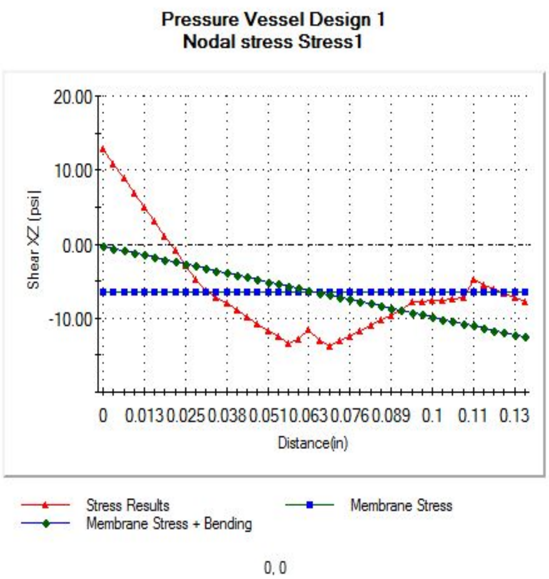
Normal Y (psi)



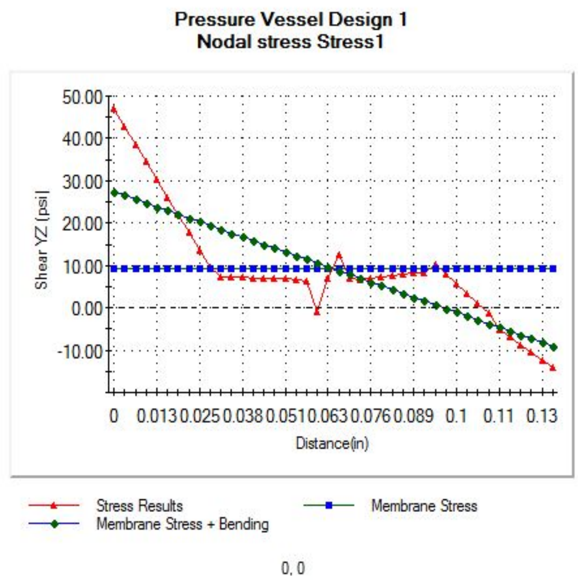
Normal Z (psi)



Shear XY (psi)



Shear XZ (psi)



Shear YZ (psi)

TABLE 4 - SCL STRESS RESULTS

Table 5 - SCL Stress Compared to Allowable Stresses compares the allowable stress criteria to the simulated model stresses. All simulated model stresses are below code allowable values.

Stress Type	Actual Value (psi)	Allowable Value (psi)	Acceptable
Pm	**16408**	**20500**	**Yes**
PL + PB (Point 1)	**20059**	**30750**	**Yes**
PL + PB (Point 2)	**12676**	**30750**	**Yes**
PL + PB + Q (Point 1)	**20528**	**63600**	**Yes**
PL + PB + Q (Point 2)	**13040**	**63600**	**Yes**

TABLE 5 - SCL STRESS COMPARED TO ALLOWABLE STRESSES

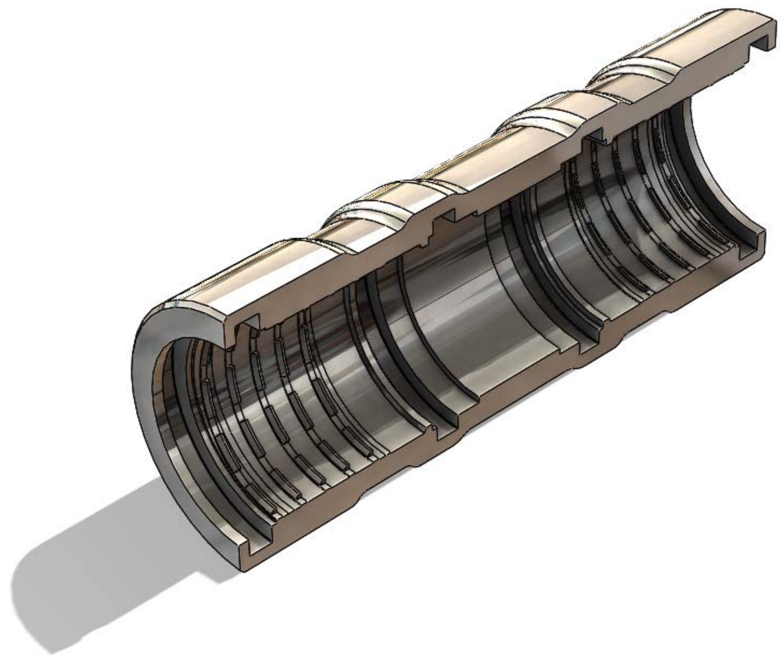
The resultant loads as shown in 7.1 are as expected. The high Y and Z values are a result of the fixed constraint which prevents any movement in those directions. Since the fixed constraint is outside the area of interest this is not a concern in terms of affecting the results. The only value of importance is the X direction which should be zero and the reaction load value is in good agreement to this value.

Figure 4 - Error Plot shows the energy norm error between the nodal stress values and element stress values. The target for the area of interest was less than 5%. The plot shows that for the area of concern the error is less than 5%. There are higher error regions; however they are not located in the area of interest, and are not part of this scope of work. Refining the mesh to account for the large error in this region has no effect on the area of interest, and thus has no bearing on results of this report.

Figure 2 - Displacement Plot shows the resultant displacement of the fitting under pressure. The displacement is low but the shape is what would be expected when pressurizing the fittings which indicates the model and approach is correct.

9 CONCLUSION

The part is acceptable for use within B31.3 systems in accordance with the requirements of B31.3 304.7.2(d). The stress state of all stress categories in the area of interest for the fitting was below the code allowable values. The displacement of the part was low and the error level in the area of interest was acceptable.



Pyplok 1” Finite Element Analysis Report – ASTM A350 LF2

Performed for: Tube-Mac piping Technologies Ltd.

Prepared by: Edward De Rubeis

Date: 30/11/2015

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2 Executive Summary

A 1" pyplok fitting was analyzed using finite element analysis (FEA). The part was created in Solidworks 2015 using drawing DM20001G16 revision 1 and DS267-16 revision 3. The part was analyzed using Solidworks Simulation; a linear elastic modelling software package. A detailed stress analysis of the simulation results were analyzed to ASME section VIII division 2 Part 5, elastic stress analysis method using allowable stress values from B31.3 Appendix A-1. The materials analyzed were ASTM A-105 and ASTM A-350 LF2 Cl. 2. The conclusion of the analysis is that the part is acceptable for use for B31.3 systems in accordance with the requirements of B31.3 304.7.2(d).

3 Introduction

It is assumed that the applicable code section for the Pyplok fittings is B31.3 - Part 4: Fluid service requirements for piping joints; specifically section 318 Special Joints. The analysis outlined in 304.7.2(d) will only apply to pressure design of the Pyplok fitting as indicated in B31.3-318.1.2 and not to the sealing mechanism or integrity of the joint. B31.3-318.2 requirements are outside of the current scope of work. Also it is assumed this fitting will be used in normal fluid service applications.

The scope of the FEA analysis will consist of the pressure design of the fitting while considering internal pressure and end load reactions only. The effect of crimping the ends will not be included in the analysis. Furthermore interaction between the fitting, pipe and o-rings will not be included in the analysis. This simplification will permit the use of a static linear elastic FEA analysis with small displacements of the fitting. Since the area of interest in this analysis is mainly the mid-section of the fitting, these simplifications will not have an adverse effect of the analysis results.

4 Design Codes

ASME B31.-3, 2014 edition

ASME Section VIII Division 2, 2013 edition

5 Material Properties

The material types and corresponding mechanical properties at 400F (the fitting's maximum allowable operating temperature) are listed in Table 1- Material Properties.

Specification	Allowable Stress at Temperature	Yield Strength at Temperature	Elastic Modulus at Temperature	Poison's Ratio
ASTM A-350 LF2 Cl. 2	20500psi	31800psi	27900000psi	0.3
ASTM A-105	20500psi	31800psi	27900000psi	0.3

TABLE 1- MATERIAL PROPERTIES

Since both materials used to manufacture this fitting have the same mechanical properties only one analysis will be done.

The allowable stress values as prescribed by ASME Section VIII Division 2 Part 5 are shown in the table below.

Stress Type	Allowable Stress (psi)
Sm (General Primary membrane Stress)	20500
PL (Local Primary Membrane Stress	30750
PL + Pb (Local Primary + Primary Bending Stress)	30750
PL + Pb + Q (Local Primary + secondary stress intesity)	63600

TABLE 2 - ALLOWABLE STRESS VALUES

6 MODEL DESCRIPTION

A three dimensional model was created using drawing DM20001G16 revision 1 and DS267-16 revision 3. The model was verified to dimensionally match the drawing.

The small manufacturing details in the part model required a more refined mesh. In order to reduce the analysis time only a quarter of the model was analyzed. Part symmetry was used to reduce the model size, free memory requirements, and allow for a more refined mesh in the area of interest for the analysis.

Below is a summary of the mesh type and elements used. A mesh control was applied to the inside surface where the element size was set at 0.05in and ratio of 1.

TABLE 3 - MESH PARAMETERS

Mesh type	Solid Mesh
Mesher Used:	Curvature based mesh
Jacobian points	4 Points
Maximum element size	0.06 in
Minimum element size	0.012 in
Mesh Quality	High
Total Nodes	248964
Total Elements	165493
Maximum Aspect Ratio	65.745
% of elements with Aspect Ratio < 3	97.9
% of elements with Aspect Ratio > 10	0.436
% of distorted elements(Jacobian)	0

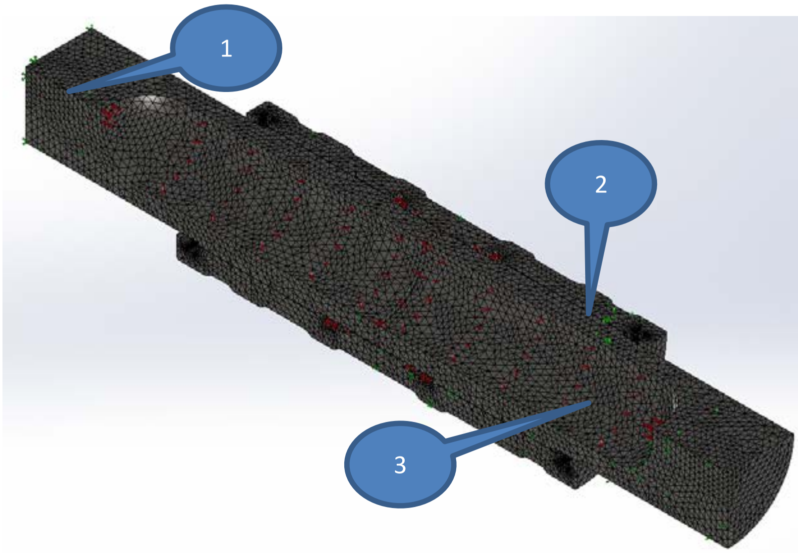


FIGURE 1- MODEL MESHED

Load / boundary Conditions	Value applied	Location Marker (Blue and White)
Fixed edge support	-	1
Symmetry end condition	-	2
Internal Pressure	4000psi	3

The following load and boundary conditions were applied to the model see, Figure 1- Model Meshed.

The internal pressure was applied up until the inner o-ring on each side of the fitting's centerline. This would represent the o-ring being pressurized up against the opposite face sealing the unit.

The pressure thrust reaction loads were modelled by introducing a 1" NPS SCH 80 pipe section in the model. Evaluating the 6 rows of barb pieces and the crimping action interacting with the pipe was beyond the capabilities of the software tool being used and beyond the scope of the analysis. Therefore a simplification was made, the barb pieces were removed and the pipe was connected to the fitting in those regions. Since the analysis was not concerned about those regions from a pressure design perspective, this simplification will not have an effect on the results. The end load reaction due to pressurization was evaluated by capping off the pipe sections and applying pressure.

7 Simulation Plot Results

The following figures and tables are the results of the simulation.

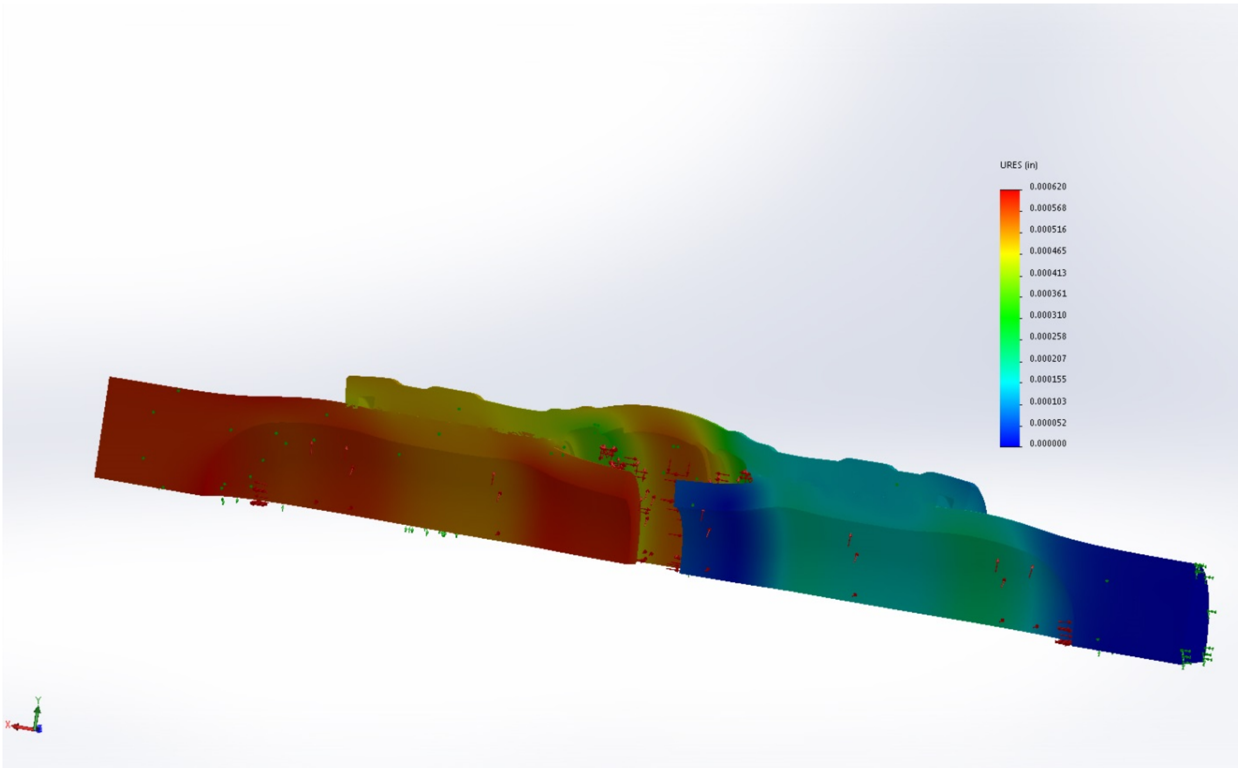


FIGURE 2 - DISPLACEMENT PLOT

The deformed shaped in Figure 2 - Displacement Plot is scaled by a factor of 500 in order actually see the deformation. The maximum resultant displacement is only 0.0006in.

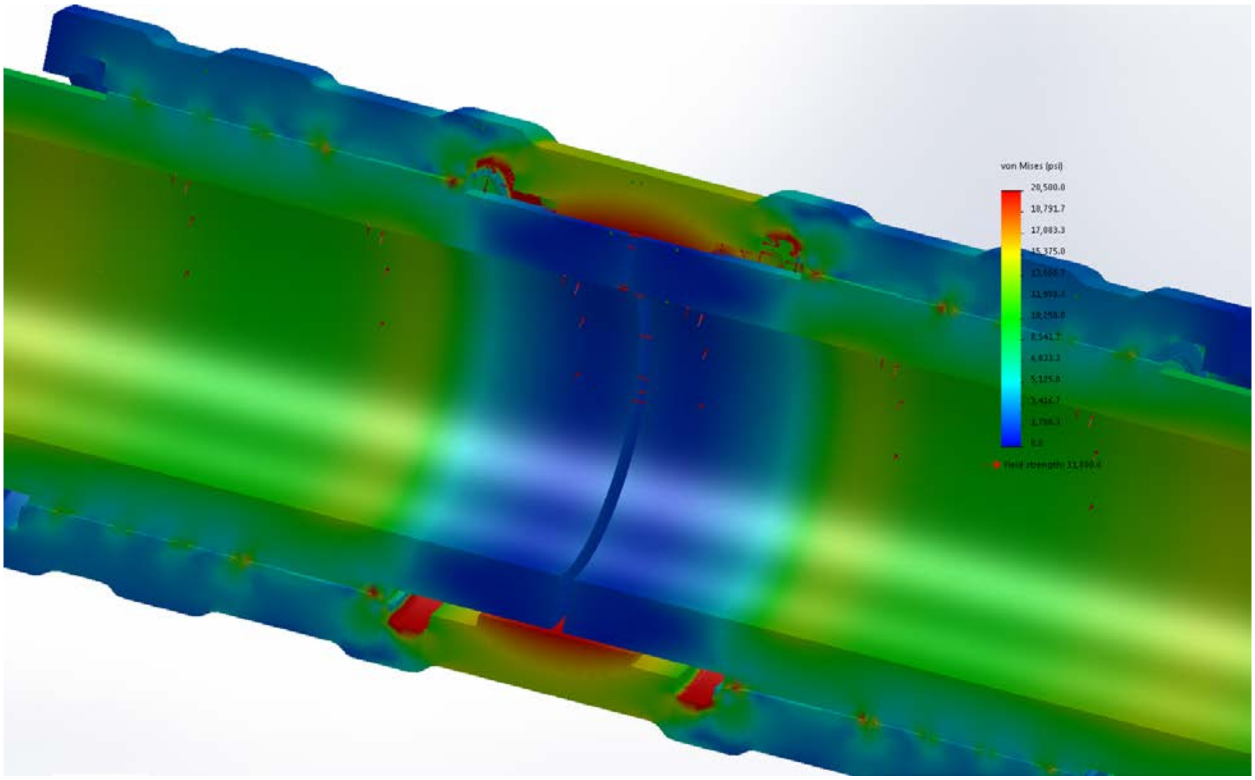


FIGURE 3- VON MISES STRESS PLOT

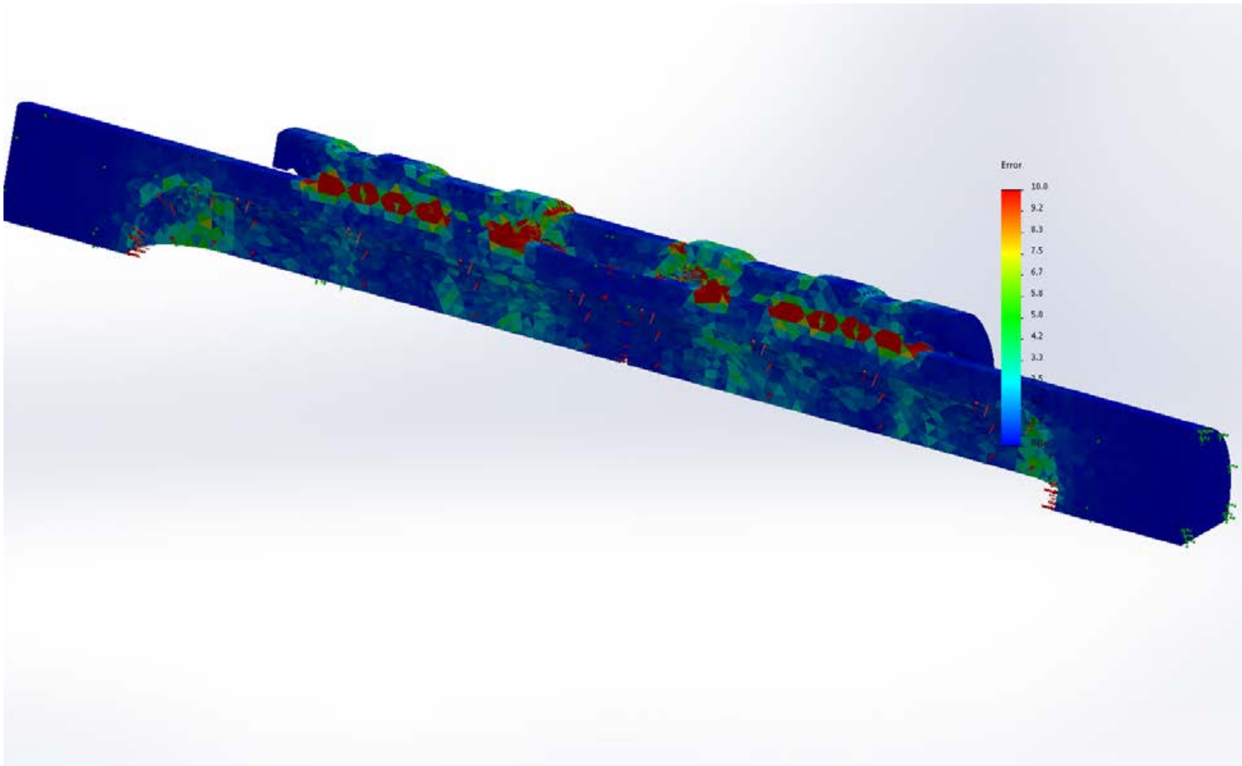


FIGURE 4 - ERROR PLOT

7.1 RESULTANT FORCES

7.1.1 REACTION FORCES

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	lbf	0.01	-10386	-10386	14688

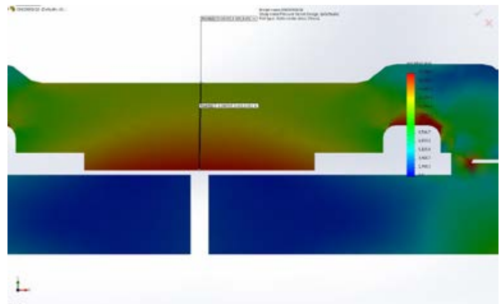
7.1.2 REACTION MOMENTS

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	lbf.in	0	0	0	0

8 DISCUSSION OF RESULTS

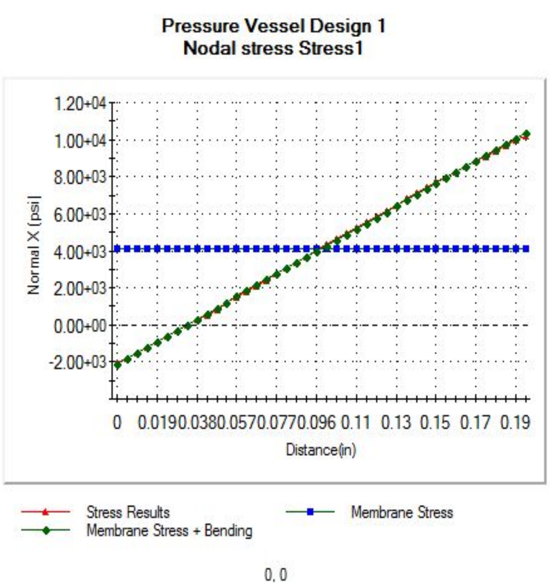
As shown in Figure 3- Von Mises Stress Plot the main point of interest from a high stress standpoint is in the middle section of the pyplok fitting. Using the assessment procedure outlined in ASME Section VIII Division 2, a stress classification line (SCL) was selected through the highest stress region to evaluate its stress state to code values.

Plot : Stress1
Point(1): -0.000585, 0.669, 0.001 in
Point(2) : 0.00315, 0.865, 0.001 in
Units : psi

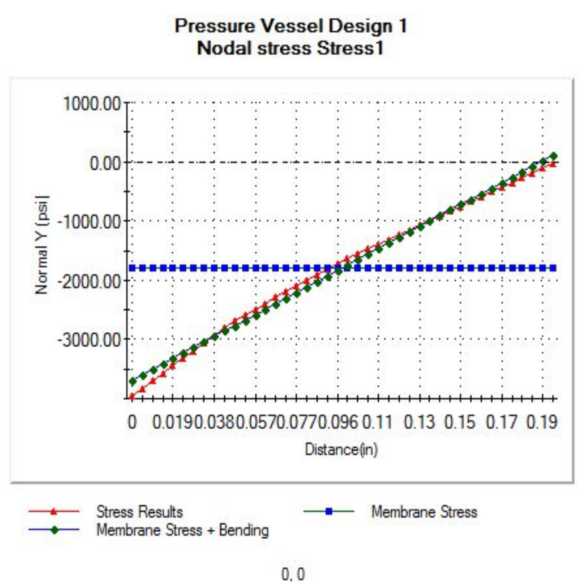


Components	Normal X	Normal Y	Normal Z	Shear XY	Shear XZ	Shear YZ	von Mises	Stress intensity (P1-P3)
Membrane Stress	4.12E+003	-1.79E+003	1.65E+004	5.33	0.91	-23.8	1.62E+004	1.83E+004
Bending (Point 1)	-6.26E+003	-1.9E+003	721	-6.94	4.66	-14.6	6.11E+003	6.98E+003
Membrane Stress + Bending (Point 1)	-2.14E+003	-3.7E+003	1.72E+004	-1.61	5.57	-38.4	2.02E+004	2.09E+004
Bending (Point 2)	6.26E+003	1.9E+003	-721	6.94	-4.66	14.6	6.11E+003	6.98E+003
Membrane Stress + Bending (Point 2)	1.04E+004	111	1.58E+004	12.3	-3.75	-9.14	1.38E+004	1.57E+004
Peak (Point 1)	57.3	-259	206	-9.61	-0.506	-16.3	412	466
Peak (Point 2)	-161	-138	157	-10.9	4	-1.04	309	323

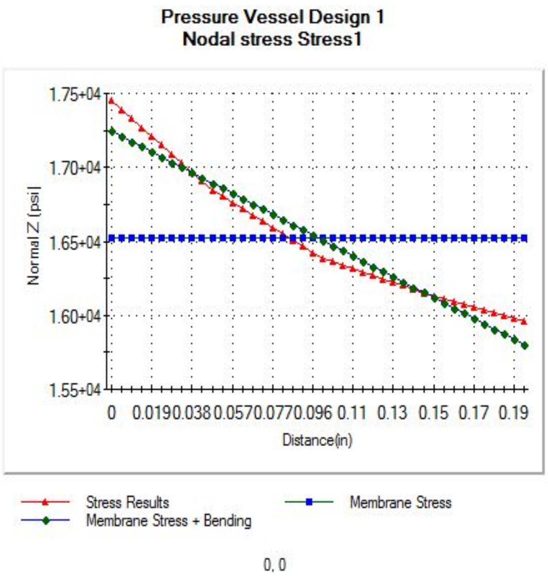
Curve Data:



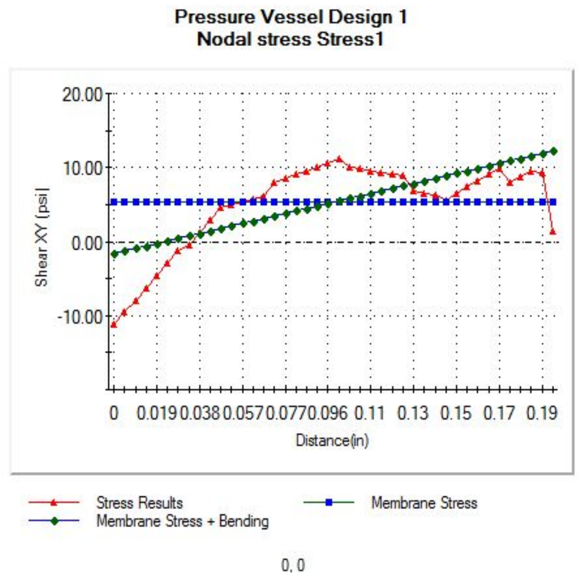
Normal X (psi)



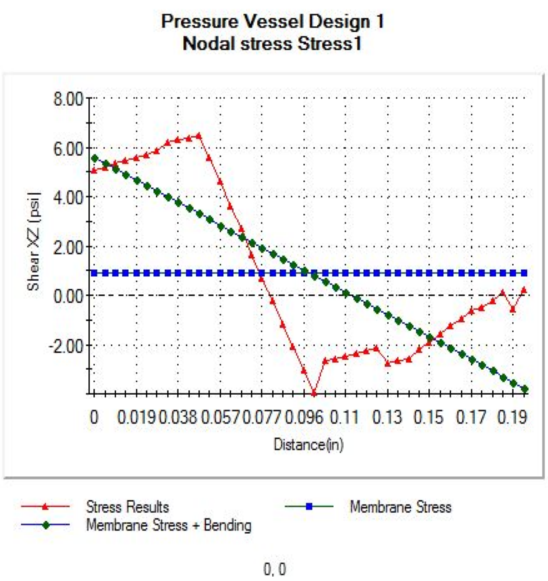
Normal Y (psi)



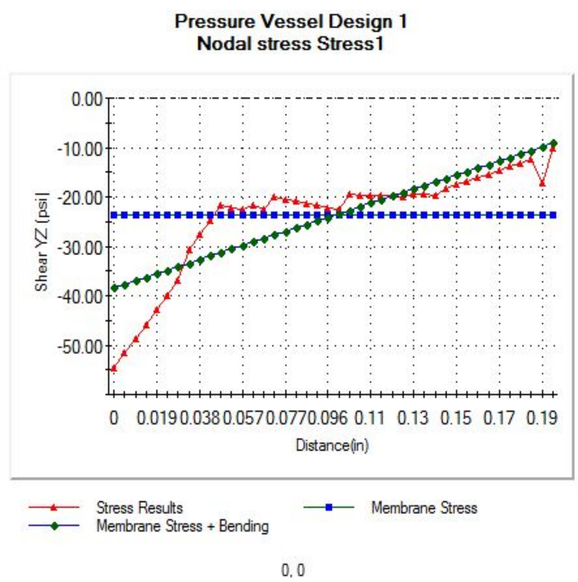
Normal Z (psi)



Shear XY (psi)



Shear XZ (psi)



Shear YZ (psi)

TABLE 4 - SCL STRESS RESULTS

Table 5 - SCL Stress compared to Allowable Stresses compares the allowable stress criteria to the simulated model stresses. All simulated model stresses are below code allowable values.

Stress Type	Actual Value (psi)	Allowable Value (psi)	Acceptable
Pm	**16167**	**20500**	**Yes**
PL + PB (Point 1)	**20165**	**30750**	**Yes**
PL + PB (Point 2)	**13805**	**30750**	**Yes**
PL + PB + Q (Point 1)	**20492**	**63600**	**Yes**
PL + PB + Q (Point 2)	**14028**	**63600**	**Yes**

TABLE 5 - SCL STRESS COMPARED TO ALLOWABLE STRESSES

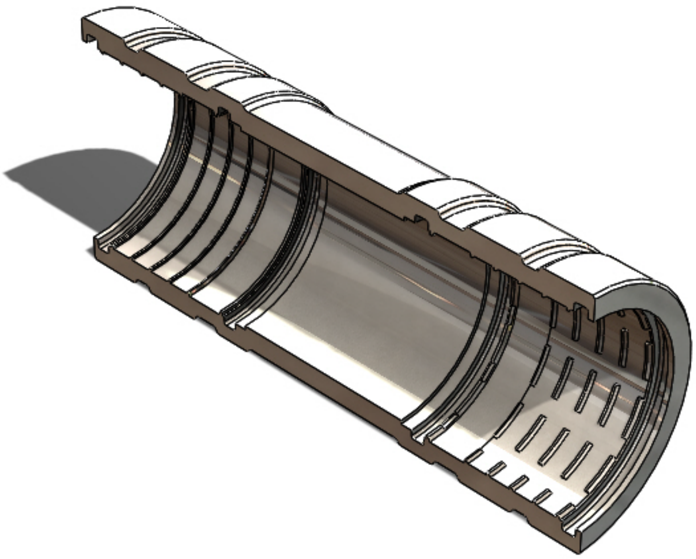
The resultant loads as shown in 7.1 are as expected. The high Y and Z values are a result of the fixed constraint which prevents any movement in those directions. Since the fixed constraint is outside the area of interest this is not a concern in terms of affecting the results. The only value of importance is the X direction which should be zero and the reaction load value is in good agreement to this value.

Figure 4 - Error Plot shows the energy norm error between the nodal stress values and element stress values. The target for the area of interest was less than 5%. The plot shows that for the area of concern the error is less than 5%. There are higher error regions, however they are not located in the area of interest, and are not part of this scope of work. Refining the mesh to account for the large error in this region has no effect on the area of interest, and thus has no bearing on results of this report.

Figure 2 - Displacement Plot shows the resultant displacement of the fitting under pressure. The displacement is low but the shape is what would be expected when pressurizing the fittings which indicates the model and approach is correct.

9 CONCLUSION

The part is acceptable for use within B31.3 systems in accordance with the requirements of B31.3 304.7.2(d). The stress state of all stress categories in the area of interest for the fitting was below the code allowable values. The displacement of the part was low and the error level in the area of interest was acceptable.



Pyplok 2” Finite Analysis Report

Performed for: TubeMac

Prepared by: Edward De Rubeis

Date: 03/06/2015

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2 EXECUTIVE SUMMARY

A 2” pyplok fitting was analyzed using finite element analysis (FEA). The part was created in Solidworks 2015 using drawing DM20001G32 Rev 1. The part was analyzed using Solidworks Simulation; a linear elastic model was created. A detailed stress analysis of the simulation results were analyzed to ASME section VIII division 2 Part 5, elastic stress analysis method using allowable stress values from B31.3 Appendix A-1. The conclusion of the analysis is that the part is acceptable for use for B31.3 systems in accordance with the requirements of B31.3 304.7.2(d).

3 INTRODUCTION

It is assumed that the applicable code section for the Pyplok fittings is B31.3 - Part 4: Fluid service requirements for piping joints; specifically section 318 Special Joints. The analysis outlined in 304.7.2(d) will only apply to pressure design of the Pyplok fitting as indicated in B31.3-318.1.2 and not to the sealing mechanism or integrity of the joint. B31.3-318.2 requirements are outside of the current scope of work. Also it is assumed this fitting will be used in normal fluid service applications.

The scope of the FEA analysis will consist of the pressure design of the fitting while considering internal pressure and end load reactions only. The effect of crimping the ends will not be included in the analysis. Furthermore interaction between the fitting, pipe and o-rings will not be included in the analysis. This simplification will permit the use of a static linear elastic FEA analysis with small displacements of the fitting. Since the area of interest in this analysis is mainly the mid-section of the fitting, these simplifications will not have an adverse effect of the analysis results.

4 DESIGN CODES

ASME B31.-3, 2014 edition

ASME Section VIII Division 2, 2013 edition

5 MATERIAL PROPERTIES

Below are the material types and properties at 400F the maximum allowable operating temperature.

Specification	Allowable Stress at Temperature	Yield Strength at Temperature	Elastic Modulus at Temperature	Poison’s Ratio
ASTM A-350 LF2 Cl. 2	20500psi	31800psi	27900000psi	0.3
ASTM A-105	20500psi	31800psi	27900000psi	0.3

Since both materials used to manufacture this fitting have the same mechanical properties only one analysis will be done.

The allowable stress values as prescribed by ASME Section VIII Division 2 Part 5 are shown in the table below.

Stress Type	Allowable Stress (psi)
Sm (General Primary membrane Stress)	20500
PL (Local Primary Membrane Stress	30750
PL + Pb (Local Primary + Primary Bending Stress)	30750
PL + Pb + Q (Local Primary + secondary stress intesity)	63600

TABLE 1 - ALLOWABLE STRESS VALUES

6 MODEL DESCRIPTION

A three dimensional model was created using drawing DM20001G32 Revision 1. The model was verified to dimensionally match the drawing.

The small manufacturing details in the part model required a more refined mesh. In order to reduce the analysis time only a quarter of the model was analyzed. Part symmetry was used to reduce the model size, free memory requirements, and allow for a more refined mesh in the area of interest for the analysis.

Below is a summary of the mesh type and elements used. A mesh control was applied to the inside surface where the element size was set at 0.05in and ratio of 1.

TABLE 2 - MESH PARAMETERS

Mesh type	Solid Mesh
Mesher Used:	Curvature based mesh
Jacobian points	4 Points
Maximum element size	0.376217 in
Minimum element size	0.0752433 in
Mesh Quality	High
Total Nodes	134519
Total Elements	87370
Maximum Aspect Ratio	96.527
% of elements with Aspect Ratio < 3	93.5
% of elements with Aspect Ratio > 10	0.46
% of distorted elements(Jacobian)	0

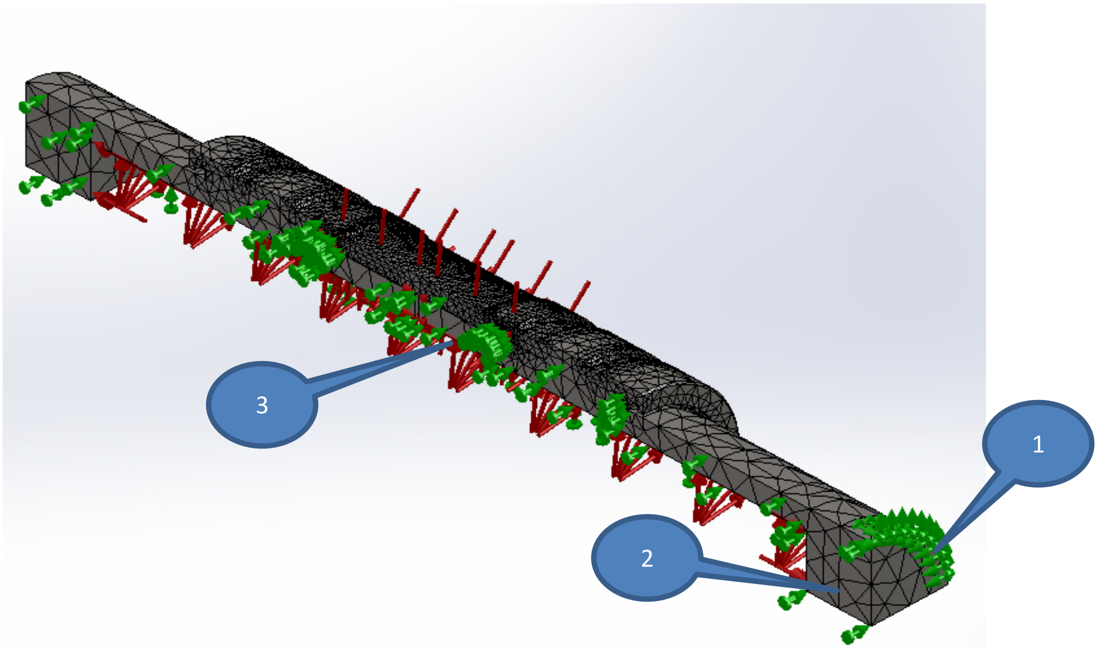


FIGURE 1- MODEL MESHED

The following load and boundary conditions were applied to the model see Figure 1- Model Meshed for location references.

Load / boundary Conditions	Value applied	Location Marker
Fixed edge support	-	1
Symmetry end condition	-	2
Internal Pressure	4000psi	3

The internal pressure was applied up until the o-ring channel area. This would represent the o-ring being pressurized up against the opposite face sealing the unit.

The pressure thrust reaction loads were modelled by introducing a 2” NPS pipe section in the model. Evaluating the 6 barb pieces and the crimping action interacting with the pipe was beyond the capabilities of the software tool being used and beyond the scope of the analysis. Therefore a simplification was made, the barb pieces were removed and the pipe was connected to the fitting in those regions. Since the analysis was not concerned about those regions from a pressure design perspective, this simplification will not have an effect on the results. The end load reaction due to pressurization was evaluated by capping off the pipe sections and applying pressure.

Figure 2 - Pyplok Dimensions displays the critical dimensions of the fitting used in the analysis.

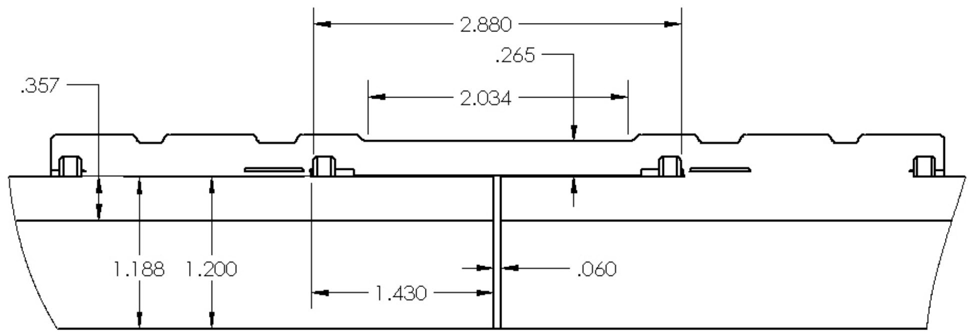


FIGURE 2 - PYPLOK DIMENSIONS

7 Simulation Plot Results

The following figures and tables are the results of the simulation.

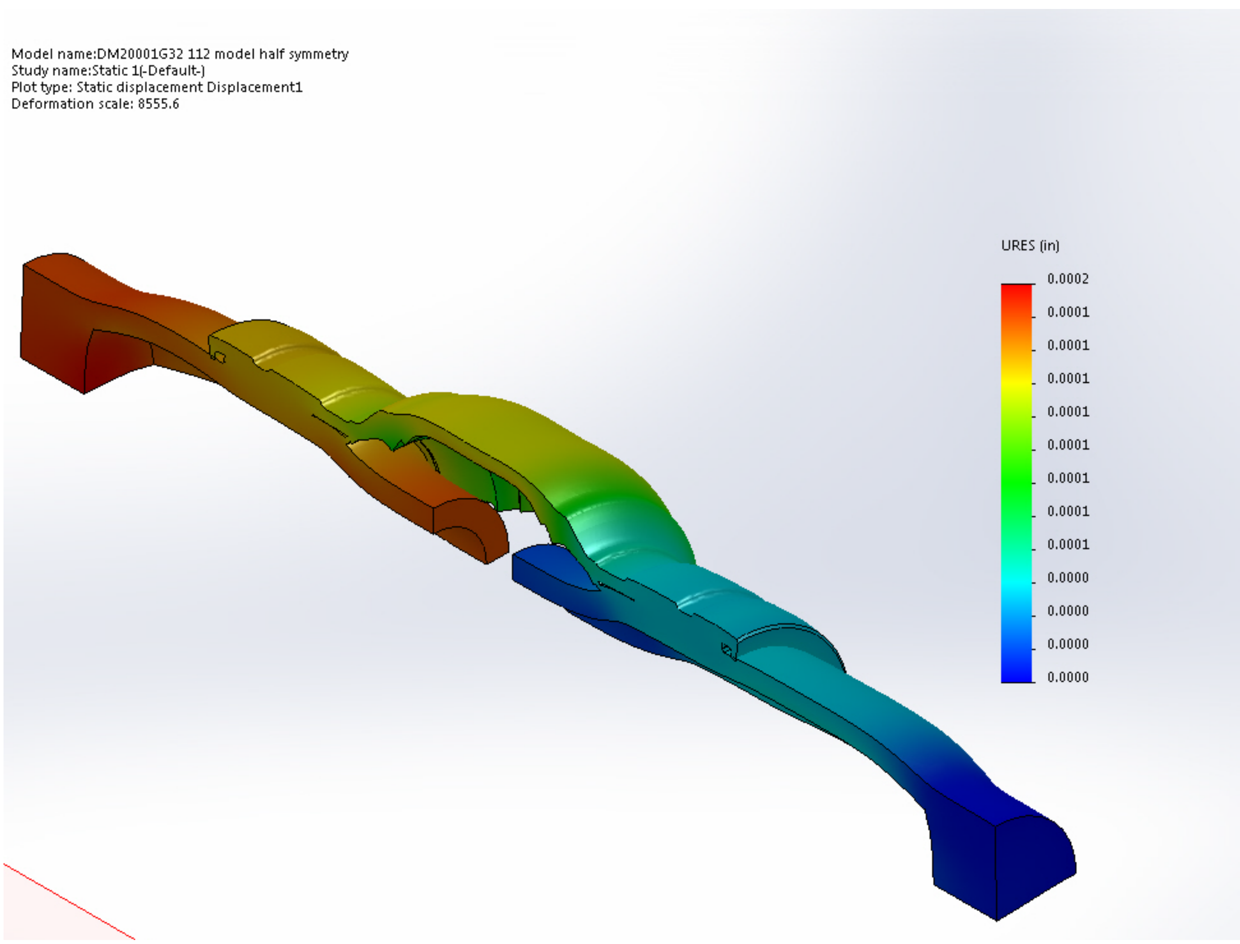


FIGURE 3 - DISPLACEMENT PLOT

The deformed shaped in Figure 2 - Displacement Plot is scaled by a factor of 8555.6 in order actually see the deformation. The maximum displacement is only 0.0002in.

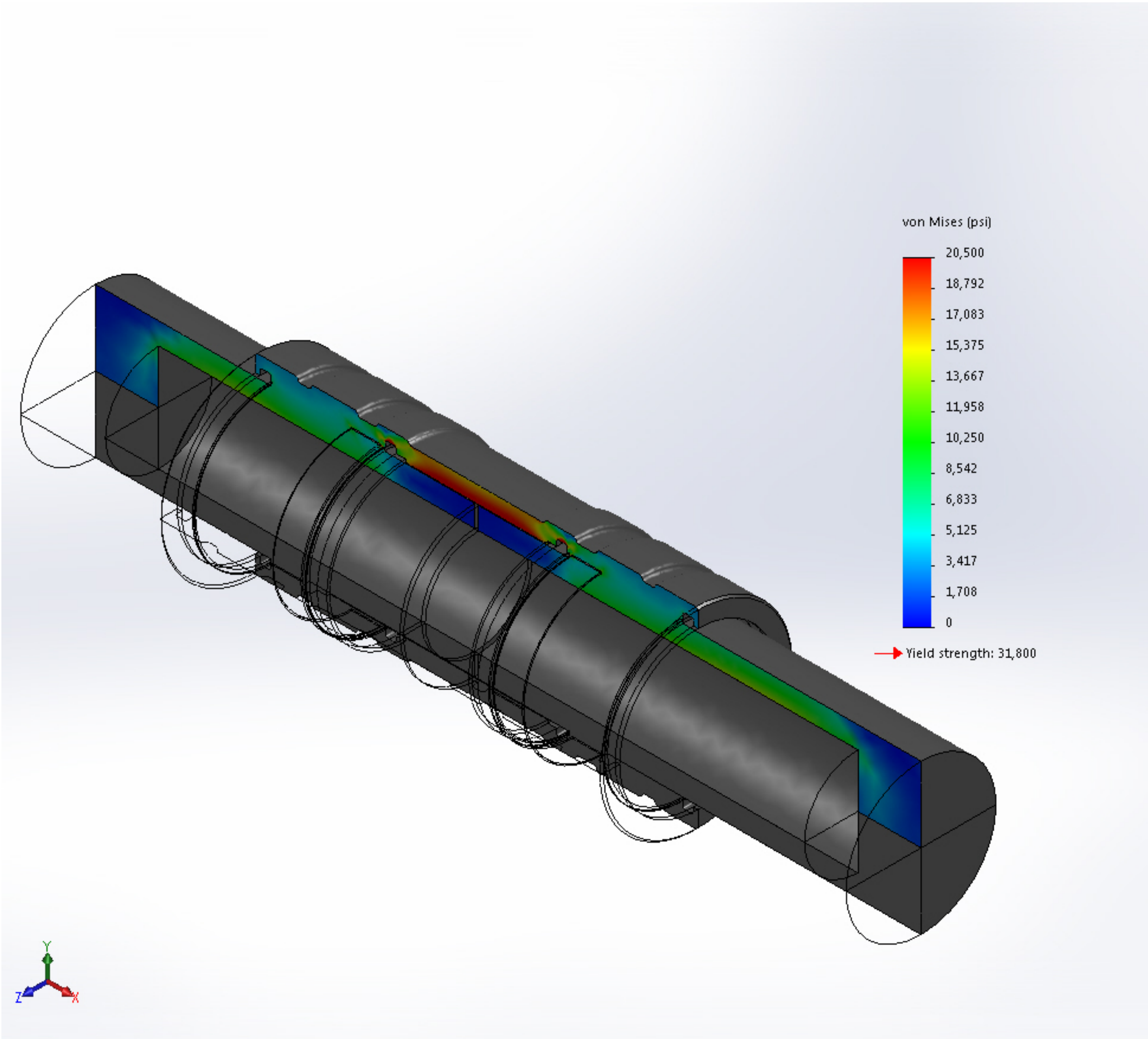


FIGURE 4- VON MISES STRESS PLOT

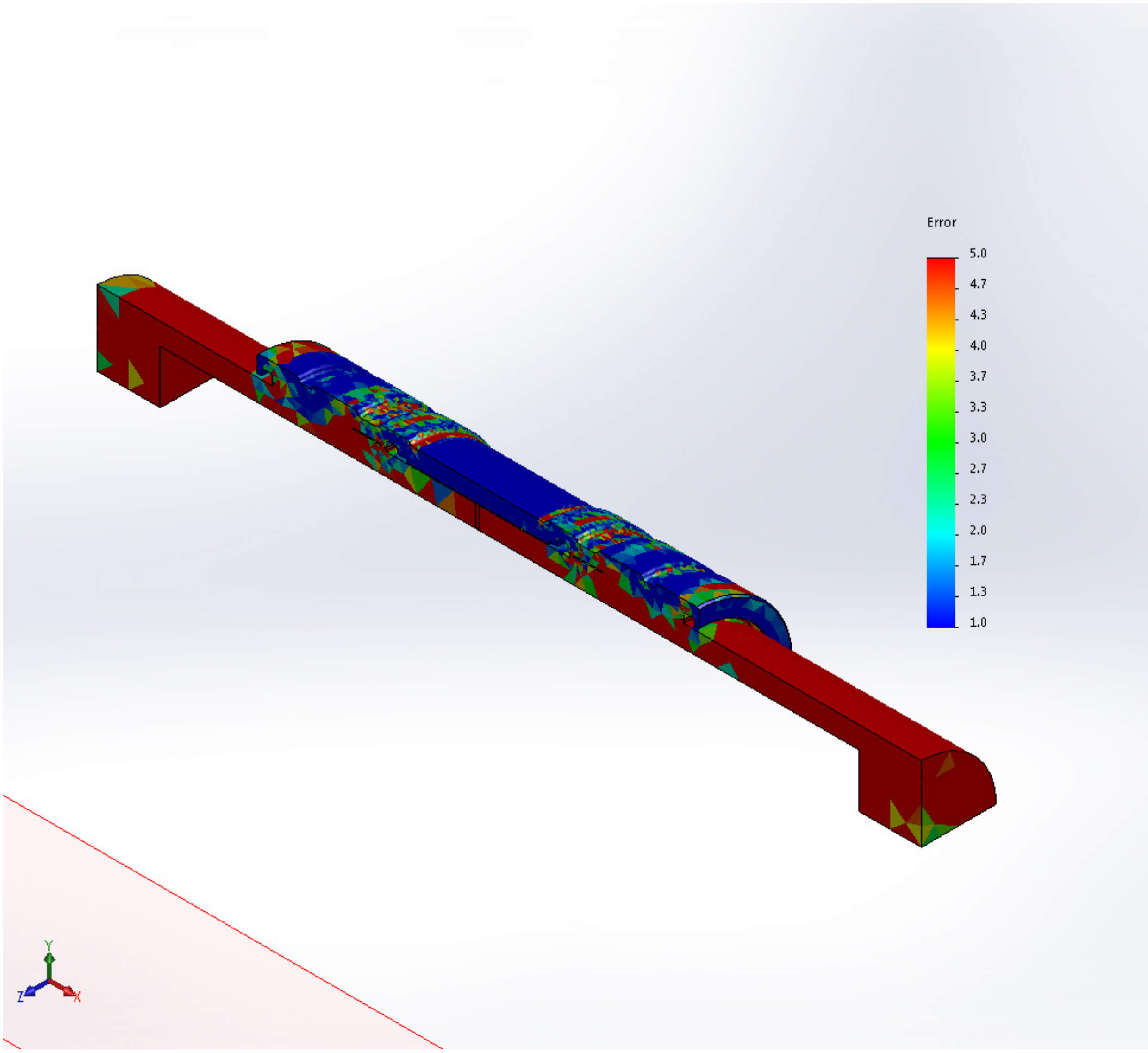


FIGURE 5 - ERROR PLOT

7.1 Resultant Forces

7.1.1 Reaction forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	lbf	-0.0105635	-37564	37565.6	53124.7

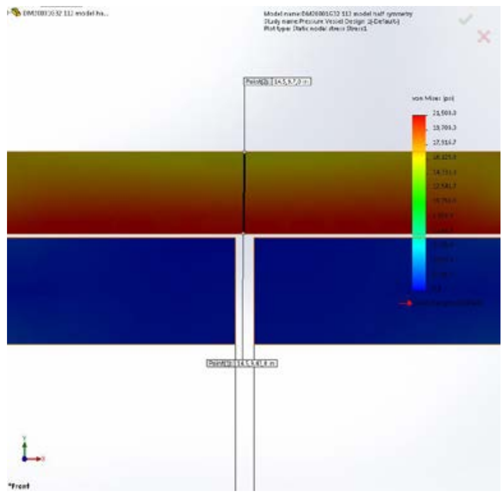
7.1.2 Reaction Moments

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	lbf.in	0	0	0	0

8 DISCUSSION OF RESULTS

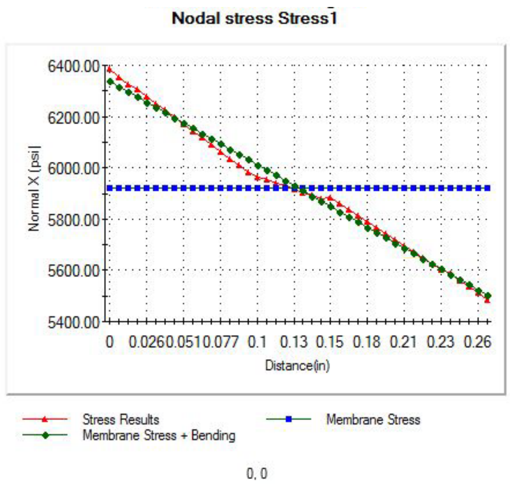
As shown in Figure 3- Von Mises Stress Plot the main point of interest from a high stress standpoint is in the middle section of the pyplok fitting. Using the assessment procedure outlined in ASME Section VIII Division 2, a stress classification line (SCL) was selected through the highest stress region to evaluate it's stress state to code values.

Plot : Stress1
Point(1): 14.5, 9.43, 0 in
Point(2) : 14.5, 9.7, 0 in
Units : psi

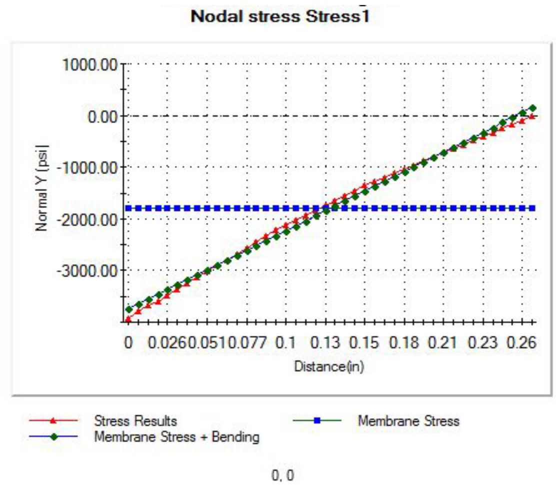


Components	Normal X	Normal Y	Normal Z	Shear XY	Shear XZ	Shear YZ	von Mises	Stress intensity (P1-P3)
Membrane Stress	5.92E+003	-1.8E+003	1.97E+004	-5.49	0.207	-7.96	1.89E+004	2.15E+004
Bending (Point 1)	417	-1.95E+003	2.3E+003	-7.45	1.46	22	3.69E+003	4.25E+003
Membrane Stress + Bending (Point 1)	6.34E+003	-3.75E+003	2.2E+004	-12.9	1.67	14	2.25E+004	2.58E+004
Bending (Point 2)	-417	1.95E+003	-2.3E+003	7.45	-1.46	-22	3.69E+003	4.25E+003
Membrane Stress + Bending (Point 2)	5.5E+003	147	1.74E+004	1.96	-1.26	-29.9	1.53E+004	1.73E+004
Peak (Point 1)	47	-170	170	14	-1.14	-2.15	299	341
Peak (Point 2)	-17.4	-161	165	1.27	0.061	-2.76	282	325

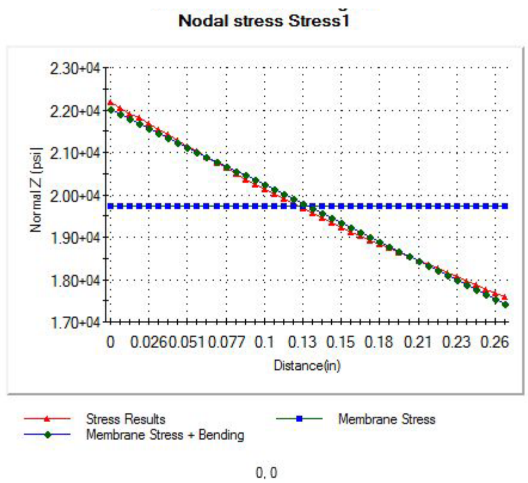
Curve Data:



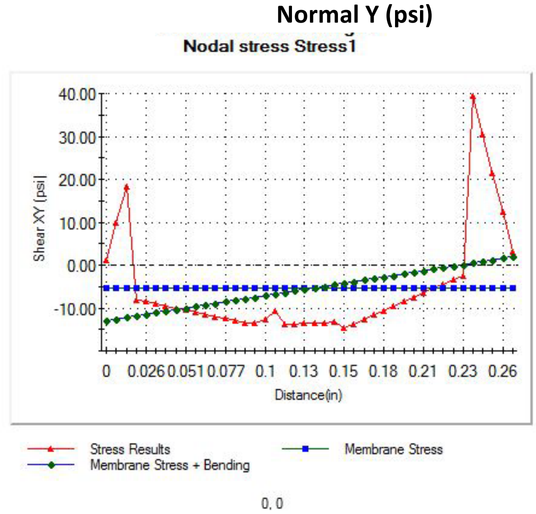
Normal X (psi)



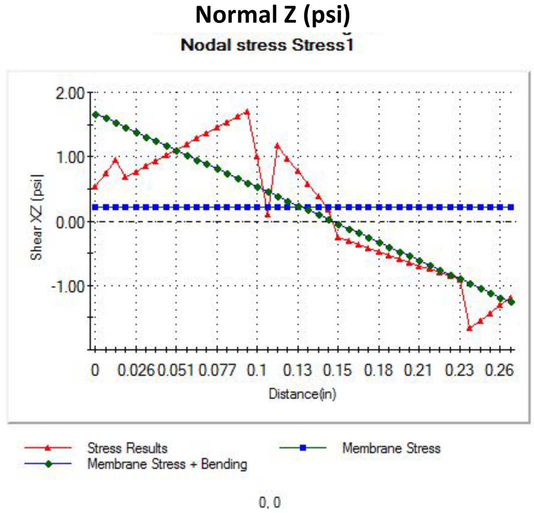
Normal Y (psi)



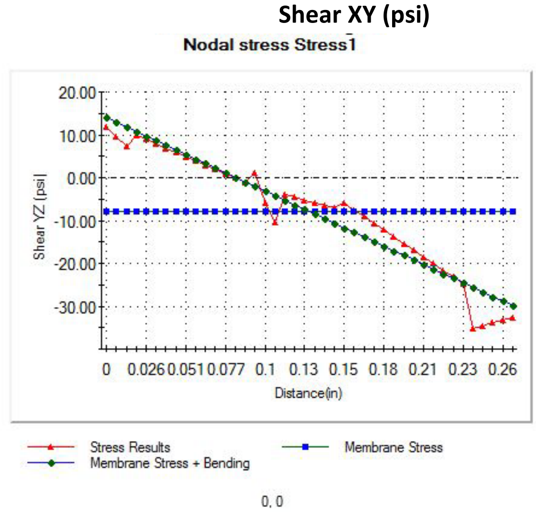
Normal Z (psi)



Shear XY (psi)



Shear XZ (psi)



Shear YZ (psi)

TABLE 3 - SCL STRESS RESULTS

Below are the results compared to the allowable criteria, all values are below code allowable values.

Stress Type	Actual Value (psi)	Allowable Value (psi)	Acceptable
Pm	**18887**	**20500**	**Yes**
PL + PB (Point 1)	**22497**	**30750**	**Yes**
PL + PB (Point 2)	**15315**	**30750**	**Yes**
PL + PB + Q (Point 1)	**22783**	**63600**	**Yes**
PL + PB + Q (Point 2)	**15594**	**63600**	**Yes**

TABLE 4 - SCL STRESS COMPARED TO ALLOWABLE STRESSES

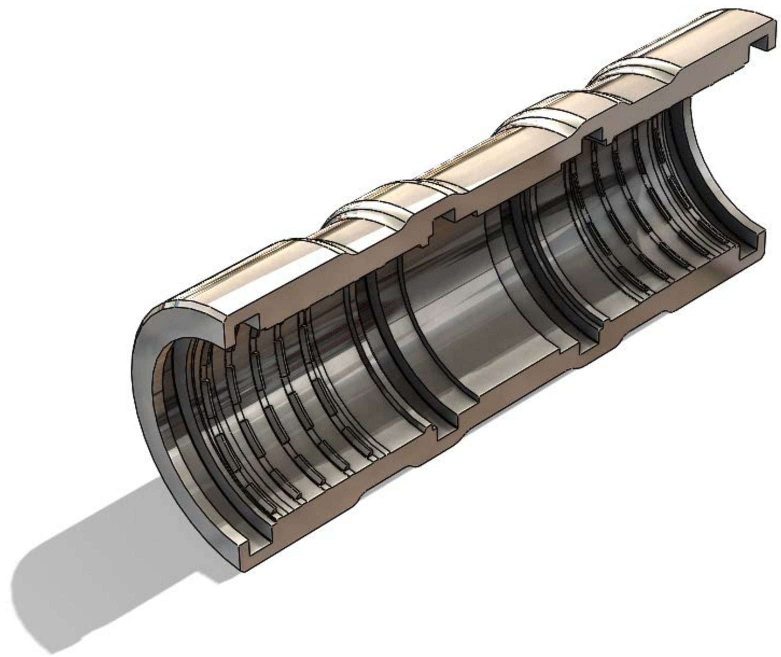
The resultant loads as shown in 7.1 are as expected. The high Y and Z values are a result of the fixed constraint which prevents any movement in those directions. Since it is outside the area of interest this is not a concern in terms of affecting the results. The only value of importance is the X direction which should be zero and the reaction load value is in good agreement to this value.

Figure 4 - Error Plot shows the energy norm error between the nodal stress values and element stress values. The target for the area of interest was less than 5%. The plot shows that for the area of concern the error is less than 5%. There are higher error regions; however they are not in the scope of the analysis. Refining the mesh to account for this error has no effect of the target region’s results.

Figure 2 - Displacement Plot shows the resultant displacement of the fitting under pressure. The displacement is low but the shape is what would be expected when pressurizing the fittings which indicates the model and approach is correct.

9 CONCLUSION

The part is acceptable for use within B31.3 systems in accordance with the requirements of B31.3 304.7.2(d). The stress state of all stress categories in the area of interest for the fitting was below the allowable values. The displacement of the part was low and the error level in the area of interest was acceptable.



Pyplok 1/2” Finite Element Analysis Report – ASTM A479 316

Performed for: Tube-Mac Piping Technologies Ltd.

Prepared by: Edward De Rubeis

Date: 7/04/2016

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2 EXECUTIVE SUMMARY

A 1/2" pyplok fitting was analyzed using finite element analysis (FEA). The part was created in Solidworks 2015 using drawing DM20001K08 revision 1 and DS267-08 revision 4. he part was analyzed using Solidworks Simulation; a linear elastic modelling software package. A detailed stress analysis of the simulation results were analyzed to ASME section VIII division 2 Part 5, elastic stress analysis method using allowable stress values from B31.3 Appendix A-1. The material analyzed was ASTM A-479 316. The conclusion of the analysis is that the part is acceptable for use for B31.3 systems in accordance with the requirements of B31.3 304.7.2(d).

3 INTRODUCTION

It is assumed that the applicable code section for the Pyplok fittings is B31.3 - Part 4: Fluid service requirements for piping joints; specifically section 318 Special Joints. The analysis outlined in 304.7.2(d) will only apply to pressure design of the Pyplok fitting as indicated in B31.3-318.1.2 and not to the sealing mechanism or integrity of the joint. B31.3-318.2 requirements are outside of the current scope of work. Also it is assumed this fitting will be used in normal fluid service applications.

The scope of the FEA analysis will consist of the pressure design of the fitting while considering internal pressure and end load reactions only. The effect of crimping the ends will not be included in the analysis. Furthermore interaction between the fitting, pipe and o-rings will not be included in the analysis. This simplification will permit the use of a static linear elastic FEA analysis with small displacements of the fitting. Since the area of interest in this analysis is mainly the mid-section of the fitting, these simplifications will not have an adverse effect of the analysis results.

4 DESIGN CODES

ASME B31.-3, 2014 edition

ASME Section VIII Division 2, 2013 edition

5 MATERIAL PROPERTIES

The material type and corresponding mechanical properties at 400F (the fitting's maximum allowable operating temperature) are listed in Table 1 - Material Properties.

Specification	Allowable Stress at Temperature	Yield Strength at Temperature	Elastic Modulus at Temperature	Poison's Ratio
ASTM A-479 316	19300psi	21400psi	26400000psi	0.3

TABLE 1 - MATERIAL PROPERTIES

The allowable stress values as prescribed by ASME Section VIII Division 2 Part 5 are shown in the table below.

Stress Type	Allowable Stress (psi)
Sm (General Primary membrane Stress)	19300
PL (Local Primary Membrane Stress	28950
PL + Pb (Local Primary + Primary Bending Stress)	28950
PL + Pb + Q (Local Primary + secondary stress intesity)	57900

TABLE 2 - ALLOWABLE STRESS VALUES

6 MODEL DESCRIPTION

A three dimensional model was created using drawing DM20001K08 revision 1 and DS267-08 revision 4. The model was verified to dimensionally match the drawing.

The small manufacturing details in the part model required a more refined mesh. In order to reduce the analysis time only a quarter of the model was analyzed. Part symmetry was used to reduce the model size, free memory requirements, and allow for a more refined mesh in the area of interest for the analysis.

Below is a summary of the mesh type and elements used. A mesh control was applied to the inside surface where the element size was set at 0.05in and ratio of 1.

TABLE 3 - MESH PARAMETERS

Mesh type	Solid Mesh
Mesher Used:	Curvature based mesh
Jacobian points	4 Points
Maximum element size	0.06 in
Minimum element size	0.012 in
Mesh Quality	High
Total Nodes	143323
Total Elements	92252
Maximum Aspect Ratio	266.04
% of elements with Aspect Ratio < 3	91.7
% of elements with Aspect Ratio > 10	1
% of distorted elements(Jacobian)	0

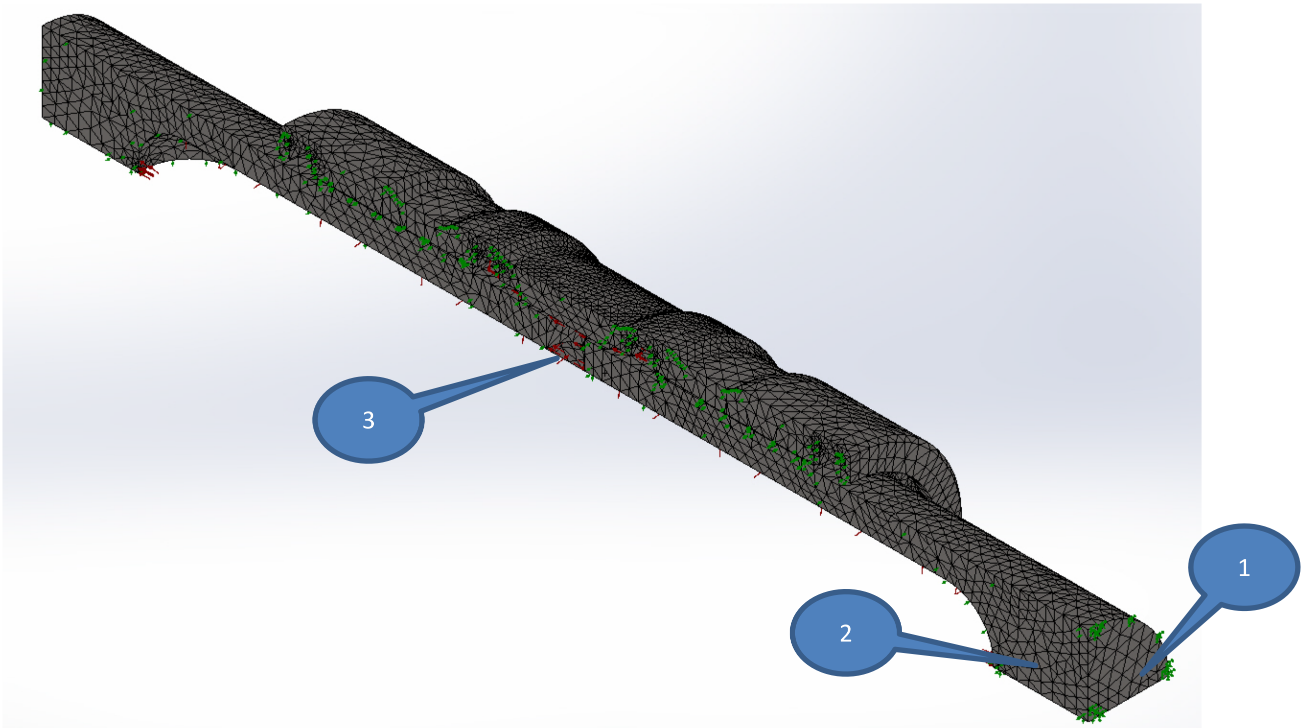


FIGURE 1- MODEL MESHED

Load / boundary Conditions	Value applied	Location Marker (Blue and White)
Fixed edge support	-	1
Symmetry end condition	-	2
Internal Pressure	4000psi	3

The following load and boundary conditions were applied to the model see, Figure 1- Model Meshed.

The internal pressure was applied up until the inner o-ring on each side of the fitting's centerline. This would represent the o-ring being pressurized up against the opposite face sealing the unit.

The pressure thrust reaction loads were modelled by introducing a 1/2" NPS SCH 80s pipe section in the model. Evaluating the 6 rows of barb pieces and the crimping action interacting with the pipe was beyond the capabilities of the software tool being used and beyond the scope of the analysis. Therefore a simplification was made, the barb pieces were removed and the pipe was connected to the fitting in those regions. Since the analysis was not concerned about those regions from a pressure design perspective, this simplification will not have an effect on the results. The end load reaction due to pressurization was evaluated by capping off the pipe sections and applying pressure.

7 Simulation Plot Results

The following figures and tables are the results of the simulation.

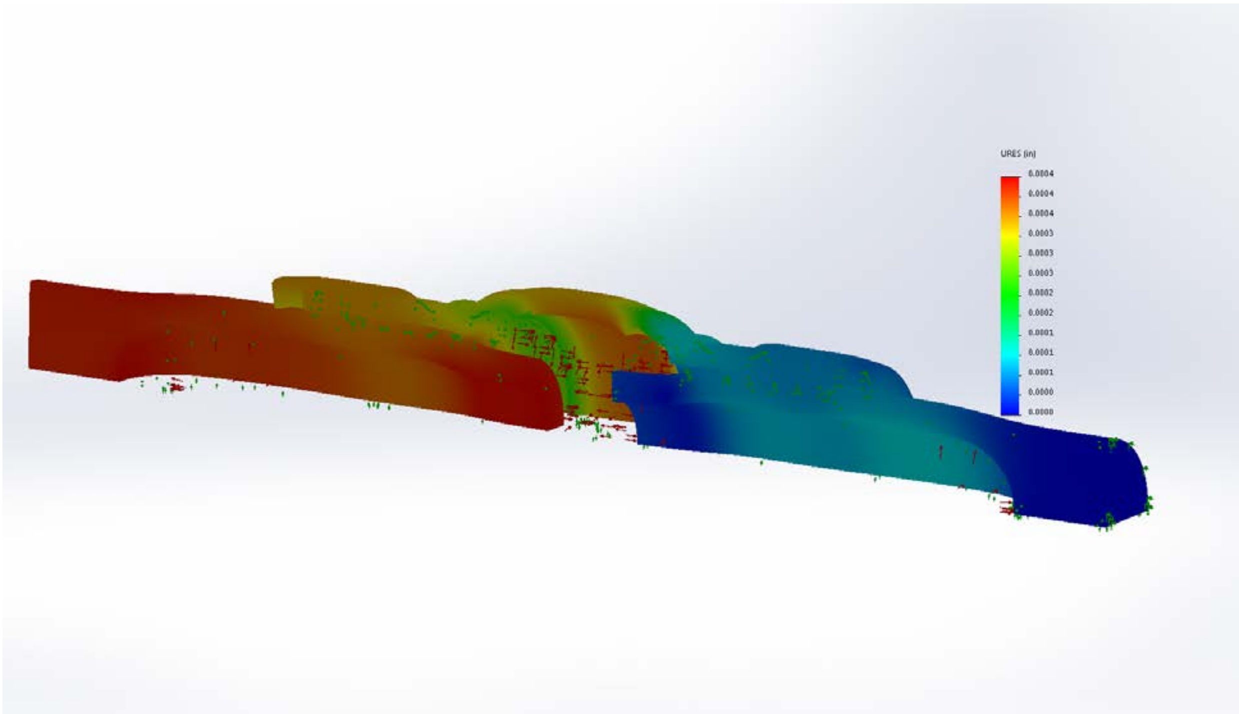


FIGURE 2 - DISPLACEMENT PLOT

The deformed shaped in Figure 2 - Displacement Plot is scaled by a factor of 600 in order actually see the deformation. The maximum resultant displacement is only 0.0004in.

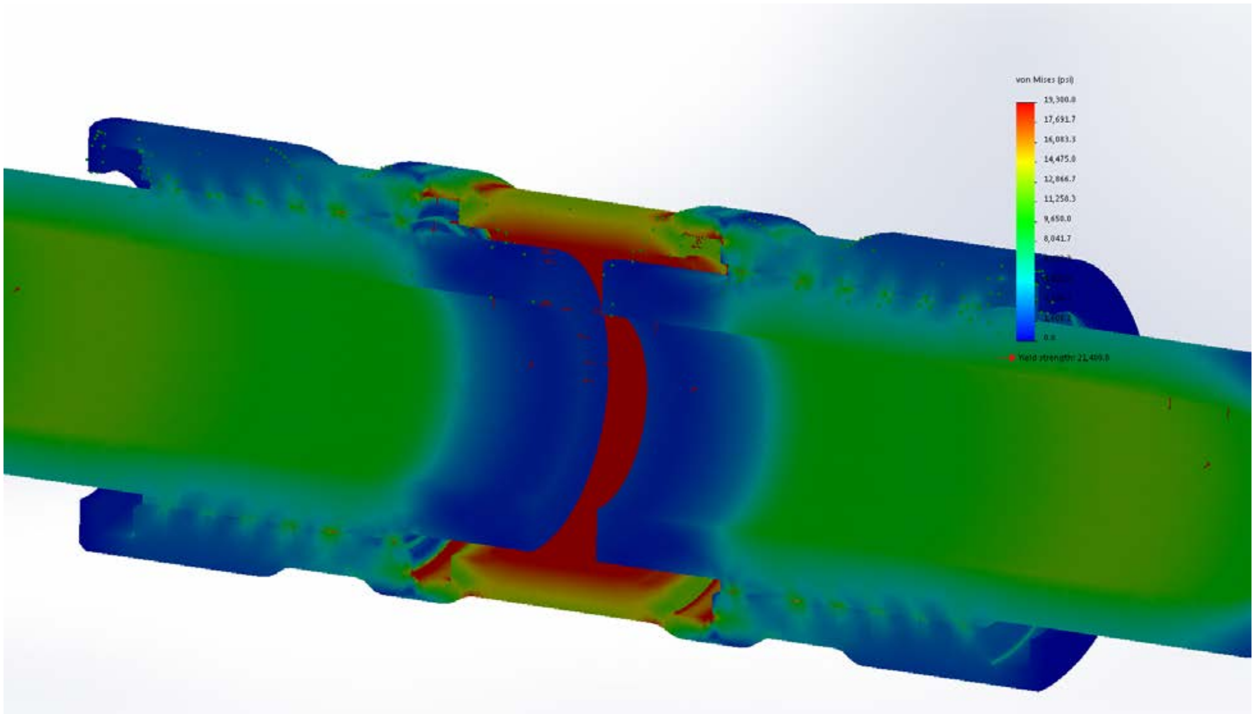


FIGURE 3- VON MISES STRESS PLOT

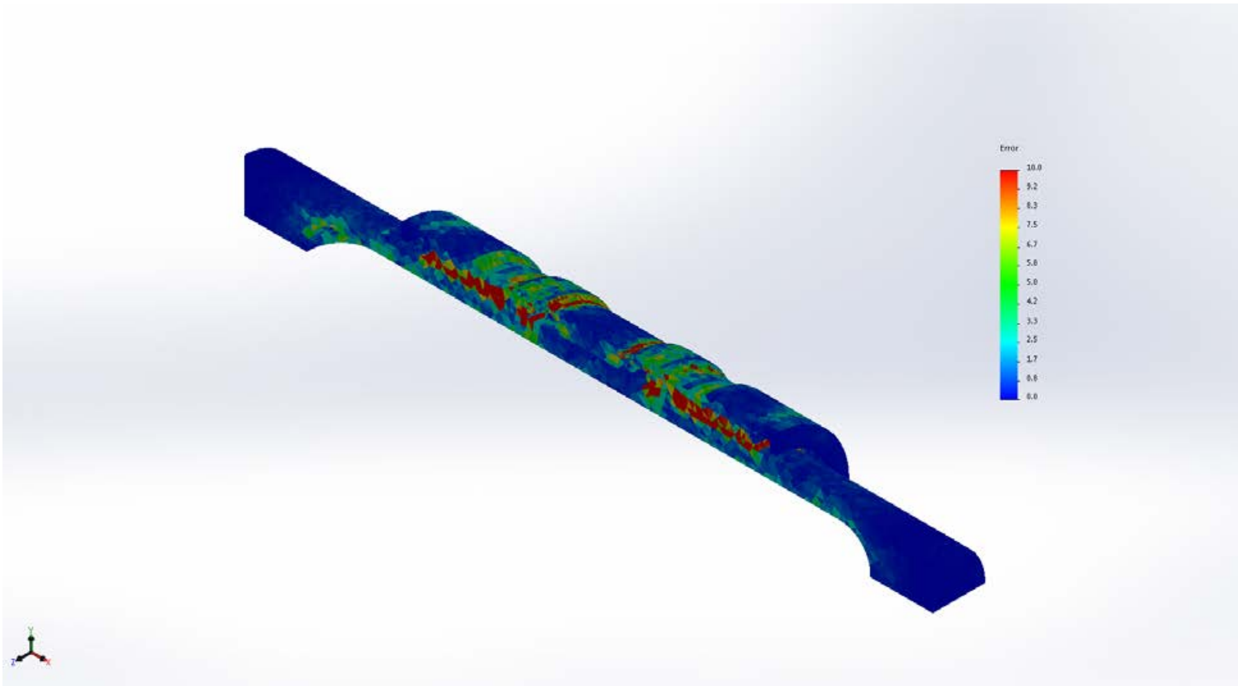


FIGURE 4 - ERROR PLOT

7.1 Resultant Forces

7.1.1 Reaction forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	lbf	0.1963	-5001.8	5001.9	7073.7

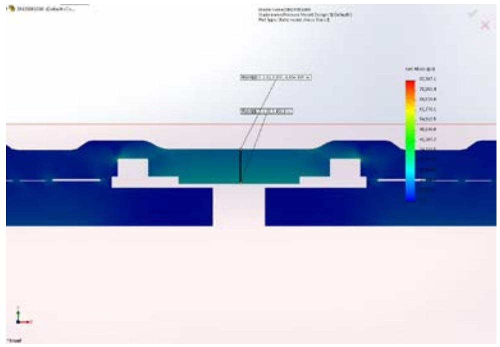
7.1.2 Reaction Moments

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	lbf.in	0	0	0	0

8 Discussion of Results

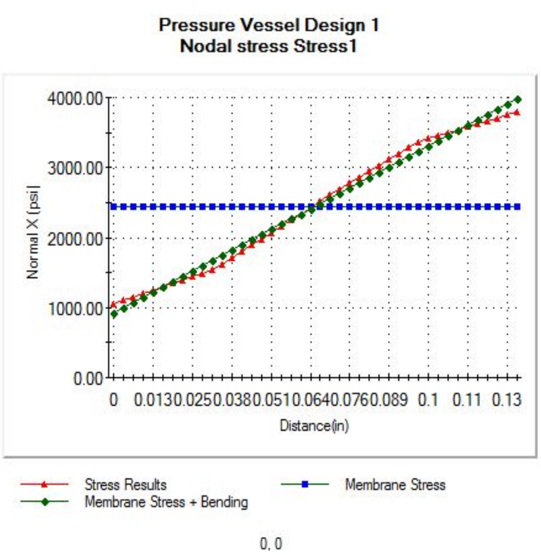
As shown in Figure 3- Von Mises Stress Plot the main point of interest from a high stress standpoint is in the middle section of the pyplok fitting. Using the assessment procedure outlined in ASME Section VIII Division 2, a stress classification line (SCL) was selected through the highest stress region to evaluate its stress state to code values.

Plot : Stress1
Point(1): -1.62, 0.436, 0 in
Point(2) : -1.62, 0.567, -4.97e-028 in
Units : psi

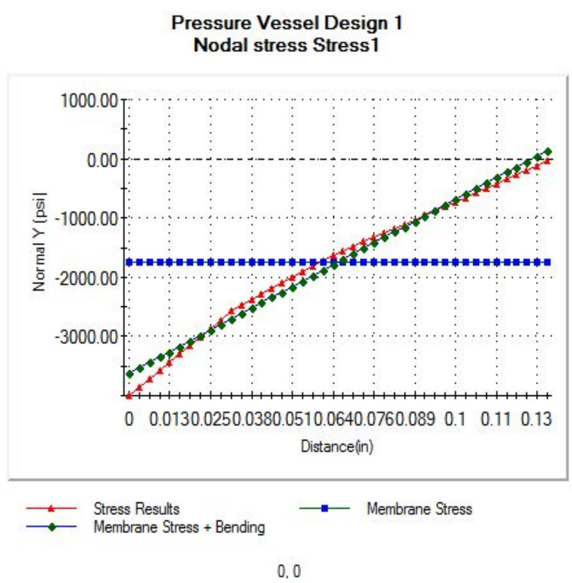


Components	Normal X	Normal Y	Normal Z	Shear XY	Shear XZ	Shear YZ	von Mises	Stress intensity (P1-P3)
Membrane Stress	2.45E+003	-1.75E+003	1.64E+004	52.7	-1.99	14.6	1.65E+004	1.82E+004
Bending (Point 1)	-1.53E+003	-1.88E+003	2.08E+003	0.109	-9.9	27.6	3.8E+003	3.96E+003
Membrane Stress + Bending (Point 1)	916	-3.63E+003	1.85E+004	52.9	-11.9	42.2	2.03E+004	2.21E+004
Bending (Point 2)	1.53E+003	1.88E+003	-2.08E+003	-0.109	9.9	-27.6	3.8E+003	3.96E+003
Membrane Stress + Bending (Point 2)	3.98E+003	135	1.44E+004	52.6	7.9	-13	1.27E+004	1.42E+004
Peak (Point 1)	137	-360	287	27.5	0.169	31	591	652
Peak (Point 2)	-185	-179	222	-11.4	4.75	7.49	405	416

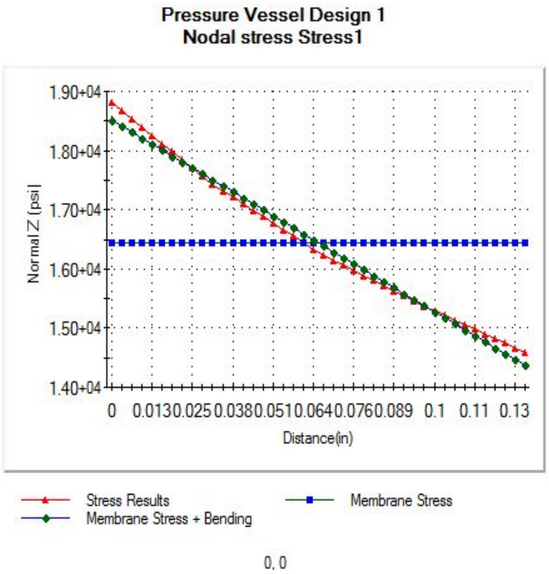
Curve Data:



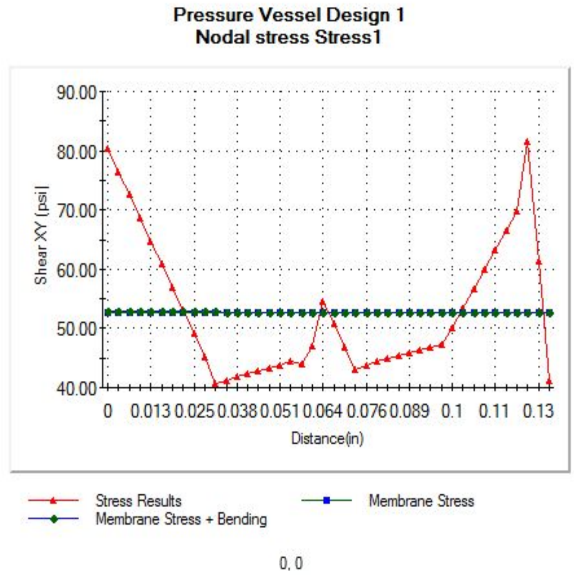
Normal X (psi)



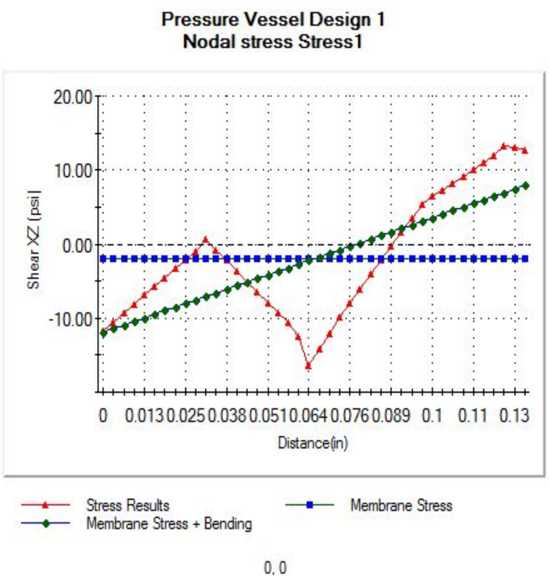
Normal Y (psi)



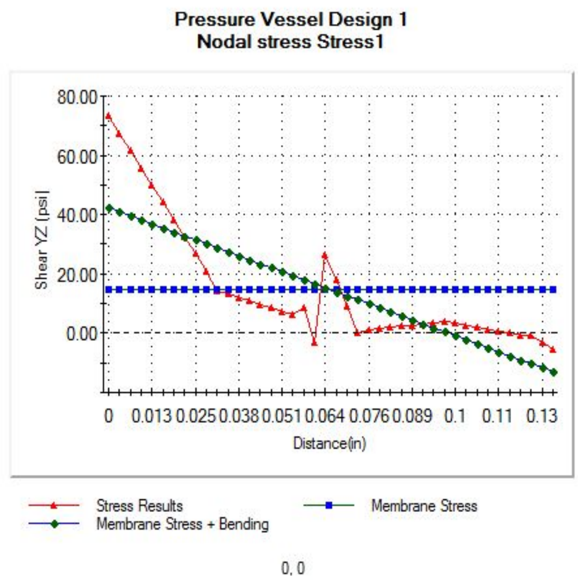
Normal Z (psi)



Shear XY (psi)



Shear XZ (psi)



Shear YZ (psi)

TABLE 4 - SCL STRESS RESULTS

Table 5 - SCL Stress Compared to Allowable Stresses compares the allowable stress criteria to the simulated model stresses. All simulated model stresses are below code allowable values.

Stress Type	Actual Value (psi)	Allowable Value (psi)	Acceptable
Pm	**16457**	**19300**	**Yes**
PL + PB (Point 1)	**20244**	**28950**	**Yes**
PL + PB (Point 2)	**12784**	**28950**	**Yes**
PL + PB + Q (Point 1)	**20722**	**57900**	**Yes**
PL + PB + Q (Point 2)	**13173**	**57900**	**Yes**

TABLE 5 - SCL STRESS COMPARED TO ALLOWABLE STRESSES

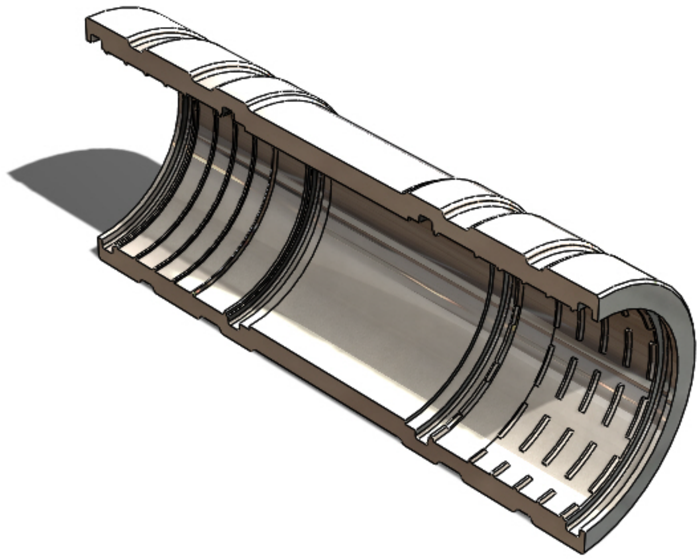
The resultant loads as shown in 7.1 are as expected. The high Y and Z values are a result of the fixed constraint which prevents any movement in those directions. Since the fixed constraint is outside the area of interest this is not a concern in terms of affecting the results. The only value of importance is the X direction which should be zero and the reaction load value is in good agreement to this value.

Figure 4 - Error Plot shows the energy norm error between the nodal stress values and element stress values. The target for the area of interest was less than 5%. The plot shows that for the area of concern the error is less than 5%. There are higher error regions; however they are not located in the area of interest, and are not part of this scope of work. Refining the mesh to account for the large error in this region has no effect on the area of interest, and thus has no bearing on results of this report.

Figure 2 - Displacement Plot shows the resultant displacement of the fitting under pressure. The displacement is low but the shape is what would be expected when pressurizing the fittings which indicates the model and approach is correct.

9 Conclusion

The part is acceptable for use within B31.3 systems in accordance with the requirements of B31.3 304.7.2(d). The stress state of all stress categories in the area of interest for the fitting was below the code allowable values. The displacement of the part was low and the error level in the area of interest was acceptable.



Pyplok 2" Finite Analysis Report – ASTM A479 316

Performed for: Tube-Mac piping Technologies Ltd.

Prepared by: Edward De Rubeis

Date: 7/04/2016

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2 EXECUTIVE SUMMARY

A 2" pyplok fitting was analyzed using finite element analysis (FEA). The part was created in Solidworks 2015 using drawing DM20001G32 Rev 1. The part was analyzed using Solidworks Simulation; a linear elastic model was created. A detailed stress analysis of the simulation results were analyzed to ASME section VIII division 2 Part 5, elastic stress analysis method using allowable stress values from B31.3 Appendix A-1. The material analyzed was ASTM A-479 316. The conclusion of the analysis is that the part is acceptable for use for B31.3 systems in accordance with the requirements of B31.3 304.7.2(d).

3 INTRODUCTION

It is assumed that the applicable code section for the Pyplok fittings is B31.3 - Part 4: Fluid service requirements for piping joints; specifically section 318 Special Joints. The analysis outlined in 304.7.2(d) will only apply to pressure design of the Pyplok fitting as indicated in B31.3-318.1.2 and not to the sealing mechanism or integrity of the joint. B31.3-318.2 requirements are outside of the current scope of work. Also it is assumed this fitting will be used in normal fluid service applications.

The scope of the FEA analysis will consist of the pressure design of the fitting while considering internal pressure and end load reactions only. The effect of crimping the ends will not be included in the analysis. Furthermore interaction between the fitting, pipe and o-rings will not be included in the analysis. This simplification will permit the use of a static linear elastic FEA analysis with small displacements of the fitting. Since the area of interest in this analysis is mainly the mid-section of the fitting, these simplifications will not have an adverse effect of the analysis results.

4 DESIGN CODES

ASME B31.-3, 2014 edition

ASME Section VIII Division 2, 2013 edition

5 MATERIAL PROPERTIES

The material type and corresponding mechanical properties at 400F (the fitting's maximum allowable operating temperature) are listed in Table 1 - Material Properties.

Specification	Allowable Stress at Temperature	Yield Strength at Temperature	Elastic Modulus at Temperature	Poison's Ratio
ASTM A-479 316	19300psi	21400psi	26400000psi	0.3

TABLE 1 - MATERIAL PROPERTIES

The allowable stress values as prescribed by ASME Section VIII Division 2 Part 5 are shown in the table below.

Stress Type	Allowable Stress (psi)
Sm (General Primary membrane Stress)	19300
PL (Local Primary Membrane Stress	28950
PL + Pb (Local Primary + Primary Bending Stress)	28950
PL + Pb + Q (Local Primary + secondary stress intesity)	57900

TABLE 2 - ALLOWABLE STRESS VALUES

6 Model Description

A three dimensional model was created using drawing DM20001G32 Revision 1. The model was verified to dimensionally match the drawing.

The small manufacturing details in the part model required a more refined mesh. In order to reduce the analysis time only a quarter of the model was analyzed. Part symmetry was used to reduce the model size, free memory requirements, and allow for a more refined mesh in the area of interest for the analysis.

Below is a summary of the mesh type and elements used. A mesh control was applied to the inside surface where the element size was set at 0.05in and ratio of 1.

TABLE 3 - MESH PARAMETERS

Mesh type	Solid Mesh
Mesher Used:	Curvature based mesh
Jacobian points	4 Points
Maximum element size	0.376217 in
Minimum element size	0.0752433 in
Mesh Quality	High
Total Nodes	134191
Total Elements	87117
Maximum Aspect Ratio	96.527
% of elements with Aspect Ratio < 3	93.7
% of elements with Aspect Ratio > 10	0.438
% of distorted elements(Jacobian)	0

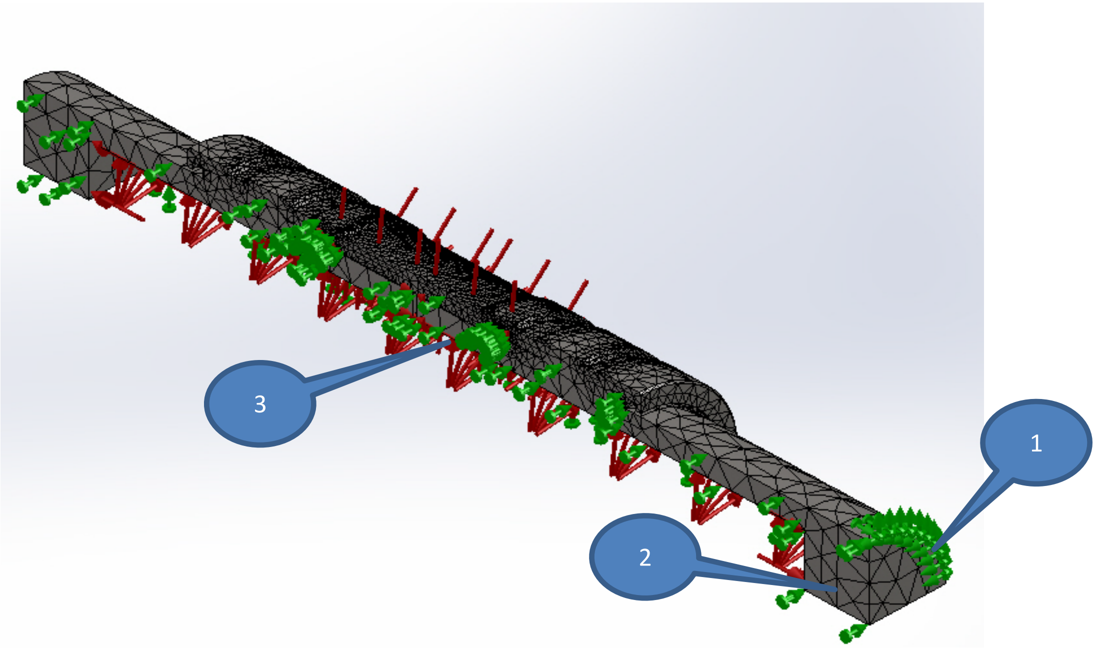


FIGURE 1- MODEL MESHED

The following load and boundary conditions were applied to the model see Figure 1- Model Meshed for location references.

Load / boundary Conditions	Value applied	Location Marker
Fixed edge support	-	1
Symmetry end condition	-	2
Internal Pressure	4000psi	3

The internal pressure was applied up until the o-ring channel area. This would represent the o-ring being pressurized up against the opposite face sealing the unit.

The pressure thrust reaction loads were modelled by introducing a 2" NPS pipe section in the model. Evaluating the 6 barb pieces and the crimping action interacting with the pipe was beyond the capabilities of the software tool being used and beyond the scope of the analysis. Therefore a simplification was made, the barb pieces were removed and the pipe was connected to the fitting in those regions. Since the analysis was not concerned about those regions from a pressure design perspective, this simplification will not have an effect on the results. The end load reaction due to pressurization was evaluated by capping off the pipe sections and applying pressure.

7 Simulation Plot Results

The following figures and tables are the results of the simulation.

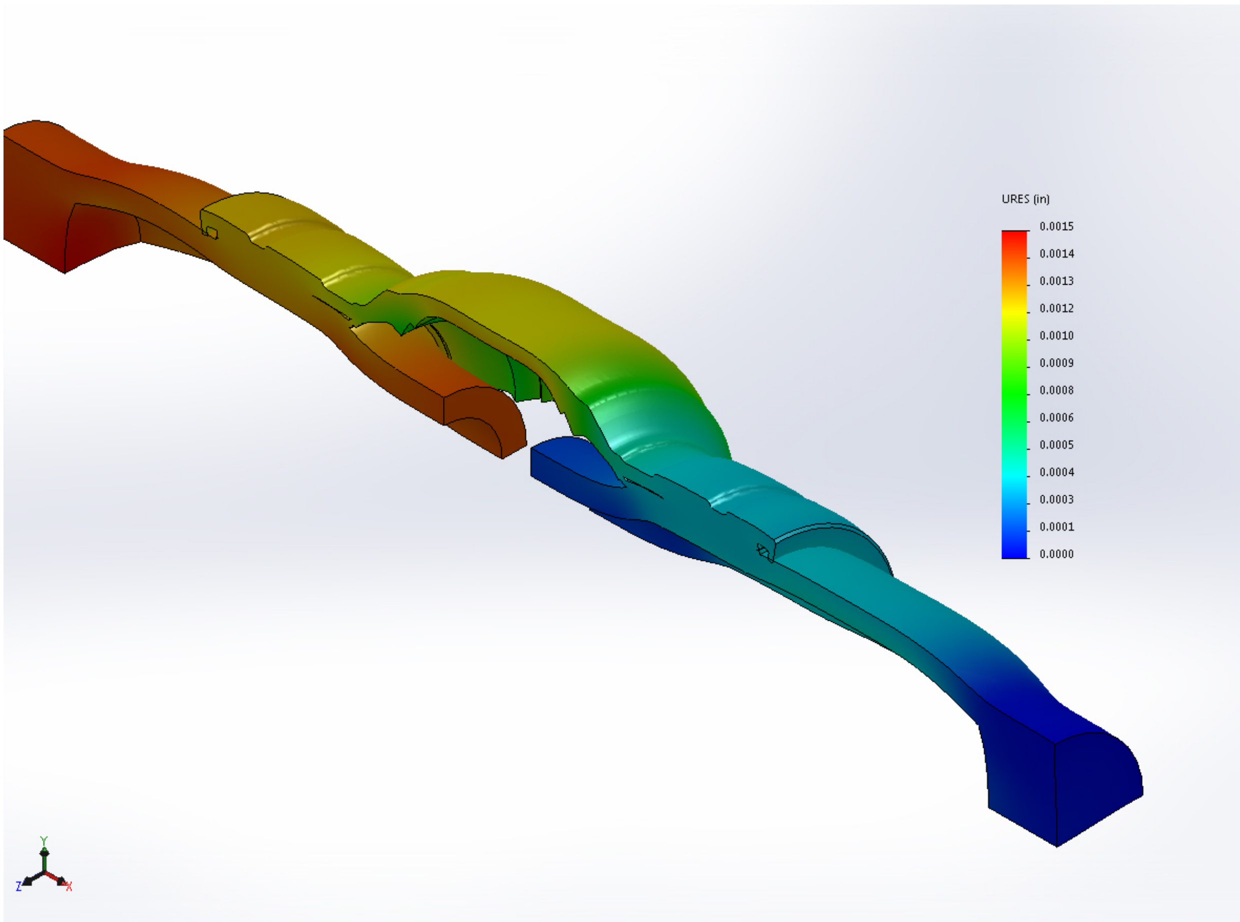


FIGURE 2 - DISPLACEMENT PLOT

The deformed shaped in Figure 2 - Displacement Plot is scaled by a factor of 845 in order actually see the deformation. The maximum resultant displacement is only 0.0015in.

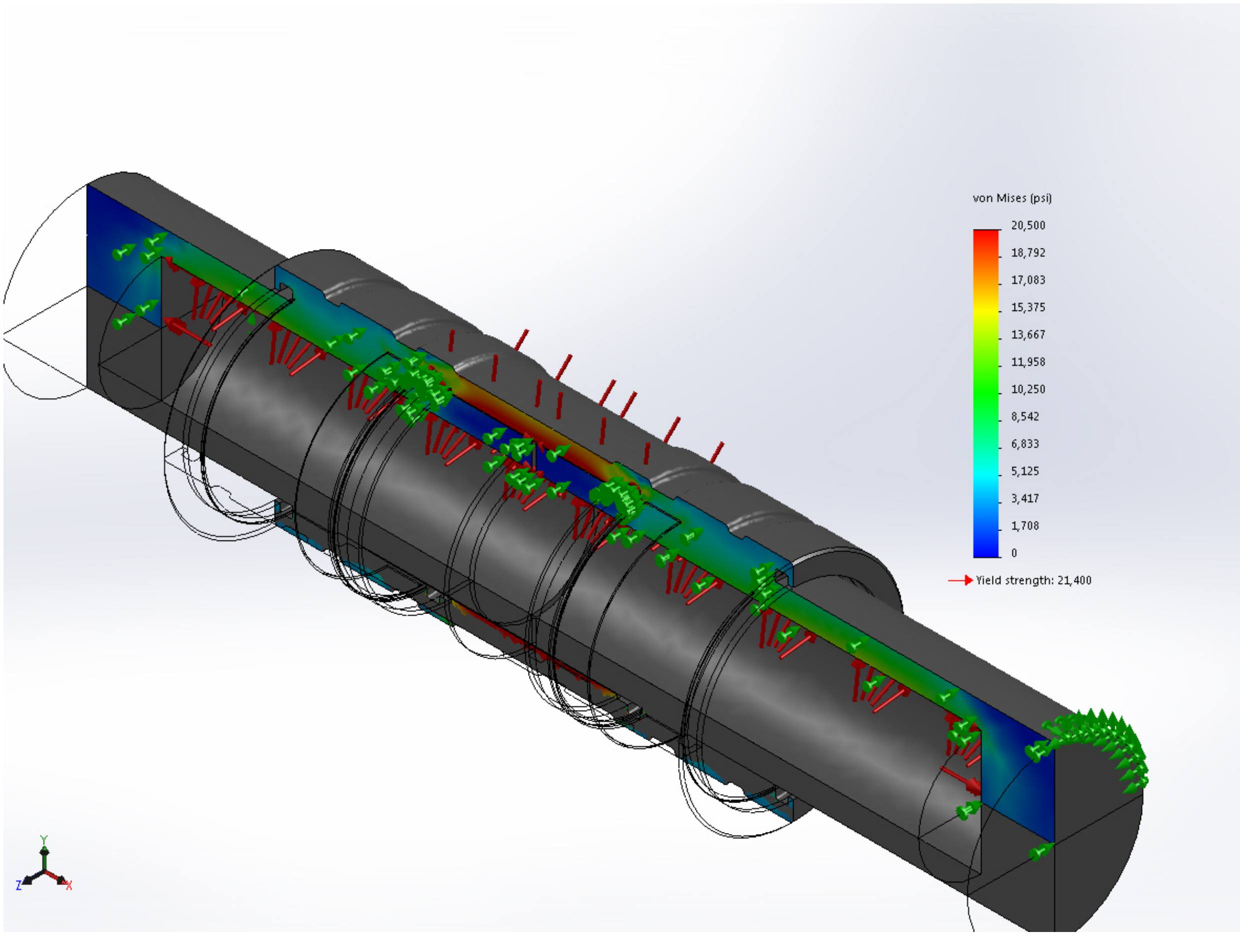


FIGURE 3- VON MISES STRESS PLOT

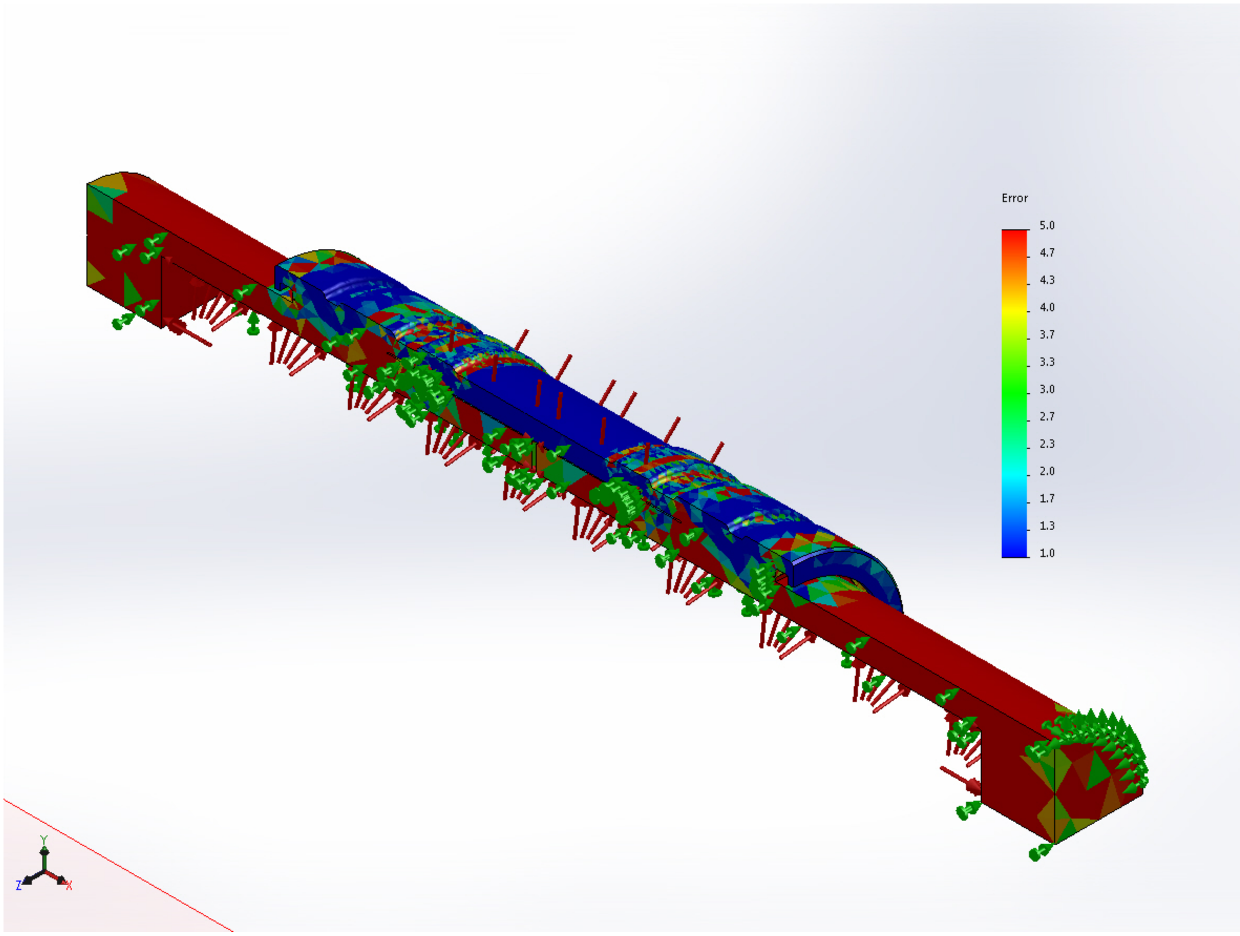


FIGURE 4 - ERROR PLOT

7.1 Resultant Forces

7.1.1 Reaction forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	lbf	-0.0105906	-37564	37565.6	53125

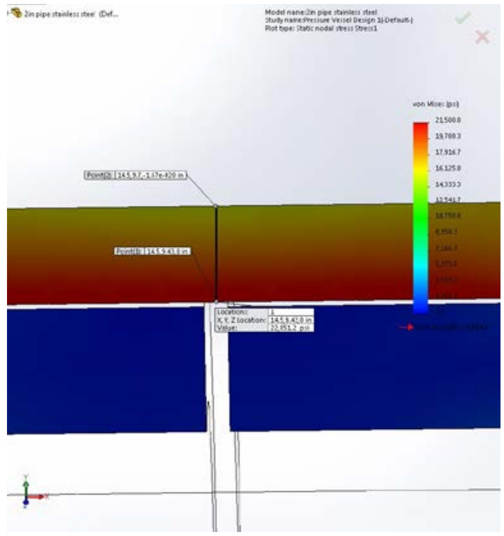
7.1.2 Reaction Moments

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	lbf.in	0	0	0	0

8 Discussion of Results

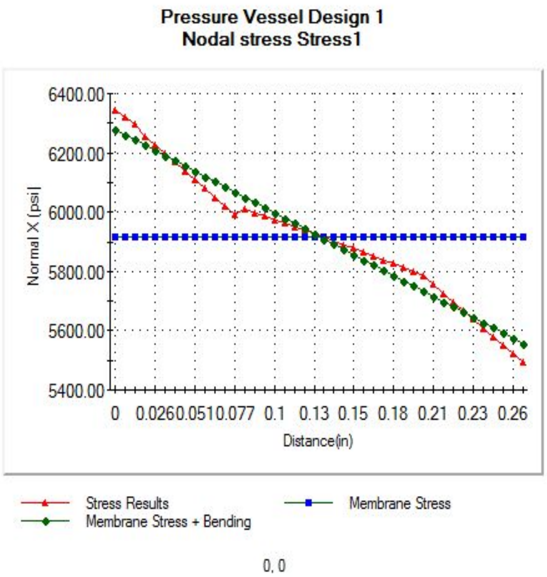
As shown in Figure 3- Von Mises Stress Plot the main point of interest from a high stress standpoint is in the middle section of the pyplok fitting. Using the assessment procedure outlined in ASME Section VIII Division 2, a stress classification line (SCL) was selected through the highest stress region to evaluate its stress state to code values.

Plot : Stress1
Point(1): 14.5, 9.43, 0 in
Point(2) : 14.5, 9.7, 0 in
Units : psi

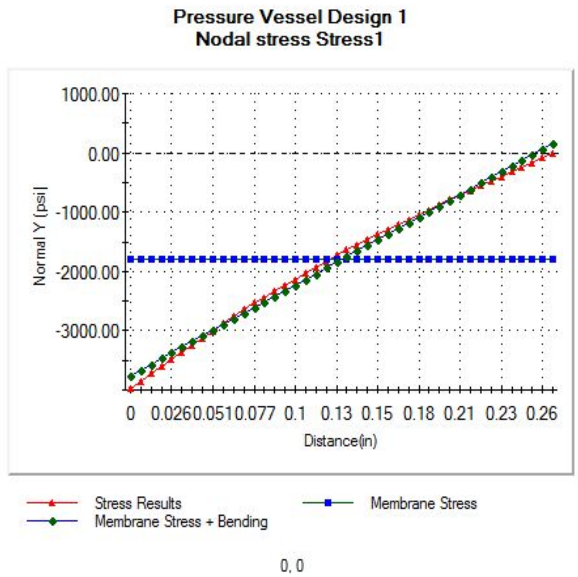


Components	Normal X	Normal Y	Normal Z	Shear XY	Shear XZ	Shear YZ	von Mises	Stress intensity (P1-P3)
Membrane Stress	5.92E+003	-1.8E+003	1.97E+004	10.4	0.412	2.5	1.89E+004	2.15E+004
Bending (Point 1)	361	-1.96E+003	2.3E+003	5.08	0.129	15.3	3.69E+003	4.26E+003
Membrane Stress + Bending (Point 1)	6.28E+003	-3.76E+003	2.2E+004	15.5	0.54	17.8	2.25E+004	2.58E+004
Bending (Point 2)	-361	1.96E+003	-2.3E+003	-5.08	-0.129	-15.3	3.69E+003	4.26E+003
Membrane Stress + Bending (Point 2)	5.56E+003	154	1.74E+004	5.33	0.283	-12.8	1.53E+004	1.73E+004
Peak (Point 1)	65.4	-211	192	0.529	0.45	18.5	359	405
Peak (Point 2)	-63.1	-168	174	-1.71	-0.409	-1.77	303	342

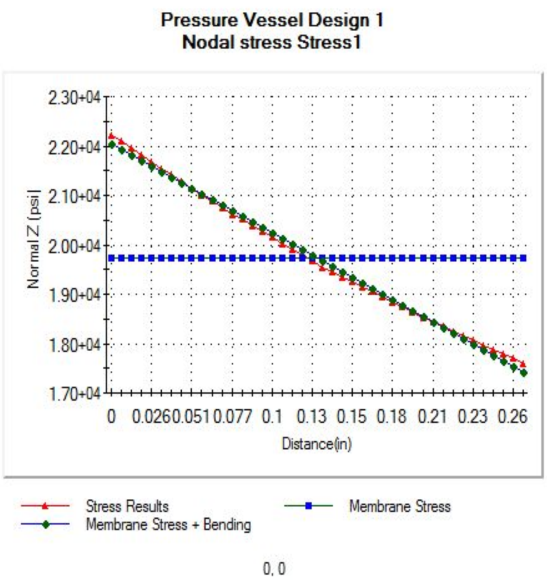
Curve Data:



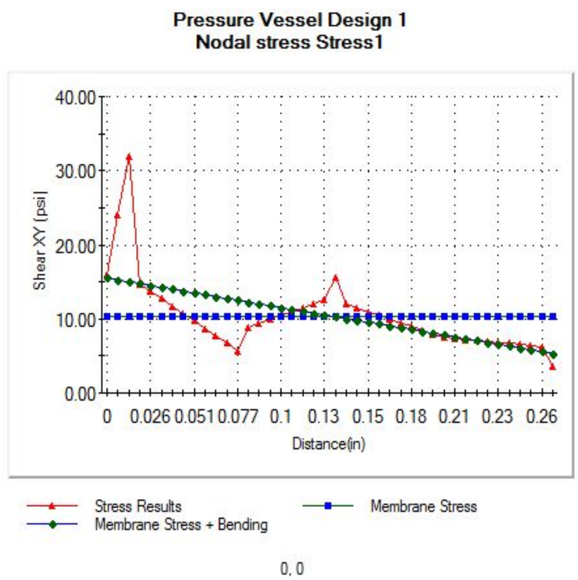
Normal X (psi)



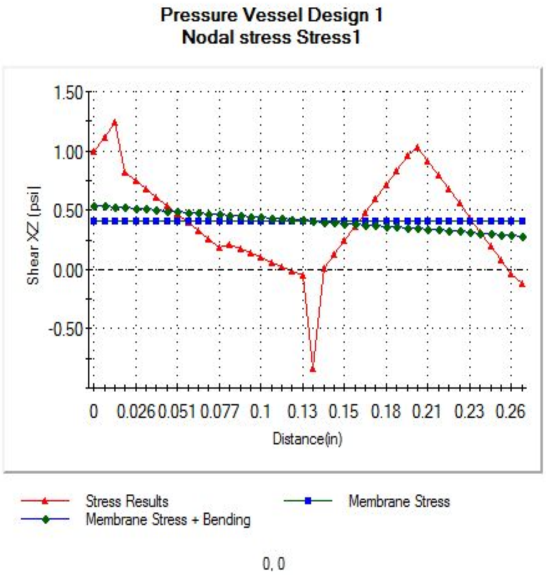
Normal Y (psi)



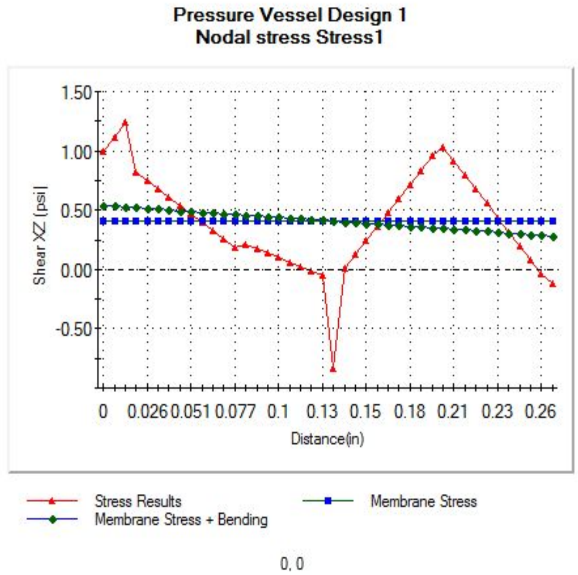
Normal Z (psi)



Shear XY (psi)



Shear XZ (psi)



Shear YZ (psi)

TABLE 4 - SCL STRESS RESULTS

Below are the results compared to the allowable criteria, all values are below code allowable values.

Stress Type	Actual Value (psi)	Allowable Value (psi)	Acceptable
Pm	**18892**	**19300**	**Yes**
PL + PB (Point 1)	**22515**	**28950**	**Yes**
PL + PB (Point 2)	**15302**	**28950**	**Yes**
PL + PB + Q (Point 1)	**22853**	**57900**	**Yes**
PL + PB + Q (Point 2)	**15605**	**57900**	**Yes**

TABLE 5 - SCL STRESS COMPARED TO ALLOWABLE STRESSES

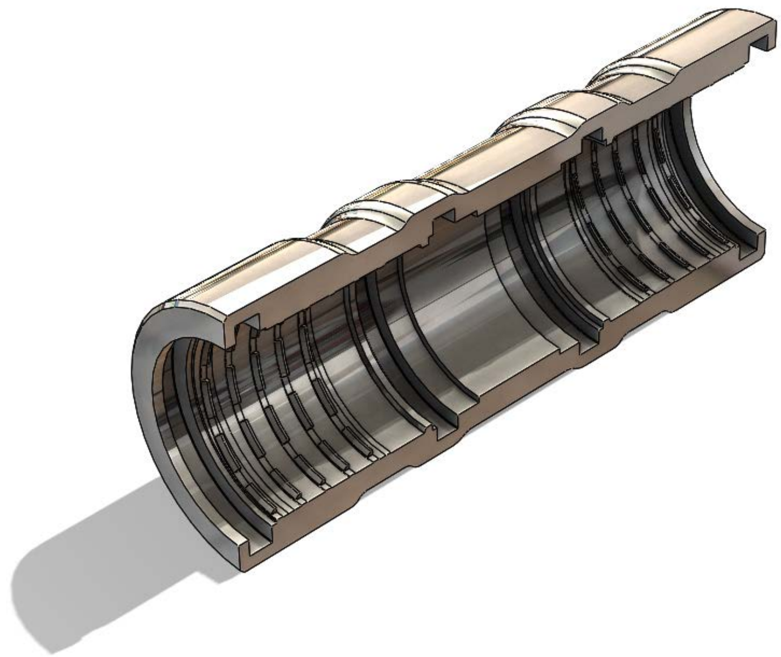
The resultant loads as shown in 7.1 are as expected. The high Y and Z values are a result of the fixed constraint which prevents any movement in those directions. Since it is outside the area of interest this is not a concern in terms of affecting the results. The only value of importance is the X direction which should be zero and the reaction load value is in good agreement to this value.

Figure 4 - Error Plot shows the energy norm error between the nodal stress values and element stress values. The target for the area of interest was less than 5%. The plot shows that for the area of concern the error is less than 5%. There are higher error regions; however they are not in the scope of the analysis. Refining the mesh to account for this error has no effect of the target region's results.

Figure 2 - Displacement Plot shows the resultant displacement of the fitting under pressure. The displacement is low but the shape is what would be expected when pressurizing the fittings which indicates the model and approach is correct.

9 CONCLUSION

The part is acceptable for use within B31.3 systems in accordance with the requirements of B31.3 304.7.2(d). The stress state of all stress categories in the area of interest for the fitting was below the allowable values. The displacement of the part was low and the error level in the area of interest was acceptable.



Pyplok 1” Finite Element Analysis Report – ASTM A479 316

Performed for: Tube-Mac Piping Technologies Ltd.

Prepared by: Edward De Rubeis

Date: 7/04/2016

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2 EXECUTIVE SUMMARY

A 1” pyplok fitting was analyzed using finite element analysis (FEA). The part was created in Solidworks 2015 using drawing DM20001K16 revision 1 and DS267-16 revision 3. The part was analyzed using Solidworks Simulation; a linear elastic modelling software package. A detailed stress analysis of the simulation results were analyzed to ASME section VIII division 2 Part 5, elastic stress analysis method using allowable stress values from B31.3 Appendix A-1. The material analyzed was ASTM A-479 316. The conclusion of the analysis is that the part is acceptable for use for B31.3 systems in accordance with the requirements of B31.3 304.7.2(d).

3 INTRODUCTION

It is assumed that the applicable code section for the Pyplok fittings is B31.3 - Part 4: Fluid service requirements for piping joints; specifically section 318 Special Joints. The analysis outlined in 304.7.2(d) will only apply to pressure design of the Pyplok fitting as indicated in B31.3-318.1.2 and not to the sealing mechanism or integrity of the joint. B31.3-318.2 requirements are outside of the current scope of work. Also it is assumed this fitting will be used in normal fluid service applications.

The scope of the FEA analysis will consist of the pressure design of the fitting while considering internal pressure and end load reactions only. The effect of crimping the ends will not be included in the analysis. Furthermore interaction between the fitting, pipe and o-rings will not be included in the analysis. This simplification will permit the use of a static linear elastic FEA analysis with small displacements of the fitting. Since the area of interest in this analysis is mainly the mid-section of the fitting, these simplifications will not have an adverse effect of the analysis results.

4 DESIGN CODES

ASME B31.-3, 2014 edition

ASME Section VIII Division 2, 2013 edition

5 MATERIAL PROPERTIES

The material type and corresponding mechanical properties at 400F (the fitting’s maximum allowable operating temperature) are listed in Table 1 - Material Properties.

Specification	Allowable Stress at Temperature	Yield Strength at Temperature	Elastic Modulus at Temperature	Poison’s Ratio
ASTM A-479 316	19300psi	21400psi	26400000psi	0.3

TABLE 1 - MATERIAL PROPERTIES

The allowable stress values as prescribed by ASME Section VIII Division 2 Part 5 are shown in the table below.

Stress Type	Allowable Stress (psi)
Sm (General Primary membrane Stress)	19300
PL (Local Primary Membrane Stress	28950
PL + Pb (Local Primary + Primary Bending Stress)	28950
PL + Pb + Q (Local Primary + secondary stress intesity)	57900

TABLE 2 - ALLOWABLE STRESS VALUES

6 MODEL DESCRIPTION

A three dimensional model was created using drawing DM20001K16 revision 1 and DS267-16 revision 3. The model was verified to dimensionally match the drawing.

The small manufacturing details in the part model required a more refined mesh. In order to reduce the analysis time only a quarter of the model was analyzed. Part symmetry was used to reduce the model size, free memory requirements, and allow for a more refined mesh in the area of interest for the analysis.

Below is a summary of the mesh type and elements used. A mesh control was applied to the inside surface where the element size was set at 0.05in and ratio of 1.

TABLE 3 - MESH PARAMETERS

Mesh type	Solid Mesh
Mesher Used:	Curvature based mesh
Jacobian points	4 Points
Maximum element size	0.06 in
Minimum element size	0.012 in
Mesh Quality	High
Total Nodes	248964
Total Elements	165493
Maximum Aspect Ratio	65.745
% of elements with Aspect Ratio < 3	97.9
% of elements with Aspect Ratio > 10	0.436
% of distorted elements(Jacobian)	0

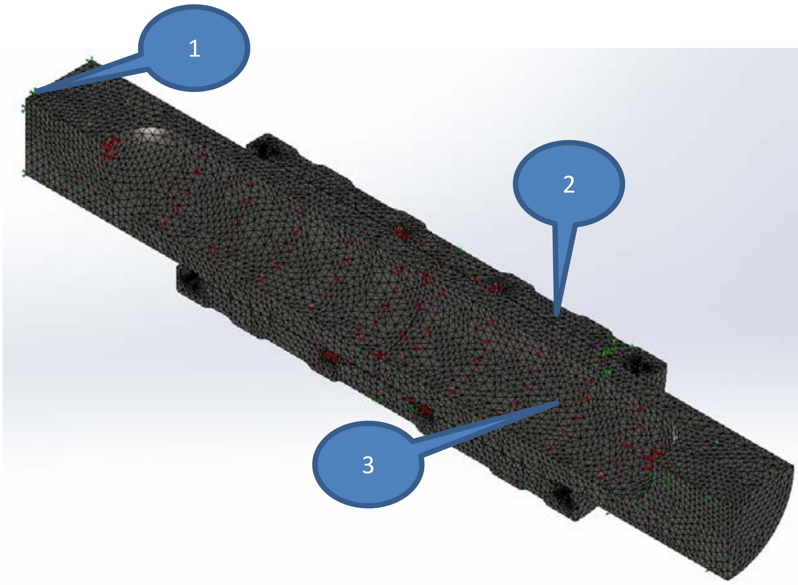


FIGURE 1- MODEL MESHED

Load / boundary Conditions	Value applied	Location Marker (Blue and White)
Fixed edge support	-	1
Symmetry end condition	-	2
Internal Pressure	4000psi	3

The following load and boundary conditions were applied to the model see, Figure 1- Model Meshed.

The internal pressure was applied up until the inner o-ring on each side of the fitting's centerline. This would represent the o-ring being pressurized up against the opposite face sealing the unit.

The pressure thrust reaction loads were modelled by introducing a 1" NPS SCH 80s pipe section in the model. Evaluating the 6 rows of barb pieces and the crimping action interacting with the pipe was beyond the capabilities of the software tool being used and beyond the scope of the analysis. Therefore a simplification was made, the barb pieces were removed and the pipe was connected to the fitting in those regions. Since the analysis was not concerned about those regions from a pressure design perspective, this simplification will not have an effect on the results. The end load reaction due to pressurization was evaluated by capping off the pipe sections and applying pressure.

7 SIMULATION PLOT RESULTS

The following figures and tables are the results of the simulation.

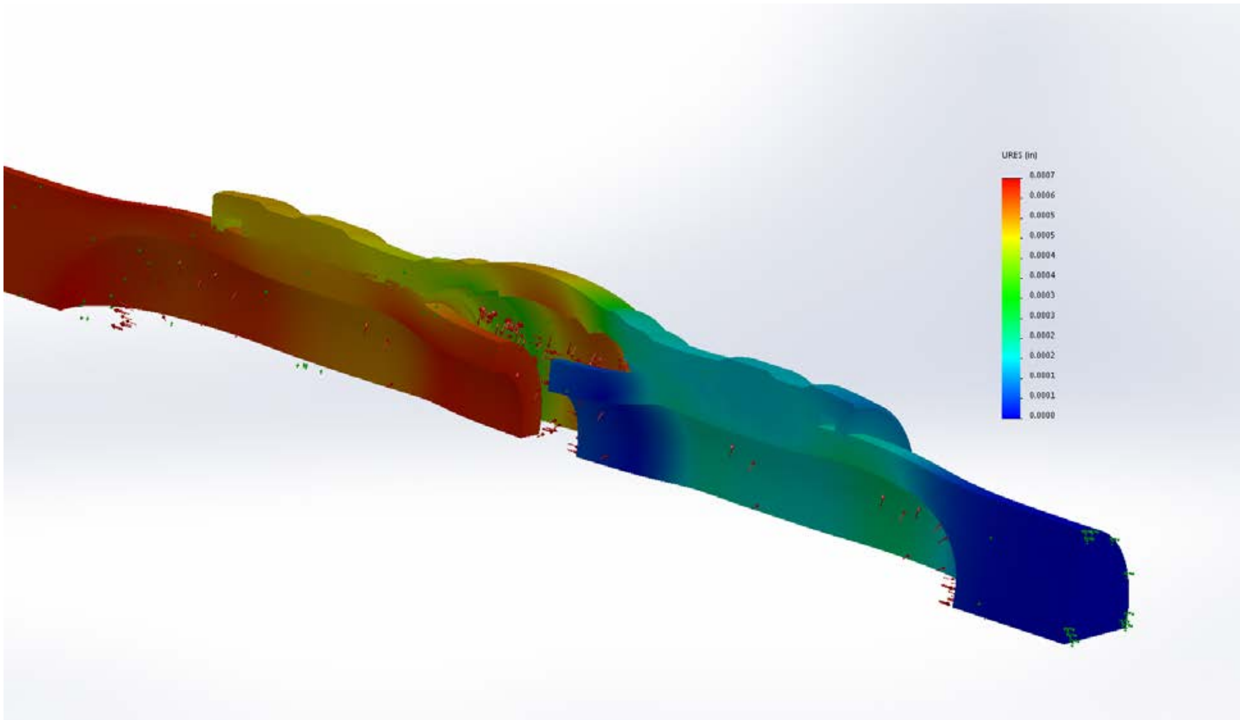


FIGURE 2 - DISPLACEMENT PLOT

The deformed shaped in Figure 2 - Displacement Plot is scaled by a factor of 500 in order actually see the deformation. The maximum resultant displacement is only 0.0007in.

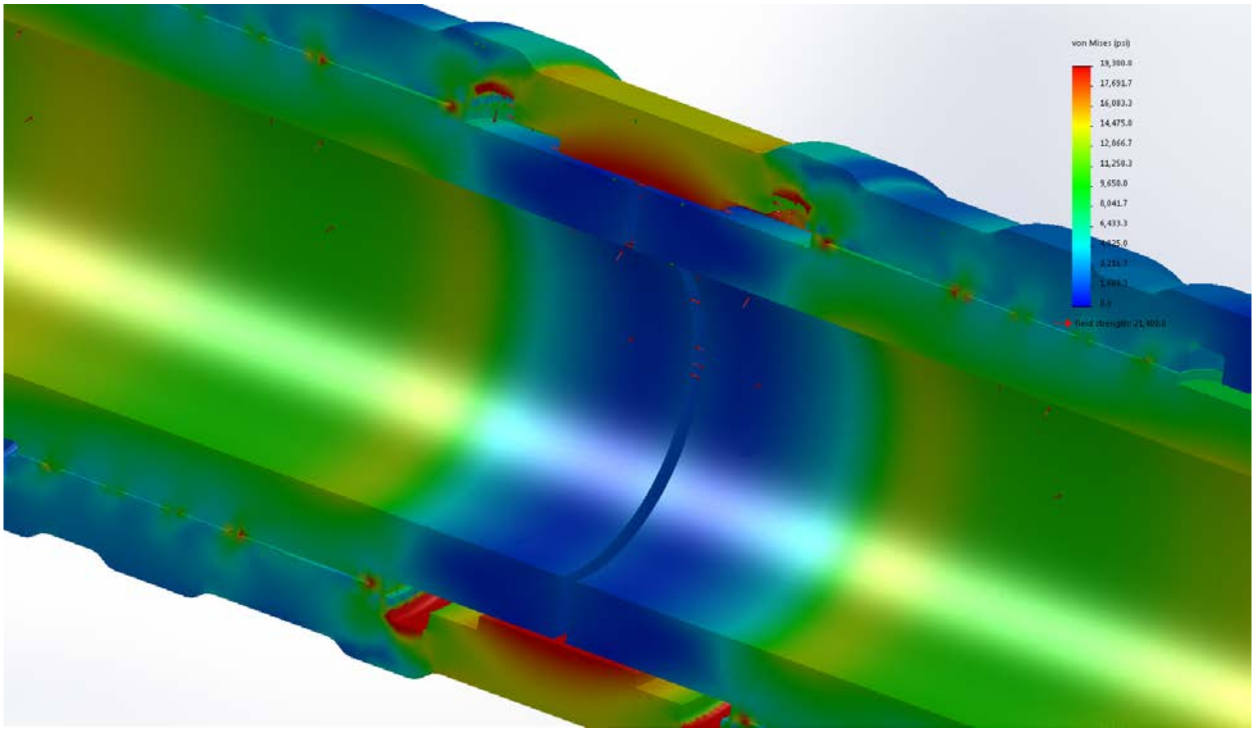


FIGURE 3- VON MISES STRESS PLOT

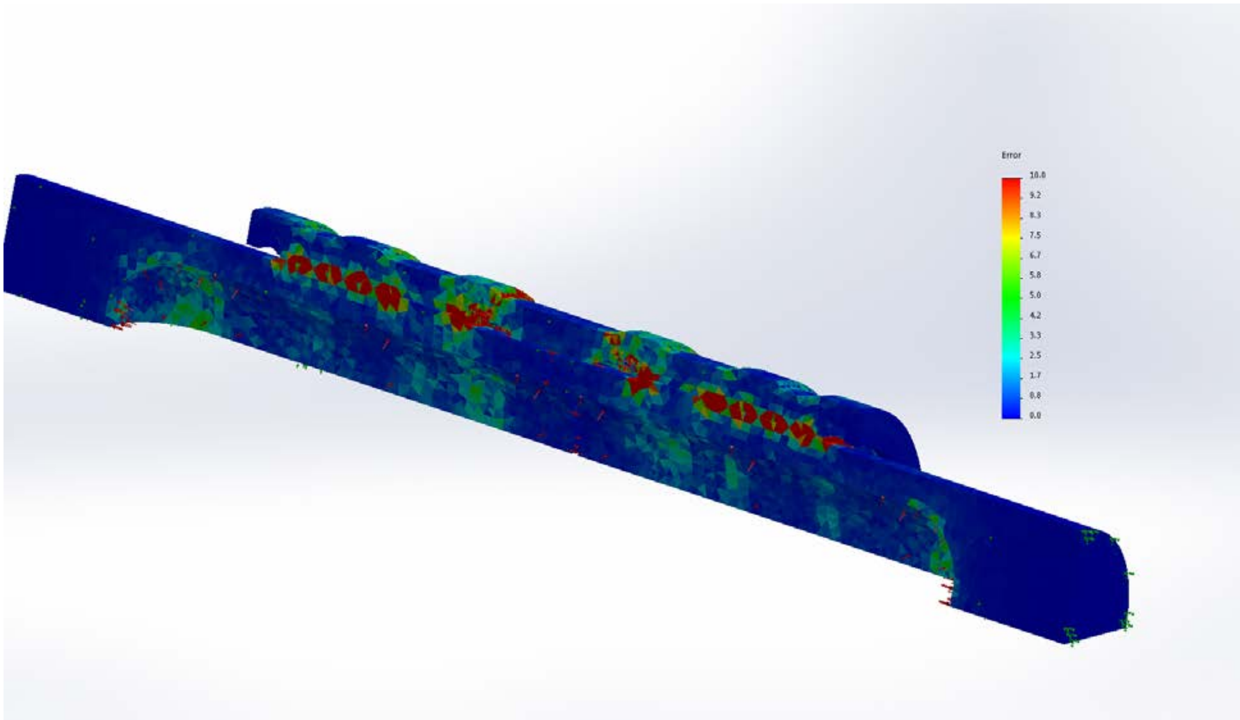


FIGURE 4 - ERROR PLOT

7.1 Resultant Forces

7.1.1 Reaction forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	lbf	0.011	-10386	-10386	14688

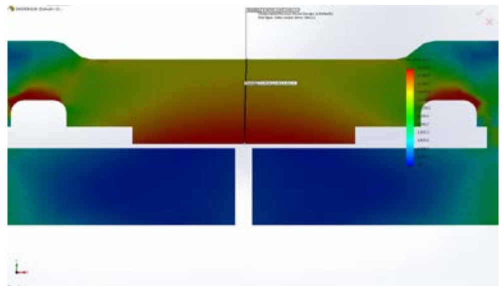
7.1.2 Reaction Moments

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	lbf.in	0	0	0	0

8 Discussion of Results

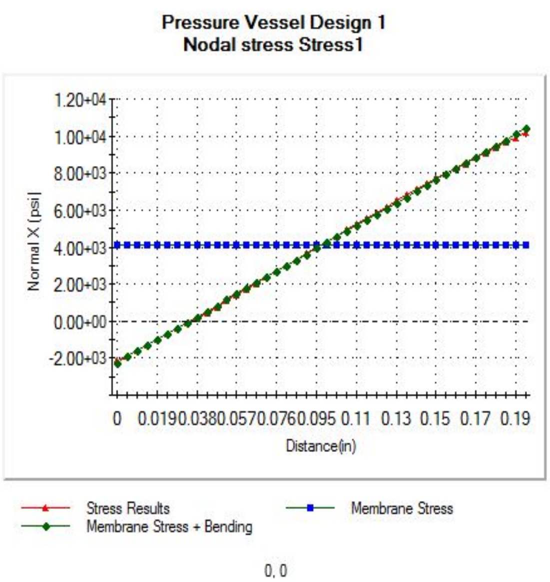
As shown in Figure 3- Von Mises Stress Plot the main point of interest from a high stress standpoint is in the middle section of the pyplok fitting. Using the assessment procedure outlined in ASME Section VIII Division 2, a stress classification line (SCL) was selected through the highest stress region to evaluate its stress state to code values.

Plot : Stress1
Point(1): 0.00161, 0.669, 0.001 in
Point(2) : 0.00595, 0.865, 0.001 in
Units : psi

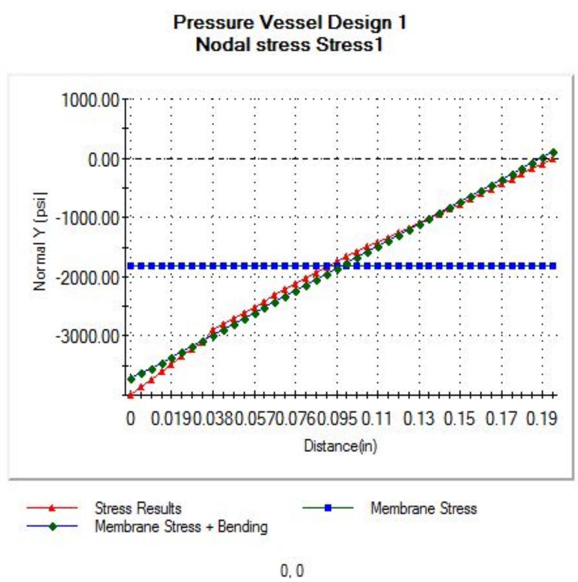


Components	Normal X	Normal Y	Normal Z	Shear XY	Shear XZ	Shear YZ	von Mises	Stress intensity (P1-P3)
Membrane Stress	4.08E+003	-1.81E+003	1.65E+004	14.3	3.14	-27.1	1.62E+004	1.83E+004
Bending (Point 1)	-6.31E+003	-1.92E+003	597	3.38	2.5	-11.6	6.06E+003	6.91E+003
Membrane Stress + Bending (Point 1)	-2.23E+003	-3.73E+003	1.71E+004	17.7	5.64	-38.7	2.01E+004	2.08E+004
Bending (Point 2)	6.31E+003	1.92E+003	-597	-3.38	-2.5	11.6	6.06E+003	6.91E+003
Membrane Stress + Bending (Point 2)	1.04E+004	104	1.59E+004	11	0.643	-15.4	1.39E+004	1.58E+004
Peak (Point 1)	81.2	-267	206	1.14	8.53	-20.8	427	475
Peak (Point 2)	-196	-119	142	-12.5	1.77	4.4	307	339

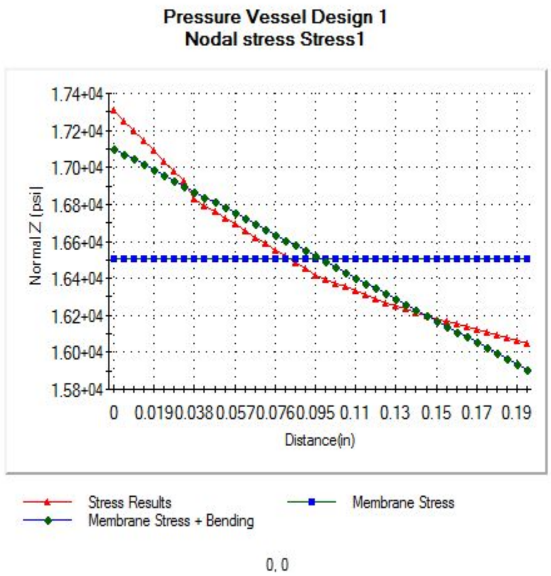
Curve Data:



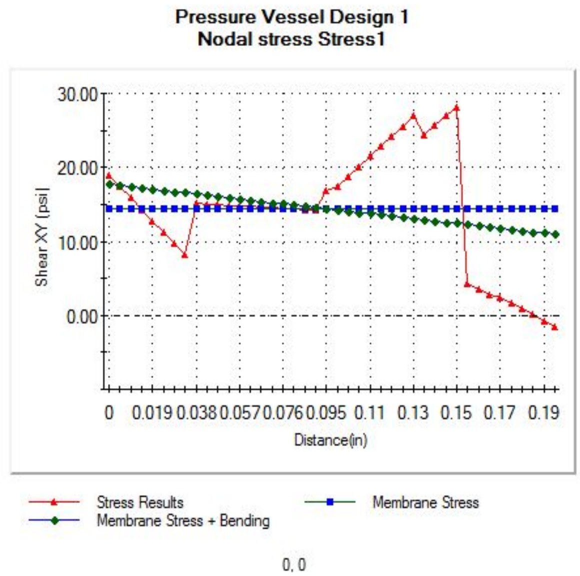
Normal X (psi)



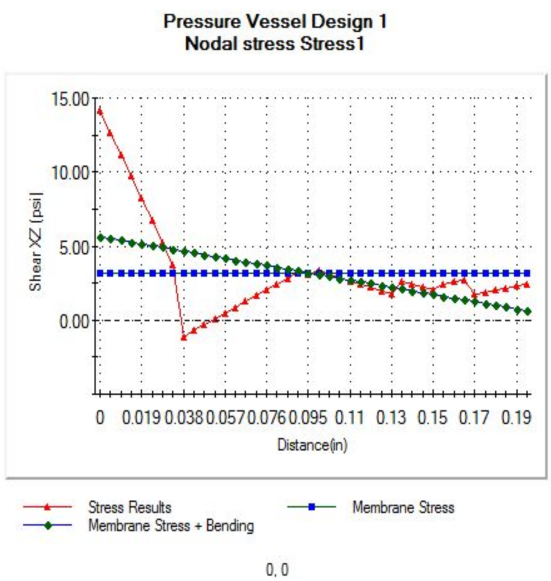
Normal Y (psi)



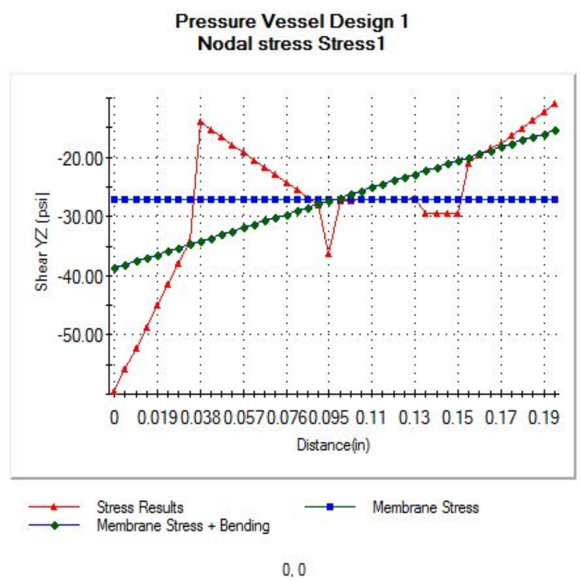
Normal Z (psi)



Shear XY (psi)



Shear XZ (psi)



Shear YZ (psi)

TABLE 4 - SCL STRESS RESULTS

Table 5 - SCL Stress Compared to Allowable Stresses compares the allowable stress criteria to the simulated model stresses. All simulated model stresses are below code allowable values.

Stress Type	Actual Value (psi)	Allowable Value (psi)	Acceptable
Pm	**16190**	**19300**	**Yes**
PL + PB (Point 1)	**20122**	**28950**	**Yes**
PL + PB (Point 2)	**11388**	**28950**	**Yes**
PL + PB + Q (Point 1)	**20442**	**57900**	**Yes**
PL + PB + Q (Point 2)	**14077**	**57900**	**Yes**

TABLE 5 - SCL STRESS COMPARED TO ALLOWABLE STRESSES

The resultant loads as shown in 7.1 are as expected. The high Y and Z values are a result of the fixed constraint which prevents any movement in those directions. Since the fixed constraint is outside the area of interest this is not a concern in terms of affecting the results. The only value of importance is the X direction which should be zero and the reaction load value is in good agreement to this value.

Figure 4 - Error Plot shows the energy norm error between the nodal stress values and element stress values. The target for the area of interest was less than 5%. The plot shows that for the area of concern the error is less than 5%. There are higher error regions; however they are not located in the area of interest, and are not part of this scope of work. Refining the mesh to account for the large error in this region has no effect on the area of interest, and thus has no bearing on results of this report.

Figure 2 - Displacement Plot shows the resultant displacement of the fitting under pressure. The displacement is low but the shape is what would be expected when pressurizing the fittings which indicates the model and approach is correct.

9 Conclusion

The part is acceptable for use within B31.3 systems in accordance with the requirements of B31.3 304.7.2(d). The stress state of all stress categories in the area of interest for the fitting was below the code allowable values. The displacement of the part was low and the error level in the area of interest was acceptable.

APPENDIX E – ALLOWABLE DESIGN PRESSURE

Carbon Steel Material									
PYPLOK Designation	Nominal Pipe Size	B31.3				B31.1			
		-20F to 100F	200F	300F	400F	-20F to 100F	200F	300F	400F
DM20001G04	1/4" NPS	5200	4900	4700	4500	5200	5200	5200	5200
DM20001G06	3/8" NPS	5000	4800	4600	4400	5000	5000	5000	5000
DM20001G08	1/2" NPS	4900	4600	4400	4300	4900	4900	4900	4900
DM20001G12	3/4" NPS	4700	4400	4200	4100	4700	4700	4700	4700
DM20001G16	1" NPS	4400	4200	4000	3900	4400	4400	4400	4400
DM20001G20	1-1/4" NPS	4100	3900	3700	3600	4100	4100	4100	4100
DM20001G24	1-1/2" NPS	3900	3700	3500	3400	3900	3900	3900	3900
DM20001G32	2" NPS	3500	3300	3100	3000	3500	3500	3500	3500
DM20001G48	3" NPS	2200	2100	2000	1900	2200	2200	2200	2200
DP40N100G48	3" NPS	2200	2100	2000	1900	2200	2200	2200	2200
DP40N100G64	4" NPS	1000	900	900	900	1000	1000	1000	1000
DP40N100G40	2.5" NPS	2900	2700	2600	2600	2900	2900	2900	2900
Stainless Steel 316 Type Material									
PYPLOK Designation	Nominal Pipe Size	B31.3				B31.1			
		-20F to 100F	200F	300F	400F	-20F to 100F	200F	300F	400F
DM20001K04	1/4" NPS	5800	5800	5800	5600	5800	5800	5800	5600
DM20001K06	3/8" NPS	5600	5600	5600	5400	5600	5600	5600	5400
DM20001K08	1/2" NPS	5400	5400	5400	5200	5400	5400	5400	5200
DM20001K12	3/4" NPS	5100	5100	5100	5000	5100	5100	5100	5000
DM20001K16	1" NPS	4800	4800	4800	4700	4800	4800	4800	4700
DM20001K20	1-1/4" NPS	4400	4400	4400	4300	4400	4400	4400	4300
DM20001K24	1-1/2" NPS	4200	4200	4200	4000	4200	4200	4200	4000
DM20001K32	2" NPS	3700	3700	3700	3600	3700	3700	3700	3600
DM20001K48	3" NPS	2600	2600	2600	2500	2600	2600	2600	2500
DP40N100K48	3" NPS	2600	2600	2600	2500	2600	2600	2600	2500
DP40N100K64	4" NPS	1600	1600	1600	1500	1600	1600	1600	1500
DP40N100K40	2.5" NPS	3300	3300	3300	3200	3300	3300	3300	3200

Carbon Steel Material									
PYPLOK Designation	Nominal Pipe Size	B31.4				B31.8			
		-20F to 100F	200F	300F	400F	-20F to 100F	200F	300F	400F
DM20001G04	1/4" NPS	5200	5200	5200	5000	4900	4500	4200	3800
DM20001G06	3/8" NPS	5000	5000	5000	4900	4800	4400	4100	3700
DM20001G08	1/2" NPS	4900	4900	4900	4900	4900	4500	4200	3800
DM20001G12	3/4" NPS	4700	4700	4700	4700	4600	4200	3900	3500
DM20001G16	1" NPS	4400	4400	4400	4400	4400	4200	3900	3500
DM20001G20	1-1/4" NPS	4100	4100	4100	4100	4100	4100	3800	3400
DM20001G24	1-1/2" NPS	3900	3900	3900	3900	3900	3900	3700	3400
DM20001G32	2" NPS	3500	3500	3500	3500	3500	3500	3500	3100
DM20001G48	3" NPS	2200	2200	2200	2200	2200	2200	2200	2200
DP40N100G48	3" NPS	2100	2000	1900	1800	1800	1600	1500	1400
DP40N100G64	4" NPS	1000	1000	1000	1000	1000	1000	1000	1000
DP40N100G40	2.5" NPS	2800	2600	2500	2400	2400	2200	2000	1800
Stainless Steel 316 Type Material									
PYPLOK Designation	Nominal Pipe Size	B31.4				B31.8			
		-20F to 100F	200F	300F	400F	-20F to 100F	200F	300F	400F
DM20001K04	1/4" NPS	4900	4200	3800	3500	4100	3500	3100	2600
DM20001K06	3/8" NPS	4800	4100	3700	3400	4000	3400	3000	2500
DM20001K08	1/2" NPS	4900	4200	3800	3500	4100	3500	3100	2600
DM20001K12	3/4" NPS	4600	4000	3600	3300	3800	3300	2900	2400
DM20001K16	1" NPS	4600	4000	3600	3300	3800	3300	2900	2400
DM20001K20	1-1/4" NPS	4400	3800	3500	3200	3700	3200	2800	2400
DM20001K24	1-1/2" NPS	4200	3800	3400	3100	3600	3100	2700	2300
DM20001K32	2" NPS	3700	3500	3200	2900	3400	2900	2600	2200
DM20001K48	3" NPS	2600	2200	2200	2200	2600	2400	2100	1700
DP40N100K48	3" NPS	1800	1500	1400	1300	1500	1300	1100	900
DP40N100K64	4" NPS	1600	1000	1000	1000	1600	1600	1400	1200
DP40N100K40	2.5" NPS	2400	2000	1800	1700	2000	1700	1500	1200