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DESIGN AND ANALYSIS OF REINFORCEMENT PAD OF NOZZLE JUNCTION IN PRESSURE VESSEL

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Abstract: The goal is to gain a better understanding of how a geometric gap between a cylindrical or spherical shell and a reinforcing pad affects the stress intensity at the nozzle penetration while the pressure vessel is under internal pressure. Nozzles are used as intake and outlet for process fluid and cooling fluid in a variety of tanks, pressure vessels, heat exchangers, and other applications. The shell strength may be reduced to establish the Nozzle hole to shell. A reinforcement pad is utilized at the nozzle junction to improve strength and reduce failure. So, the nozzle to shell junction is analyzed, and whether or not a pad is required, is determined by taking into account a variety of elements that influence the strength of a junction. If a pad is required, the thickness and diameter are calculated according to ASME guidelines. In addition, a finite element analysis (FEA) of the junction is performed to calculate the stress generated at the junction. As a result, the magnitudes and distributions of the local stresses caused by the geometric discontinuity and internal pressure loading are unknown. Perfect contact between the shell and the pad cannot be maintained for a variety of reasons, resulting in a gap. Both designers and manufacturers are interested in the influence of the gap on the stresses in the nozzle reinforcement region.

Keywords: Shell, Nozzle Junction, Pressure Vessel , Reinforcement Pad, Meshing, Finite Element Analysis

I. INTRODUCTION

In terms of structural design, pressure vessels, pipe tees, boilers, and reactors are typical examples of applications where safe and economical design requirements must be employed. In many technical applications, nozzle connections subjected to internal pressure and external loads are the most typical types. One of the issues with nozzle connection design is the application of appropriate stressrelieving reinforcements. Different types of connections are utilised to assure the safety of nozzle connections. Welded pad reinforcement, self-reinforced nozzles, and internally protruded connections and toros transitions are examples of these connections. Because of the importance of pressure vessels in engineering applications and the risk of safety issues in the event of an accident, a number of studies have been done to assess pressure vessel safety under various loading conditions. There are numerous codes that outline the rules and regulations that must be followed to guarantee that equipment is designed safely. The tensions near nozzle connections have been the subjectof extensive research. Stresses at cylindrical junctions can be accurately assessed to guarantee a safe and cost-effective design. Traditional pressure vessel design codes, such as ASME Section VIII, are unable to cover all design scenarios. External loads on nozzles, for example, are not addressed in the Code. Engineers must step outside of the Code in such instances and use acknowledged design processes such as (FEA) finite element analysis. WRC 107/297 and other simplified calculation methods used in the PVP sector arebased on limited test data and have geometric restrictions. When these geometric constraints are not adhered to, the results become erroneous. Finite element analysis has no restrictions and can deliver accurate results in any situation.

II. METHODOLOGY

Process of the work:

- The provided Pressure Vessel data sheets are thoroughly examined, and all required standard dimensions, such as WRNF 150, are taken as dimensional references, along with NPS numbers as reference numbers.
- Parts are generated in 2D (line diagrams) using Auto-CAD utilizing standard measurements and data from data sheets, and part drawings are put together to make a full drawing.
- In Siemens NX 11.0, 3D modelling is done on the pieces, and then the parts are linked to complete the assembly.
- Ansys software is used to simulate the pressure vessel analysis, and the results are observed.

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III.DESIGN OF PRESSURE VESSEL

All of the parts were modelled in NX 11.0 using the same technique with minor adjustments to the design parameters. Pressure Vessel data sheets take into account design parameters and design standards.

Fig3.01: 3D sketch of Shell 1 in NX

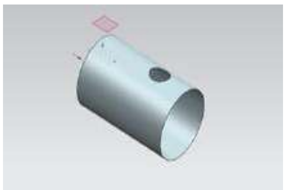

Fig3.02: 3D sketch of Shell 2 in NX

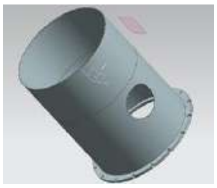

Fig3.03: 3D sketch of Skirt in NX

Fig3.04: 3D sketch of Dishend 1 in NX

Fig3.05: 3D sketch of Nozzle 1 & 2 in NX

Fig3.06: 3D sketch of Nozzle 4,5,6,7
in NX

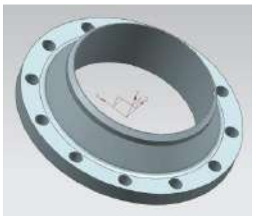

Fig3.07: 3D sketch of Nozzle 8 in NX

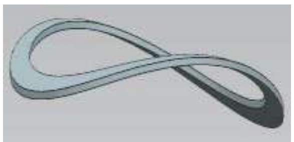

Fig3.08: 3D sketch of Reinforcement Pad 1 &2 in NX

Fig3.09: 3D sketch of Nozzle 3
in NX

Fig3.10: 3D sketch of Manhole in NX

Fig3.11: 3D sketch of Dishend 2 in NX

Fig3.12: 3D sketch of Manhole
Blank in NX

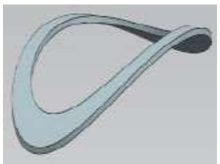

Fig3.13: 3D sketch of MH RF Pad

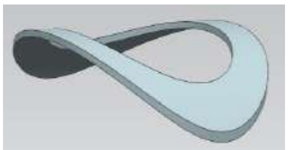

Fig3.14: 3D sketch of ReinforcementPad 8 in NX

Fig3.15: 3D sketch of RF Pad 1 in NX

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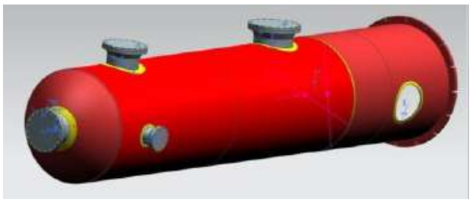
RF Pad in NX



⇨ **Total Assembly in NX**

IV.ANALYSIS

Following the technique, all of the parts were analyzed using ANSYS 16.0. With Pressure Vessel data sheets, the analysis parameters arecompared to design specifications.

TOTAL ASSEMBLY - ANALYSIS

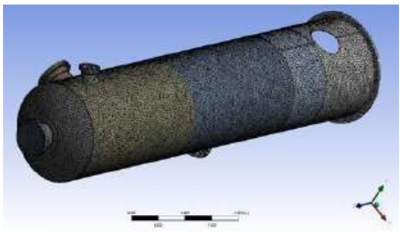


Fig4.01: Meshing of total assembly

Statistics	
Bodies	26
Active Bodies	26
Nodes	376354
Elements	182514

Fig4.0 2: Nodes and elements

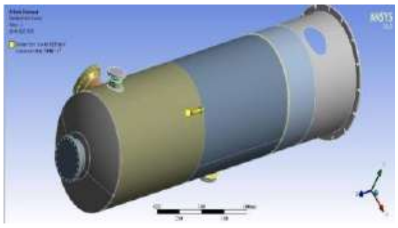


Fig4.03: Standard Earth Gravity

Define By	Normal To
Magnitude	13789 Pa (ramped)

Fig4.04: Pressure

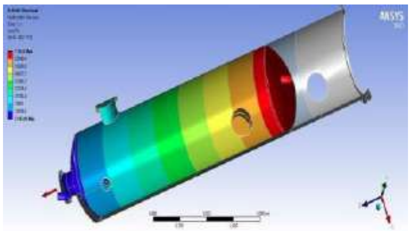


Fig4.05: Hydrostatic Pressure

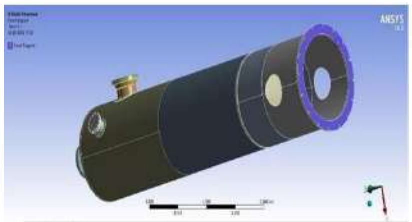
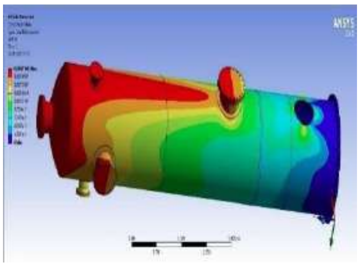


Fig4.07: Fixed Support



Static Structural

Fig4.08: Total Deformation

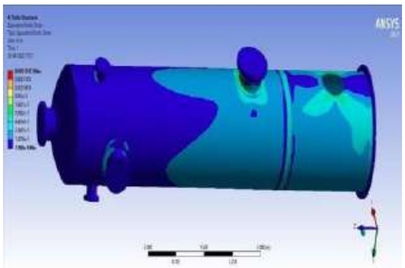


Fig4.09: Equivalent Elastic Strain

Results	
Minimum	343.3 °C
Maximum	343.3 °C

Fig4.10: Temperature

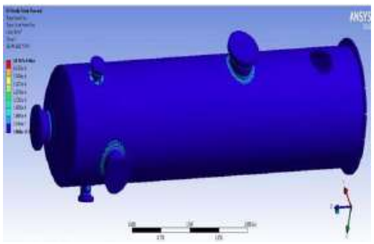


Fig4.11: Total Heat Flux
(Steady State Thermal)

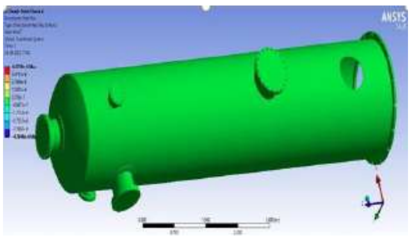


Fig4.12: Directional Heat Flux
(Steady State Thermal)

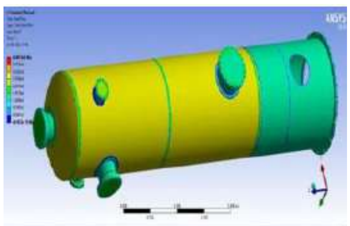


Fig4.13: Total Heat Flux
(Transient Thermal)

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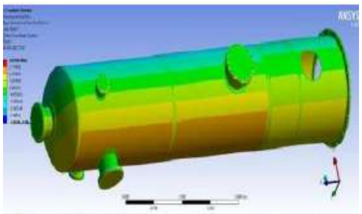

Fig4.14: Directional Heat Flux
(Transient Thermal)

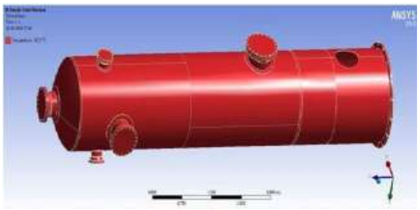

Fig4.15: Design Temperature

Definition	
Type	Temperature
Magnitude	343.3 °C (ramped)

Fig4.16: Design Temperature

Static Structural

REINFORCEMENT PAD – ANALYSIS

RF PAD – K1,N8

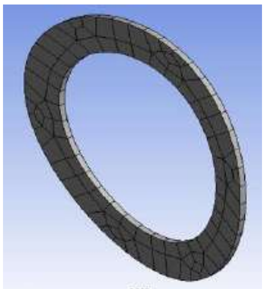

Fig4.17: Meshing

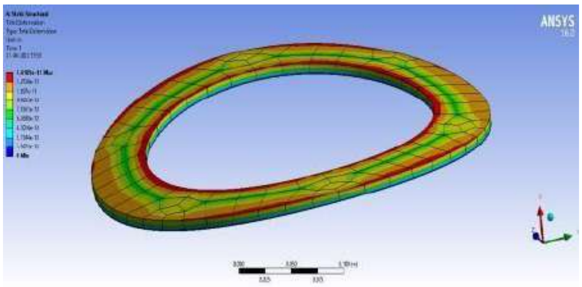

Fig4.18: Total Deformation

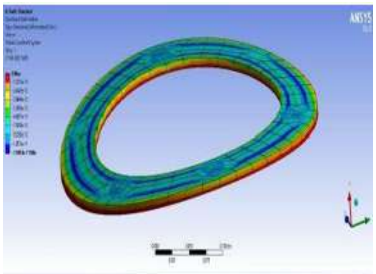

Fig4.19: Directional Deformation

Type	Temperature
Magnitude	343.3 °C (ramped)

Fig4.20: Temperature

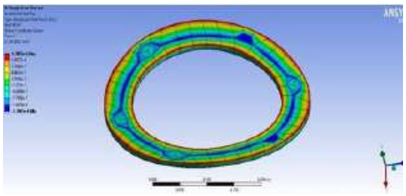

Fig4.21: Total Heat Flux
(Steady State Thermal)

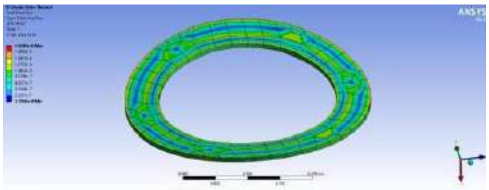

Fig4.22: Directional Heat Flux
(Steady State Thermal)

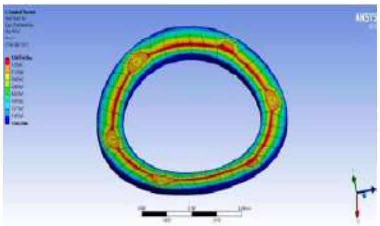

Fig4.23: Total Heat Flux
(Transient Thermal)

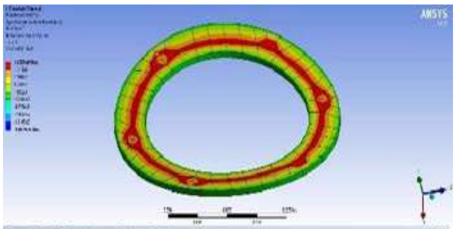

Fig4.24: Directional Heat Flux
(Transient Thermal)

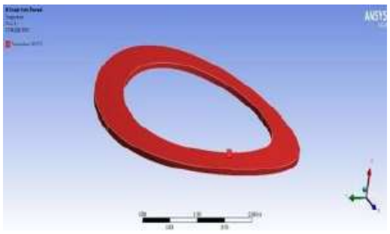

Fig4.25: Temperature

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RF PADS	MESHING TYPE	MESHING		DESIGN PRESSURE	TOTAL DEFORMATION		DIRECTIONAL DEFORMATION		EQUIVALENT STRESS		EQUIVALENT ELASTIC STRAIN	
		ELEMENTS	NODES		MAXIMUM	MINIMUM	MAXIMUM	MINIMUM	MAXIMUM	MINIMUM	MAXIMUM	MINIMUM
K1 & N8	QUADRILATERAL	94	858	345 KPa	1.4105e-008 mm	0. mm	0. mm	-1.1893e-008 mm	3.2489e-004 MPa	1.2785e-004 MPa	1.6245e-009 mm/mm	6.7759e-010 mm/mm
MH	QUADRILATERAL	62	624	345 KPa	2.5939e-007 mm	0. mm	2.3089e-007 mm	-1.2586e-007 mm	2.9766e-004 MPa	1.2016e-004 MPa	1.5723e-009 mm/mm	6.8324e-010 mm/mm
N1	QUADRILATERAL	88	816	345 KPa	2.0008e-008 mm	0. mm	5.9495e-009 mm	-1.6671e-008 mm	2.9522e-004 MPa	1.2461e-004 MPa	1.4761e-009 mm/mm	6.2347e-010 mm/mm
N2	QUADRILATERAL	680	1720	345 KPa	2.7177e-008 mm	0. mm	2.268e-008 mm	-2.2681e-008 mm	4.4978e-004 MPa	1.2021e-004 MPa	2.2489e-009 mm/mm	6.148e-010 mm/mm

ANALYSIS OF ALL REINFORCEMENT PADS AND THEIR RESULTS

RESULTS

ASSEMBLY – ANALYSIS

Model (A4, B4, C4) > Static Structural (A5) > Solution (A6) > Results

Object Name	*Total Deformation*	*Equivalent Elastic Strain*	*Equivalent Stress*
State	Solved		
Scope			
Scoping Method	Geometry Selection		
Geometry	All Bodies		
Definition			
Type	Total Deformation	Equivalent Elastic Strain	Equivalent (von-Mises) Stress
By	Time		
Display Time	Last		
Calculate Time History	Yes		
Identifier			
Suppressed	No		
Results			
Minimum	0. m	7.189e-009 m/m	825.13 Pa
Maximum	2.1943e-004 m	1.3473e-004 m/m	2.6929e+007 Pa
Minimum Occurs On	Part 1		
Maximum Occurs On	Part 8	Part 1	
Information			
Time	1. s		
Load Step	1		
Substep	1		
Iteration Number	1		
Integration Point Results			
Display Option		Averaged	
Average Across Bodies		No	

Model (A4, B4, C4) > Steady-State Thermal (B5) > Solution (B6) > Results

Object Name	*Total Heat Flux*	*Directional Heat Flux*	*Temperature*
State	Solved		
Scope			
Scoping Method	Geometry Selection		
Geometry	All Bodies		
Definition			
Type	Total Heat Flux	Directional Heat Flux	Temperature
By	Time		
Display Time	Last		
Calculate Time History	Yes		
Identifier			
Suppressed	No		
Orientation		X Axis	
Coordinate System		Global Coordinate System	
Integration Point Results			
Display Option	Averaged		
Average Across Bodies	No		
Results			
Minimum	1.909e-011 W/m²	-4.7848e-006 W/m²	343.3 °C
Maximum	4.8107e-006 W/m²	4.4359e-006 W/m²	343.3 °C
Minimum Occurs On	Part 21	Part 24	Part 1
Maximum Occurs On	Part 24	Part 4	Part 1
Information			
Time	1. s		
Load Step	1		
Substep	1		
Iteration Number	1		

Model (A4, B4, C4) > Transient Thermal (C5) > Solution (C6) > Results

Object Name	*Total Heat Flux*	*Directional Heat Flux*	*Tempe*
State	Solved		
Scope			
Scoping Method	Geometry Selection		
Geometry	All Bodies		
Definition			
Type	Total Heat Flux	Directional Heat Flux	Tempe
By	Time		
Display Time	Last		
Calculate Time History	Yes		
Identifier			
Suppressed	No		
Orientation		X Axis	
Coordinate System		Global Coordinate System	
Integration Point Results			
Display Option	Averaged		
Average Across Bodies	No		
Results			
Minimum	4.1453e-010 W/m²	-4.4049e+006 W/m²	-140.7
Maximum	4.4053e+006 W/m²	4.054e+006 W/m²	343.3
Minimum Occurs On	Part 1	Part 24	Part
Maximum Occurs On	Part 24	Part 13	Part
Minimum Value Over Time			

Model (A4, B4, C4) > Transient Thermal (C5) > Solution (C6) > Solution Information > Result

Object Name	*Temperature - Global Maximum*	*Temperature - Global Minimum*
State	Solved	
Definition		
Type	Temperature	
Suppressed	No	
Scope		
Scoping Method	Global Maximum	Global Minimum
Results		
Minimum	343.3 °C	-587.63 °C
Maximum	540.86 °C	-140.76 °C

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REINFORCEMENT PAD – ANALYSIS

RF PAD – K1,N8

Model (A4, B4, C4) > Static Structural (A5) > Solution (A6) > Results

Object Name	*Total Deformation*	*Directional Deformation*	*Equivalent Stress*
State	Solved		
Scope			
Scoping Method	Geometry Selection		
Geometry	All Bodies		
Definition			
Type	Total Deformation	Directional Deformation	Equivalent (von-Mises) Stress
By	Time		
Display Time	Last		
Calculate Time History	Yes		
Identifier			
Suppressed	No		
Orientation		X Axis	
Coordinate System		Global Coordinate System	
Results			
Minimum	0. m	-1.1893e-011 m	127.85 Pa
Maximum	1.4105e-011 m	0. m	324.89 Pa
Information			
Time	1. s		
Load Step	1		
Substep	1		
Iteration Number	1		
Integration Point Results			
Display Option			Averaged
Average Across Bodies			No

Model (A4, B4, C4) > Steady-State Thermal (B5) > Solution (B6) > Results

Object Name	*Temperature*	*Total Heat Flux*	*Directional Heat Flux*
State	Solved		
Scope			
Scoping Method	Geometry Selection		
Geometry	All Bodies		
Definition			
Type	Temperature	Total Heat Flux	Directional Heat Flux
By	Time		
Display Time	Last		
Calculate Time History	Yes		
Identifier			
Suppressed	No		
Orientation			X Axis
Coordinate System			Global Coordinate System
Results			
Minimum	343.3 °C	1.1966e-008 W/m²	-1.3983e-006 W/m²
Maximum	343.3 °C	1.9042e-006 W/m²	1.3985e-006 W/m²
Information			
Time	1. s		
Load Step	1		
Substep	1		
Iteration Number	1		
Integration Point Results			
Display Option		Averaged	
Average Across Bodies		No	

Model (A4, B4, C4) > Transient Thermal (C5) > Solution (C6) > Results

Object Name	*Temperature*	*Total Heat Flux*	*Directional Heat Flux*
State	Solved		
Scope			
Scoping Method	Geometry Selection		
Geometry	All Bodies		
Definition			
Type	Temperature	Total Heat Flux	Directional Heat Flux
By	Time		
Display Time	Last		
Calculate Time History	Yes		
Identifier			
Suppressed	No		
Orientation			X Axis
Coordinate System			Global Coordinate System
Results			
Minimum	295.67 °C	1346.3 W/m²	-1.4329e+006 W/m²
Maximum	343.3 °C	1.4432e+006 W/m²	1.4329e+006 W/m²
Minimum Value Over Time			
Minimum	-254.45 °C	1063.8 W/m²	-1.7889e+007 W/m²
Maximum	295.67 °C	9808.9 W/m²	-1.4329e+006 W/m²
Maximum Value Over Time			
Minimum	343.3 °C	1.4432e+006 W/m²	1.4329e+006 W/m²
Maximum	343.3 °C	1.8111e+007 W/m²	1.7889e+007 W/m²
Information			
Time	1. s		
Load Step	1		
Substep	13		
Iteration Number	13		
Integration Point Results			
Display Option		Averaged	
Average Across Bodies		No	

RF PAD – MH (MANHOLE)

Model (A4, B4, C4) > Static Structural (A5) > Solution (A6) > Results

Object Name	*Total Deformation*	*Directional Deformation*	*Equivalent Stress*
State	Solved		
Scope			
Scoping Method	Geometry Selection		
Geometry	All Bodies		
Definition			
Type	Total Deformation	Directional Deformation	Equivalent (von-Mises) Stress
By	Time		
Display Time	Last		
Calculate Time History	Yes		
Identifier			
Suppressed	No		
Orientation		X Axis	
Coordinate System		Global Coordinate System	
Results			
Minimum	0. m	-1.2586e-010 m	120.16 Pa
Maximum	2.5939e-010 m	2.3089e-010 m	297.66 Pa
Information			
Time	1. s		
Load Step	1		
Substep	1		
Iteration Number	1		
Integration Point Results			
Display Option			Averaged
Average Across Bodies			No

Model (A4, B4, C4) > Steady-State Thermal (B5) > Solution (B6) > Results

Object Name	*Temperature*	*Total Heat Flux*	*Directional Heat Flux*
State	Solved		
Scope			
Scoping Method	Geometry Selection		
Geometry	All Bodies		
Definition			
Type	Temperature	Total Heat Flux	Directional Heat Flux
By	Time		
Display Time	Last		
Calculate Time History	Yes		
Identifier			
Suppressed	No		
Orientation			X Axis
Coordinate System			Global Coordinate System
Results			
Minimum	343.3 °C	1.5658e-008 W/m²	-2.9703e-006 W/m²
Maximum	343.3 °C	3.0391e-006 W/m²	2.9721e-006 W/m²
Information			
Time	1. s		
Load Step	1		
Substep	1		
Iteration Number	1		
Integration Point Results			
Display Option		Averaged	
Average Across Bodies		No	

Model (A4, B4, C4) > Transient Thermal (C5) > Solution (C6) > Results

Object Name	*Temperature*	*Total Heat Flux*	*Directional Heat Flux*
State	Solved		
Scope			
Scoping Method	Geometry Selection		
Geometry	All Bodies		
Definition			
Type	Temperature	Total Heat Flux	Directional Heat Flux
By	Time		
Display Time	Last		
Calculate Time History	Yes		
Identifier			
Suppressed	No		
Orientation			X Axis
Coordinate System			Global Coordinate System
Results			
Minimum	269. °C	1.4224e-007 W/m²	-2.2211e+006 W/m²
Maximum	343.3 °C	2.2481e+006 W/m²	2.2211e+006 W/m²
Minimum Value Over Time			
Minimum	-596.4 °C	1.4224e-007 W/m²	-2.8327e+007 W/m²
Maximum	269. °C	1.4224e-007 W/m²	-2.2211e+006 W/m²
Maximum Value Over Time			
Minimum	343.3 °C	2.2481e+006 W/m²	2.2211e+006 W/m²
Maximum	343.3 °C	2.8439e+007 W/m²	2.8327e+007 W/m²
Information			
Time	1. s		
Load Step	1		
Substep	13		
Iteration Number	13		
Integration Point Results			
Display Option		Averaged	
Average Across Bodies		No	

RF PAD – N1

Model (A4, B4, C4) > Steady-State Thermal (B5) > Solution (B6) > Results

Object Name	*Temperature*	*Total Heat Flux*	*Directional Heat Flux*
State	Solved		
Scope			
Scoping Method	Geometry Selection		
Geometry	All Bodies		
Definition			
Type	Temperature	Total Heat Flux	Directional Heat Flux
By	Time		
Display Time	Last		
Calculate Time History	Yes		
Identifier			
Suppressed	No		
Orientation			X Axis
Coordinate System			Global Coordinate System
Results			
Minimum	343.3 °C	1.5039e-008 W/m²	-1.496e-006 W/m²
Maximum	343.3 °C	1.6267e-006 W/m²	1.4946e-006 W/m²
Information			
Time	1. s		
Load Step	1		
Substep	1		
Iteration Number	1		
Integration Point Results			
Display Option		Averaged	
Average Across Bodies		No	

Model (A4, B4, C4) > Transient Thermal (C5) > Solution (C6) > Results

Object Name	*Temperature*	*Total Heat Flux*	*Directional Heat Flux*
State	Solved		
Scope			
Scoping Method	Geometry Selection		
Geometry	All Bodies		
Definition			
Type	Temperature	Total Heat Flux	Directional Heat Flux
By	Time		
Display Time	Last		
Calculate Time History	Yes		
Identifier			
Suppressed	No		
Orientation			X Axis
Coordinate System			Global Coordinate System
Results			
Minimum	293.03 °C	910.46 W/m²	-1.5195e+006 W/m²
Maximum	343.3 °C	1.5216e+006 W/m²	1.5195e+006 W/m²
Minimum Value Over Time			
Minimum	-254.81 °C	910.46 W/m²	-1.8078e+007 W/m²
Maximum	293.03 °C	5664.6 W/m²	-1.5195e+006 W/m²
Maximum Value Over Time			
Minimum	343.3 °C	1.5216e+006 W/m²	1.5195e+006 W/m²
Maximum	343.3 °C	1.8116e+007 W/m²	1.8078e+007 W/m²
Information			
Time	1. s		
Load Step	1		
Substep	13		
Iteration Number	13		
Integration Point Results			
Display Option		Averaged	
Average Across Bodies		No	

Model (A4, B4, C4) > Transient Thermal (C5) > Solution (C6) > Temperature

Time [s]	Minimum [°C]	Maximum [°C]
1.e-002	-254.81	
2.e-002	-238.44	
5.e-002	-193.14	
0.14	-84.688	
0.24	9.3477	
0.34	82.73	343.3
0.44	139.99	
0.54	184.67	
0.64	219.54	
0.74	246.74	
0.84	267.97	

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RF PAD – N2

Model (A4, B4, C4) > Static Structural (A5) > Solution (A6) > Results

Object Name	*Total Deformation*	*Directional Deformation*	*Equivalent Stress*
State	Solved		
Scope			
Scoping Method	Geometry Selection		
Geometry	All Bodies		
Definition			
Type	Total Deformation	Directional Deformation	Equivalent (von-Mises) Stress
By	Time		
Display Time	Last		
Calculate Time History	Yes		
Identifier			
Suppressed	No		
Orientation		X Axis	
Coordinate System		Global Coordinate System	
Results			
Minimum	0. m	-2.2681e-011 m	120.21 Pa
Maximum	2.7177e-011 m	2.268e-011 m	449.78 Pa
Information			
Time	1. s		
Load Step	1		
Substep	1		
Iteration Number	1		
Integration Point Results			
Display Option			Averaged
Average Across Bodies			No

Model (A4, B4, C4) > Steady-State Thermal (B5) > Solution (B6) > Results

Object Name	*Temperature*	*Total Heat Flux*	*Directional Heat Flux*
State	Solved		
Scope			
Scoping Method	Geometry Selection		
Geometry	All Bodies		
Definition			
Type	Temperature	Total Heat Flux	Directional Heat Flux
By	Time		
Display Time	Last		
Calculate Time History	Yes		
Identifier			
Suppressed	No		
Orientation			X Axis
Coordinate System			Global Coordinate System
Results			
Minimum	343.3 °C	3.8367e-009 W/m^2	-9.5303e-007 W/m^2
Maximum	343.3 °C	1.3127e-006 W/m^2	9.5335e-007 W/m^2
Information			
Time	1. s		
Load Step	1		
Substep	1		
Iteration Number	1		
Integration Point Results			
Display Option		Averaged	
Average Across Bodies		No	

Model (A4, B4, C4) > Transient Thermal (C5) > Solution (C6) > Results

Object Name	*Temperature*	*Total Heat Flux*	*Directional Heat Flux*
State	Solved		
Scope			
Scoping Method	Geometry Selection		
Geometry	All Bodies		
Definition			
Type	Temperature	Total Heat Flux	Directional Heat Flux
By	Time		
Display Time	Last		
Calculate Time History	Yes		
Identifier			
Suppressed	No		
Orientation			X Axis
Coordinate System			Global Coordinate System
Results			
Minimum	100.49 °C	2340.4 W/m^2	-2.5453e+006 W/m^2
Maximum	343.3 °C	3.7538e+006 W/m^2	2.5453e+006 W/m^2
Minimum Value Over Time			
Minimum	-272.39 °C	2340.4 W/m^2	-1.5912e+007 W/m^2
Maximum	100.49 °C	20981 W/m^2	-2.5453e+006 W/m^2
Maximum Value Over Time			
Minimum	343.3 °C	3.7538e+006 W/m^2	2.5453e+006 W/m^2
Maximum	401.13 °C	2.8487e+007 W/m^2	1.5913e+007 W/m^2
Information			
Time	1. s		
Load Step	1		
Substep	13		
Iteration Number	13		
Integration Point Results			
Display Option		Averaged	
Average Across Bodies		No	

FUTURE SCOPE

Global Pressure Vessels Market 2020 by Manufacturers, Regions, Type, and Application, Forecast to 2025 is the most recent credible market research study that provides a deep analysis of the global market situation, providing several benefits and enhancing absorption adoption among several industrial users. A market overview, study objectives, product definition, and market concentration are all included in the report. Depending on the quantity of data and information presented, the report is beautifully characterised by the use of several charts, graphs, and tables. For the forecast period, the report includes critical data on market share, market size, and growth rate. It sheds light on global Pressure Vessels industry information, helping organisations to better understand the market and make critical business decisions.

CONCLUSIONS

These results can be followed as:

1) The internal design pressure, design temperature, and component dimension of a pressure vessel are all designed in compliance with ASME boiler and pressurevessel standards.

2) The examination of the blind flange,shell flange, eye boil, drain pipe, drain pipeflange, and junction region of the pressure vessel was carried out using FEA and ASME methods under the various loads.

3) The allowed stress of the material is lessthan the stress equivalent and stress classification lines of pressure vessel components.

4) The findings of the analysis for the usual operating condition were within acceptable limits. As a result, the present blind flange,shell flange, and eye bolt designs are strongenough to withstand the intended load circumstances.

5) The pressure vessels are designed to be safe. The level of safety that we consider acceptable and by which we judge the design to be safe. The bursting pressure is below the design's permissible stress, ensuring that it does not fail. And because the analysis is so near to the analyticaldesign, both the data and the design are regarded safe. In addition, no pressure vessel failures have occurred.

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