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Two-Phase Scrubber Design as Test Separator for Gas Wells

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Abstract. Natural gas production from the wellhead is a complex mixture of gas and liquids contained in the gas. The liquid that is also produced from natural gas production will be in the form of liquid droplets and needs to be separated from the gas. A two-phase scrubber is a two-phase separator used to recover liquids carried away from natural gas production. Gas from the wellhead will enter the scrubber with a certain pressure and temperature according to the operating pressure and operating temperature and is held in the scrubber for some time (retention time). Due to the high working pressure, the scrubber tank is included in the pressure vessel category, and therefore the design process must be carried out correctly and follow the latest ASME BPVC standard (American Society of Mechanical Engineers standard of Boiler and Pressure Vessel Code) documentation. The design carried out is to determine the design, material, and dimensions of the main components of the two-phase scrubber tank. The results of the design are technical drawings and welding recommendations, as well as the finishing process of the two-phase scrubber.

INTRODUCTION

Natural gas production from the wellhead is a complex mixture of gas and liquid contained in the gas. The liquid that is also produced from natural gas production will be in the form of liquid droplets and needs to be separated from gas. This separation process is important so that the gas produced is pure in composition and does not contain liquid in it. The device for physically separating the liquid content from the gas is called a separator.

A two-phase scrubber is a two-phase separator used to recover liquids carried away from natural gas production [1]. The amount of liquid contained in the scrubber is lower than in the separator. Vertical scrubbers are more often used because they require a smaller placement area than horizontal scrubbers. Gas from the wellhead which has liquid content in it will enter the scrubber with a particular pressure and temperature according to the wellhead's operating condition and is held in the scrubber for some time interval, which is known as the retention time. Retention time is needed to ensure that the gas and liquid in the scrubber will be completely separated. The existence of high pressure, temperature, and retention time of the gas entering the scrubber causes the scrubber to be included in the pressure vessel category, so the design process and determination of dimensions must be carried out correctly and follow the ASME BPVC standard (American Society of Mechanical Engineers standard of Boiler and Pressure Vessel Code) in order to avoid equipment failure and reduce the production capacity of the facility.

The two-phase scrubber can also be used as a test separator. The separator test is used to study the characteristics of the fluid when the fluid flows from the reservoir to the surface conditions in testing the performance of a well (well surveillance). The separator test takes a small part of the production separator and there is a measuring instrument to determine the gas and liquid production rate from the well.

A new gas receiving station to deliver gas from the Temelat wellhead to Gunung Kembang Station in the South Sumatra Block will be built due to the increase in gas production capacity from the well. This gas flow requires several equipment, one of which is a test separator in the form of a two-phase scrubber. In this study, a two-phase scrubber tank used as a test separator was designed to meet the design conditions to ensure that gas and liquid can be separated completely. The design process of the scrubber needs to follow the ASME BPVC Section VIII Div standard. 1 latest

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year's issue because ASME is a code that is binding and has legal force, so its use must follow the latest code issued, namely ASME BPVC 2017 Section VIII Div. 1. [2]

The design input parameters are shown in Table 1 which includes the installation location and design conditions that have been determined in advance by the process engineer team.

TABLE 1. Design condition of two-phase scrubber

Location: at Temelat wellhead on the South Sumatra Block	
Operating condition	
Temperature	: 100°F
Pressure	: 260 psig
Design condition	
Temperature	: 200°F
Internal pressure (P)	: 890 psig
Design flow rate	
Gas (Q_{gas})	: 6 MMscfd
Liquid (Q_{liquid})	: 200 BLPD
Corrosion allowance (CA)	: 0.125 in
Vessel Dimension	
Internal diameter (ID)	: 42 in
Height ($h_{(shell\ (S/S))}$)	: 7.5 ft
Retention time (RT)	: 3 minutes

RESEARCH METHODS

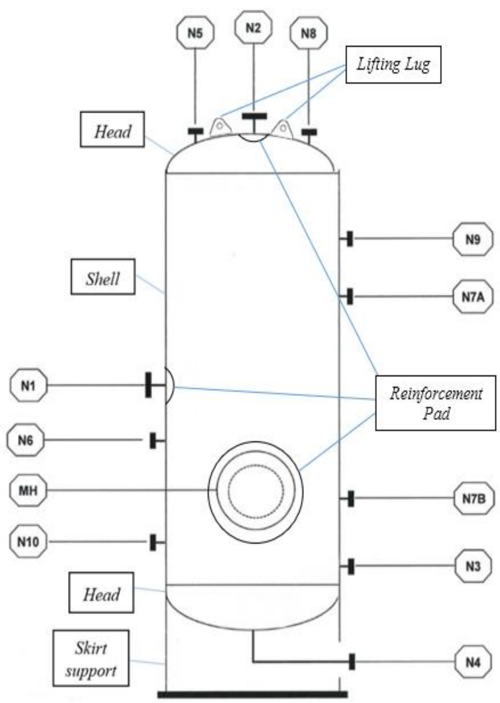


FIGURE 1. Design Concept of Two-Phase Scrubber

TABLE 2. Openings list

Connecting Schedule					
Nozzle	**Size NPS**	**No.**	**Service**	**Rating**	**Facing**
N1	12”	1	Gas Inlet	600	RFWN
N2	12”	1	Gas Outlet	600	RFWN
N3	2”	1	Condensate Outlet	600	RFWN
N4	2”	1	Drain	600	RFWN
N5	2”	1	PSV	600	RFWN
N6	2”	1	TI & TW	600	RFWN
N7A/B	2”	1	Bridle for LG& LC/LT	600	RFWN
N8	2”	1	Spare c/w valve ½”	600	RFWN
N9	2”	1	PI c/w ¾”	600	RFWN
N10	2”	1	Spare c/w ballvalve 2”-600# and blind flange 2”-600#	600	RFWN
MH	2”	1	Manhole	600	RFWN

Figure 1 shows the parts of a two-phase scrubber. The main components of the tank body consisting of heads and a shell, fluid channels and manholes are shown in the openings list on Table 2, then complementary components such as lifting lugs, reinforcement pads, and skirt support. Meanwhile, internal parts such as mist eliminator/separator or mesh pad were not included in this study according to user requests. The research was carried out initially by designing the basic shape two-phase scrubber, then determining the material used and calculating the dimensions of these components: shell, head, openings (nozzles & manhole), flanges (for openings), reinforcement pads, skirt support, and lifting lug. The list of standards used in the selection of materials and the calculation of the dimensions for each component is shown in Table 3.

After getting the calculated dimensions, the next step was to create a complete 3D drawing of the two-phase scrubber with the components installed. This 3D drawing was then used to perform a structural analysis simulation using a software to ensure that the calculated scrubber design is able to accept the load or internal pressure at the design conditions, and then make design modifications if necessary.

TABLE 3. List of standards used in the selection of materials and the dimension calculation

Component	Material Selection Standard	Calculation Standard	Formula
Shell	ASME BPVC 2017 Section IID [3]	ASME BPVC 2017 Section VIII Div. 1 Part UG-27	Longitudinal joints $t = \frac{PR}{SE - 0.6P} + CA$ Circumferential joints $t = \frac{PR}{2SE - 0.4P} + CA$
Head	ASME BPVC 2017 Section IID [3]	ASME BPVC 2017 Section VIII Div. 1 Part UG-32	Hemispherical head $t = \frac{PL}{2SE - 0.2P}$ 2:1 Ellipsoidal head $t = \frac{PD}{2SE - 0.2P}$ Conical Head $t = \frac{PD}{2cos\alpha(SE - 0.6P)}$
Opening's wall	ASME B31.3-2016 [4]	ASME BPVC 2017 Section VIII Div. 1 Part UG-45 ASME B36.10M-2018 [5]	$t_b = min[t_{b3}, max\ (t_{b1}, t_{b2})]$ $t = max[t_a - t_b]$ $t_a = \frac{PR}{SE - 0.6P} + CA$ $t_{b1} = t_{shell} + CA$ $t_{b2} = \frac{1}{16} + CA$ $t_{b3} = table\ UG - 45$
Flange and Bolt	ASME B16.5-2017	ASME B16.5-2017 [6]	ASME B16.5-2017 [6]
Reinforcement Pad	ASME BPVC 2017 Section IID [3]	ASME BPVC 2017 Section VIII Div.1 Part UG-37	Figure UG-37.1
Skirt Support	ASME BPVC 2017 Section VIII Div.1 Part UG-4 ASME BPVC 2017 Section 2017 Section IID [3]	Pressure Vessel Handbook 12th Edition [7]	Wind load [8] $t = \frac{12M_T}{R^2\pi SE} + \frac{m_{operation}}{D\pi SE} + CA$ $M = F_W h_1$ $M_T = M - h_T(F_W - 0.5P_W D_e h_T)$ Seismic load [9] $t = \frac{12M_X}{R^2\pi SE} + CA$ $M_X = F_T X + (V - F_T)\left(X - \frac{H}{3}\right)$
Lifting lug	Pressure Vessel Handbook 12th Edition [7]	Pressure Vessel Handbook 12th Edition [7]	Table 3

RESULTS AND DISCUSSIONS

The pressure vessel material used is determined by referring to the ASME BPVC Standard 2017 Section VIII Div. 1. The determination of this material must also consider the nature and composition of the working fluid flowing in the two-phase scrubber. The composition of the working fluid must be ensured that it does not change the properties of the material to be used in the two-phase scrubber. The material used must also be able to withstand the design pressure of the working fluid on the two-phase scrubber. In addition, the selected material must also ensure its ease of availability in the Indonesian market.

Table 4 shows the material property data that have been selected according to the standard. Meanwhile, the dimension data is calculated according to the standard calculation method for each component, and the results are presented in Table 5 for shell and head components, Table 6 for openings, Table 7 for reinforcement pads, and Table 8 for flanges.

TABLE 4. Properties of selected material for each component

Component	Material	Mechanical Properties
Shell, Head, Reinforcement Pad, Lifting Lug	SA 516 Grade 70	Tensile strength :70000 psi Yield strength : 38000 psi Max allowable stress at 200°F :20000 psi
Pipe Openings wall	SA 106 Grade B	Tensile strength :60000 psi Yield strength : 35000 psi Max allowable stress at 200°F :20000 psi
Skirt Support	SA 36	Tensile strength :58000 psi Yield strength : 36000 psi Max allowable stress at 100°F :16600 psi
Flange	SA 105	Rating 600 with working pressure 1480 psi at temperature -20 to 100°F
Bolt	SA 193 Grade B7	High strength bolting

TABLE 5. Calculated dimension for Shell and Head

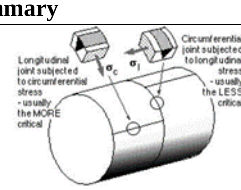
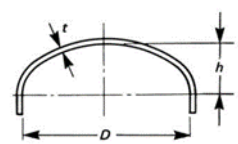
<table>
<tr><th>Component</th><th>Calculated dimension</th><th>Summary</th></tr>
<tr><td>Shell</td><td>Longitudinal joint
$t = 1.085\ in$
Circumferential joint
$t = 0.586\ in$</td><td>1⅛ in (28mm) thick plate

</td></tr>
<tr><td>Head</td><td>Hemispherical head
$t = 0.667\ in$
2:1 Ellipsoidal head
$t = 1.064\ in$
Conical head
$t = 1.234\ in$</td><td>2:1 Ellipsoidal head with 1⅛ in (28 mm) plate thickness

</td></tr>
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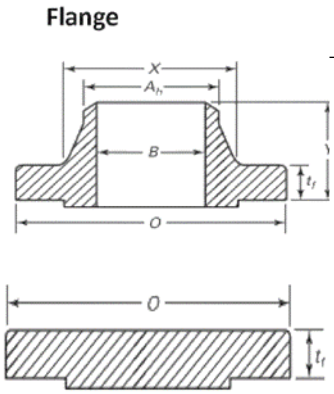
TABLE 6. Calculated dimension for openings

Component	Calculated dimension		Summary
N1 & N2 NPS 12" Diameter	$t_a = 0.399\ in$ $t_{b1} = 1.085\ in$ $t_{b2} = 0.188\ in$	$t_{b3} = 0.453\ in$ $t_b = 0.453 in$ $t = 0.453\ in$	Schedule 80 pipe with a thickness of 0.688 in, outside diameter 12.75in
N2 s/d N10 NPS 2" Diameter	$t_a = 0.171\ in$ $t_{b1} = 1.085\ in$ $t_{b2} = 0.188\ in$	$t_{b3} = 0.26\ in$ $t_b = 0.26 in$ $t = 0.26\ in$	Schedule 160 pipe with a thickness of 0.344 in, outside diameter 2.375in
MH NPS 24" Diameter	$t_a = 0.674\ in$ $t_{b1} = 1.085\ in$ $t_{b2} = 0.188\ in$	$t_{b3} = 0.453\ in$ $t_b = 0.453 in$ $t = 0.674\ in$	Schedule 40 pipe with a thickness of 0.688 -> SA 516 Grade 70 plate with a thickness of 1 1/8 in or 28mm, outside diameter 24 in.

TABLE 7. Calculated dimension for reinforcement pads

Component	Calculated dimension	Summary
N1 & N2 NPS 12" Diameter Shell	$D_p = 23.6\ in$	Plate with a thickness of 0.875 in (22.225mm) with an outside diameter of 23.59 in
N2 s/d N10 NPS 2" Diameter Head	$D_p = 20.6\ in$	Plate with a thickness of 0.875 in (22.225mm) with an outside diameter of 20.555 in
MH NPS 24" Diameter Shell	$D_p = 45.33\ in$	Plate with a thickness of 0.875 in (22.225mm) with an outside diameter of 45.331 in

TABLE 8. Calculated dimension for flanges



Nozzle	Diameter NPS	Flange			Dimension					
		Rating	Type	Facing	A_h	X	B	Y	t_f	0
N1	12"	600#	WN	RF	12.75	15.75	11.37	6.12	2.62	22
N2										
N3										
N4										
N5										
N6	2"	600#	WN	RF						
N7 A/B					2.38	3.31	1.687	2.88	1	6.5
N8										
N9										
N10	2"	600#	WN	RF						
			BLIND			-				
MH	24"	600#	WN	RF	24	28.25	21.75	8	4	37
			BLIND			-				

The two-phase scrubber that has been designed is then analyzed using structural numerical simulation software. The simulation is carried out using internal pressure data of 890 psi which is the design pressure of the two-phase scrubber. The results of this stress simulation are shown in Fig. 2 which is a von Mises stress analysis. A material is said to start yielding when the von Mises stress reaches its yield strength [10]. The simulation results show that the maximum stress experienced by the material is almost 54000 psi. This value is well above the yield strength of the material which is 38000 psi and is dangerous if left unchecked because the material subjected to stress exceeding the yield strength can be plastically deformed and cannot return to its original shape.

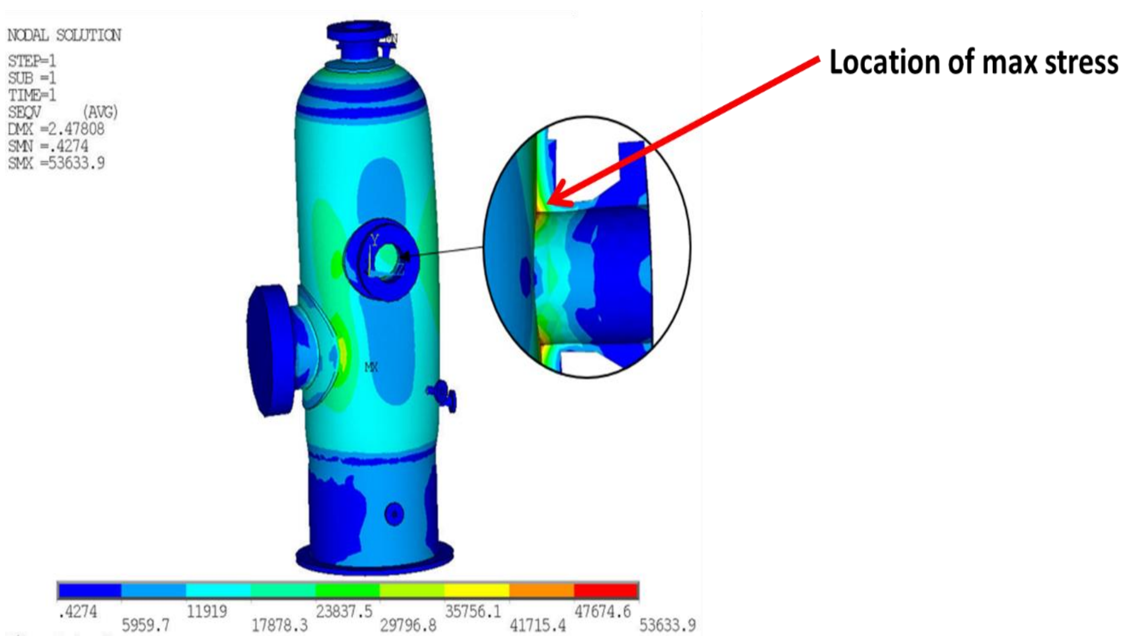


FIGURE 2. Von Mises stress analysis on two-phase scrubber using structural simulation (before modification)

Observations made on the simulation results show that the maximum stress occurs at the boundary between the shell and the nozzle pipe of the two-phase scrubber. This boundary contains a sharp edge of 90 degrees which is a sudden reduction of the cross-sectional area. From the results of this analysis, modifications were made to the 3D image of the two-phase scrubber by adding a fillet or radius on this risky edge.

Simulation on the modified two-phase scrubber was also carried out at an internal pressure of 890 psi. The results of the von Mises stress analysis of the two-phase scrubber are shown in figure 3. Here we can see that the maximum stress experienced by the two-phase scrubber is almost 36200 psi at the same location as before. This value is still within the safe limit of the yield strength of the material, which is 38000 psi, so it can be concluded that applying a fillet or radius at the boundary between the shell and the nozzle pipe is an acceptable solution.

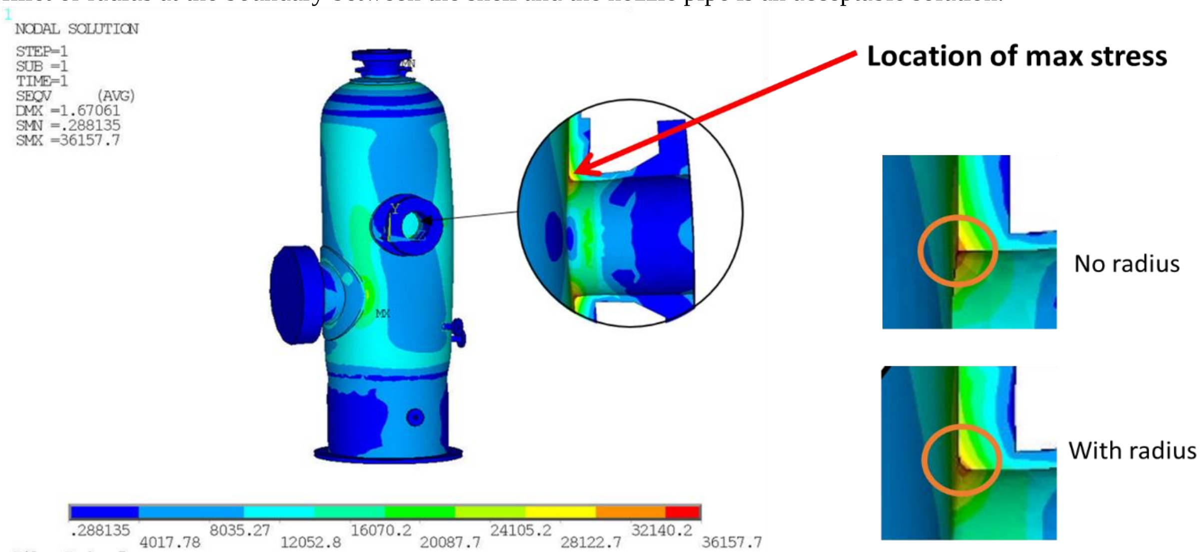


FIGURE 3. Von Mises stress analysis on two-phase scrubber using structural simulation (after adding radius on the critical edge)

CONCLUSION

A Two-phase scrubber has been designed to meet the design conditions and complies with ASME BPVC 2017 Section VIII Div. 1 standards. The output of this research is the design, material, and dimensions of the components of the two-phase scrubber.

The simulation results on the original two-phase scrubber design show that the value of von Mises stress in some places exceeds the yield strength of the material. Modifications made by eliminating sharp corners at the shell connection with the nozzle pipe have successfully minimized the stress at this critical location, so that the maximum stress is still within the safe limit of the material. The use of structural numerical simulation software allows the implementation of engineering analysis on a 3D virtual structure against applied loads. Thus, design improvements can be made so that the chances of problems arising can be minimized before the product is made.

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