PETROGAS JAHAN
ENGINEERING CO.

SW² at a Glance: ★ Freeware

Sizing Wizard SoftWare v2.0

SEPARATOR DESIGN

TWO PHASE
&
THREE PHASE

A computer approach based on
Wayne D.Monnery and William Y.Svrcek's articles

By:

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Overview:

SW^2 provides simple macro-based Excel files which can size Two and Three Phase separators.

These files have been developed based on the well-known articles of **W.D.Monnery** and **W.Y.Svrcek's**.

There are 2 methods to get outputs from these files:

- Shortcut
- Detailed

The advantages of each method will be explained later.

Below abbreviations have been considered for mentioned files:

- **2pH:** Sizing of 2 phase HORIZONTAL separators. (vapor/liquid)
- **2pV:** Sizing of 2 phase VERTICAL separators. (vapor/liquid)
- **3pHw:** Sizing of 3 phase HORIZONTAL separators with Weir. (vapor/liquid/liquid)
- **3pHb:** Sizing of 3 phase HORIZONTAL separators with Boot. (vapor/liquid/liquid)
- **3pV:** Sizing of 3 phase VERTICAL separators. (vapor/liquid/liquid)

➤ Shortcut Mode:

This method calculates vessel size based on minimum requirements. So it assumes some assumption to find the optimum result.

User should only enter process parameters (holdup and surge times, vapor/liquid rates, operating pressure, viscosities and densities of fluids and also the particle sizes in 3-phase cases) to evaluate the drum size.

Program will set some default values to obtain minimum vessel weight. Therefore, the Dimensions (Diameter, Length and level heights) are exact, but the total weight and nozzles size are estimated.

These are some of the default values where are fixed in this method:

. Max. Allowable Tensile Stress for the Alloy = 17500 psi (1207 Bar)
. Joint Efficiency = 0.85
. Corrosion Allowance = $1/16$ inch (1.6 mm)
. Alloy Density = 490 lb/ft³ (7850 kg/m³)

Total weight will be calculated as below:

$$W_T = 1.1 \times \text{Alloy thickness} \times \text{Surface Area} \times \text{Alloy density}$$

Where Alloy thickness = Max (Head thickness, Shell thickness)
***10%** overhead is considered as the weight of nozzles, joints and other accessories.*

User shall fill all ***red bordered*** cells. But during fill-up, some cells will be recolored to ***green***, ***gray*** or ***pale-red***, because these are depended on some other cells and by entering that parameters, these cells will be deactivated.

After filling the essential red-bordered cells, the first estimation of vessel sizing will be shown, but it isn't an optimum case and maybe some design constraints have not been satisfied. So by pressing *Optimize* button, the best result will be recalculated by program.

One of the design constraints is L/D that sets to be between 1.5~6[1]. Users are able to change this range.

Nozzle sizing are based on minimum fluid velocity.

Note: In horizontal separators, final dimension is optimum for selected default values such as corrosion allowance. By changing default values, the solution will converge to a different dimension as an optimum case. (Some inputs such as corrosion allowance, joint efficiency and design pressure effect on the shell and head thickness and therefore on the final vessel weight.)

[1] L/D is based on operating pressure. For details refer to Table.5 of reference 1 (Table 7 of reference 2).

Detailed Mode:

This method is similar to shortcut, but users have more options to customize their design such as selecting the alloy type, changing the corrosion allowance, updating design pressure and temperature, introducing slug volume and customizing holdup volume and exact nozzle sizing by selecting standards flanges, introduce nozzle sizing criteria, etc.

So by these options, we will have some more exact data for the vessel weight.

In addition, in this mode, user can press *Show Detailed Calculation Steps* to view internal calculations.

Notes:

- For more information, view **Help** sheet of each file.
- A *Reset* button considered to undo Optimized case to the first estimated data.
- There is a *Reset All* button, which undo all calculations and clear input fields to original blank one. **It's important to be informed that this action is not undo-able**.

Limits and Inabilities:

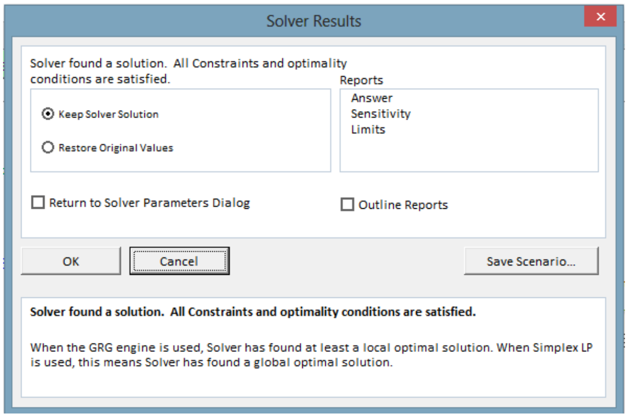
1. The horizontal vessels cannot calculate pure single phase feeds. (Typically more than 99.99% vapor quality). So in these cases, assume a bit liquid volume instead of ZERO to avoid uncertain "divided by zero" in the program.
2. These files could evaluate K factor[1] for a wide pressure range as 0~5500 Pisa (379 Bara). Also for high pressure conditions, the vapor viscosity and particle size will be asked to evaluate theoretical **K**.

   After v2.0 a *Kalculator* button has been considered to evaluate theoretical K based on physical properties of vapor and liquid. K will be calculated according to Table 1 of Ref.1

[1] Calculation of K is based on two methods: GPSA and York Demister.

(Table 2 of Ref.2) and dose not included process modification factors where mentioned in that tables.

3. In this version, we have not considered "Round It" button. So the output dimensions are exact and user should round it manually as we have shown in the **finalization** section of the **Sample Case**.
4. Optimization procedure is provided by **SOLVER**[1]. So final result is depending on solvers algorithm. Read its conversation dialog box after optimization:



- ❖ According to Ref.2 Examples, we added a modification factor (α) for vapor disengagement area height (**H_V**) in horizontal drums with high vapor load. I could not found any reference for this factor, so I have considered it as below (in my own judge):

$$Hv=Max\ \{\alpha D,\ 2\ (1)\} \quad ;ft \quad \text{where} \begin{cases} \alpha = 0.2 & ;q \le 0.353 \\ \alpha = 0.85\,q & ;q > 0.353 \end{cases}$$

q is feed quality (mass fraction of vapor in the feed)

- ❖ In v2.0 we provided a built-in macro to install Solver add-in automatically by opening of *Sω² Launcher.xlsm*. If it won't work properly, please refer to **Startup** sheet in each Excel file and follow instruction to install it manually.
- ❖ A movie has been provided that shows you running of a sample case step by step. [Click here] to watch it.

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[1] **Frontline Systems Inc.**

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We are looking forward to your advice: **Email:** Sizing.Wizard@gmail.com

Discussion & Comments:

Website: https://sites.google.com/site/sizingwizards/Version-2-0

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Revision History:

Version	Updated Items	Note	Release Date
1.0	First Release.	All files	R20140513
1.1	Modify initial guess of vessel diameter for high load vapors.(To run solver in the right way)	2pH,2pHs	R20150520
2.0	- Modify L/D optimization range based on Operating Pressure. - Velocity criteria effects modified in Inlet Nozzle Sizing. - Nozzle sizing tips and visualization modified. - Modify Surge/Holdup calculation - Adding User input option for K factor. - Modify Boot weight calculation on 3pHb & 3pHb_s	All files	R20160605

References:

1. Wayne D. Monnery and William Y. Svrcek. "**Design Two-Phase Separators Within The Right Limits**"; University of Calgary; October 1993. Chemical Engineering Progress (CEP).

2. Wayne D. Monnery and William Y. Svrcek. "**Successfully Specify Three-Phase Separators**"; University of Calgary; September 1994. Chemical Engineering Progress(CEP).

3. Eugene F. Megyesy. "**Pressure Vessel Handbook**", 10th Edition, University of Tulsa, 1997.

4. Stanley M. Walas, "**Chemical Process Equipment Selection and Design**", University of Kansas, 1990.

5. "**Process Engineering Design Manual**", TOTAL, 1985.

Note: There are some typos in the referenced articles. We have provided a marked / corrected files. You can download them from the website.

A Sample Case:

A mixture of petroleum feed flows at **146.2 Pisa** and **63 °C** and should pre-separate for further treating.

So we desired to use a drum to reach this propose. The downstream operation condition does not let us to have more liquid droplets in vapor phase.

Feed properties are as the below table. **10%** oversize in nozzles shall be considered. All fluids are non-corrosive.

The products will be fed to another drum with pump.

Assume a **SA-515_60** alloy for the material with examined joints.

	Flow Rate (kg/hr)	*Density (kg/m³)*	*Viscosity (cp)*
Vapor phase	7,000	10.3	-
Light Liquid (HC)	37,650	400.0	0.7
Heavy Liquid (Water)	4,510	1,020.0	0.5

Particle sizes:

Heavy liquid in the light liquid = 89 micron.

Light liquid in the heavy liquid = 127 micron.

Fluids properties input page:

Specify Input Units and Required Values:

	Quantity	Symbol	Unit	Value
	Pressure	P	Psia	146.2
Vapor Properties	Vapor Density	ρ_V	Kg/m3	10.3
	Vapor Mass Flow Rate	W_v	kg/hr	7,000
Light Liquid Properties (Usually Hydrocarbon)	Light Liquid Density	ρ_L	Kg/m3	400.0
	Light Liquid Viscosity	μ_L	cP	0.7
	Light liquid Flow Rate	W_{LL}	kg/hr	37,650
Heavy Liquid Properties (Usually Water)	Heavy Liquid Density	ρ_H	Kg/m3	1020.0
	Heavy Liquid Viscosity	μ_H	cP	0.5
	Heavy liquid Flow Rate	W_{HL}	kg/hr	4,510

kg/hr
kg/min
kg/s
lb/hr
lb/min
lb/s
ton/hr

Warnings & Errors:

It seems everything is OK; jump to calculation tab :)

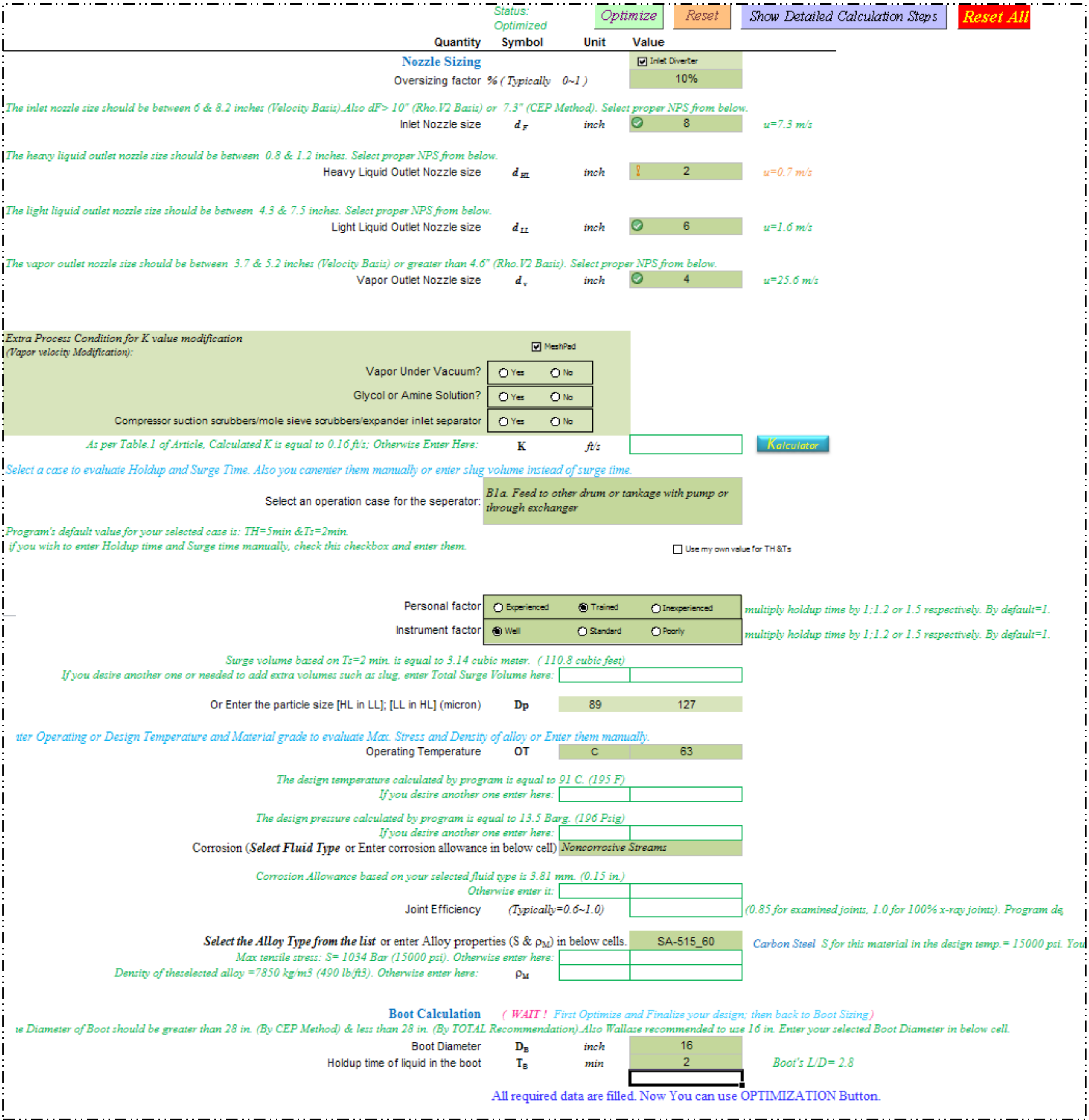
Press Here

It is recommended to use a 3-phase Horizontal drum with Boot; [because of W(Heavy Liquid)/W(Total liquid)<0.2]

Warning: *By clicking on* **"Reset ALL";** *All Input Data will be deleted permanently!*

Reset All

Additional Customization Options:



Output:

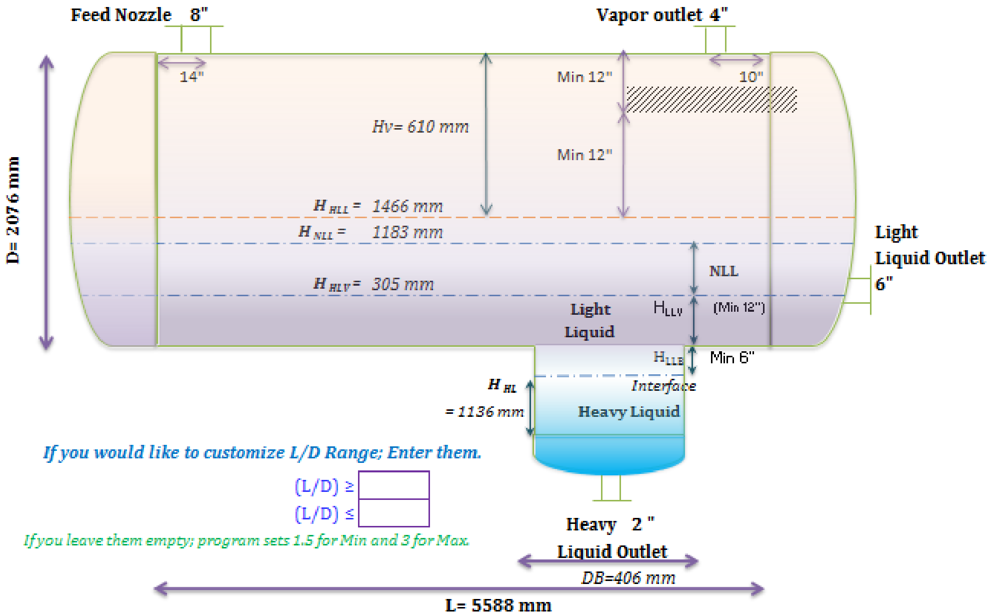
Sizing Summary			
Diameter of Drum	D	mm	2076
Vessel Tan-Tan Length	L	mm	5588
Shell Thickness	t_s	mm	19
Head thickness	t_H	mm	30
Weight of Vessel (without boot)	W_D	kg	7773
Weight of Boot (approx.)	W_B	kg	564
Total Weight of Vessel (approx.)	W	kg	8337
Nozzle Sizing:			
Inlet Nozzle size	d_F	inch	8
Heavy Liquid Outlet Nozzle size	d_{HL}	inch	2
Heavy Liquid Outlet Nozzle size	d_{LL}	inch	6
Vapor Outlet Nozzle size	d_v	inch	4
Nozzle Oversizing Factor			10%
Boot:			
Diameter of Boot	D_B	mm	406
Height heavy liquid in the Boot	H_{HL}	mm	1136
Boot Holdup Time	T_B	min	2.00
Holdup Time	T_H	min	6.0
Surge Time	T_S	min	2.0
MeshPad	Yes		
Head Type	2:1 Eliptical		
Material/Alloy grade and type:	SA-515_60; Carbon Steel		
Max. Operating Pressure	MOP	Barg	10.66
Design Pressure	DP	Barg	12.36
Design Temperature	DT	°C	90.78
Corrosion Allowance	C	mm	3.81
Joint Efficiency	E	0.85	(Examined Joints)

L/D= 2.7
Hv/D =0.29
Feed quality= 0.14

Before Optimization (Based on Initial guess)

Diameter of Drum	D	mm	2502
Vessel Tan-Tan Length	L	mm	3506
Shell Thickness	t_s	mm	22
Head thickness	t_H	mm	35
Weight of Vessel (without boot)	W_D	kg	8409
Weight of Boot (approx.)	W_B	kg	665
Total Weight of Vessel (approx.)	W	kg	9075

L/D= 1.4
Hv/D =0.24
Feed quality= 0.14
L/D is not OK



If you would like to customize L/D Range; Enter them.

(L/D) ≥
(L/D) ≤

If you leave them empty; program sets 1.5 for Min and 3 for Max.

User Input Option:
D= mm
Initial guess for D=2502 mm

User Input Option:
Hv/D= (0~1)
Before Enteing D & Hv/D; First Press RESET
First enter Diameter and then fill Hv/D.

Notice:
After Using solver; Should Reset to recalculation all values!

Detailed Steps. Pg. 1 of 2.

Status: Optimized — Optimize | Reset | Show Detailed Calculation Steps | Reset All

Quantity	Symbol	Unit	Value	
Pressure	P	psig	131.7	
Vapor Density	ρ_V	lb/ft^3	0.64	
Vapor Mass Flow Rate	W_v	lb/hr	15432	
Light Liquid Density	ρ_L	lb/ft^3	25.0	
Light Liquid Viscosity	μ_L	cP	0.70	
Light liquid Flow Rate	W_{LL}	lb/hr	83004	
Heavy Liquid Density	ρ_H	lb/ft^3	63.7	
Heavy Liquid Viscosity	μ_H	cP	0.50	
Heavy liquid Flow Rate	W_{HL}	lb/hr	9943	
Vapor Volumetric Flow Rate	Q_v	ft3/s	6.67	
Light Liquid Volumetric Flow Rate	Q_{LL}	ft3/min	55.40	
Heavy Liquid Volumetric Flow Rate	Q_{HL}	ft3/min	2.60	
Nozzle Sizing			☑ Inlet Diverter	
Oversizing factor	% (Typically 0~1)		10%	

The inlet nozzle size should be between 6 & 8.2 inches (Velocity Basis).Also dF> 10" (Rho.V2 Basis) or 7.3" (CEP Method). Select proper NPS from below.

Inlet Nozzle size	d_F	inch	8	u=7.3 m/s

The heavy liquid outlet nozzle size should be between 0.8 & 1.2 inches. Select proper NPS from below.

Heavy Liquid Outlet Nozzle size	d_{HL}	inch	2	u=0.7 m/s

The light liquid outlet nozzle size should be between 4.3 & 7.5 inches. Select proper NPS from below.

Light Liquid Outlet Nozzle size	d_{LL}	inch	6	u=1.6 m/s

The vapor outlet nozzle size should be between 3.7 & 5.2 inches (Velocity Basis) or greater than 4.6" (Rho.V2 Basis). Select proper NPS from below.

Vapor Outlet Nozzle size	d_v	inch	4	u=25.6 m/s
Mean Liq Density	ρ_L	lb/ft^3	29.1	
Min Flow	Q_M	ft^3/s	7.63	
Lambda Factor	λ	-	0.1266	
Mean density	ρ_M	lb/ft^3	4.25	
Min_Inlet Nozzle Size	d_N	ft	0.606	
K_York Demister	K	ft/s	0.3153	
K_GPSA	K	ft/s	0.3468	
Min-K	K	ft/s	0.3153	
		X=	#DIV/0!	
		Y=	#DIV/0!	
		CD=	#DIV/0!	
		K=	#DIV/0!	
K_Min	K	ft/s	0.3153	

Extra Process Condition for K value modification (Vapor velocity Modification): ☑ MeshPad

Vapor Under Vacuum?	○ Yes	○ No
Glycol or Amine Solution?	○ Yes	○ No
Compressor suction scrubbers/mole sieve scrubbers/expander inlet separator	○ Yes	○ No

As per Table.1 of Article, Calculated K is equal to 0.16 ft/s; Otherwise Enter Here:	K	ft/s		Kalculator
Final K Value	K	ft/s	0.158	
Vertical Terminal Vapor Velocity	U_T	ft/s	0.97	
Vapor Velocity	U_v	ft/s	0.73	

Select a case to evaluate Holdup and Surge Time. Also you canenter them manually or enter slug volume instead of surge time.

Select an operation case for the seperator: *B1a. Feed to other drum or tankage with pump or through exchanger*

Program's default value for your selected case is: TH=5min &Ts=2min.
if you wish to enter Holdup time and Surge time manually, check this checkbox and enter them. ☐ Use my own value for TH &Ts

Personal factor	○ Experienced	◉ Trained	○ Inexperienced	multiply holdup tim
Instrument factor	◉ Well	○ Standard	○ Poorly	multiply holdup tim

Holdup time_*Final*	T_H	min	6	
Surge Time_*Final*	T_S	min	2	
Holdup Volume	V_H	ft^3	332.4	
Surge Volume_final	V_S	ft^3	110.8	
Set L/D	L/D	-	1.7	The proper L/D for
Inner Diameter of vessel_*Initial guess*	D	ft	8.21	
Final D	D	ft	6.81	

Detailed Steps. Pg 2 of 2.

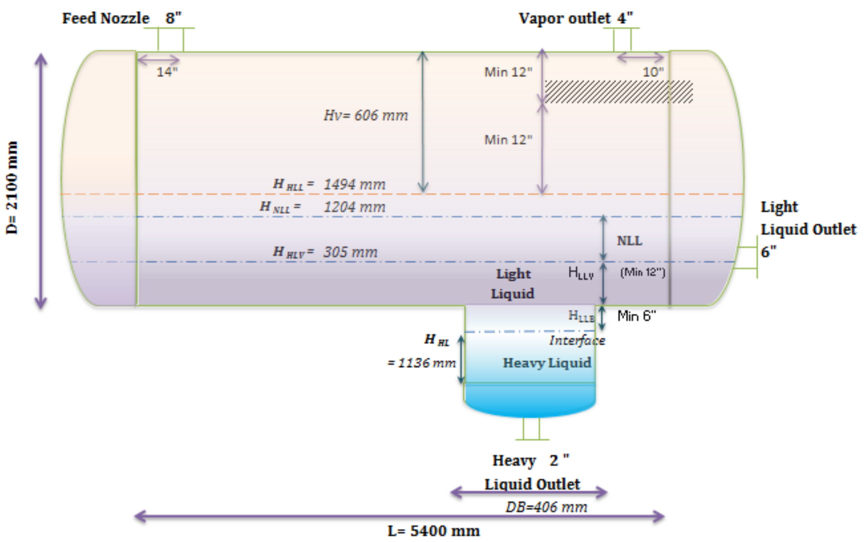
Quantity	Symbol	Unit	Value	
Total Cross-sectional Area	A_T	ft^2	36.42	
Factor of Vapor space	α	-	0.20	
Vapor Space Height	Hv	ft	2.00	
Hv/D	x	-	0.29	
Av/A_T	y	-	0.245	
Vapor Space cross-sectional	Av	ft^2	8.93	
Height of LLL in the Vessel	H_{LLV}	in	12.0	
H_{LLV}/D	x	-	0.147	
A_{LLV}/A_T	y	-	0.091	
cross-sectional area of the LLL in Light liquid @Vessel	A_{LLV}	ft^2	3.32	
Height of LL in the Boot	H_{LLB}	in	6.00	
Min Length to accommodate the liq. Holdup/Surge	L	ft	18.33	
Surge volume based on Ts=2 min. is equal to 3.14 cubic meter. (110.8 cubic feet)				
If you desire another one or needed to add extra volumes such as slug, enter Total Surge Volume here:				
Time weight base on holdup	tw		0.750	
Final holdup volume based on Vs	V_H	ft^3	332.4	
	$Vs+V_H$	ft^3	443.2	
surge volume based on Ts	V_s	ft^3	110.80	
Or Enter the particle size [HL in LL]; [LL in HL] (micron)	Dp	89	127	
Final Ks [HL in LL]; [LL in HL]	ks	0.163	0.333	
Settling velocity of heavy liquid out of the light liquid	U_{HL}	in./min	9	
Rising velocity of light liquid out of the heavy liquid	U_{LH}	in./min	10	
Time of Heavy liquid settling out of the light liquid	t_{HL}	min	7.1	
Residence Time of Light Liquid	θ_{LL}	min	9.1	
Modified Length (When $\theta_{LL}<T_{HL}$)	L_Mod	ft	14.22	
Tan. To Tan. Length	L	ft	18.33	
Liquid drop out time	ϕ	sec	2.75	
Actual Vapor Velocity	U_{VA}	ft/s	0.75	
Min Length required for vapor/liquid separation	L_{MIN}	ft	2.05	
Status			L>>Lmin	
Final L	L	ft	18.33	
	L/D		2.69	
Head Type			2:1 Eliptical	
Enter Operating or Design Temperature and Material grade to evaluate Max. Stress and Density of alloy or Enter them manually.				
Operating Temperature	OT	C	63	
Design Temperature	DT	°F	195	
The design temperature calculated by program is equal to 91 C (195 F)				
If you desire another one enter here:				
Design Temperature_Final	DT	°F	195	
Normal Operating Pressure	NOP	psig	132	
Maximum Operating Pressure	MOP	psig	157	
Design Pressure	DP	psig	182	
The design pressure calculated by program is equal to 12.5 Barg. (182 Psig)				
If you desire another one enter here:				
Design Pressure_Final	DP	psig	182	
Corrosion (***Select Fluid Type*** or Enter corrosion allowance in below cell)		*Noncorrosive Streams*		
Corrosion Allowance based on your selected fluid type is 3.81 mm. (0.15 in.)				
Otherwise enter it:				
Final Corrosion Allowance	tc	in	0.15	
Joint Efficiency	*(Typically=0.6~1.0)*			*(0.85 for examined j*
Select the Alloy Type from the list or enter Alloy properties (S & ρ_M) in below cells.			SA-515_60	*Carbon Steel S*
Max tensile stress: S= 1034 Bar (15000 psi). Otherwise enter here:				
Shell Thickness	t_s	in	0.737	
Head Thickness	t_H	in	1.182	
Final thickness_Max	t	in	1.182	
Shell Side Surface Area	A_s	ft^2	392	
Head Surface Area	A_H	ft^2	39.0	
Volume of needed materials	V_{steel}	ft^3	31.8	
Density of theselected alloy =7850 kg/m3 (490 lb/ft3). Otherwise enter here:	ρ_M			
Light Liquid:				
High Liquid Level	H_{HLL}	ft	4.8	
Low Liquid Level	H_{LLL}	in	12.0	
Normal Level Area	A_{NLL}	ft^2	21.5	
A_{NLL}/A_T	x	-	0.589	
H_{NLL}/D	y	-	0.570	
Normal Liquid Level	H_{NLL}	ft	3.88	
Boot Calculation	*(WAIT ! First Optimize and Finalize your design; then back to Bo*			
Effective light/heavy liq. separation Velocity	U_p	in./min	7.50	
D_{Boot}_Min	D_{B_Min}	ft	2.30	
D_{Boot}_Max	D_{B_Max}	ft	2.38	
The Diameter of Boot should be greater than 28 in. (By CEP Method) & less than 28 in. (By TOTAL Recommendation).Also Wallase recommended to use 16 in. Ent				
Boot Diameter	D_B	inch	16	
Holdup time of liquid in the boot	T_B	min	2	*Boot's L/D= 2.8*
Height heavy liquid in the Boot	H_{HL}	ft	3.73	

Finalization:

After optimization, you can round dimensions manually. (Automatically round mode is not considered yet.)
For this case, we first <u>set</u> **D** to **2100mm** and then tried to round **L** with changing the **H_v/D**.
In this step, consider the valid range for H_v/D. The result is as below:

Sizing Summary			
Diameter of Drum	**D**	*mm*	2100
Vessel Tan-Tan Length	**L**	*mm*	5400
Shell Thickness	t_s	*mm*	19
Head thickness	t_H	*mm*	30
Weight of Vessel (without boot)	W_D	*kg*	7759
Weight of Boot (approx.)	W_B	*kg*	570
Total Weight of Vessel (approx.)	**W**	*kg*	8329
Nozzle Sizing:			
Inlet Nozzle size	d_F	*inch*	8
Heavy Liquid Outlet Nozzle size	d_{HL}	*inch*	2
Heavy Liquid Outlet Nozzle size	d_{LL}	*inch*	6
Vapor Outlet Nozzle size	d_v	*inch*	4
Nozzle Oversizing Factor			10%
Boot:			
Diameter of Boot	D_B	*mm*	406
Height heavy liquid in the Boot	H_{HL}	*mm*	1136
Boot Holdup Time	T_B	*min*	2.00
Holdup Time	T_H	*min*	6.0
Surge Time	T_S	*min*	2.0
MeshPad	Yes		
Head Type	2:1 Elliptical		
Material/Alloy grade and type:	*SA-515_60; Carbon Steel*		
Max. Operating Pressure	**MOP**	*Barg*	10.66
Design Pressure	**DP**	*Barg*	12.36
Design Temperature	**DT**	*°C*	90.78
Corrosion Allowance	**C**	*mm*	3.81
Joint Efficiency	**E**	0.85	*(Examined Joints)*

L/D= 2.6
Hv/D =0.29
Feed quality= 0.14



User Input Option:		
D=	2100	*mm*

User Input Option:		
Hv/D=	0.2887	*(0~1)*

Notice:
After Using solver; Should Reset to recalculation all values!

Before Enteing D & Hv/D; First Press RESET
Hv/D should be 0.2 ~ 0.29. (minimum)