Education Institute for

Equipment & Process Design

Doc.PV-2005
Rev.1

Vertical Vessel

With Mesh Mist Eliminator

D-2005

Design and Principles

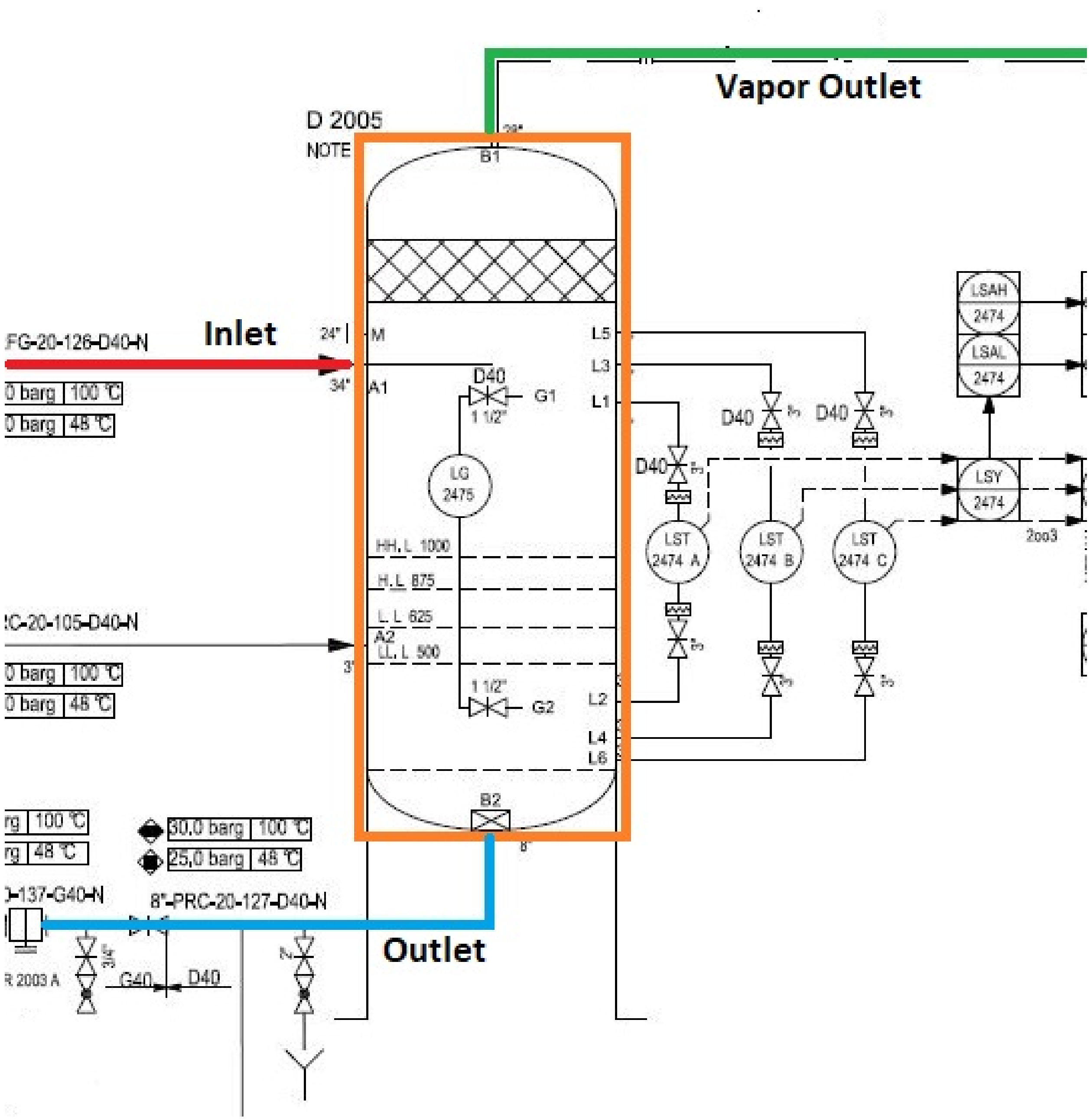
Content

Description

The objective of this vessel is to separate liquid particle from the gas. The vessel is located at the suction of a centrifugal compressor so that maximum droplet size contained in gas stream to compressor should be max 10 micron.

Operating Parameters

Operating temperature	48	°C	Operating pressure	24,0	bar g
Liquid Outlet					
Liquid flow	68415	kg/h	Liquid density	989	kg/m³
Vapor Outlet					
Gas flow	282206	kg/h	Gas density	10,7	kg/m³
Gas molecular weight	11,44	kg/kmol			


Vapor Outlet
D 2005
NOTE
Inlet
Outlet
B1
B2
M
A1
A2
L1
L2
L3
L4
L5
L6
G1
G2
LG
2475
HH.L 1000
H.L 875
L.L 625
LL.L 500
LSAH
2474
LSAL
2474
LSY
2474
2oo3
LST
2474 A
LST
2474 B
LST
2474 C
8"-PRC-20-127-D40-N
30,0 barg
100 ℃
25,0 barg
48 ℃

Design Procedure

1. Select proper Orientation

2. Select and Size proper Inlet Device, Inlet and Outlet ID

3.Calculate Vessel Diameter

4. Calculate Vessel Height

5.Select and Size Manholes, Vent, Drain, Vortex Breaker

6. Select a well-designed mist eliminator pad

1st Step: Select proper orientation

Since the application is gas dominant a vertical vessel is selected.

Due to its being at the suction of the compressor, a mesh mist eliminator should be installed

Equipment Type	Contaminant Removed	Micron Rating Achievable	Pressure Drop Clean & Wet	Relative Operating Cost
Separator with internals	Liquids	3-40	Low 0.7 kPa-10.3 kPa	Low to higher
Filter – Separator	Liquids & Solids	1 micron	13.8 kPa or less	Higher
Gas Coalescer	Liquids & Solids	0.3 micron	13.8 kPa	Highest
Dry Gas Filter	Solids	Various	13.8 kPa or less	Higher

Separator Type:	No Demisting Internals	Mesh Pad	Vert. Vane Pack	Horiz. Vane Pack	In-line Vane Pack	Axial Flow Multi-Cyclone	Horiz. Flood Mesh/ Vane	Vert. Flood Mesh/Vane	Flood Mesh/ Multi-Cyclone
Gas Handling									
Capacity	Low	Moderate	High	Very High	Very High	Very High	Very High	Very High	Very High
Turndown Capability	∞	4:1	3:1	3:1	3:1	2:1	4:1 or higher	4:1 or higher	4:1 or higher
Liquid Removal Efficiency									
Efficiency Overall	Low	Very High	Moderate	Low/Mod	Low/Mod	High	Moderate	High	High
Efficiency – Fine Mist	Very Low	Very High	Moderate	Moderate	Moderate	High-Very high	Very High	Very High	Very High
Liquid Handling Capacity									
Slugs	High	High	High	Very High	Very Low	High	High	High	High
Droplets	High	High	Moderate	Moderate	Low	High	High	High	High
Fouling Tolerance									
Particulate	Very High	Low	Moderate	Moderate	Moderate	Moderate	Low	Low	Low
Fouling Material	Very High	Very Low	Moderate	Moderate	Moderate	Moderate	Low	Low	Low
Pressure Drop	Very Low	Very Low	Low	Low	Low	High	Low	Low	High

2nd Step: Select and Size proper Inlet Device

Half Pipe has proven itself to be not only effective in large capacities but cost-effective as well and in many applications is preferred to Diffuser whose performance is superior but too costly.

Type of Device	None	Baffle	Elbow	Half Pipe	Diffuser	Cyclone
Momentum Reduction	Poor	Good	Good	Good	Good	Good
Bulk Separation	Good	Poor	Average	Average	Good	Good
Prevent Re-entrainment	Good	Average	Average	Average	Good	Average
Substantial Liquid in Gas	Poor	Ave/Poor	Average	Average	Good	Good
Prevent Liquid Shatter	Good	Poor	Poor	Average	Good	Good
Low Differential Pressure	Good	Good	Good	Good	Good	Average
Prevent Foam Creation	Poor	Poor	Poor	Poor	Average	Good
Gas Distribution	Poor	Average	Average	Poor	Good	Avg/ Poor
Prevent Liquid Surge Entrainment	Good	Good	Good	Poor	Good	Good
Orientation	H/V	H/V	H/T	H/V	H/V/T	H/T
Three Phase	Poor	Average	Average	No	Good	Good

It is also necessary to maintain the inlet velocity head, J, within proper limits for the selected inlet device to insure good gas distribution and minimum liquid shattering.

Where,

$$J = (\rho V^2)$$

The maximum mixed phase velocity head range used in the industry guidelines varies for the different inlet devices. Some typical maximums are:

•6000-9000 max. typ, up to 15 000 max kg/m s2 for diffuser distributor

•975-2250 max kg/m. s2 for no inlet distributor

•1500-3750 max kg/m. s2 for inlet half pipe or elbow distributor

•1500-3750 max kg/m. s2 for v-baffle or other simple inlet diverter designs

In addition, some users limit the inlet vapor phase velocity to 9 m/s or 18 m/s. The velocity should always be below the erosion velocity for the service.

In order to calculate head velocity, at first, we need to perform the followings:

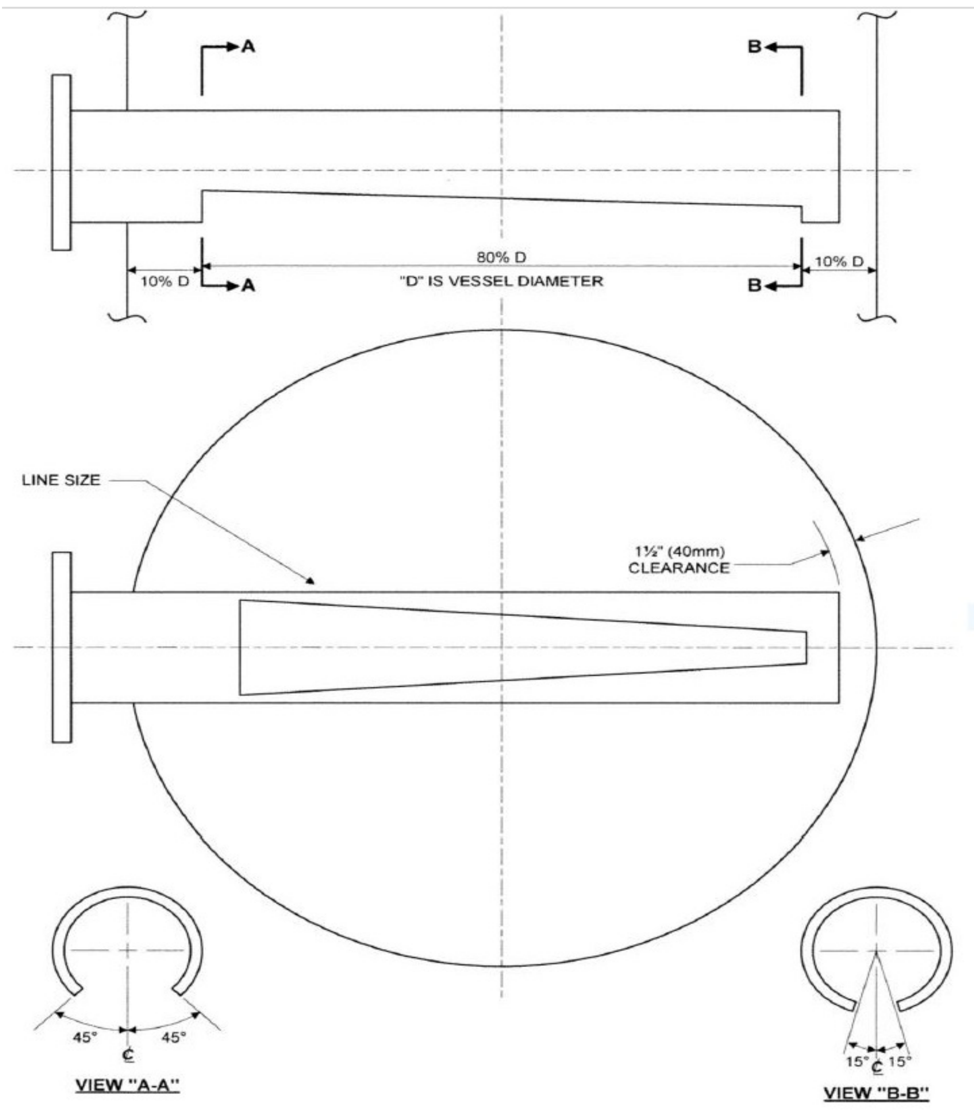
1. Estimation of inlet nozzle ID; Consider inlet pipe ID near the vessel as first and best estimation.

2. Calculate $\rho_{mixture}$ and subsequently $V_{mixture}$

3. Calculate J by multiplying $\rho_{mixture} \times (V_{mixture})^2$ and compare it with the last-page criterion.

Parameter	Value	Value	Unit
Estimated ID	**34**	**30**	**inch**
Nozzle Area	**0.58**	**0.45**	**m2**
$\rho_{mixture}$	**13.25**	**13.25**	**kg/m3**
$V_{mixture}$	**12.5**	**16.1**	**m/s**
J	**2085**	**3439**	**kg/m. s2**
Criterion	**3750**	**3750**	**kg/m. s2**

So, both 30 and 34 inches are accepted but it is recommended that inlet piping diameter match the velocity requirement of the inlet to the separator 10 pipe diameters upstream of the separator to provide a flow regime which is fully developed before entering the separator. Thus, 34 inch is accepted.



Vapor Outlet Section

The sizing of the vapor outlet nozzle should be such that given the above placement of the mesh pad, the velocity is not high enough to cause channeling of the gas through the mesh pad. The nozzle outlet size is typically based on the lesser of that required for piping pressure drop, or a maximum velocity head criterion. Typical ranges for the maximum velocity head allowed for the vapor outlet are 4500–5400 kg/m • s2. In addition, some users limit the absolute velocity to 18 m/s. The pipe size can be decreased to the appropriate size based on pressure drop considerations, 5-10 pipe diameters downstream of the separator, as required.

Parameter	Value	Unit
Estimated ID	28	inch
Area	0.39	m2
Vg	18.44	m/s
ρVg2	3639	Kg/m. s2
Criterion	4500	Kg/m. s2

Liquid Outlet Nozzle

Many users limit the liquid outlet nozzle velocity based on pump suction line criteria

Liquid line type	ΔP (bar/km)		Max. Velocity. (m/s) (2)			
	Norm.	Max.	To 2"	3" to 6"	8" to 18"	from 20"
Pump suction						
- Liquid at bubble point with dissolved gas	0.6	0.9	0.6	0.9	1.2	1.5
- Non boiling liquid	2.3	3.5	0.9	1.2	1.5	1.8
Unit lines						
- Liquid at bubble point with dissolved gas	0.6	1.0	0.6	1.0	1.4	1.8
- Non boiling liquid	2.3	3.5	0.9	1.2	1.8	2.4

Parameter	Value	Value	Unit
Estimated ID	6	8	inch
Area	0.018	0.032	m2
Vl	1.05	0.59	m/s
Criterion	Max 1.5	Max 1.5	m/s

3rd Step: Calculate Vessel Diameter

Each and every licensor and company has developed a design basis procedure for sizing vessels. In this article, a GPSA-based method, Foster-Wheeler-based method and the Licensor method will be explored.

GPSA

1. Use the following equation and next-page K-values to calculate terminal velocity

$$U_T = K\sqrt{\frac{(\rho_L - \rho_V)}{\rho_V}}$$

where

$$\text{where } K = \sqrt{\frac{4gD_p}{3\,C_D}}$$

De-rating factor to K-value for pressure

Pressure, kPa (ga)	De-rating For Mesh Demisters At Elevated Pressure
Atmospheric	1.00
1034	0.90
2068	0.85
4137	0.80
7929	0.75

Typical Saunders Brown K values for mist eliminator devices

Device	Typical Souders-Brown K Value* m/s
Mesh Vertical Flow to Mesh	0.11
Mesh Horizontal Flow to Mesh	0.13
Vane (simple profile) — Vertical Flow to Vane	0.15
Vane (simple profile) — Horizontal Flow to Vane	0.20
Vanes with single or double pockets — Vertical and Horizontal Flow to Vane	0.20 to 0.30
Vertical Flow To Axial cyclone	0.15 to 0.24
Combination Vane / Mesh Vertical Flow	0.15
Combination Vane / Mesh Horizontal Flow	0.20
Axial cyclone Combinations Vertical Flow	0.15 to 0.24

According to Saunders-Brown K-value, thanks to the fact that a vertical vessel with demister pad has been chosen, a K value of 0.11 is selected. Furthermore, since the performance of demister pad varies According to operating pressure, the selected K should be de-rated in accord with last-page Table.

$$K_{de\text{-}rated} = 0.11 \times 0.83 = 0.09$$

Parameter	Value	Unit
ρ_l	989	kg/m3
ρ_v	10.7	kg/m3
$K_{selected}$	0.09	
U_g	0.86	m/s
Q_g	7.32	m3/s
ID	3293	mm
Required-ID	3443	mm
Selected-ID	3500	mm

Notes

For ID calculation, the following equation has been utilized.

$$D_{VD} = \sqrt{\frac{4\,Q_V}{\pi\,U_V}}$$

Also since the demister pad is mounted on a support ring , then 150 mm or 6 inch is added to calculated ID, which results in 3293 + 150 = 3443 mm, which is regarded as the required ID.

The selected ID would be rounded to 3500 mm.

The selected ID is in complete harmony with the Licensor selected ID, which is 3500 mm.

Foster-Wheeler

The basis of sizing is the critical velocity Vc (m/s)

$$V_c = 0.048\left(\frac{\rho l - \rho g}{\rho g}\right)^{0.5}$$

The maximum gas velocity is K×Vc

K is a coefficient depending on the service, and the use or the absence of wire mesh.

Recommended K values are given hereafter for different services.

Service	Without wire mesh	With wire mesh
Production separator	1.7	2.2
Fuel gas drum	0.8	1.7
Compressor suction drum	0.8	1.7
Glycol or amine contactor inlet drum	0.8	1.7
Reflux drum	1.7	2.2
Steam drum	-	1.3

If a vane pack internal is used, the recommended K value is 3.3.

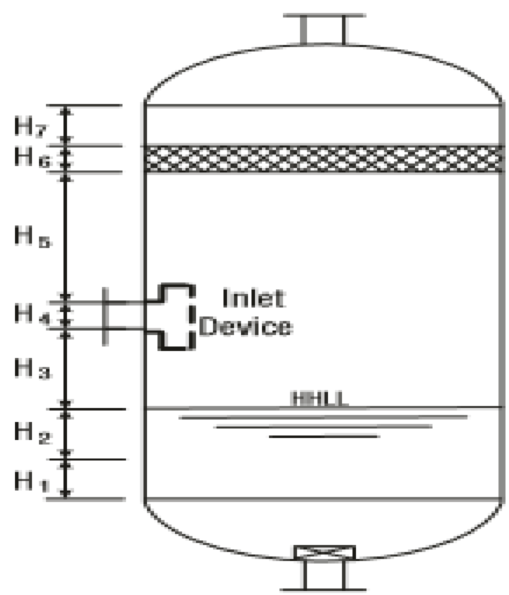
Parameter	Value	Unit
ρ_l	989	kg/m3
ρ_v	10.7	kg/m3
$K_{selected}$	1.7	
V_c	0.45	m/s
V_{max}	0.78	
Q_g	7.32	m3/s
ID	3450	mm
Required-ID	3600	mm
Selected-ID	3600	mm

4th Step: Height Calculation

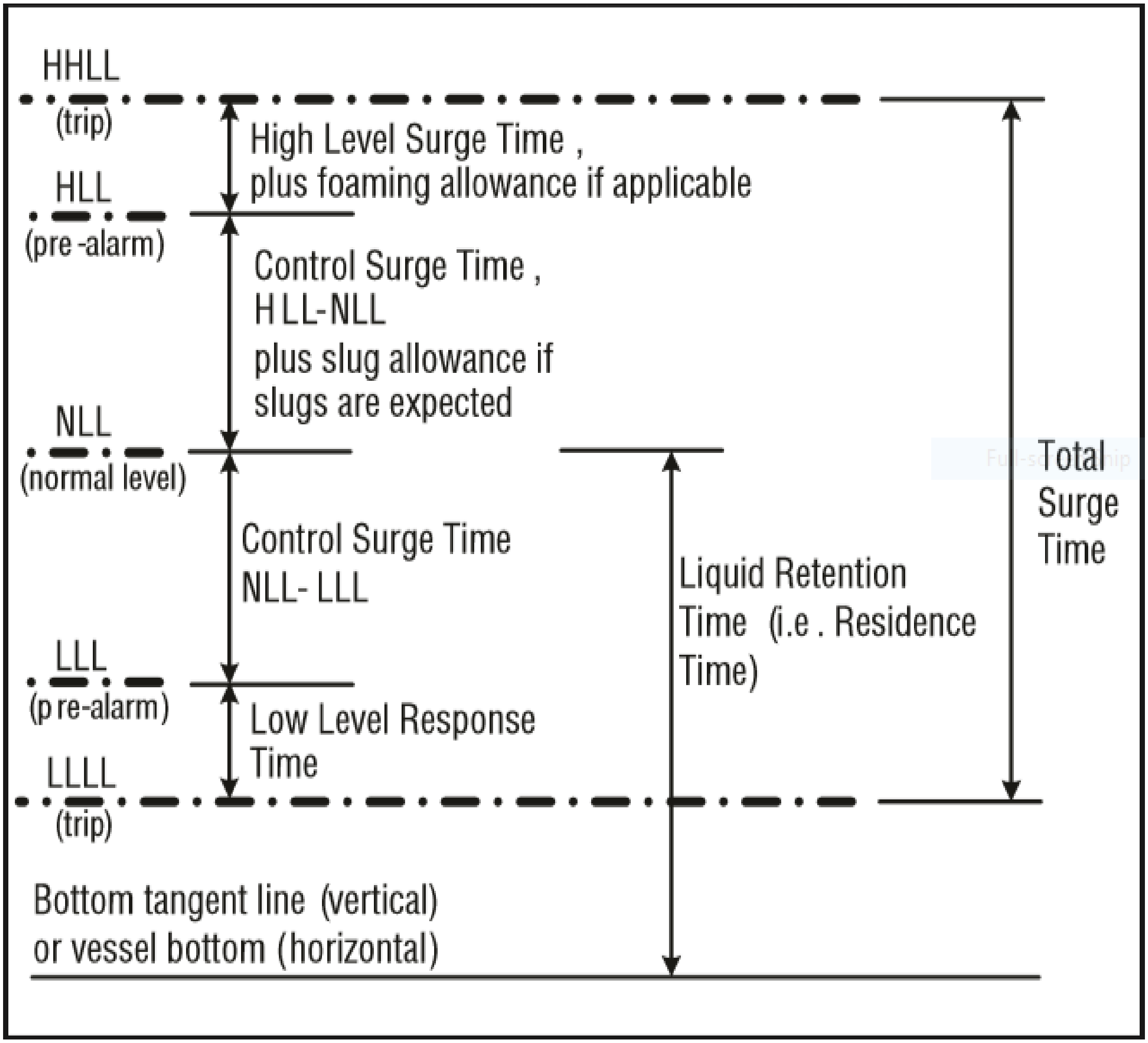
Each and every licensor and company has developed a design basis procedure for sizing vessels. In this article, a GPSA-based method, Foster-Wheeler-based method and the Licensor method will be explored.

GPSA

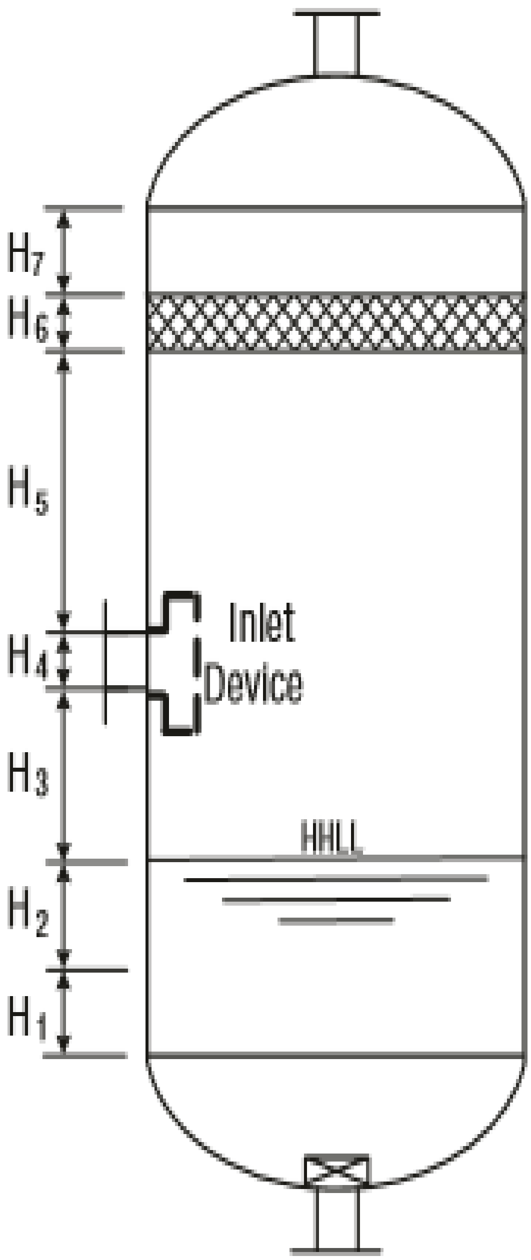
Dim	Section	Distance
H_1	Bottom Tangent to LLLL	300–450 mm, can be lower depending on instrument mount
H_2	LLLL to HHLL	Per required surge time or retention time
H_3	HHLL to Feed Nozzle Bottom	300–600 mm for diffuser 0.25 D for all other inlet devices, with 600 mm minimum
H_4	Nozzle Diameter	Larger of piping size or velocity head criteria
H_5	Nozzle Top to Mist Eliminator Bottom	300–900 mm for diffuser 0.5D for all other inlet devices
H_6	Mist Eliminator	100-150 mm typical
H_7	Mist Eliminator to Top Tangent	150 mm minimum or per Fig. 7-38



Retention/Surge Time


HHLL
(trip)
High Level Surge Time ,
plus foaming allowance if applicable
HLL
(pre -alarm)
Control Surge Time ,
H LL-NLL
plus slug allowance if
slugs are expected
NLL
(normal level)
Control Surge Time
NLL- LLL
LLL
(p re-alarm)
Low Level Response
Time
LLLL
(trip)
Liquid Retention
Time (i.e . Residence
Time)
Total
Surge
Time
Bottom tangent line (vertical)
or vessel bottom (horizontal)

Service	Control Surge Time LLL to HLL	Retention time
Compressor Drum	2 minutes	—
Flash Drum	2-5 minutes	—
Reflux Drum	5 minutes on product plus reflux	—
Surge Drum Upstream of a Tower	5-10 minutes	—
Surge Drum Upstream of a Fired Heat	10 minutes	—
Net Product to Storage	5 Minutes	
Amine Flash Drum	—	5-10 minutes, depending on presence of hydrocarbons
Glycol Flash Drum	—	10-20 minutes depending on presence of hydrocarbons
Refrigeration Accumulator	5 minutes, or based on system or storage requirements	—
Refrigeration Economizer	3 minutes	—
Heat Medium Surge Drum	Maximum liquid expansion, based on 25% to 75% full	—



Height Elements	GPSA	LICENSOR	Unit
H1	450	500	mm
H2	575	500	mm
H3	875	600	mm
H4	865	865	mm
H5	1750	1700	mm
H6	150	150	mm
H7	150	525	mm
HT	4815	4825	mm

Calculation, Explanation, and Discussion

H1 mostly depends on instrument mount position and the number of instrument devices used. The Licensor for most of his vertical vessel has selected 500 mm in accord with his FCS and ESD Control System, whereas in GPSA 450 mm is selected as the basis.

H2 is a function of retention time. It seems from the back-calculation that the licensor has selected 5 minutes for retention time. Likewise, in GPSA a retention time of 2-5 minutes has been selected for Flash drums. The licensor general retention time table is given in next-page

H3 in GPSA for Half Open pipes is 0.25D and has been the basis for calculation.

H4 is the size of inlet Half Open pipe which is the same size of upstream pipe for both licensor and GPSA.

H5 in GPSA for Half Open pipes is 0. 5D and has been the basis for calculation.

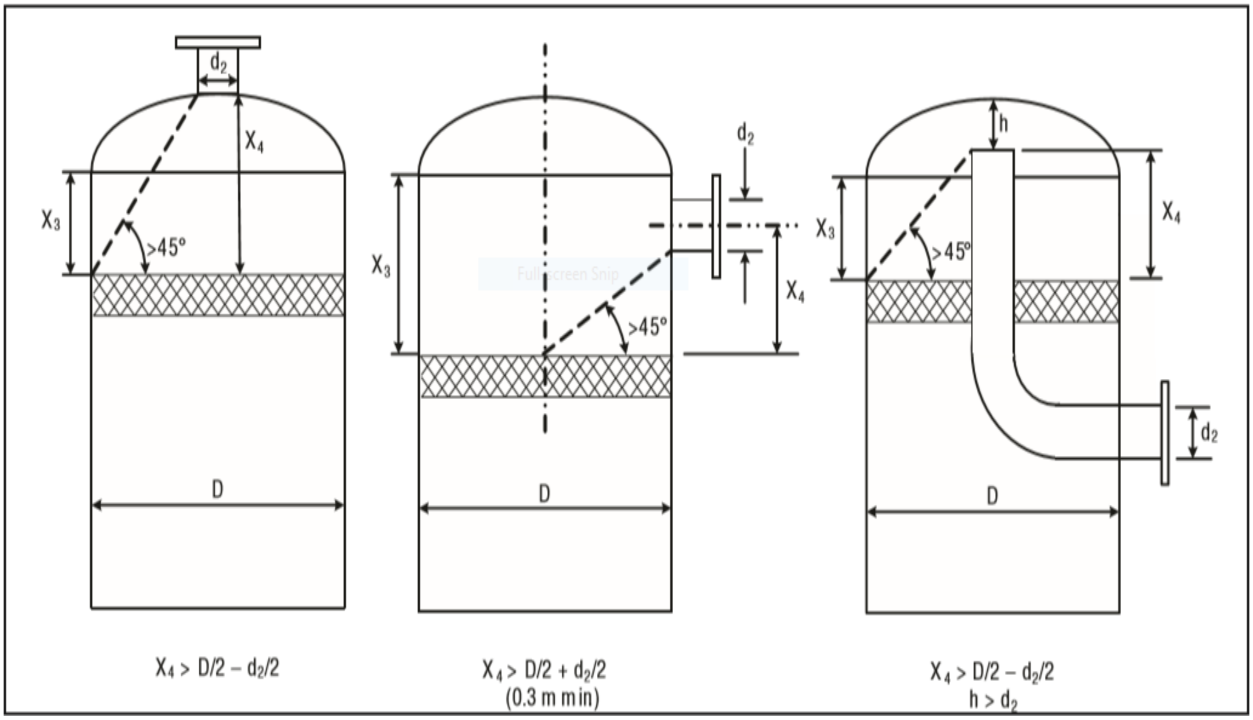
H6 is the demister pad thickness which is 150 mm for both licensor and GPSA.

H7 in GPSA is minimum 150 mm but in other sketch in GPSA there is a formula for X4 which connects the upper part of demister pad to outlet nozzle which cannot be used for comparison here.

Retention Time provided by the licensor

Hydraulic retention time (hold up requirements) is defined between low level (LL) and high level (LH).

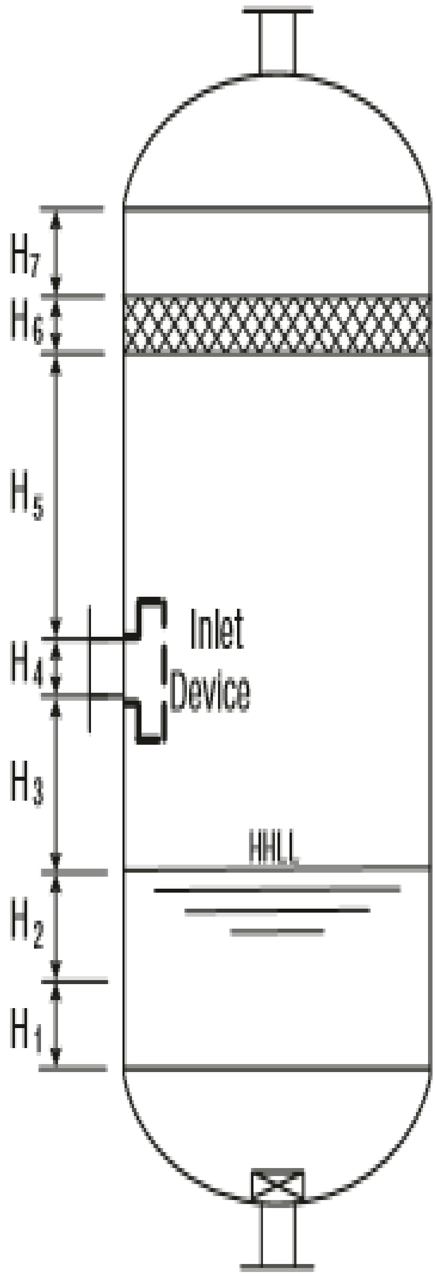
Type of service	Retention time
Feed surge drum	30 minutes
Reflux only	5 minutes
Column feed	
on flow control	15 minutes
on cascade level/flow control	8 minutes
Reboiling by fired heater on feed to heater	8 minutes
Reboiling by thermo siphon on circulation	10 to 30 seconds
Products to storage	
without pump	5 minutes
with pump	7 minutes
Feeds and products feeding another unit	
on flow control	15 minutes
on cascade/level flow control	8 minutes
Tanks	Individually, according to the agreement
Steam drum (LL to empty), min	
From high level to empty	12 minutes
From low level to empty	10 minutes
Deaerator, min	15 minutes


d2
X4
X3
>45°
D
X4 > D/2 – d2/2
d2
X3
X4
>45°
D
X4 > D/2 + d2/2
(0.3 m min)
h
X3
X4
>45°
d2
D
X4 > D/2 – d2/2
h > d2

Foster-Wheeler

SERVICES	TIME (MINUTES)
Feed Surge Drum	
A. to heater	5
B. to others	3 without pump
	5 with pump
Reflux Drum	5
Fractionation tower bottom : the largest of	
A. product to next process	5
B. product to other column	5
C. product to storage tank	3 without pump
	5 with pump
Steam flash drum (process units)	5
Steam drum (utility generation)	10
Desalter	15
Deaerator (note1)	15
Atmospheric degassing drum	15
Others Drums	3 without pump
	5 with pump

DATA SHEET SYMBOL	VERTICAL DRUM	HORIZONTAL DRUM
HHLA/HHLS (HLL)		
	at least 1 to 2 min. with 150 mm min. to verify : min. 10% of control range IF only HLL : HLA-HLL : 10% of control range	at least 1 to 2 min. with 100 mm min. to verify : min. 10% of control range IF only HLL : HLA-HLL : 10% of control range
HLA		
	liquid hold up time to be considered with 300 mm min.	liquid hold up time to be considered with 300 mm min.
LLA		
	at least 1 to 2 min. with 200 mm min. to verify : min. 10% of control range IF only LLL : LLA-LLL : 10% of control range	at least 1 to 2 min. with 100 mm min. to verify : min. 10% of control range IF only LLL : LLA-LLL : 10% of control range
LLLA/LLLS (LLL)		
	300 mm min., but to be compatible with time required to close a SDV	150 mm min., but to becompatible with time required to close a SDV
Tangent line (1)		



Height Elements	FW	LICENSOR	Unit
H1	300	500	mm
H2	575	500	mm
H3	-	600	mm
H4	865	865	mm
H5	-	1700	mm
H6	150	150	mm
H7	-	525	mm
HT	-	4825	mm

Manholes, Drain and Vents

Foster-Wheeler

Size of manholes

For vessel diameter < 1000 mm

Flanged vessel shall be considered if equipment contains internals

Otherwise, size of manholes = 18”

For vessel diameter ≥ 1000 mm

Toxic service size of manholes = 24”

Non-toxic service size of manholes = 20”

(Or up to 24” if internals need to be removable through manhole.)

The drain of the vessel shall always be at the lowest point of a vessel. For vertical vessels they shall be connected to the bottom outlet line at the low point. For horizontal vessels the drain point shall be directly on the bottom of the drum at the lowest point ensured through vessel slope (1:100).

Volume or diameter of vessel (m^3 or mm)	Vent diameter	Drain diameter
V ≤ 15 OR D ≤ 2500	2"	2"
15 < V ≤ 75 or 2500 < D ≤ 4500	2"	3"
75 < V ≤ 220 or 4500 < D ≤ 6000	3"	4"
220 < V ≤ 420 or D > 6000	4"	4"
V > 420	6"	4"

Licensor Criteria

Manhole

Manhole size	24 inches (*1)

Manhole installation for tray tower:

For tray towers, manholes are to be provided at top, bottom, feed point and draw-off point of tower and for each 20 trays or 15 m elevation distance, whichever is the shorter distance, as minimum.

(*1) In case there is restriction for diameter, minimum 20" should be used.

Hand hole or inspection hole

Preferable size	8 inches
Minimum size	6 inches

Vent and drain

Vent and drain for vessels will normally be provided at the minimum length on overhead or bottom line in accordance to the following table:

Volume or diameter of vessel (m^3 or mm)	Vent diameter (inches)	Drain diameter (inches)
V < 75 or D <= 4,500	2	2
75 < V <= 220 4,500 < D <= 6,000	3	3
20 < V <= 420 or D > 6,000	4	4
V > 420	6	4

Note: Vent and drain connections are not necessarily located on vessels.

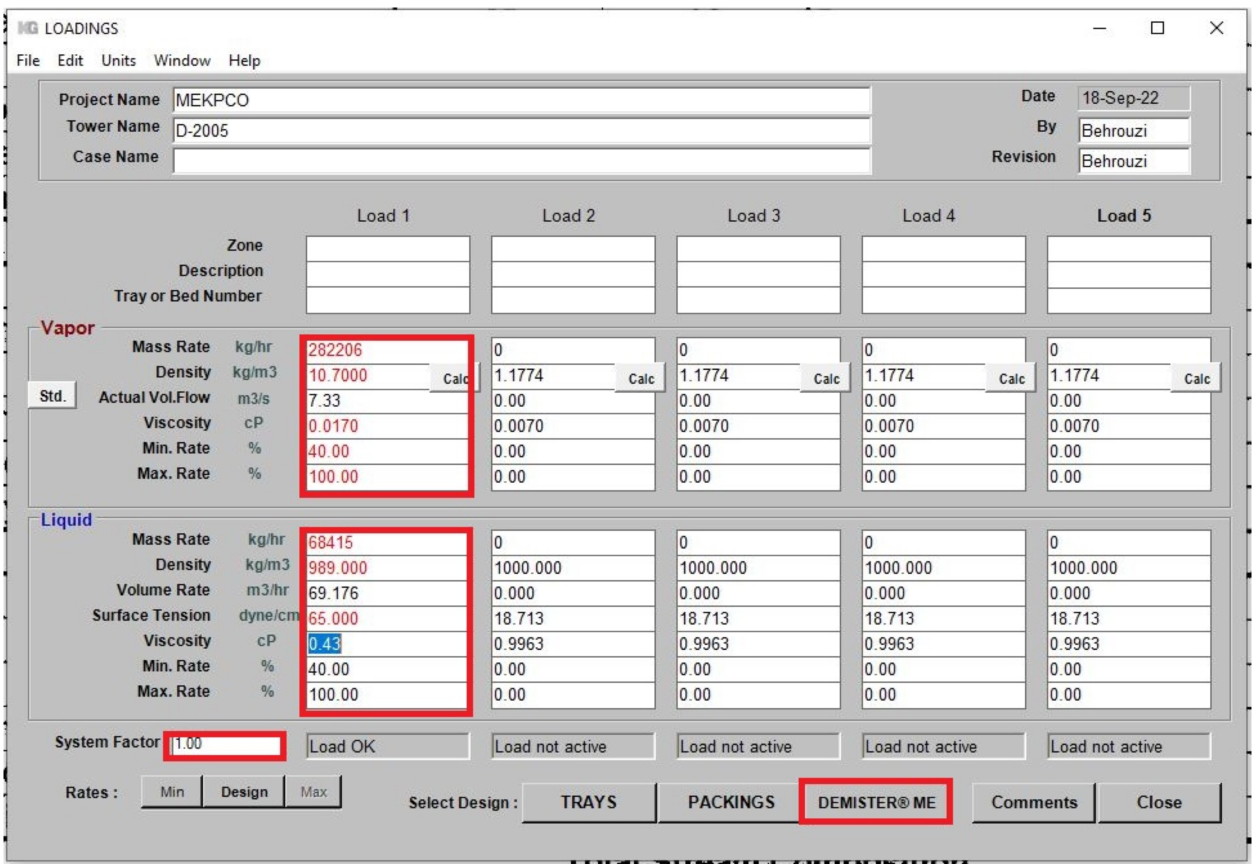
Comparison

1. The size of manhole for both licensor and FW is 24'.
2. There is no need to have Vent on this drum since there is a control valve to flare system and if purging is required then by use of these means the task could be performed.
3. The drain valve sized by licensor is 2' and but by Foster-Wheeler is 3'

Parameter	FW	Licensor
Manhole	**20-24**	**24**
Vent	**2**	**2**
Drain	**3**	**2**
Vortex Breaker	**Yes**	**Yes**

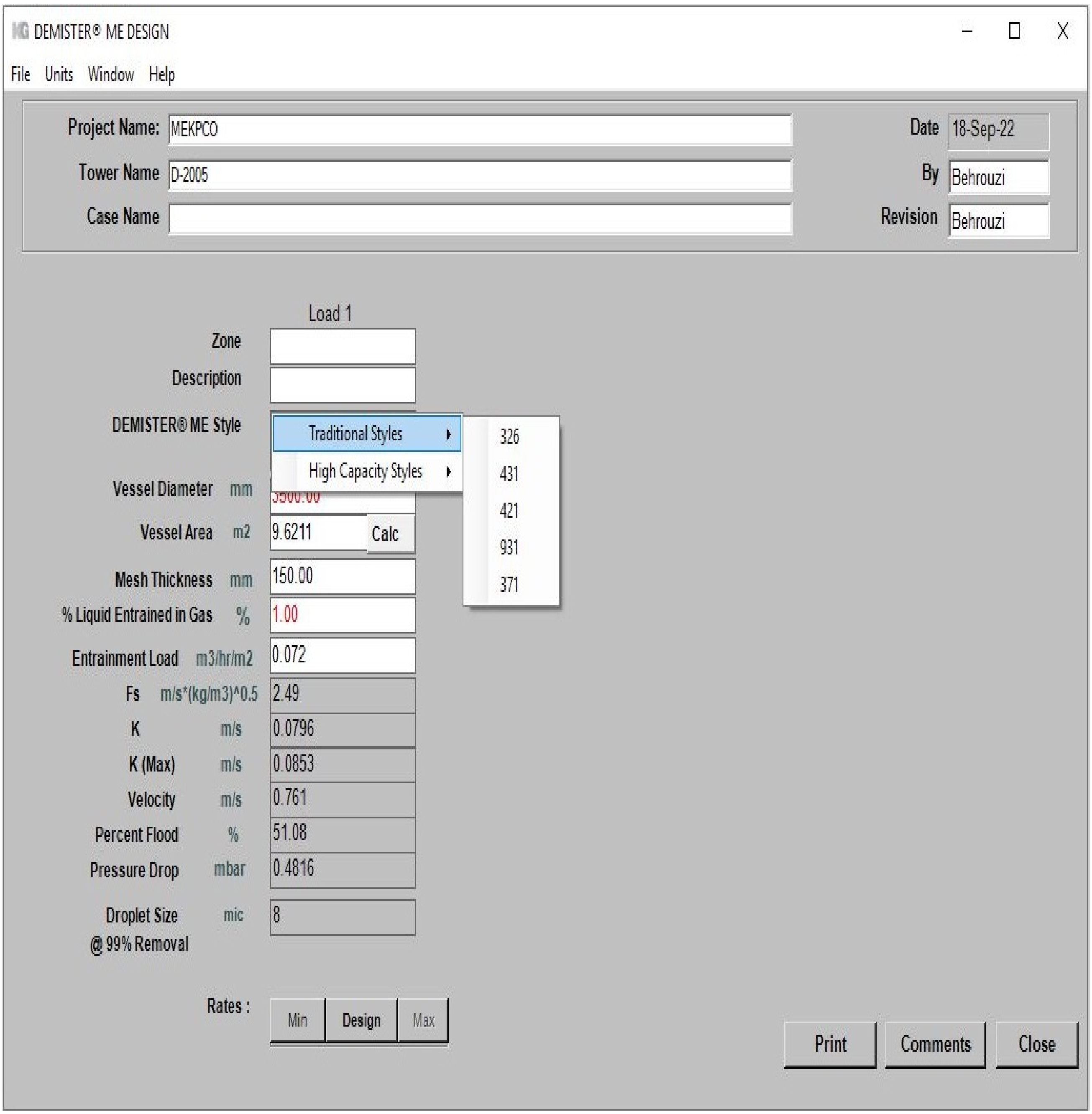
6th Step: Select a well-designed Mist Eliminator pad using KG TOWER

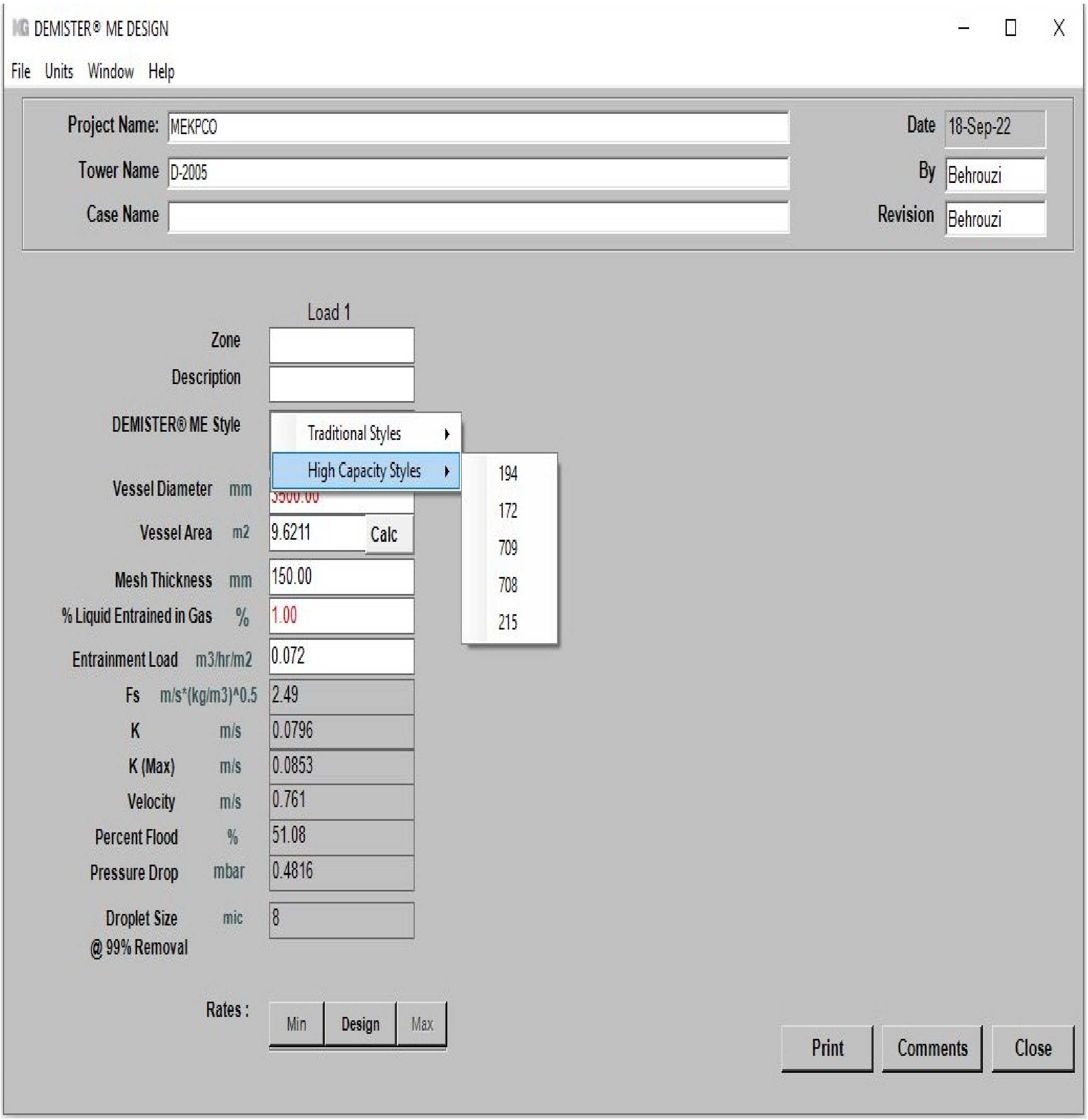
Put operating data as input like below



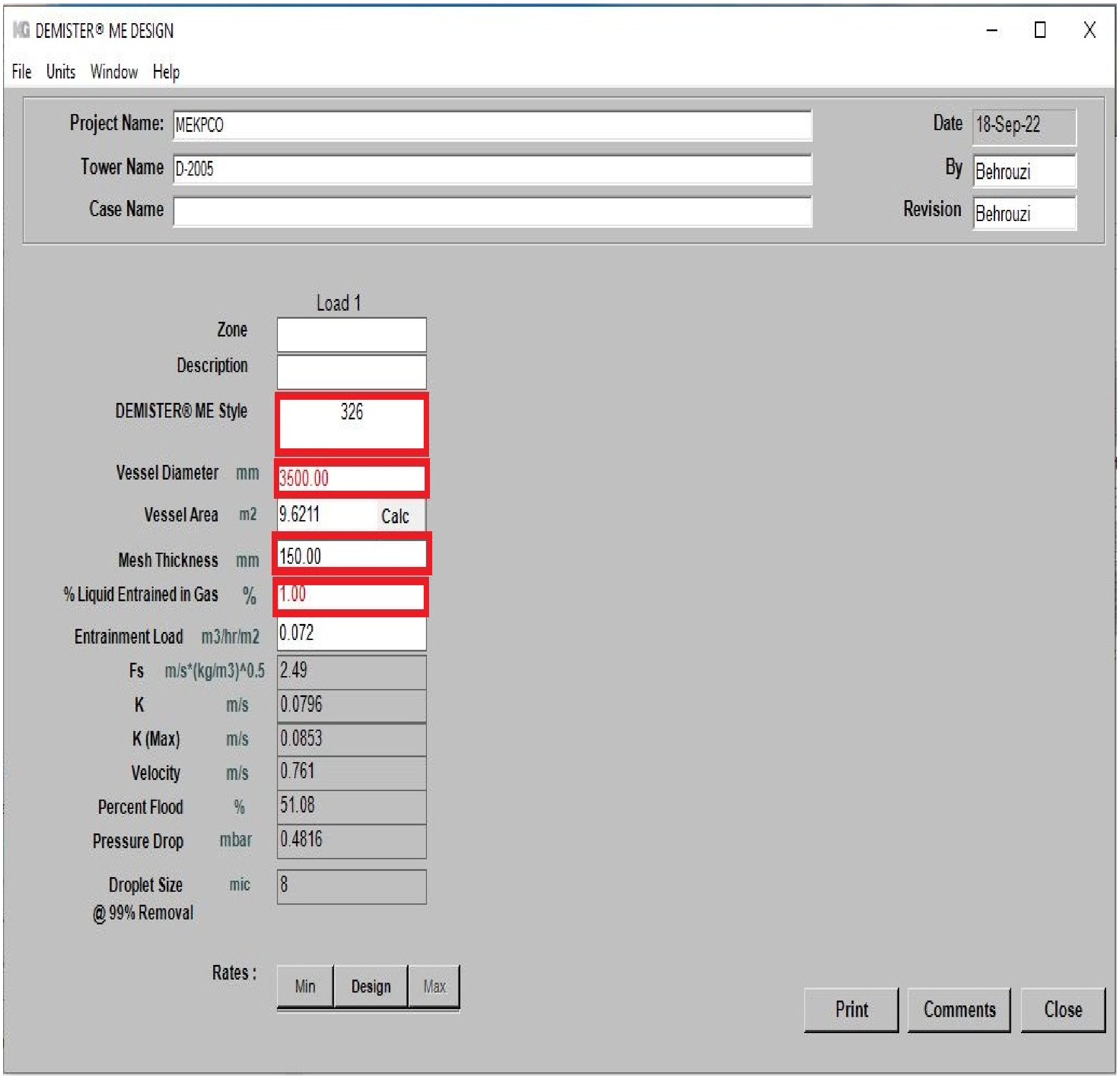
In Koch-Glitsch products there are two types of demister pads:

1. Traditional demister pads
2. High efficiency demister pads


DEMISTER® ME DESIGN
File Units Window Help
Project Name: MEKPCO
Tower Name D-2005
Case Name
Date 18-Sep-22
By Behrouzi
Revision Behrouzi
Load 1
Zone
Description
DEMISTER® ME Style
Traditional Styles
High Capacity Styles
326
431
421
931
371
Vessel Diameter mm
Vessel Area m2 9.6211 Calc
Mesh Thickness mm 150.00
% Liquid Entrained in Gas % 1.00
Entrainment Load m3/hr/m2 0.072
Fs m/s*(kg/m3)^0.5 2.49
K m/s 0.0796
K (Max) m/s 0.0853
Velocity m/s 0.761
Percent Flood % 51.08
Pressure Drop mbar 0.4816
Droplet Size @ 99% Removal mic 8
Rates : Min Design Max
Print Comments Close


DEMISTER® ME DESIGN
File
Units
Window
Help
Project Name:
MEKPCO
Tower Name
D-2005
Case Name
Date
18-Sep-22
By
Behrouzi
Revision
Behrouzi
Load 1
Zone
Description
DEMISTER® ME Style
Traditional Styles
High Capacity Styles
194
172
709
708
215
Vessel Diameter
mm
Vessel Area
m2
9.6211
Calc
Mesh Thickness
mm
150.00
% Liquid Entrained in Gas
%
1.00
Entrainment Load
m3/hr/m2
0.072
Fs
m/s*(kg/m3)^0.5
2.49
K
m/s
0.0796
K (Max)
m/s
0.0853
Velocity
m/s
0.761
Percent Flood
%
51.08
Pressure Drop
mbar
0.4816
Droplet Size
@ 99% Removal
mic
8
Rates :
Min
Design
Max
Print
Comments
Close

All types will be selected and the results are compared



326	421	931	371
3500.00	3500.00	3500.00	3500.00
9.6211 Calc	9.6211 Calc	9.6211 Calc	9.6211 Calc
150.00	150.00	150.00	150.00
1.00	1.00	1.00	1.00
0.072	0.072	0.072	0.072
2.49	2.49	2.49	2.49
0.0796	0.0796	0.0796	0.0796
0.0853	0.1067	0.1067	0.0671
0.761	0.761	0.761	0.761
51.08	49.07	42.31	74.12
0.4816	0.3504	0.1607	11.7727
8	10	18	2
			Warning

High Efficiency Demister Pad

194	172	709	708	215
3500.00	3500.00	3500.00	3500.00	3500.00
9.6211 Calc	9.6211 Calc	9.6211 Calc	9.6211 Calc	9.6211 Calc
150.00	150.00	150.00	150.00	150.00
1.00	1.00	1.00	1.00	1.00
0.072	0.072	0.072	0.072	0.072
2.49	2.49	2.49	2.49	2.49
0.0796	0.0796	0.0796	0.0796	0.0796
0.1067	0.1280	0.1280	0.1280	0.0914
0.761	0.761	0.761	0.761	0.761
49.07	42.31	42.31	42.31	68.37
0.4772	0.2878	0.3220	0.1607	8.0034
8	11	11	18	3

The best options that could be selected seem to be York mesh 172, 709 and 421

Traditional Style	High Capacity	Capacity Gain	Efficiency Gain	Description
371	215	>35%	Same	Glass fiber & metal for maximum efficiency
326	194	>25%	Same	Ultra-efficiency design for fine particles
421	709	>20%	Same	Heavy duty, high efficiency design
431	172	>20%	Same	General purpose style
931	708	>22%	Same	High open area for viscous or dirty liquid