

OWNER

Filter Separator V-101

Calculation



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1. OBJECTIVE

This calculation checks the size of filter separator V-101 for every operating case: the number and loading of the coalescing filter elements, the vane mist extractor capacity, the nozzle momentum, the liquid barrel volume for normal liquids and a pig slug, the level settings, and the liquid dump valve LCV-104.

2. METHODOLOGY

The actual gas flow at the V-101 inlet was taken from the station hydraulic model (PRO-CAL-002) for each case, with gas properties from the GERG-2008 equation of state. The number of coalescing elements was set by the larger of two limits: the gas loading per unit of element surface, and the velocity at which gas leaves each element core. The vane section was checked with the Souders-Brown relation, using the pressure correction for K that the GPSA Engineering Data Book recommends. Because the basis vessel diameter did not pass, the calculation also reports the minimum diameter for each type of vane pack and checks the selected diameter.

The lower liquid barrel was sized to hold the design pig slug between normal liquid level and the high-high trip while LCV-104 dumps. LCV-104 was sized with the ISA-75.01.01 liquid equation for flashing service, because the liquid is saturated with gas at separator pressure and flashes as it crosses the valve. The gas blow-by through LCV-104 if level is lost was calculated with the compressible form of the same equation, using the isentropic exponent $\kappa = \rho c^2 / p$.

3. DESIGN INPUTS

Table 3-1 lists the inputs.

Table 3-1: Design Inputs

Input	Value	Source
Basis vessel size	36 in ID x 15 ft S/S, horizontal two-stage	GEN-DB-001
Gas flow and inlet conditions	Cases C1 to C7	PRO-CAL-002
Coalescing elements	4.5 in OD x 3.25 in core x 72 in, 1 micron	Typical, HOLD H-15
Element loading limit	15 acfm per ft ² of element surface	Typical vendor range 10 to 20, HOLD H-15
Element core exit velocity limit	25 ft/s	Typical re-entrainment limit, HOLD H-15

Input	Value	Source
Vane K, horizontal flow	0.65 ft/s standard, 0.9 ft/s high-capacity	Typical vendor ratings, HOLD H-15
Vane face area	85 % of vessel cross-section	Allowance for the vane frame
Liquid density for Souders-Brown	Condensate, SG 0.72	Lighter liquid governs, HOLD H-12
Nozzle momentum limit	4,000 lb/ft-s ²	Industry guidance for a vane-type inlet device
Normal free liquids	2 bbl/d	Assumed, HOLD H-20
Design pig slug	5 bbl arriving over 2 min	Assumed, HOLD H-16
LCV-104 design dump rate	30 gpm	Selected to drain the slug in about 7 min

4. ASSUMPTIONS

1. Element dimensions and loading, the vane ratings, the clean pressure drop (2 psi) and the removal efficiency are typical values. *Verification required (HOLD H-15).*
2. The liquid is a mixture of condensate and water. The lighter condensate governs the vane check, and water governs the flashing-liquid valve sizing, which gives the larger C_v .
3. The normal liquid rate and the pig slug volume depend on the Owner's treating facility and pigging program. *Verification required (HOLD H-20, H-16).*
4. The pressure correction to K is about 1 % per 100 psi above 100 psig, with a floor of 0.80.

5. REFERENCES

1. GPSA Engineering Data Book, 14th Edition, Section 7, Separation Equipment.
2. API Specification 12J, Specification for Oil and Gas Separators.
3. ASME Boiler and Pressure Vessel Code, Section VIII Division 1 (2023).
4. ANSI/ISA-75.01.01 (IEC 60534-2-1), Flow Equations for Sizing Control Valves.
5. GEN-DB-001, Basis of Design.
6. PRO-CAL-002, Line Sizing and Station Hydraulics; PRO-CAL-007, Pressure Relief Devices and Tank Venting.

6. CALCULATION

6.1. GAS FLOW AT THE V-101 INLET

Table 6-1 gives the actual gas flow in each case. Case C4 has the lowest gas density at 120 MMSCFD and the largest actual flow, and governs the vane and element checks.

Table 6-1: Gas Flow at the V-101 Inlet

Case	Flow, MMSCFD	Pressure, psig	Temperature, °F	Density, lb/ft ³	Actual flow, acfm
C1	120	1,150	45	5.10	799
C2	90	1,050	70	4.15	736
C3	10	1,000	60	4.07	84
C4	120	1,100	120	3.75	1,090
C5	120	899	60	3.59	1,130
C6	120	1,150	45	5.10	799
C7	120	1,100	60	5.08	856

6.2. VANE SECTION AND VESSEL DIAMETER

In case C4 the gas density is 3.755 lb/ft³ and the actual flow is 18.08 ft³/s. Across the vane face of the 36 in vessel (6.01 ft²) the gas velocity is 3.01 ft/s. With the pressure correction $C_p = 0.90$, the K the vane pack would have to carry is:

GPSA Section 7, Souders-Brown

$$K = \frac{V}{C_p \sqrt{(\rho_L - \rho_G)/\rho_G}} = \frac{3.01}{0.90 \sqrt{(44.9 - 3.755)/3.755}} = 1.01 \text{ ft/s}$$

That exceeds a standard single-pocket vane pack (0.65 ft/s), which would need a 45 in vessel, and a high-capacity double-pocket pack (0.9 ft/s), which would need 38 in. Some vendors rate the second-stage vane higher, because the elements upstream have already coalesced the mist into large drops. TORUS did not rely on that: at 36 in the design would rest entirely on an unverified vendor rating with no margin. At 42 in ID the largest K is 0.74 ft/s (case C4), which a high-capacity vane pack carries with 21 % margin. Table 6-2 and Figure 6-1 show every case.

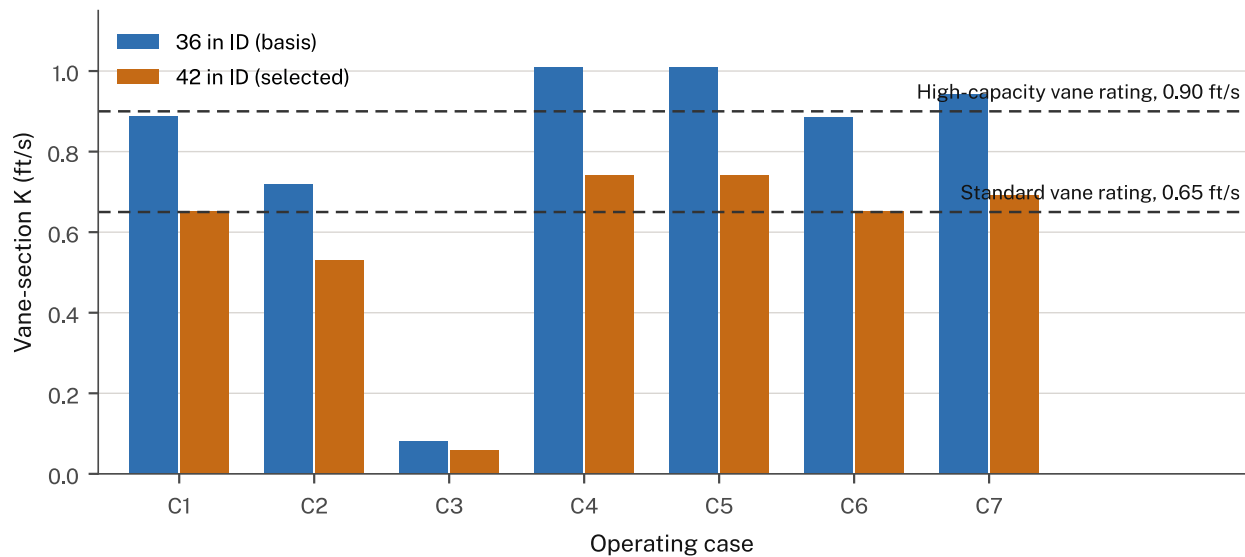
Table 6-2: Vane-Section K and Minimum Vessel Diameter

Case	K at 36 in ID, ft/s	K at 42 in ID, ft/s	Allowable velocity, high-capacity vane, ft/s	Minimum ID, high-capacity vane, in	Minimum ID, standard vane, in
C1	0.89	0.65	2.25	36	42
C2	0.72	0.53	2.55	32	38
C3	0.08	0.06	2.60	11	13



Case	K at 36 in ID, ft/s	K at 42 in ID, ft/s	Allowable velocity, high-capacity vane, ft/s	Minimum ID, high-capacity vane, in	Minimum ID, standard vane, in
C4	1.01	0.74	2.68	38	45
C5	1.01	0.74	2.81	38	45
C6	0.89	0.65	2.25	36	42
C7	0.94	0.69	2.27	37	43

Figure 6-1. Vane-Section K by Operating Case



V-101 shall be 42 in ID x 15 ft S/S with a high-capacity vane pack rated for at least K = 0.9 ft/s at operating pressure, removing 99 % of droplets of 8 micron and larger in case C5.

6.3. FILTER ELEMENTS

The element count is set by the larger of the loading limit and the core velocity limit:

$$N = \max \left(\frac{60 Q}{q_{max} \pi D_o L}, \frac{Q}{V_{core} \pi D_i^2 / 4} \right)$$

Table 6-3 shows that the core velocity governs, with 13.1 elements required in the worst case. With 15 % spare positions, rounded to an even number, V-101 has 16 element positions. The tube sheet holds 33 positions at 6.0 in triangular pitch in the 42 in shell, so the layout is not constrained.

Table 6-3: Filter Element Count

Case	Actual flow, acfm	Elements by loading	Elements by core velocity	Elements required
C1	799	7.5	9.3	9.3

Case	Actual flow, acfm	Elements by loading	Elements by core velocity	Elements required
C2	736	6.9	8.5	8.5
C3	84	0.8	1.0	1.0
C4	1,090	10.2	12.6	12.6
C5	1,130	10.7	13.1	13.1
C6	799	7.5	9.2	9.2
C7	856	8.1	9.9	9.9

V-101 has 16 coalescing element positions. Elements shall be rated for at least 50 psid collapse; change-out is at 10 psid.

6.4. NOZZLES

Table 6-4 gives the momentum flux in the 12 in inlet and outlet nozzles. The largest value, 2,080 lb/ft·s², is well within the 4,000 lb/ft·s² limit for an inlet with a vane-type inlet device.

Table 6-4: Nozzle Momentum

Case	Velocity, ft/s	Momentum flux ρv^2 , lb/ft·s ²
C1	17	1,470
C2	16	1,010
C3	2	13
C4	23	1,990
C5	24	2,080
C6	17	1,470
C7	18	1,680

6.5. LIQUID BARREL AND LEVEL SETTINGS

The basis shows a liquid sump without a size. TORUS sized a lower liquid barrel to hold the design pig slug. While the slug arrives, LCV-104 is already dumping, so the barrel only needs to hold the net inflow:

$$V_{slug, net} = V_{slug} - q_{dump} t = 5 - 0.714(2) = 3.57 \text{ bbl} = 20.1 \text{ ft}^3$$

An NPS 24 barrel (22.5 in ID) 14 ft long holds 25.3 ft³ between normal liquid level (30 %) and the high-high trip (85 %), which is more than the net slug. A 12 ft barrel was considered and rejected because it gave less than 10 % margin on the slug. Table 6-5 gives the level settings.

Table 6-5: V-101 Liquid Barrel Level Settings

Level	Percent of barrel ID	Height, in	Volume below, ft ³	Volume below, bbl
LSLL-106 (low-low, closes LCV-104 and SDV-106)	10	2.2	2.0	0.36
LAL (LT-104)	20	4.5	5.5	0.98
NLL / LCV-104 control band center	30	6.8	9.8	1.74
LAH (LT-104)	70	15.7	28.9	5.15
LSHH-105 (high-high, trips SDV-101)	85	19.1	35.0	6.24

The high alarm will sound during a design slug, about 0.6 min before the trip would be reached, but the trip is not reached. The slug drains in 7 min at the design dump rate.

6.6. LCV-104 DUMP VALVE

The liquid entering LCV-104 is at its bubble point, so its vapor pressure equals the separator pressure and the flow chokes by flashing. With water properties (critical pressure 3,206 psia), which give the smaller choked pressure drop and therefore the larger valve, and $F_L = 0.9$:

ISA-75.01.01, choked liquid flow

$$F_F = 0.96 - 0.28 \sqrt{\frac{P_v}{P_c}}, \quad \Delta P_{choked} = F_L^2 (P_1 - F_F P_v), \quad C_v = Q \sqrt{\frac{G}{\Delta P_{choked}}}$$

In case C5, at the lowest separator pressure (913.3 psia), $F_F = 0.811$, the choked pressure drop is 140 psi and the required C_v is 2.53. Table 6-6 gives both pressure extremes.

Table 6-6: LCV-104 Sizing

Case	Inlet pressure, psia	F_F	Choked pressure drop, psi	Required C_v	Percent of rated C_v
C1	1,164	0.791	197	2.14	53
C5	913	0.811	140	2.53	63

LCV-104 is an NPS 2 Class 600 angle valve with hardened reduced trim, rated C_v 4.0, running at 63 % of capacity at the design dump rate.

If the barrel empties with LCV-104 open, gas blows through to the atmospheric tank T-101. At 1,150 psig and 45 °F ($\kappa = 1.429$) the flow through LCV-104 alone would be 11,000 lb/h (5.4 MMSCFD). With the dump valve fully open and no inflow, the barrel drains from normal level to the low-low switch in about 116 s. The same valve cannot both fail open and provide the protection, so the design adds SDV-106, an independent spring-return shutoff valve closed by LSLL-106 through the safety PLC, and restriction orifice RO-104 downstream of LCV-104. PRO-CAL-007 sizes RO-104 and the T-101 emergency vent for the remaining blow-by.

7. RESULTS AND CONCLUSIONS

TORUS draws the following conclusions:

1. V-101 shall be 42 in ID x 15 ft S/S, larger than the 36 in basis size, with a high-capacity vane pack. At 36 in the vane section would need $K = 1.01$ ft/s, above the rating of either vane type.
2. V-101 has 16 positions for 4.5 in x 72 in coalescing elements. The 12 in nozzles are adequate.
3. V-101 has a lower liquid barrel, NPS 24 x 14 ft in two compartments, which holds the 5 bbl design slug without reaching the high-high trip.
4. LCV-104 is an NPS 2 angle valve with C_v 4.0. SDV-106 and RO-104 protect T-101 against gas blow-by.

The following items remain open: vendor confirmation of the vane rating and element loading (HOLD H-15), the normal liquid rate (HOLD H-20) and the pig slug volume (HOLD H-16). A vendor offering a 36 in vessel would need to submit test data at $K = 1.01$ ft/s and 1,100 psig.

