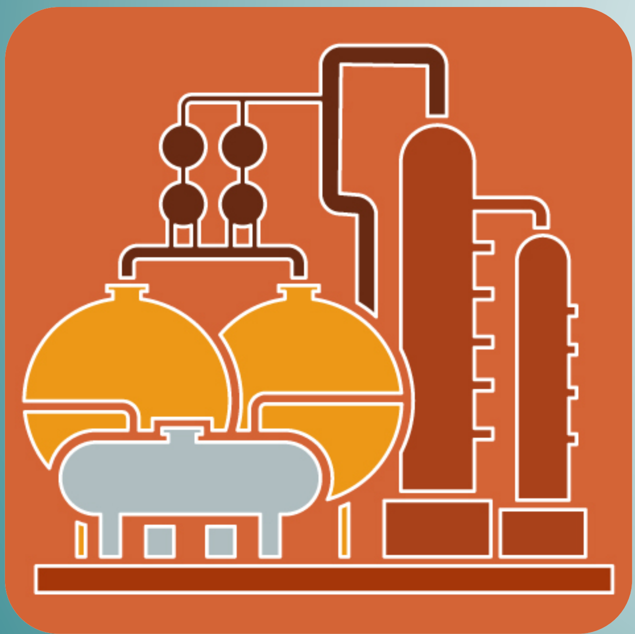
Chemical Process Design / Diseño de Procesos Químicos

Topic 5.2. Vessels and reactors

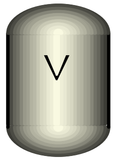
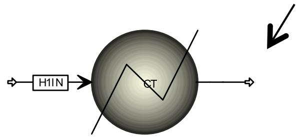
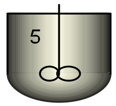
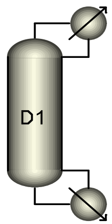
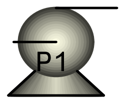
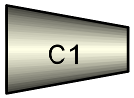
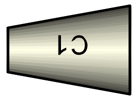


Javier R. Viguri Fuente
Eva Cifrian Bemposta

Department of Chemistry and Process & Resource Engineering
GER Green Engineering and Resources Research Group

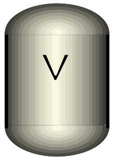
2.- Equipment Sizing Procedures

Shortcut calculations for the main equipment sizing

Q, P maintenance	**Vessels.**	
Δ Heat contents	**Heat transfer equipment: Heat exchangers Furnaces and Direct Fired Heaters Refrigeration.**	
Δ Composition	**Reactors, Columns, Distillation and Absorption.**	
Q, P streams setting	**Pumps, Compressors and Turbines.**	

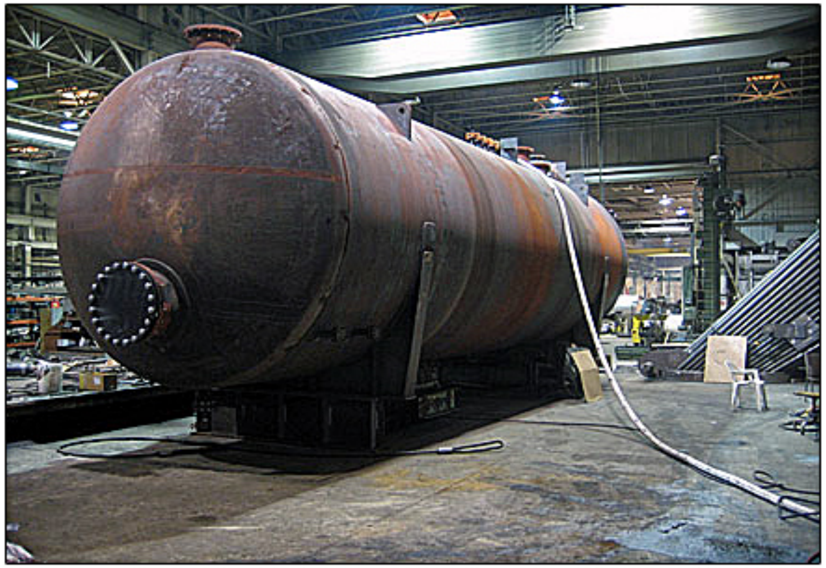
Shortcuts For Vessel Sizing

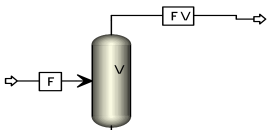
(storage tanks, flash drums, decanters and some reactors)

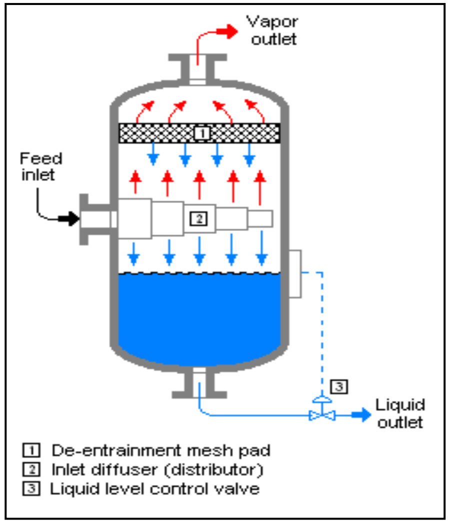


Shortcuts For Vessel Sizing

(storage tanks, flash drums, decanters and some reactors)







© Milton Beychok. Wikimedia Commons.

- **Pressure Vessel Type Pictured Above**: Flash Drum (vapor–liquid separator).
- **Fabrication Date:** 2006.
- **Description:** 144” Inside Diameter x 36′-0” Straight Shell, 70,000 pounds.
- **Material (s):** ASME SA516 Grade 70 Carbon Steel Plate.
- **Industry or Application:** Refinery.
- **Pressure Vessel Manufacturing and Fabrication.**
- **Process Description:** Spot Radiographic Testing and Inspection (Spot RT), Post Weld Heat Treated (PWHT), Furnished with Platform and Ladder. Pictured above is a type of pressure vessel called a flash drum manufactured by The Halvorsen Company. This vessel is used for flash evaporation which occurs inside the pressure.

Halvorsen Company: http://www.halvorsenusa.com/.

Shortcuts For Vessel Sizing

1) Select the V for liquid holdup; τ = 5 min + equal vapor volume:

$$V = 2 \cdot [(F_L \cdot \tau) / \rho_L]$$

2) Select L = 4D:

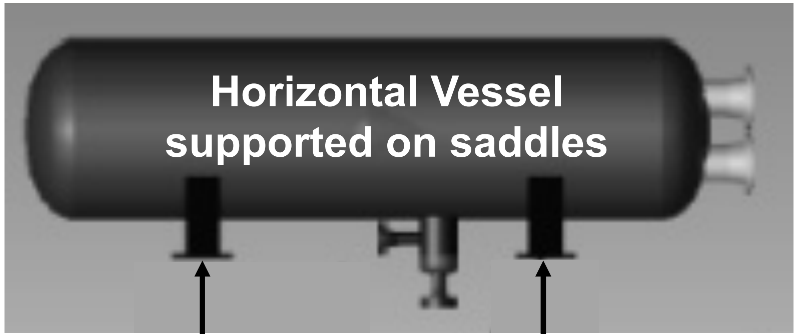
$V = \pi D^2 / 4 \cdot L \rightarrow$ **$D = (V / \pi)^{1/3}$** ; If $D \leq 1.2$ m Vertical, else Horizontal.

- **Materials of Construction appropriate for use with Guthrie's factors and pressure ($P_{rated\ (nominal)} = 1.5\ P_{actual}$).**

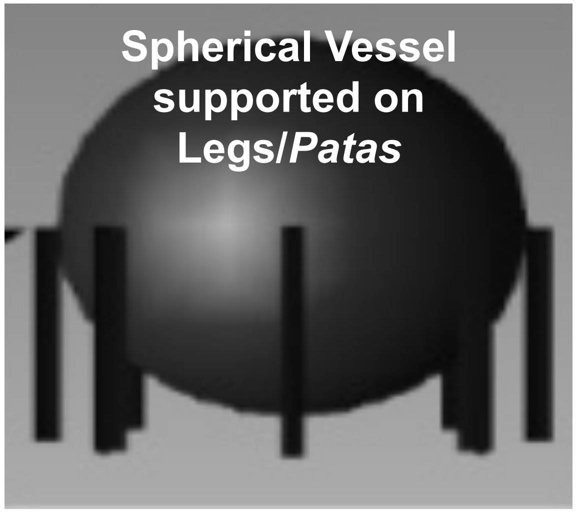
- **Basic Configuration for pressure vessels:**
  - Carbon steel vessel with 50 psig design P and average nozzles *(boquillas)* and manways *(bocas de hombre)*.
  - Vertical construction includes shell and two heads *(cubierta y cabezales)*, the skirt *(faldón)*, base rings and lugs *(aros y agarraderas, patas, ménsulas, etc.)* and possible tray supports *(soportes de platos)*.
  - Horizontal construction includes shell *(carcasa)*, two heads *(cabezales)* and two saddles *(sillas de montar)*.

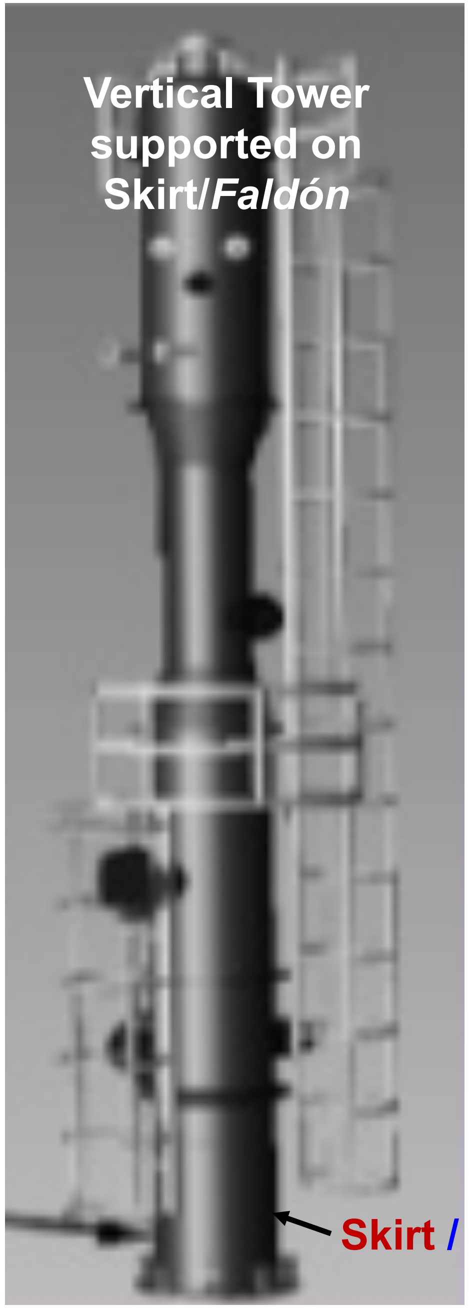
$MPF = F_m \cdot F_p$; F_m depending on shell material configuration (clad or solid).

Shortcuts For Vessel Sizing



Saddles / *Silla de montar*





Skirt / *Faldón*

Materials of Construction for Pressure Vessels

High Temperature Service

Tmax (ºF)	Steel
950	Carbon steel (CS).
1150	502 stainless steels (SS).
1300	410 SS; 330 SS.
1500	304, 321, 347, 316 SS. Hastelloy C, X Inconel.
2000	446 SS, Cast stainless, HC.

Low Temperature Service

Tmin (ºF)	Steel
–50	Carbon steel (CS)
–75	Nickel steel (A203)
–320	Nickel steel (A353)
–425	302, 304, 310, 347 (SS)

Guthrie Material and pressure factors for pressure vessels: MPF = $F_m \cdot F_p$

Shell Material	Clad *(Revestimiento)*, F_m	Solid *(Macizo)*, F_m
Carbon Steel (CS)	1.00	1.00
Stainless 316 (SS)	2.25	3.67
Monel (Ni:Cr/2:1 alloy)	3.89	6.34
Titanium	4.23	7.89

Vessel Pressure (psig)

Up to	50	100	200	300	400	500	900	1000
Fp	1.00	1.05	1.15	1.20	1.35	1.45	2.30	2.50

Shortcut For Reactor Sizing

- First step of the preliminary design → No kinetic model available.
- **Assumptions:** reactor equivalent to laboratory reactor, constant conversion, adiabatic reactors are isotherm at average T.

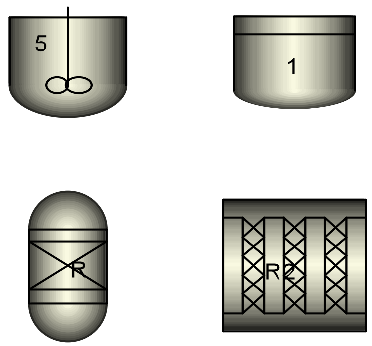
- **Assume space velocity (S in h^{-1})**

$S = (1 / \tau) = \upsilon_0 / V = \mu / (\rho \cdot V)$;

If a catalyst is used: $S = \mu / (\rho \cdot V_{cat})$, with $V = V_{cat} / (1 - \varepsilon)$

υ_0 = Volumetric flow rate; **V** = Reactor volume; **μ** = Molar flow rate; **ρ** = molar density;

V_{cat} = Volume of catalyst; **ε** = Void fraction of catalyst (e.g. ε = 0.5)



Tiempo Espacial y Velocidad Espacial / Space time and Space velocity

Remember !!

τ = 1 / S = *Tiempo Espacial* / Space time =

= *(Tiempo necesario para tratar un volumen de alimentación igual al volumen del reactor en condiciones determinadas) = (Tiempo)*.

= Time necessary to process one reactor volume of fluid, given a particular set of entrance conditions = [time].

S = (1 / τ) = *Velocidad Espacial* / Space velocity =

= *(Número de volúmenes de la alimentación en condiciones determinadas que puede tratarse en la unidad de tiempo, medidos en volúmenes de reactor) = (Tiempo)$^{-1}$*.

= The number of reactor volumes of feed that can be treated in a unit time = [time $^{-1}$].

Tiempo Espacial y Velocidad Espacial / Space time and Space velocity

Remember !!

$\tau = 1 / S = C_{A0} V / F_{A0} =$

= (*Moles de A que entran / Volumen de la alimentación) (Volumen del reactor*) =
(Moles de A que entran / Tiempo)

$= V / \upsilon_0 =$ (*Volumen del reactor) / (Caudal volumétrico de la alimentación).*

$\tau = 1 / S = C_{A0} V / F_{A0} =$

= (Input of A Moles / Feed volume) (Reactor volume) =
(Input of A Moles / Time)

$= V / \upsilon_0 =$ (Reactor volume) / (Feed volume flow rate)