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This program uses GPSA Engineering Data Book, 12th Edition, Design and Engineering Practices, and guidance from publications by Manning, Thompson, and Svrcek to calculate 3-phase horizontal separator sizing.

User can input values into the Light Blue shaded cells. Program indicates acceptable checks with Green text or shaded cells, and deficiencies with Red text.

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3-Phase Horizontal Separator

Project:
Client:
Job Number: Tag No:
General Notes:
Project Notes:

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YOUR LOGO HERE

Rev.	Description	By	Checked	Approved	Date

Assumptions:

1
2
3
4
5

Input Data:

	Case 1 - (Enter Case Description)						Case 2 - (Enter Case Description)					
Maximum Design Temp/Press		°F				psig		°F				psig
Operating Temp/Press		°F				psig		°F				psig
Atmospheric Temp/Press		°F				psig		°F				psig
Bulk Fluid Description	Gas		Oil		Water		Gas		Oil		Water	
Fluid Flowrate MSCFD/BPD												
Oil API Gravity				API						API		
Fluid Specific Gravity		SG	1.076	SG		SG		SG	1.076	SG		SG
Fluid Viscosity, μ cP												
Gas MW												
Compressibility/Density Correction, Z												

Fluid Calculations:

	Case 1 - (Enter Case Description)						Case 2 - (Enter Case Description)					
	Gas		Oil		Water		Gas		Oil		Water	
Standard Fluid Flowrate	#DIV/0!	ft^3/s	#DIV/0!	ft^3/min	-	ft^3/min	#DIV/0!	ft^3/s	#DIV/0!	ft^3/min	-	ft^3/min
Actual Mass Flowrate	#DIV/0!	lb/s	#DIV/0!	lb/hr	-	lb/hr	#DIV/0!	lb/s	#DIV/0!	lb/hr	-	lb/hr
Fluid Density	#DIV/0!	lb/ft^3	-	lb/ft^3	-	lb/ft^3	#DIV/0!	lb/ft^3	-	lb/ft^3	-	lb/ft^3

Inlet Gas/Liquid Density at Operating Press and Temp, ρ_m	#DIV/0!	lb/ft^3	#DIV/0!	lb/ft^3
Inlet Liquid Density at Operating Press and Temp, ρ_L	#DIV/0!	lb/ft^3	######	lb/ft^3

Vessel Specification:

Direct Fired
Burner Tube:

	Case 1 - (Enter Case Description)		Case 2 - (Enter Case Description)	
Required Slug Capacity:		BBL		BBL
Allowable Liquid Level:		%		%
3-Phase Liquid Retention Time:		min		min
L_{eff}/D:				
Burner Tube Nominal Diameter:		NPS		NPS
Burner Tube Outside Diameter:	#N/A	in	#N/A	in
Burner Tube Total Length:		ft		ft
Burner Tube Volume:	#N/A	ft^3	#N/A	ft^3

Mist Extractor:
Flow Direction:

	Case 1 - (Enter Case Description)		Case 2 - (Enter Case Description)	
K Factor Pressure Adjustment:	100	100	100	100
Souders-Brown K Factor:	0.30		0.30	
Pressure Adjusted K Factor:	0.30	ft/s	0.30	ft/s

Gas Capacity:

		Case 1 - (Enter Case Description)			Case 2 - (Enter Case Description)		
Volume in Separator		v_L =	#DIV/0!	ft^3	v_L =	#DIV/0!	ft^3
Calculated Reqrd Vessel Inside Diameter		D =	#DIV/0!	in	D =	#DIV/0!	in
Approximate Reqrd Outside Diameter		D_O =	#DIV/0!	in	D_O =	#DIV/0!	in
Calculated Vessel Effective Length		L_{eff} =	#DIV/0!	ft	L_{eff} =	#DIV/0!	ft
Select Outside Diameter		D_O =		in	D_O =		in
Approximate Resulting Inside Diameter		D =	-0.25	in	D =	-0.25	in
Approximate Resulting Inside Diameter		D =	-0.02	ft	D =	-0.02	ft
Select Effective Length		L_{eff} =		ft	L_{eff} =		ft
Calculated Total Available Inside Area		A_{tot} =	#N/A	ft^2	$A_{tot} = A_V$ =	#N/A	ft^2
Verify L_{eff}/D is between 3 and 5		L_{eff}/D =	0.00		L_{eff}/D =	0.00	
Gas Capacity - Souders-Brown K Factor	(Pressure Adjusted Lilly)	K_{SB} =	#DIV/0!	ft/s	K_{SB} =	#DIV/0!	ft/s
Gas Capacity - Souders-Brown K Factor		K_{SB} =	#DIV/0!	ft/s	K_{SB} =	#DIV/0!	ft/s
Maximum Gas Velocity		V_{max} =	#DIV/0!	ft/s	V_{max} =	#DIV/0!	ft/s
Min Reqrd Vessel Inside Area for Gas		A_G =	#DIV/0!	ft^2	A_G =	#DIV/0!	ft^2

Liquid Phase Capacity - Retention Time:

		Case 1 - (Enter Case Description)				Case 2 - (Enter Case Description)			
Cross Sectional Area for Liquid Flow		A_L =	#DIV/0!	ft^2		A_L =	#DIV/0!	ft^2	
Total Min Required Vessel Inside Area		$A_{min} = A_G + A_L$	#DIV/0!	ft^2		$A_{min} = A_G + A_L$	#DIV/0!	ft^2	
		$A_{tot} > A_{min}$	#N/A			$A_{tot} > A_{min}$	#N/A		
		D_{min} =	#DIV/0!	ft^2		D_{min} =	#DIV/0!	ft^2	
Diameter Check		$D > D_{min}$	#DIV/0!			$D > D_{min}$	#DIV/0!		
Liquid Phase Velocity		V_{liq} =	#DIV/0!	ft/s		V_{liq} =	#DIV/0!	ft/s	
DEP Recommendation Check	$V_{liq} < 0.049$ ft/s		#DIV/0!				#DIV/0!		
Liquid Filled Fraction of Vessel		M =	#DIV/0!			M =	#DIV/0!		
Liquid Level Depth to Diameter Ratio		h_D =	#DIV/0!			h_D =	#DIV/0!		
Height to Top of Oil		H_L =	#DIV/0!	ft		H_L =	#DIV/0!	ft	
Recommend 1.5ft minimum		$D-H_L$ =	#DIV/0!		#DIV/0!	$D-H_L$ =	#DIV/0!		#DIV/0!
Recommend 0.8 maximum		H_L/D =	#DIV/0!		#DIV/0!	H_L/D =	#DIV/0!		#DIV/0!
Water Volume		V_w =	-	ft^3		V_w =	-	ft^3	
Water Area		A_w =	#DIV/0!	ft^2		A_w =	#DIV/0!	ft^2	
		A_w/A_{tot} =	#DIV/0!			A_w/A_{tot} =	#DIV/0!		
		$H_{o/w}/D$ =	#DIV/0!			$H_{o/w}/D$ =	#DIV/0!		
Height to Top of Water		$H_{o/w}$ =	#DIV/0!	ft		$H_{o/w}$ =	#DIV/0!	ft	
Actual Cross Sectional Area for Gas Flow		$A_V = A_{tot} - A_L$ =	#N/A	ft^2		$A_V = A_{tot} - A_L$ =	#N/A	ft^2	
			#N/A				#N/A		

Superficial Gas Velocity	$V_R = q_R/A_V$ =	#DIV/0!	ft/s		$V_R = q_R/A_V$ =	#DIV/0!	ft/s	
		#DIV/0!				#DIV/0!		
Gas Capacity - Oil Drop in Gas Phase								
Gas Retention Time	t_{rR} =	#DIV/0!	s		t_{rR} =	#DIV/0!	s	
Velocity of Oil Drop Falling in Gas Phase	V_{od} =	#DIV/0!	ft/s		V_{od} =	#DIV/0!	ft/s	
Assume a drag coefficient	**C_{D1} =**	**1000.00**			**C_{D1} =**	**1000.00**		
Diameter of smallest oil drop that will fall	d_{od} =	#DIV/0!	µm		d_{od} =	#DIV/0!	µm	
		#DIV/0!	in			#DIV/0!	in	
	Re =	#DIV/0!			Re =	#DIV/0!		
Iterate C_{D1} until $C_{D1} = C_{D2}$ (+/- 0.02)	**C_{D2} =**	**#DIV/0!**			**C_{D2} =**	**#DIV/0!**		
Liquid Capacity - Water Drop in Oil Phase								
Velocity of Water Drop	V_{wd} =	#DIV/0!	ft/s		V_{wd} =	#DIV/0!	ft/s	
Assume a drag coefficient	**C_{D1} =**	**1000.00**			**C_{D1} =**			
Diameter of smallest water drop that	d_{wd} =	#DIV/0!	µm		d_{wd} =	#DIV/0!	µm	
will settle		#DIV/0!	in			#DIV/0!	in	
	Re =	#DIV/0!			Re =	#DIV/0!		
Iterate C_{D1} until $C_{D1} = C_{D2}$ (+/- 0.02)	**C_{D2} =**	**#DIV/0!**			**C_{D2} =**	**#DIV/0!**		
Liquid Phase Capacity: Oil Drop in Water Phase								
Velocity of Oil Drop Rising in Water Phase	V_{od} =	#DIV/0!	ft/s		V_{od} =	#DIV/0!	ft/s	
Assume a drag coefficient	**C_{D1} =**	**1000.00**			**C_{D1} =**	**1000.00**		
Diameter of smallest oil drop that will rise	d_{od} =	#DIV/0!	µm		d_{od} =	#DIV/0!	µm	
		#DIV/0!	in			#DIV/0!	in	
	Re =	#DIV/0!			Re =	#DIV/0!		
Iterate C_{D1} until $C_{D1} = C_{D2}$ (+/- 0.02)	**C_{D2} =**	**#DIV/0!**			**C_{D2} =**	**#DIV/0!**		
Weir and Bucket Heights:								
Height of Oil Weir	H_{ow} =	#DIV/0!	ft		H_{ow} =	#DIV/0!	ft	
Height of Water Weir	H_{ww} =	#DIV/0!	ft		H_{ww} =	#DIV/0!	ft	
Separator Dimensions:								
Length, Option 1:	L_1 =	0.0	ft		L_1 =	0.0	ft	
Length, Option 2:	L_2 =	0.0	ft		L_2 =	0.0	ft	
Select next largest standard size:	L =		ft		L =		ft	
Nozzle Dimensions:								
Inlet Nozzle Allowable Erosional Velocity	V_e =	#DIV/0!	ft/s		V_e =	#DIV/0!	ft/s	
	A_1 =	#DIV/0!	in^2/1000bbl/day		A_1 =	#DIV/0!	in^2/1000bbl/day	
Minimum Allowable Inlet Nozzle Cross Sectional Area	A =	#DIV/0!	in^2		A =	#DIV/0!	in^2	
Minimum Inlet Inside Diameter	d_i =	#DIV/0!	in		d_i =	#DIV/0!	in	
Slug Flow Inlet Nozzle Allowable Erosional Velocity	V_{es} =	#DIV/0!	ft/s		V_{es} =	#DIV/0!	ft/s	
Slug Flow Min Allow Inlet Nozzle Cross Sectional Area	A_s =	#DIV/0!	in^2		A_s =	#DIV/0!	in^2	
Slug Flow Minimum Inlet Inside Diameter	d_{is} =	#DIV/0!	in		d_{is} =	#DIV/0!	in	
Recommended Inlet Nozzle Inside Diameter	d_i =	#DIV/0!	in		d_i =	#DIV/0!	in	
Recommended Inlet Nozzle Min Nom Size	d_{iNPS} =	#DIV/0!	NPS		d_{iNPS} =	#DIV/0!	NPS	
Resulting Inlet Nozzle Mixture Velocity	$v_{m,in}$ =	#DIV/0!	ft/s		$v_{m,in}$ =	#DIV/0!	ft/s	
Resulting Inlet Nozzle Feed Momentum	$\rho_m v^2_{m,in}$ =	#DIV/0!	$lb/ft\text{-}s^2$		$\rho_m v^2_{m,in}$ =	#DIV/0!	$lb/ft\text{-}s^2$	
Select Inlet Device, Allowable Momentum	$\rho_m v^2_{m,in}$ =	Select Inlet	$lb/ft\text{-}s^2$		$\rho_m v^2_{m,in}$ =	Select Inlet	$lb/ft\text{-}s^2$	
Select Feed Inlet Nozzle Nom Diameter	d_{iNPS} =		NPS		d_{iNPS} =		NPS	
Resulting Inlet Nozzle Mixture Velocity	$v_{m,in}$ =	#DIV/0!	ft/s		$v_{m,in}$ =	#DIV/0!	ft/s	
Resulting Inlet Nozzle Feed Momentum	$\rho_m v^2_{m,in}$ =	#DIV/0!	$lb/ft\text{-}s^2$		$\rho_m v^2_{m,in}$ =	#DIV/0!	$lb/ft\text{-}s^2$	
Momentum Criteria Check	#DIV/0!				#DIV/0!			
Superficial Gas Velocity in Feed Nozzle	$v_{G,in}$ =	#DIV/0!	ft/s		$v_{G,in}$ =	#DIV/0!	ft/s	
Superficial Liquid Velocity in Feed Nozzle	$v_{L,in}$ =	#DIV/0!	ft/s		$v_{L,in}$ =	#DIV/0!	ft/s	
Gas Froude Number (see 'Flow Map' tab)	Fr_G =	#DIV/0!			Fr_G =	#DIV/0!		
Liquid Froude Number ('Flow Map' tab)	Fr_L =	#DIV/0!			Fr_L =	#DIV/0!		
Minimum Gas Outlet Nozzle ID	d_{go} =	#DIV/0!	in		d_{go} =	#DIV/0!	in	
Resulting Gas Outlet Nozzle Nominal	d_{goNPS} =	#DIV/0!	NPS		d_{goNPS} =	#DIV/0!	NPS	
Select Gas Oulet Nozzle Nom Diameter	d_{oNPS} =		NPS		d_{oNPS} =		NPS	
Resulting Gas Outlet Nozzle Velocity		#DIV/0!				#DIV/0!		
Resulting Gas Outlet Nozzle Momentum		#DIV/0!				#DIV/0!		
Recommended Allowable Momentum		3025				3025		
Gas Outlet Momentum Criteria Check	#DIV/0!				#DIV/0!			
Minimum Water Outlet Nozzle ID	d_{wo} =	0.00	in		d_{wo} =	0.00	in	
Minimum Water Outlet Nominal Pipe Size	d_{woNPS} =	#N/A	NPS		d_{woNPS} =	#N/A	NPS	
Minimum Oil Outlet Nozzle ID	d_{oo} =	0.00	in		d_{oo} =	0.00	in	
Minimum Oil Outlet Nominal Pipe Size	d_{ooNPS} =	#N/A	NPS		d_{ooNPS} =	#N/A	NPS	
Mist Extractor Velocity	V_{mistex} =	#DIV/0!	ft/s		V_{mistex} =	#DIV/0!	ft/s	
Minimum Mist Extractor OD	M_{od} =	#DIV/0!	in		M_{od} =	#DIV/0!	in	

Design Optimization:

	Calculated	Possible Alternatives			Calculated	Possible Alternatives		
Outside Diameter (in)	0	-6	6	12	0	-6	6	12
Seam to Seam Length (ft)	0	-2	2	4	0	-2	2	4
Approximate Wall Thickness (in)	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063
Approximate Shell Weight (1,000lb)	0.00	0.01	0.01	0.03	0.00	0.01	0.01	0.03
Approximate Head Weight (1,000lb)	0.000	0.000	0.001	0.003	0.000	0.000	0.001	0.003
Approximate Vessel Weight (1,000 lb)	0.10	0.11	0.11	0.14	0.10	0.11	0.11	0.14
Relative Cost/1000	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.02

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ASME VIII, Div. 1 Design Optimization

Project:
Client:
Job Number: **By:**
Date: **Checked By:**
Revision: **Revision Date:**
General Notes: These calculations run a GRG nonlinear solver to minimize an objective function with given constraints to determine the most efficient vessel design
Project Notes:

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Design Parameters			Objective Function	
MAWP, P (psi)	500		$f(\mathbf{x})$	0.55
O.D. (in.)	24			
C.A. (in.)	0.0625			

Design Variables		Equations
Thickness, t (in.)	0.360	$f(x) = t * t_w + \frac{S}{20} * S_w + E * E_w$
Yield Strength, S (ksi)	20.00	$t = \frac{P * R_0}{S * E + 0.40 * P}$
Joint Efficiency, E	1.00	$10.0 \le S \le 20.0$
		$0.70 \le E \le 1.0$
		$t \ge 0.188$

Weight Function		Constraints	
Thickness Weight, tw	0.70	$g_1(\mathbf{x})$	-10
Material Grade Weight, Sw	0.15	$g_2(\mathbf{x})$	0.00E+00
Joint Efficiency Weight, Ew	0.15	$g_3(\mathbf{x})$	-0.3
		$g_4(\mathbf{x})$	0
Total Weight	1.00	$g_5(\mathbf{x})$	-0.172

Yellow = Spreadsheet Input Cells | Blue = Spreadsheet Calculation Cells

Input Vessel MAWP — Shows Objective Function Results
Input Vessel Outside Diameter
Input Vessel Corrosion Allowance

Design Variables and Constraint Functions
Optimized Vessel Wall Thickness
Optimized Yield Strength
Optimized Joint Efficiency

Input Manufacturers Relative Cost for Material Weight
Input Manufacturers Relative Cost for Material Grade
Input Manufacturers Relative Cost for NDT/NDE

Weight Inputs Must Total to 1.00

1. Load the Excel 2013 Solver Add-in: Click **File** tab, then click **Options**. Click **Add-Ins**, and then in the **Manage** box, select **Excel Add-Ins**. Click **Go**. In the **Add-Ins available** box, select the **Solver Add-In** check box and click **OK**. If **Solver Add-Ins** is not listed in the **Add-Ins available** box, click **Browse** to locate the add-in. If you get prompted that the Solver add-in is not currently installed on your computer, click **Yes** to install it. After you load the Solver add-in, the **Solver** command is available in the **Analysis** group on the **Data** tab.
2. Select the **Solver** command from the **Analysis** box under the **Data** tab.
3. Make sure the objective function is set to cell E11 (Green Cell), if it is not, click on the green cell (E11)
4. Make sure the "Min" box is selected, if not select "Min"
5. Make sure the "Make Unconstrained Variables Non-Negative" check box is selected
6. Make sure the GRG Nonlinear Solving Method is selected
7. Click "Solve"
8. Make sure "Keep Solver Solution" check box is selected, and click **OK**
9. The resulting output provides the most efficient thickness, material, and NDE combination based on the input weights assigned by the manufacturer

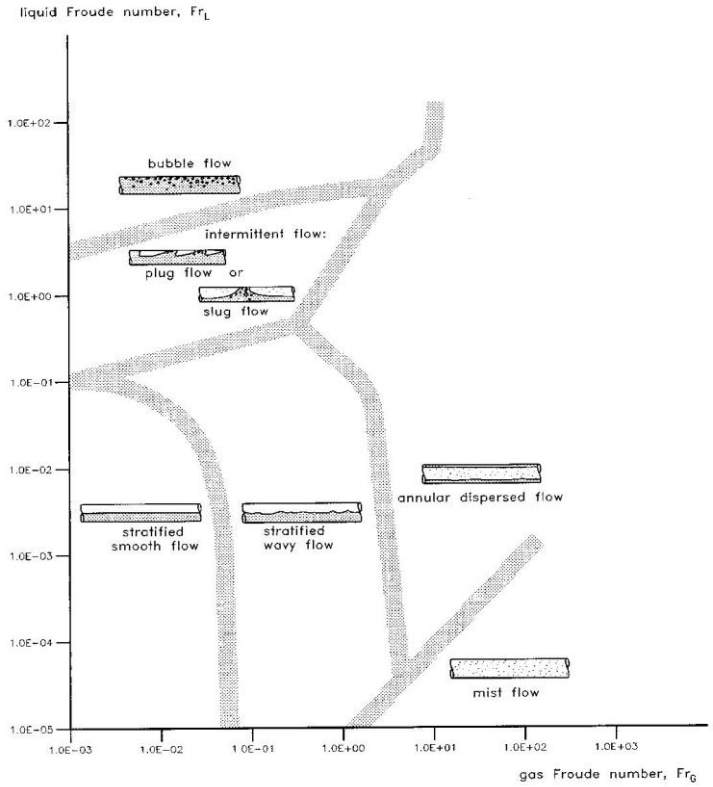
Developed by Sandstone Engineering, Ryan K. Malone, P.E.

3-Phase Horizontal Separator

Project:
Client:
Job Number: Tag No:
General Notes:
Project Notes:

Rev.	Description	By	Checked	Approved	Date

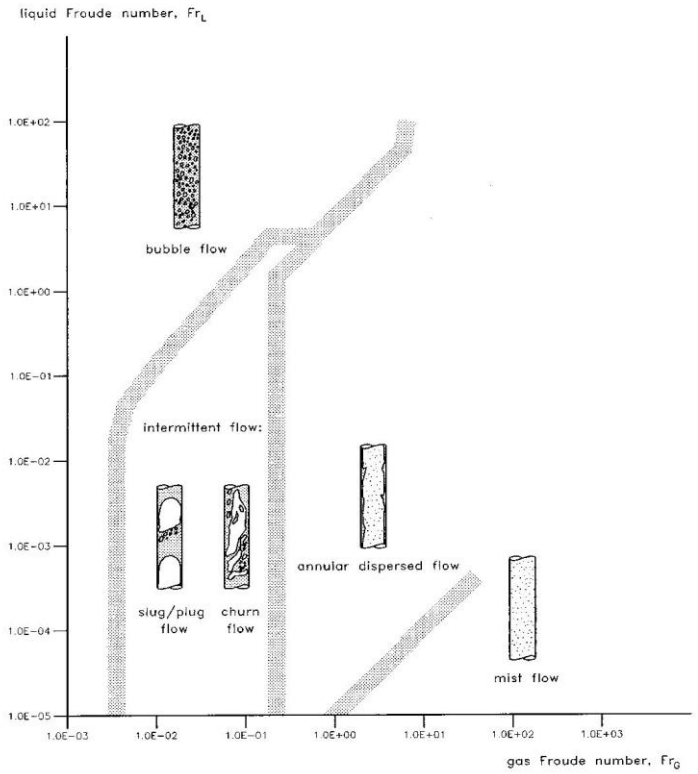
Two-Phase Flow Map for Horizontal Feed Pipes



Case 1:
Fr_L = #DIV/0!

Case 2:
Fr_L = #DIV/0!

Two-Phase Flow Map for Vertical Feed Pipes



Case 1: Fr_G = #DIV/0!
Case 2: Fr_G = #DIV/0!

Note: The flow maps are only applicable to very long pipes with equilibrium two-phase flow. However, if the feed pipe is longer than ten pipe diameters, the flow maps still give a fair indication of the prevailing flow regime for a given set of conditions.

FIG. 23-21
Viscosities of Hydrocarbon Liquids

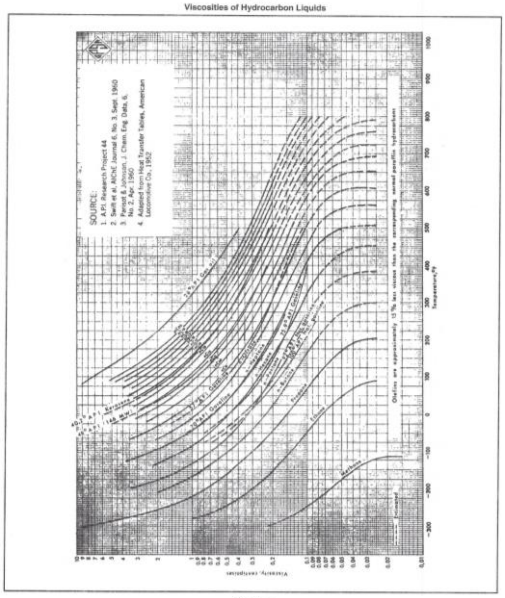
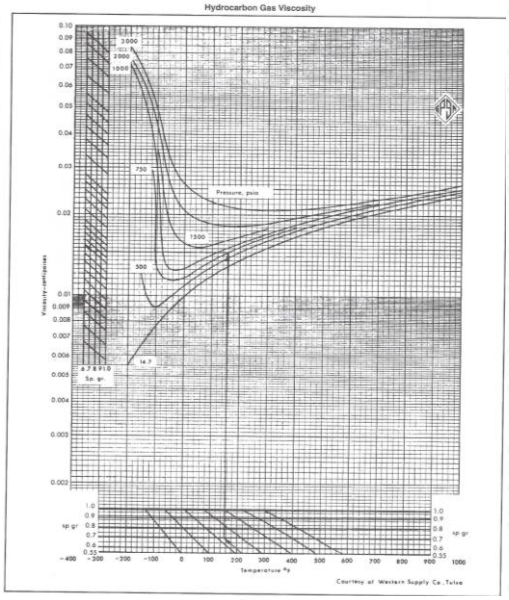


FIG. 23-23
Hydrocarbon Gas Viscosity



Gas or Vapor	Molecular Weight (kg/kmole)
Acetylene, C_2H_2	26.04
Air	28.966
Ammonia (R-717)	17.02
Argon, Ar	39.948
Benzene	78.11
N-Butane, C_4H_{10}	58.12
Iso-Butane (2-Metyl propane)	58.12
Butadiene	54.09
1-Butene	56.108
cis -2-Butene	56.108
trans-2-Butene	56.108
Isobutene	56.108
Carbon Dioxide, CO_2	44.01
Carbon Disulphide	76.13
Carbon Monoxide, CO	28.011
Chlorine	70.906
Cyclohexane	84.16
Deuterium	2.014
Ethane, C_2H_6	30.070
Ethyl Alcohol	46.07
Ethyl Chloride	64.515
Ethylene, C_2H_4	28.054
Fluorine	37.996
Helium, He	4.002602
N-Heptane	100.20
Hexane	86.17
Hydrochloric Acid	36.47
Hydrogen, H_2	2.016
Hydrogen Chloride	36.461
Hydrogen Sulfide	34.076
Hydroxyl, OH	17.01
Krypton	83.80
Methane, CH_4	16.044
Methyl Alcohol	32.04
Methyl Butane	72.15
Methyl Chloride	50.488
Natural Gas	19.00
Neon, Ne	20.179
Nitric Oxide, NO_2	30.006
Nitrogen, N_2	28.0134
Nitrous Oxide	44.012
N-Octane	114.22
Oxygen, O_2	31.9988
Ozone	47.998
N-Pentane	72.15
Iso-Pentane	72.15
Propane, C_3H_8	44.097
Propylene	42.08
R-11	137.37
R-12	120.92
R-22	86.48
R-114	170.93
R-123	152.93
R-134a	102.03
R-611	60.05
Sulfur	32.02
Sulfur Dioxide (Sulphur Dioxide)	64.06
Sulfuric Oxide	48.1
Toluene	92.13
Xenon	131.30
Water Vapor - Steam, H_2O	18.02

FIG. 23-5
Compressibility of Low-Molecular-Weight Natural Gases[11]

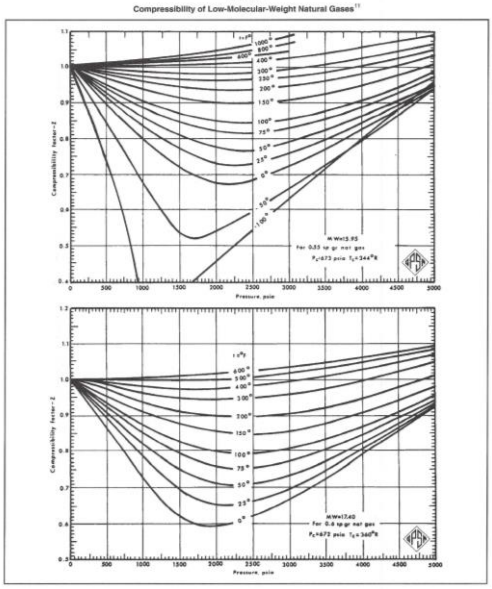


FIG. 23-6
Compressibility of Low-Molecular-Weight Natural Gases[11]

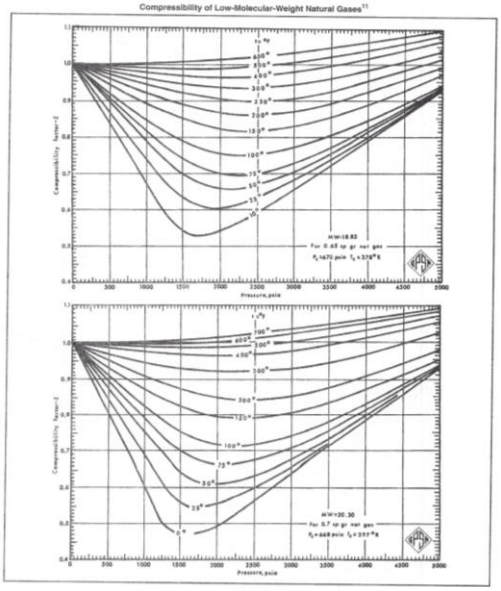


FIG. 23-7
Compressibility of Low-Molecular-Weight Natural Gases[11]

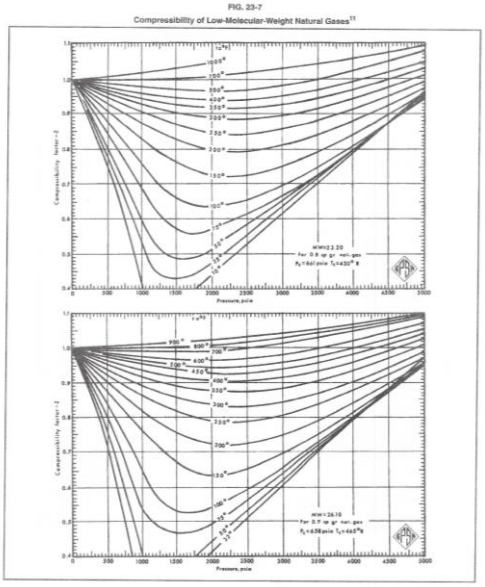


FIG. 7-22
Typical Retention Times for Liquid-Liquid Separation

Type of Separation	Retention Time, minutes
Hydrocarbon/Water Separators	
Above 35º API hydrocarbon	**3 - 5**
Below 35º API hydrocarbon	
100ºF and above	**5 - 10**
80ºF	**10 - 20**
60ºF	**20 - 30**

Table 7-4
Typical Liquid Retention Times

Type of Treater	Typical Liquid Phase Retention Time
Gun Barrels or Wash Tanks	8 - 24 hr
Vertical Heater-Treater	0.5 - 4 hr
Horizontal Heater-Treater	0.5 - 4 hr
Electrostatic Treater	15 - 120 min
Free-Water Knockouts	25-30 min at 60ºF
	20-25 min at 70ºF
	15-20 min at 80ºF
	10-15 min at 90ºF
	5-10 min at 100+ºF