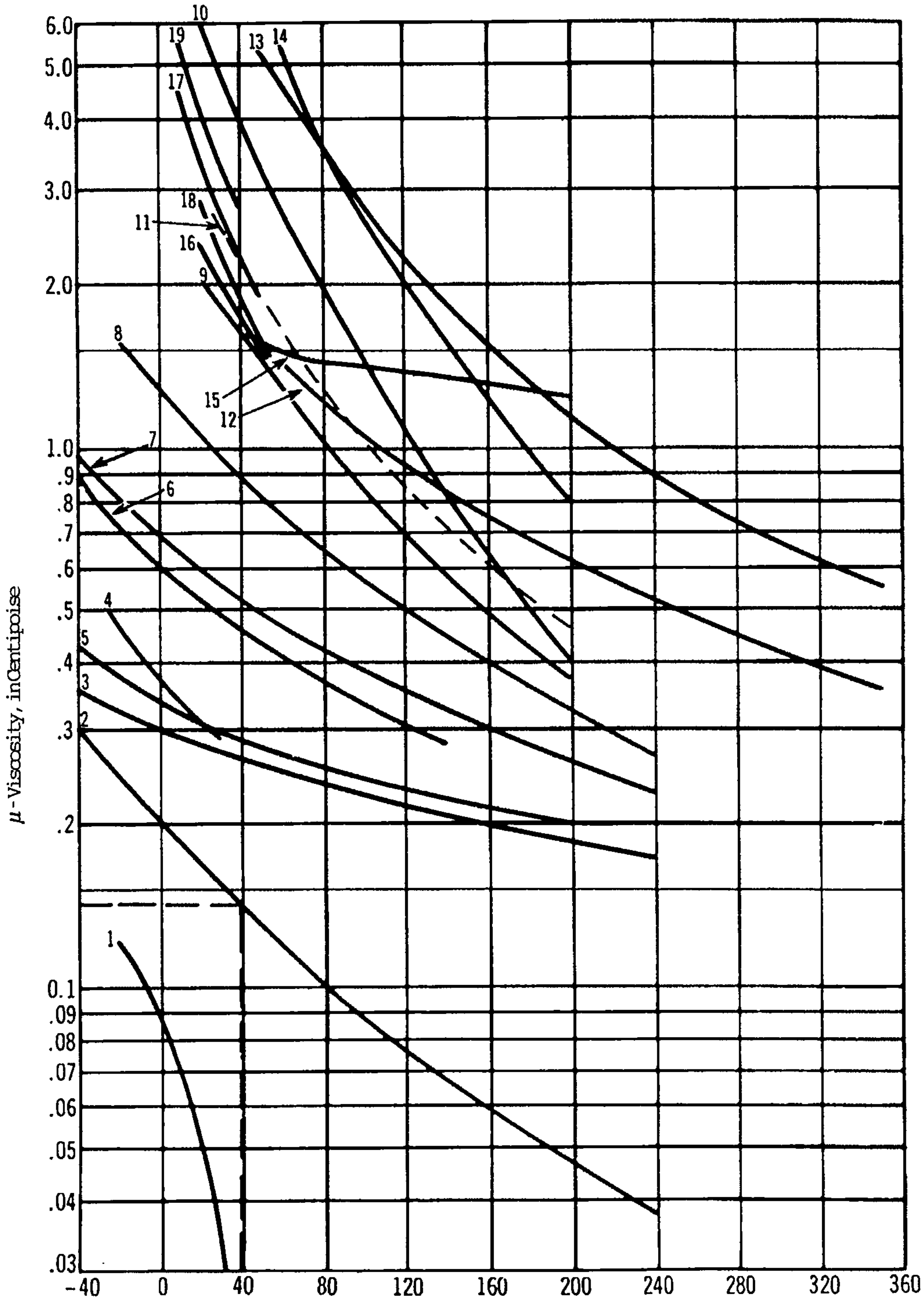
Viscosity of Various Liquids

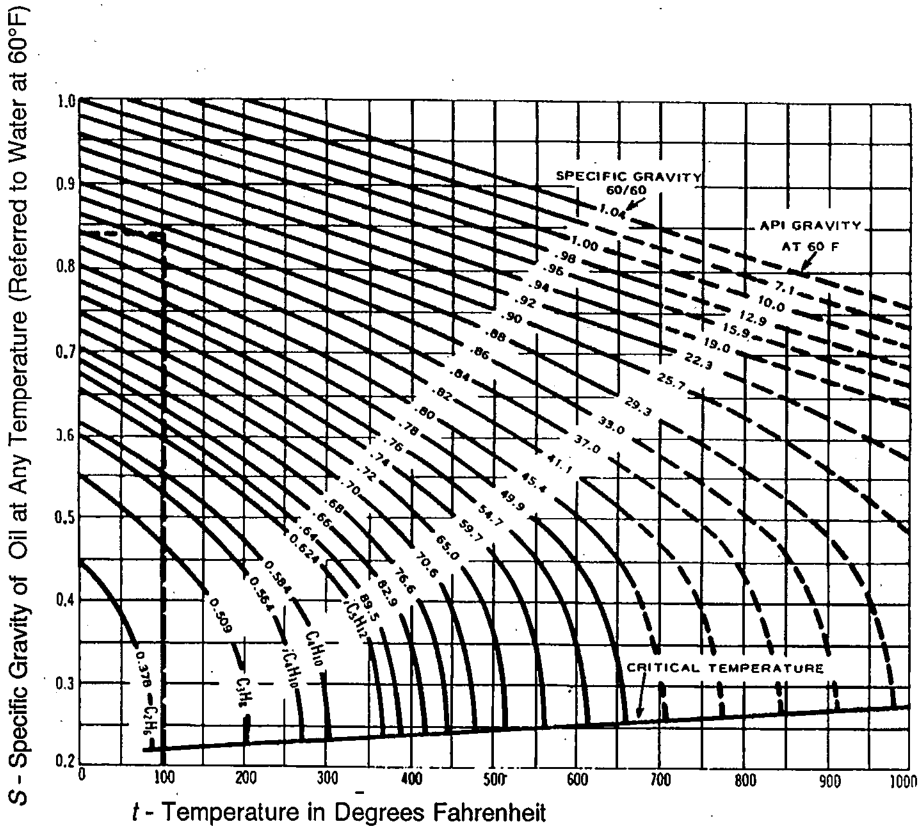


1. Carbon Dioxide (CO)
2. Ammonia (NH_4)
3. Methyl Chloride (CH_3Cl)
4. Sulphur Dioxide (SO_2)
5. Freon 12 (F-12)
6. Freon 114 (F-114)
7. Freon 11 (F-11)
8. Freon 113 (F-113)
9. Ethyl Alcohol
10. Isopropyl Alcohol
11. 20% Sulphuric Acid (20% H2SO4)
12. Dowtherm E
13. Dowtherm A
14. 20% Sodium Hydroxide (20% H_2SO4)
15. Mercury
16. 10% Soduim Chloride Brine
17. 20% Sodium Chloride Brine
18. 10% Calcium Chloride Brine
19. 20% Calcium Chloride Brine

Example: The viscosity of ammonia at 40°F is 0.14 centipoise.

Specific Gravity - Temperature Relationship for Petroleum Oils

(Reprinted by permission from the *Oil and Gas Journal)*



C_2H6 = Ethane　iC_4H_{10} = Isobutane
C_3H_8 = Propane　iC_5H_{10} = Isopentane
C_4H_{10} = Butane

Example: The specific gravity of an oil at 60°F is 0.85. The specific gravity at 100°F is 0.81.

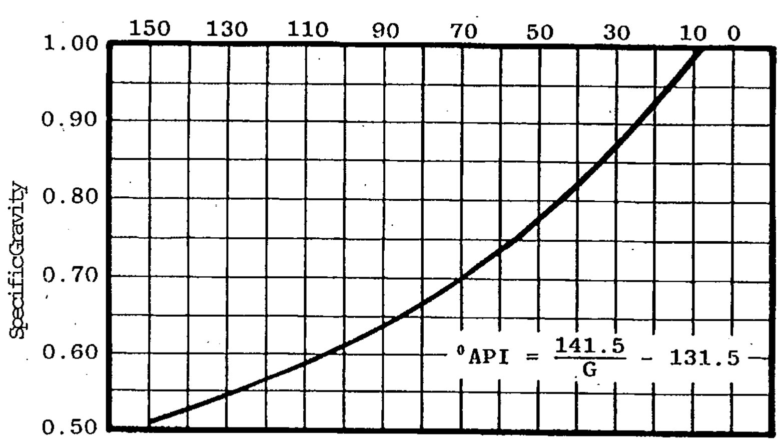
* Reprinted from Crane Company's Technical Paper 410.

To find the weight density of a petroleum oil at its flowing temperature when the specific gravity at 60°F is known, multiply the specific gravity of the oil at flowing temperature (see chart above) by 62.4, the density of water at 60°F.

Chart For Specific Gravity Versus API Gravity

For Hydrocarbon Based Products and Water

Gravity °A.P.I.



Properties of Selected Liquids

Liquid	Temp °F	Density* lb/ft^3	Specific** Gravity
Acetaldehyde	64	48.9	0.784
Acetone	60	49.4	0.792
Acetic Anhydride	68	67.5	1.083
Acid, Acetic Conc.	68	65.5	1.050
Acid, Benzoic	59	79.0	1.267
Acid, Butyric, Conc.	68	60.2	0.965
Acid, Hydrochloric, 42.5%	64	92.3	1.400
Acid, Hydrocyanic	64	43.5	0.697
Acid, Nitric, Conc. Boil.	64	93.7	1.502
Acid, Ortho-phosphoric	65	114.4	1.834
Ammonia, Saturated	10	40.9	0.656
Aniline	68	63.8	1.023
Benzene	32	56.1	0.899
Brine, 10% CaCl	32	68.1	1.091
Brine, 10% NaCl	32	67.2	1.078
Bunker C Fuel Max	60	63.3	1.014
Carbon Disulphide	32	80.6	1.292
Carbon Tetrachloride	68	99.6	1.597
Chlorobenzene	68	69.1	1.108
Cresol, Meta	68	64.5	1.035
Diphenyl	163	61.9	0.993
Distillate	60	53.0	0.850
Fuel 3 Max	60	56.0	0.898
Fuel 5 Min	60	60.2	0.966
Fuel 5 Max	60	61.9	0.993
Fuel 6 Min	60	61.9	0.993
Furfural	68	72.3	1.160
Gasoline	60	46.8	0.751
Gasoline, Natural	60	42.4	0.680
Glycerol	122	78.6	1.261
Heptane	68	42.7	0.685
Kerosene	60	50.8	0.815
M. C. Residuum	60	58.3	0.935
Mercury	20	849.7	13.623
Mercury	40	848.0	13.596
Mercury	60	846.3	13.568
Mercury	80	844.6	13.541
Mercury	100	842.9	13.514
Methylene Chloride	68	83.4	1.337
Milk	---	64.2-64.6	---
Oil, Olive	59	57.3	0.919
Pentane	59	38.9	0.624
Phenol	77	66.8	1.072
Pyridine	68	61.3	0.983
SAE 10 Lube	60	54.6	0.876
SAE 30 Lube	60	56.0	0.898
SAE 70 Lube	60	57.1	0.916
Salt Creek Crude	60	52.6	0.843
32.6° API Crude	60	53.8	0.862
35.6° API Crude	60	52.8	0.847
40° API	60	51.4	0.825
48° API Crude	60	49.2	0.788
Toluene (Toluol)	68	54.1	0.867
Trichloroethylene	68	91.5	1.468
Water	60	62.3707	1.000
Xylol (Xylene)	68	55.0	0.882

* Density is shown for the temperature listed.
** Specific gravity uses water at 60°F as base conditions.

Air Density

	Air Density lbm/ft³											
Temp °F	14.73 PSIA	100 PSIA	200 PSIA	300 PSIA	400 PSIA	500 PSIA	600 PSIA	700 PSIA	800 PSIA	900 PSIA	1000 PSIA	1100 PSIA
-40	0.0949	0.6488	1.3087	1.9796	2.661	3.3525	4.0533	4.7628	5.4798	6.2031	6.9315	7.6632
-20	0.0905	0.6182	1.245	1.8799	2.5227	3.1728	3.8295	4.492	5.1594	5.8308	6.5051	7.1811
0	0.0866	0.5905	1.1875	1.7906	2.3995	3.0135	3.6321	4.2547	4.8805	5.5086	6.1382	6.7684
20	0.0830	0.5652	1.1353	1.71	2.2887	2.8711	3.4567	4.0447	4.6347	5.2258	5.8175	6.409
40	0.0797	0.5421	1.0878	1.6368	2.1886	2.7429	3.2992	3.857	4.4157	4.9748	5.5338	6.092
60	0.0765	0.5208	1.0442	1.5699	2.0974	2.6266	3.1569	3.6879	4.2191	4.7502	5.2805	5.8098
80	0.0737	0.5012	1.0041	1.5085	2.0141	2.5205	3.0275	3.5347	4.0416	4.5478	5.0529	5.5567
100	0.0711	0.4829	0.9670	1.4519	1.9375	2.4234	2.9093	3.3949	3.8798	4.3637	4.8464	5.3274
120	0.0687	0.4660	0.9327	1.3997	1.8668	2.3339	2.8006	3.2666	3.7316	4.1954	4.6577	5.1184
140	0.0664	0.4503	0.9007	1.3511	1.8013	2.2511	2.7001	3.1482	3.5951	4.0406	4.4845	4.9265
160	0.0641	0.4356	0.871	1.3061	1.7406	2.1744	2.6073	3.0391	3.4695	3.8985	4.3257	4.7509
180	0.0621	04218	0.8432	1.264	1.684	2.103	2.521	2.938	3.3529	3.7665	4.1783	4.5882
200	0.0602	0.4089	0.8171	1.2246	1.6311	2.0364	2.4405	2.8432	3.2444	3.6439	4.0417	4.4375
220	0.0585	0.3967	0.7927	1.1877	1.5815	1.9741	2.3654	2.7551	3.1432	3.5296	3.9144	4.2972
240	0.0568	0.3853	0.7697	1.1529	1.5349	1.9156	2.2948	2.6725	3.0485	3.4228	3.7953	4.1658
260	0.0552	0.3745	0.7480	1.1202	1.4911	1.8606	2.2288	2.5956	2.9608	3.3239	3.6846	4.0424
280	0.0537	0.3644	0.7275	1.0893	1.4497	1.8088	2.1666	2.5231	2.8779	3.2306	3.5803	3.9264
300	0.0523	0.3547	0.7081	1.0601	1.4107	1.7599	2.1078	2.4546	2.7997	3.1424	3.4819	3.8174
320	0.0510	0.3456	0.6898	1.0325	1.3737	1.7136	2.0523	2.3897	2.7356	3.059	3.389	3.7147
340	0.0497	0.3369	0.6724	1.0063	1.3388	1.6698	1.9997	2.3283	2.7553	2.98	3.3013	3.6184

Properties of Selected Gases

Gas	Chemical Formula	Molecular Weight	Density* lb/ft^3	Specific** Gravity	Individual Gas Constant R	Ratio of Specific Heat $K = C_p/C_v$
Acetylene	C_2H_2	26.0382	.06858	0.897	59.348	1.28
Air	---	28.9644	.07649	1.000	53.352	1.40
Ammonia	NH_3	17.0306	.04488	0.587	90.738	1.29
Argon	A	39.9480	.10553	1.379	38.683	1.67
Butane-N	C_4H_{10}	58.1243	.15873	2.075	26.586	1.09
Carbon Dioxide	CO_2	44.0100	.11684	1.528	35.113	1.28
Carbon Monoxide	CO	28.0106	.07397	0.967	55.169	1.41
Chlorine	Cl_2	70.9060	.19046 0°C	2.490 0°C	21.794	1.36
Ethane	C_2H_6	30.0701	.08005	1.047	51.391	1.19
Ethylene	C2H4	28.0542	.07392	0.967	55.083	1.22
Helium	He	4.00260	.01056	0.138	386.07	1.66
Heptane, Average	C_7H_{16}	100.2060	.26451	3.458	15.421	
Hexane, Average	C_6H_{14}	86.1785	.22748	2.974	17.932	1.08
Hydrochloric Acid	HCl	36.4610	.09606	1.256	42.383	1.40
Hydrogen	H_2	2.01594	.00532	0.070	766.55	1.40
Hydrogen Sulfide	H_2S	34.0799	.09024	1.177	45.344	1.32
Methane	CH_4	16.0430	.04243	0.555	96.324	1.31
Methyl Chloride	CH_3Cl	50.4881	.13292	1.738	30.606	1.20
Neon	Ne	20.1830	.05155	0.674	76.565	1.64
Nitric Oxide	NO	30.0061	.07908	1.034	51.500	1.40
Nitrogen	N_2	28.0130	.07397	0.967	55.164	1.40
Nitrous Oxide	N_2O	44.0128	.11606	1.518	35.111	1.26
Octane, Average	C_8H_{18}	114.2330	.30153	3.942	13.528	
Oxygen	O_2	31.9988	.08453	1.105	48.293	1.40
Pentane, ISO	C_5H_{12}	72.1514	.19045	2.490	21.418	1.06
Propane	C_3H_8	44.0972	.11854	1.550	35.044	1.33
Propylene	C_3H_6	42.081	.04842 -47°C	0.634 -47°C	36.722	1.14
Sulphur Dioxide	SO_2	64.0630	.16886	2.208	24.122	1.25

* Density is given for gas at 14.73 psia and 60°F unless noted.
** Specific gravity used air at 14.73 and 60°F as base conditions.

Viscosity of Gases and Vapors

The curves for hydrocarbon vapors and natural gases in the chart at the upper right are taken from Maxwell. The curves for all other gases (except helium) in the chart are based upon Sutherland's formula, as follows:

$$\mu = \mu_0 \left(\frac{0.555T_0 + C}{0.555T + C} \right) \left(\frac{T}{T_0} \right)^{\frac{3}{2}}$$

where:

μ = viscosity, in centipoise at temperature T.

μ_o = viscosity, in centipoise at temperature T_o.

T = absolute temperature, in degrees Rankine (460 + deg. F) for which viscosity is desired.

To = absolute temperature, in degrees Rankine, for which viscosity is known.

C = Sutherland's constant.

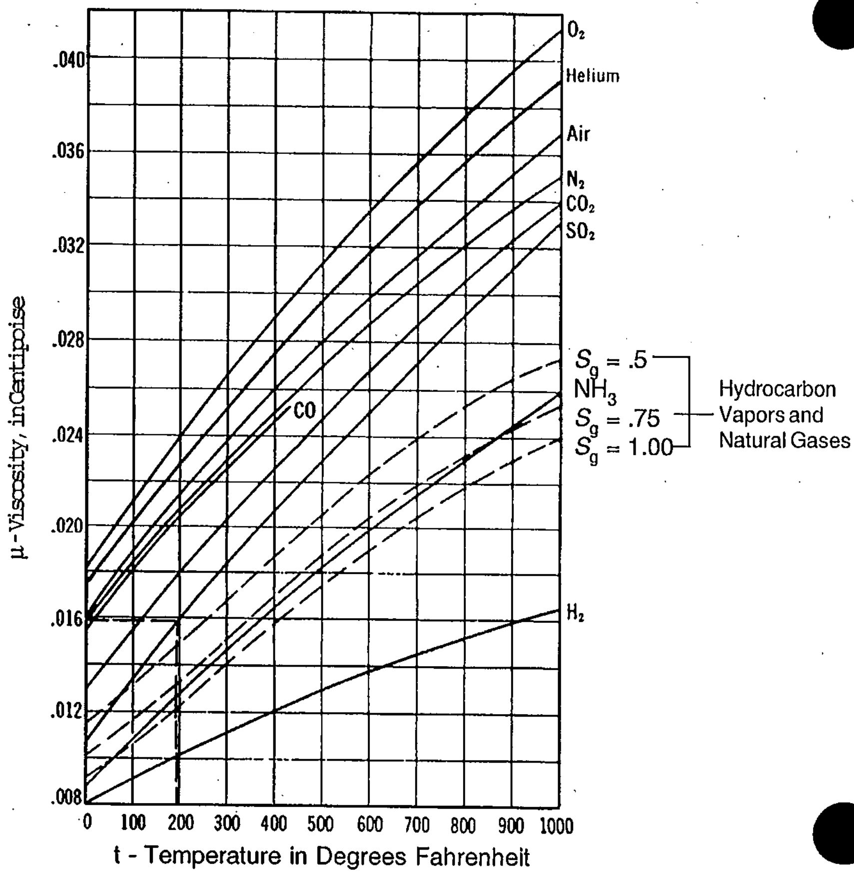
Note: The variation of viscosity with pressure is small for most gases. For gases given on this page, the correction of viscosity for pressure is less than 10 percent for pressures up to 500 pounds per square inch.

Fluid	Approximate Values of "C"
O2	127
Air	120
N2	111
CO2	240
CO	118
SO2	416
NH3	370
H2	72

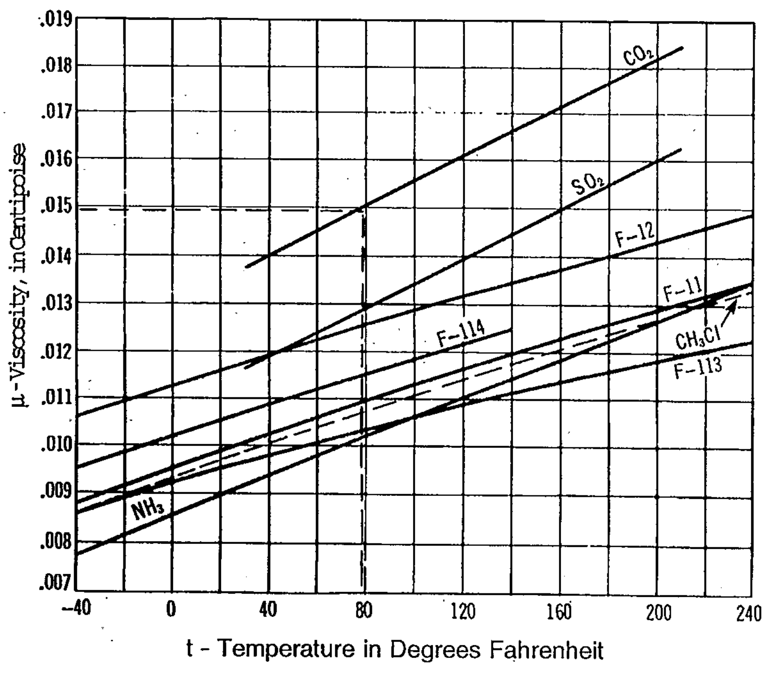
Upper chart example: The viscosity of sulphur dioxide gas (SO_2) at 200°F is 0.016 centipoise.

Lower chart example: The viscosity of carbon dioxide gas (CO_2) at about 80°F is 0.015 centipoise.

Viscosity of Various Gases



Viscosity of Refrigerant Vapors
(saturated and superheated vapors)



Appendix B

Units and Conversion Factors

NOTES

Equivalents of Absolute Viscosity

Absolute or Dynamic Viscosity		*Centipoise* (μ)	*Poise* $\frac{Gram}{CmSec}$ $\frac{DyneSec}{Cm^2}$ (100μ)	$\frac{Slugs}{FtSec}$ $\frac{Pound_f Sec}{Ft^2}$ (μ'_e)	$\frac{Pounds_m}{FtSec}$ $\frac{PoundalSec}{Ft^2}$ (μ_e)
Centipoise	(μ)	**1**	**0.01**	**2.09 (10^{-3})**	**6.72 (10^{-4})**
Poise $\frac{Gram}{CmSec}$ $\frac{DyneSec}{Cm^2}$	**(100μ)**	**100**	**1**	**2.09 (10-3**	**0.0672**
$\frac{Slugs}{FtSec}$ $\frac{Pound_f Sec}{Ft^2}$	(μ'_e)	**47,900**	**479**	**1**	***g* or 32.3**
$\frac{Pounds_m}{FtSec}$ $\frac{PoundalSec}{Ft^2}$	(μ_e)	**1487**	**14.87**	**1/*g* or .0311**	**1**

$Pound_f$ = Pound of Force *$Pound_m$ = Pound of Mass*

To convert absolute or dynamic viscosity from one set of units to another, locate the given set of units in the left hand column and multiply the numerical value by the factor shown horizontally to the right under the set of units desired.

As an example, suppose a given absolute viscosity of 2 poise is to be converted to slugs/foot-second. By referring to the table, we find the conversion factor to be 2.09 (10^{-3}). Then, 2 (poise) times 2.09 (10^{-3}) = 4.18 (10^{-3}) = 0.00418 slugs/foot-second.

Equivalents of Kinematic Viscosity

Kinematic Viscosity		*Centistokes* (ν)	*Stokes* $\frac{Cm^2}{Sec}$ (100ν)	$\frac{Ft^2}{Sec}$ (ν')
Centistokes	**(ν)**	**1**	**0.01**	**1.076 (10^{-3})**
Stokes $\frac{Cm^2}{Sec}$	**(100ν)**	**100**	**1**	**2.09 (10-3)**
$\frac{Ft^2}{Sec}$	(ν')	**92,900**	**929**	**1**

To convert kinematic viscosity from one set of units to another, locate the given set of units in the left hand column and multiply the numerical value by the factor shown horizontally to the right under the set of units desired.

As an example, suppose a given kinematic viscosity of 0.5 square foot/second is to be converted to centistokes. By referring to the table, we find the conversion factor to be 92,900. Then, 0.5 (sq ft/sec) times 92,900 = 46,450 centistokes.

Equivalents of Kinematic Viscosity and Saybolt Universal Viscosity

Kinematic Viscosity Centistokes ν	Equivalent Saybolt Universal Viscosity, Sec. At 100°F Basic Values	At 210°F
1.83	32.01	32.23
2.0	32.62	32.85
4.0	39.14	39.41
6.0	45.56	45.88
8.0	52.09	52.45
10.0	58.91	59.32
15.0	77.39	77.93
20.0	97.77	98.45
25.0	119.3	120.1
30.0	141.3	142.3
35.0	163.7	164.9
40.0	186.3	187.6
45.0	209.1	210.5
50.0	232.1	233.8
55.0	255.2	257.0
60.0	278.3	280.2
65.0	301.4	303.5
70.0	324.4	326.7
75.0	347.6	350.0
80.0	370.8	373.4
85.0	393.9	396.7
90.0	417.1	420.0
95.0	440.3	443.4
100.0	463.5	466.7
120.0	556.2	560.1
140.0	648.9	653.4
160.0	741.6	
180.0	834.2	
200.0	926.9	
220.0	1019.6	
240.0	1112.3	
260.0	1205.0	
280.0	1297.7	
300.0	1390.4	
320.0	1483.1	
340.0	1575.8	
360.0	1668.5	
380.0	1761.2	
400.0	1853.9	
420.0	1946.6	
440.0	2039.3	
460.0	2132.0	
480.0	2224.7	
500.0	2317.4	
Over 500	Saybolt Seconds equal Centistokes times 4.6347	Saybolt Seconds equal Centistokes times 4.6673

Note: To obtain the Saybolt Universal viscosity equivalent to a kinematic viscosity determined at *t*, multiply the equivalent Saybolt Universal viscosity at 100°F by 1 + (*t* - 100) 0.000 064.

For example: 10ν at 210°F are equivalent to 58.91 multiplied by 1.0070 or 59.32 sec Saybolt Universal at 210°F.

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Equivalents of Kinematic Viscosity and Saybolt Furol Viscosity

Kinematic Viscosity Centistokes ν	Equivalent Saybolt Furol Viscosity, Sec. At 122°F	At 210°F
48	25.3	
50	26.1	25.2
60	30.6	29.8
70	35.1	34.4
80	39.6	39.0
90	44.1	43.7
100	48.6	48.3
125	60.1	60.1
150	71.7	71.8
175	83.8	83.7
200	95.0	95.6
225	106.7	107.5
250	118.4	119.4
275	130.1	131.4
300	141.8	143.5
325	153.6	155.5
350	165.3	167.6
375	177.0	179.7
400	188.8	191.8
425	200.6	204.0
459	212.4	216.1
475	224.1	228.3
500	235.9	240.5
525	247.7	252.8
550	259.5	265.0
575	271.3	277.2
600	283.1	289.5
625	294.9	301.8
650	306.7	314.1
675	318.4	326.4
700	330.2	338.7
725	342.0	351.0
750	353.8	363.4
775	365.5	375.7
800	377.4	388.1
825	389.2	400.5
850	400.9	412.9
875	412.7	425.3
900	424.5	437.7
925	483.5	450.1
950	488.1	462.5
975	459.9	474.9
1000	471.7	487.4
1025	483.5	499.8
1050	495.2	512.3
1075	507.0	524.8
1100	518.8	537.2
1125	530.6	549.7
1150	542.4	562.2
1175	554.2	574.7
1200	566.0	587.2
1225	577.8	599.7
1150	589.5	612.2
1275	601.3	624.8
1300	613.1	637.3
Over 1300	*	**

***Over 1300 Centistokes at 122°F:**
Saybolt Fluid Sec = Centistokes x 0.4717

****Over 1300 Centistokes at 210°F:**
Log (Saybolt Furol Sec - 2.87) = 1.0276 [Log (Centistokes)] - 0.3975

Equivalents of Degrees API, Degrees Baume, Specific Gravity, Weight Density, and Pounds Per Gallon at 60°F / 60°F

Degrees on API or Baume Scale	Values for API Scale			Values for Baume Scale					
	Oil			Liquids lighter than water			Liquids heavier than water		
	Specific Gravity S	Weight Density Lb/Ft^3 ρ	Pounds per Gallon	Specific Gravity S	Weight Density Lb/Ft^3Gallon ρ	Pounds per S	Specific Gravity Lb/Ft^3 ρ	Weight Density Gallon	Pounds per
0							1.0000	62.36	8.337
2							1.0140	63.24	8.454
4							1.0284	64.14	8.574
6							1.0432	65.06	8.697
8							1.0584	66.01	8.824
10	1.0000	62.36	8.337	1.0000	62.36	8.337	1.0741	66.99	8.955
12	0.9861	61.50	8.221	0.9859	61.49	8.219	1.0902	67.99	9.089
14	0.9725	60.65	8.108	0.9722	60.63	8.105	1.1069	69.03	9.228
16	0.9593	59.83	7.998	0.9589	59.80	7.994	1.1240	70.10	9.371
18	0.9465	59.03	7.891	0.9459	58.99	7.886	1.1417	71.20	9.518
20	0.9340	58.25	7.787	0.9333	58.20	7.781	1.1600	72.34	9.671
22	0.9218	57.87	7.736	0.9211	57.44	7.679	1.1789	73.52	9.828
24	0.9100	56.75	7.587	0.9091	56.70	7.579	1.1983	74.73	9.990
26	0.8984	56.03	7.490	0.8974	55.97	7.482	1.2185	75.99	10.159
28	0.8871	55.32	7.396	0.8861	55.26	7.387	1.2393	77.29	10.332
30	0.8762	54.64	7.305	0.8750	54.57	7.295	1.2609	78.64	10.512
32	0.8654	53.97	7.215	0.8642	53.90	7.205	1.2832	80.03	10.698
34	0.8550	53.32	7.128	0.8537	53.24	7.117	1.3063	81.47	10.891
36	0.8448	52.69	7.043	0.8434	52.60	7.031	1.3303	82.96	11.091
38	0.8348	52.06	6.960	0.8333	51.97	6.947	1.3551	84.51	11.297
40	0.8251	51.46	6.879	0.8235	51.36	6.865	1.3810	86.13	11.513
42	0.8155	50.86	6.799	0.8140	50.76	6.786	1.4078	87.80	11.737
44	0.8063	50.28	6.722	0.8046	50.18	6.708	1.4356	89.53	11.969
46	0.7972	49.72	6.646	0.7955	49.61	6.632	1.4646	91.34	12.210
48	0.7883	49.16	6.572	0.7865	49.05	6.557	1.4948	93.22	12.462
50	0.7796	48.62	6.499	0.7778	48.51	6.484	1.5263	95.19	12.725
52	0.7711	48.09	6.429	0.7692	47.97	6.413	1.5591	97.23	12.998
54	0.7628	47.57	6.359	0.7609	47.45	6.344	1.5934	99.37	13.284
56	0.7547	47.07	6.292	0.7527	46.94	6.275	1.6292	101.60	13.583
58	0.7467	46.57	6.225	0.7447	46.44	6.209	1.6667	103.94	13.895
60	0.7389	46.08	6.160	0.7368	45.95	6.143	1.7059	106.39	14.222
62	0.7313	45.61	6.097	0.7292	45.48	6.079	1.7470	108.95	14.565
64	0.7238	45.14	6.034	0.7216	45.00	6.016	1.7901	111.64	14.924
66	0.7165	44.68	5.973	0.7143	44.55	5.955	1.8354	114.46	15.302
68	0.7093	44.23	5.913	0.7071	44.10	5.895	1.8831	117.44	15.699
70	0.7022	43.79	5.854	0.7000	43.66	5.836	1.9333	120.57	16.118
72	0.6953	43.36	5.797	0.6931	43.22	5.778			
74	0.6886	42.94	5.741	0.6863	42.80	5.722			
76	0.6819	42.53	5.685	0.6796	42.38	5.666			
78	0.6754	42.12	5.631	0.6731	41.98	5.612			
80	0.6690	41.72	5.577	0.6667	41.58	5.558			
82	0.6628	41.33	5.526	0.6604	41.19	5.506			
84	0.6566	40.95	5.474	0.6542	40.80	5.454			
86	0.6506	40.57	5.424	0.6482	40.42	5.404			
88	0.6446	40.20	5.374	0.6422	40.05	5.354			
90	0.6388	39.84	5.326	0.6364	39.69	5.306			
92	0.6331	39.48	5.278	0.6306	39.33	5.257			
94	0.6275	39.13	5.231	0.6250	38.98	5.211			
96	0.6220	38.79	5.186	0.6195	38.63	5.165			
98	0.6166	38.45	5.141	0.6140	38.29	5.119			
100	0.6112	38.12	5.096	0.6087	37.96	5.075			

Equivalents

Measure

1 in.	=	25.4mm
1 in.	=	2.54 cm
1mm	=	0.03937 in
1mm	=	0.00328 ft
1 micron	=	0.000001 meter
1torr	=	1 mm mercury
10^2	=	1 atom mercury
1 ft	=	304.8mm
1ft	=	30.48 cm
1 sq in	=	6.4516 sq cm
1 sq cm	=	0.155 sq in
1 sq cm	=	0.00108 sq ft
1 sq ft	=	929.03 sq cm

Circumference of a circle = $2\pi r = \pi d$

Area of a circle = $\pi r^2 = \pi d^2/4$

Weight

1 kg	=	2.205 lb
1 cu in of water (60°F)	=	0.073551 cu in of mercury (32°F)
1cu in of mercury (32°F)	=	13.596 cu in of water (60°F)
1cu in of mercury (32°F)	=	0.4905 lb

Velocity

1 ft per sec	=	0.3048 m per sec
1 m per sec	=	3.208 ft per sec

Density

1 lb per cu in	=	27.68 gram per cu cm
1 gr per cu cm	=	0.03613 lb per cu in
1 lb per cu ft	=	16.0184 kg per cu m
1 kg per cu m	=	0.06243 lb per cu ft

Physical Constants

Base of Natural Logarithms (*e*) 2.718 281 828 5
Acceleration of Gravity (*g*) .... 32.174 ft/sec^2....... (980.665 cm/sec^2)
Pi (π) 3.141 592 653 6

	Degrees Kelvin	Degrees Rankine	Degrees Celcius	Degrees Fahrenheit
Absolute Zero	0	0	-273.15	-459.67
Water Freezing Point (14.696 psia)	273.15	491.67	0	0
Water Boiling Point (14.696 psia)	373.15	671.67	100	212

Physical Constants

To convert degrees Celsuis to degrees Fahrenheit: $t = 1.8t_C + 32$

To convert degrees Fahrenheit to degrees Celsuis: $t_C = \dfrac{t-32}{1.8}$

where t_C = temperature in degrees Celcius

Prefixes

atto .... a ... one-quintillionth .... 0.000 000 000 000 000 001 .... 10^{-18}
femto .... f .... one-quadrillionth .... 0.000 000 000 000 001 .... 10^{-15}
pico ...... p ... one-trillionth .... 0.000 000 000 001 .... 10^{-12}
nano ..... n ... one-billionth .... 0.000 000 001 .... 10^{-9}
micro .... m .. one-millionth .... 0.000 001 .... 10^{-6}
milli .... m .. one-thousandth .... 0.001 .... 10^{-3}
centi ..... c ... one-hundredth .... 0.01 .... 10^{-2}
deci ...... d ... one-tenth .... 0.1 .... 10^{-1}
uni .... one .... 1.0 .... 10^{-0}
deka ..... da . ten .... 10.0 .... 10^{1}
hecto .... h ... one-hundred .... 100.0 .... 10^{2}
kilo .... k ... one-thousand .... 1 000.0 .... 10^{3}
mega .... M .. one-million .... 1 000 000.0 .... 10^{6}
giga ...... G .. one-billion .... 1 000 000 000.0 .... 10^{9}
tera .... T .. one-trillion .... 1 000 000 000 000.0 .... 10^{12}

Equivalents of Liquid Measures and Weights

To Obtain ☞ Multiply Column x Row	U.S. Gallon	Imperial Gallon	U.S. Pint	U.S. Pound Water *	U.S. Cubic Foot	U.S. Cubic Inch	Liter	Cubic Meter
U.S. Gallon	1	0.833	8	8.337	0.13368	231	3.78533	0.003785
Imperial Gallon	1.2009	1	9.60752	10	0.16054	277.42	4.54596	0.004546
U.S. Pint	0.125	0-.1041	1	1.042	0.01671	28.875	0.473166	0.000473
U.S. Pound Water	0.11995	0.1	0.9596	1	0.016035	27.708	0.45405	0.000454
U.S. Cubic Foot	7.48052	6.22888	59.8442	62.365	1	1728	28.31702	0.028317
U.S. Cubic Inch	0.004329	0.00361	0.034632	0.03609	0.0005787	1	0.016387	0.0000164
Liter	0.2641779	0.2199756	2.113423	2.202	0.0353154	61.02509	1	0.001000
Cubic Meter	264.170	219.969	2113.34	2202	35.31446	61023.38	999.972	1

* Water at 60°F (15.6°C) 1 Barrel = 42 gallons (petroleum measure)

Example:
(8 Imperial gallons) (4.54596 = 36.36768 liters

To convert from one set of units to another, locate the given unit in the left column and multiply the numerical value by the factor shown horizontally to the right under the set of units desired.

Equivalents of Pressure and Head

To Obtain ☞ Multiply Column x Row	lb/in²	lb/ft²	Atmo-spheres	kg/cm²	kg/m²	in. water (68°F/20°C)	ft. water (68°F/20°C)	in. mercury (32°F/0°C)	mm mercury (32°F/0°C)	Bars	MPa*	KPa	mm water (68°F/20°C)
lb/in²	1	.144	0.068046	0.070307	703.070	27.7300	2.3108	2.03602	51.7149	0.068948	0.0068948	6.8948	704.342
lb/ft²	0.0069444	1	0.000473	0.000488	4.88243	0.19257	0.016048	0.014139	0.35913	0.004788	0.0000479	0.04788	4.89127
Atmospheres	14.696	2116.22	1	1.0332	10332	407.520	33.9600	29.921	760.00	1.01325	0.101325	101.325	10351.0
kg/cm²	14.2233	2048.16	0.96784	1	10000	394.41	32.868	28.959	735.558	0.98066	0.098066	98.066	10018.1
kg/m²	0.001422	0.204816	0.0000968	0.0001	1	0.3944	0.003287	0.002896	0.073556	0.000098	0.0000098	0.0098	1.00181
in/water	0.036062	5.1929	0.002454	0.00253	29.354	1	0.08333	0.073423	1.8649	0.002486	0.000249	0.24864	25.4
ft/water	0.432744	62.315	0.029446	0.030425	304.249	12	1	0.88108	22.3793	0.029837	0.0029837	2.9837	304.800
in. mercury	0.491154	70.7262	0.033420	0.03453	345.319	13.6197	1.1350	1	25.4	0.033864	0.0033864	3.3864	345.94
mm mercury	0.0193368	2.78450	0.0013158	0.0013595	13.595	0.53621	0.044684	0.03937	1	0.001333	0.0001333	0.13332	13.6197
Bars	14.5038	2088.54	0.98692	1.01972	10197.2	402.190	33.5158	29.5300	750.061	1	0.10	100	10215.6
MPa	145.038	20885.4	9.8692	10.1972	101972.0	4021.90	335.158	295.300	7500.61	10.0	1	1000	102156
KPa	0.145038	20.8854	0.0098692	0.0101972	101.972	4.02190	0.33516	0.2953	7.50061	0.01	0.001	1	102.156
mm water	.0014198	.20445	.0000966	.0000998	.99819	.039370	.003281	.002891	.073423	.0000979	.0000098	.0097889	1

* MPa (MegaPascal) = 10 Bars = 1,000,000 N/m² (Newtons/meter²)

Example:
(5 kg/cm²) (2048.16) = 10240.8 lb/ft²

To convert from one set of units to another, locate the given unit in the left column and multiply the numerical value by the factor shown horizontally to the right under the set of units desired.

Temperature Conversion

-459.4° TO 0°			1° TO 60°			61° TO 290°			300° TO 890°			900° TO 3000°		
C	F/C	F	C	F/C	F	C	F/C	F	C	F/C	F	C	F/C	F
-273	-459.4		-17.2	1	33.8	16.1	61	141.8	149	300	572	482	900	1652
-268	-450		-16.7	2	35.6	16.7	62	143.6	154	310	590	488	910	1670
-262	-440		-16.1	3	37.4	17.2	63	145.4	160	320	608	493	920	1688
-257	-430		-15.6	4	39.2	17.8	64	147.2	166	330	626	499	930	1706
-251	-420		-15.0	5	41.0	18.3	65	149.0	171	340	644	504	940	1724
-246	-410		-14.4	6	42.8	18.9	66	150.8	177	350	662	510	950	1742
-240	-400		-13.9	7	44.6	19.4	67	152.6	182	360	680	516	960	1760
-234	-390		-13.3	8	46.4	20.0	68	154.4	188	370	698	521	970	1778
-229	-380		-12.8	9	48.2	20.6	69	156.2	193	380	716	527	980	1796
-223	-370		-12.2	10	50.0	21.1	70	158.0	199	390	734	532	990	1814
-218	-360		-11.7	11	51.8	21.7	71	159.8	204	400	752	538	1000	1832
-212	-350		-11.1	12	53.6	22.2	72	161.6	210	410	770	549	1020	1868
-207	-340		-10.6	13	55.4	22.8	73	163.4	216	420	788	560	1040	1904
-201	-330		-10.0	14	57.2	23.3	74	165.2	221	430	806	571	1060	1940
-196	-320		-9.4	15	59.0	23.9	75	167.0	227	440	824	582	1080	1976
-190	-310		-8.9	16	60.8	24.4	76	168.8	232	450	842	593	1100	2012
-184	-300		-8.3	17	62.6	25.0	77	170.6	238	460	860	604	1120	2048
-179	-290		-7.8	18	64.4	25.6	78	172.4	243	470	878	616	1140	2084
-173	-280		-7.2	19	66.2	26.1	79	174.2	249	480	896	627	1160	2120
-169	-273	-459.4	-6.7	20	68.0	26.7	80	176.0	254	490	914	638	1180	2156
-168	-270	-454	-6.1	21	69.8	27.2	81	177.8	260	500	932	649	1200	2192
-162	-260	-436	-5.6	22	71.6	27.8	82	179.6	266	510	950	660	1220	2228
-157	-250	-418	-5.0	23	73.4	28.3	83	181.4	271	520	968	671	1240	2264
-151	-240	-400	-4.4	24	75.2	28.9	84	183.2	277	530	986	682	1260	2300
-146	-230	-382	-3.9	25	77.0	29.4	85	185.0	282	540	1004	693	1280	2336
-140	-220	-364	-3.3	26	78,8	30.0	86	186.8	288	550	1022	704	1300	2372
-134	-210	-346	-2.8	27	80.6	30.6	87	188.6	293	560	1040	732	1350	2462
-129	-200	-328	-2.2	28	82.4	31.1	88	190.4	299	570	1058	760	1400	2552
-123	-190	-310	-1.7	29	84.2	31.7	89	192.2	304	580	1076	788	1450	2642
-118	-180	-292	-1.1	30	86.0	32.2	90	194.0	310	590	1094	816	1500	2732
-112	-170	-274	-0.6	31	87.8	32.8	91	195.8	316	600	1112	843	1550	2822
-107	-160	-256	0.0	32	89.6	33.3	92	197.6	321	610	1130	871	1600	2912
-101	-150	-238	0.6	34	91.4	33.9	93	199.4	327	620	1148	899	1650	3002
-96	-140	-220	1.1	34	93.2	34.4	94	201.2	332	630	1166	927	1700	3092
-90	-130	-202	1.7	35	95.0	35.0	95	203.0	338	640	1184	954	1750	3182
-84	-120	-184	2.2	36	96.8	35.6	96	204.8	343	650	1202	982	1800	3272
-79	-110	-166	2.8	37	98.6	36.1	97	206.6	349	660	1220	1010	1850	3362
-73	-100	-148	3.3	38	100.4	36.7	98	208.4	354	670	1238	1038	1900	3452
-68	-90	-130	3.9	39	102.2	37.2	99	210.2	360	680	1256	1066	1950	3542
-62	-80	-112	4.4	40	104.0	37.8	100	212.0	366	690	1274	1093	2000	3632
-57	-70	-94	5.0	41	105.8	43	110	230	371	700	1292	1121	2050	3722
-51	-60	-76	5.6	42	107.6	49	120	248	377	710	1310	1149	2100	3812
-46	-50	-58	6.1	43	109.4	54	130	266	382	720	1328	1177	2150	3902
-40	-40	-40	6.7	44	111.2	60	140	284	388	730	1346	1204	2200	3992
-34	-30	-22	7.2	45	113.0	66	150	302	393	740	1364	1232	2250	4082
-29	-20	-4	7.8	46	114.8	71	160	320	399	750	1382	1260	2300	4172
-23	-10	14	8.3	47	116.6	77	170	338	404	760	1400	1288	2350	4262
-17.8	0	32	8.9	48	118.4	82	180	356	410	770	1418	1316	2400	4352
			9.4	49	120.2	88	190	374	416	780	1436	1343	2450	4442
			10.0	50	122.0	93	200	392	421	790	1454	1371	2500	4532
			10.6	51	123.8	99	210	410	427	800	1472	1399	2550	4622
			11.1	52	125.6	100	212	413.6	432	810	1490	1427	2600	4712
			11.7	53	127.4	104	220	428	438	820	1508	1454	2650	4802
			12.2	54	129.2	110	230	446	443	830	1526	1482	2700	4892
			12.8	55	131.0	116	240	464	449	840	1544	1510	2750	4982
			13.3	56	132.8	121	250	482	454	850	1562	1538	2800	5072
			13.9	57	134.6	127	260	500	460	860	1580	1566	2850	5162
			14.4	58	136.4	132	270	518	466	870	1598	1593	2900	5252
			15.0	59	138.2	138	280	536	471	880	1616	1621	2950	5342
			15.6	60	140.0	143	290	554	477	890	1634	1649	3000	5432

Locate temperature in middle column. If in degrees Celcius, read Fahrenheit equivalent in right hand column; if in degrees Fahrenheit, read Celcius equivalent in left hand column.

Pipe Data

Cast Iron Pipe ... ASA Standard

Pipe Size	Pipe O.D.	Class 50 50 PSIG		Class 100 100 PSIG		Class 150 150 PSIG		Class 200 200 PSIG		Class 250 250 PSIG		Class 300 300 PSIG		Class350 350 PSIG	
		Wall	I.D.	Wall	I.D.	Wall	I.D.	Wall	I.D.	Wall	I.D.	Wall	I.D.	Wall	I.D.
2	3.96	0.32	3.32	0.32	3.32	0.32	3.32	0.32	3.32	0.32	3.32	0.32	3.32	0.32	3.32
4	4.80	.35	4.10	.35	4.10	.35	4.10	.35	4.10	.35	4.10	.35	4.10	.35	4.10
6	6.90	.38	6.14	.38	6.14	.38	6.14	.38	6.14	.38	6.14	.38	6.14	.38	6.14
8	9.05	.41	8.23	.41	8.23	.41	8.23	.41	8.23	.41	8.23	.41	8.23	.41	8.23
10	11.10	.44	10.22	.44	10.22	.44	10.22	.44	10.22	.44	10.22	.48	10.14	.52	10.06
12	13.20	.48	12.24	.48	12.24	.48	12.24	.48	12.24	.52	12.16	.52	12.16	.56	12.08
14	15.30	.48	14.34	.51	14.28	.51	14.28	.55	14.20	.59	14.12	.59	14.12	.64	14.02
16	17.40	.54	16.32	.54	16.32	.54	16.32	.58	16.24	.63	16.14	.68	16.04	.68	16.04
18	19.50	.54	18.42	.58	18.34	.58	18.34	.63	18.24	.68	18.14	.73	18.04	.79	17.92
20	21.60	.57	20.46	.62	21.36	.62	20.36	.67	20.26	.72	20.16	.78	20.04	.84	19.92
24	25.80	.63	24.54	.68	24.44	.73	24.34	.79	24.22	.79	24.22	.85	24.10	.92	23.96

Cast Iron Pipe ... AWWA Standard

Pipe Size	Class A 100 Ft. 43 PSIG			Class B 200 Ft. 86 PSIG			Class C 300 Ft. 130 PSIG			Class D 400 Ft. 173 PSIG		
	O.D.	Wall	I.D.	O.D.	Wall	I.D.	O.D.	Wall	I.D.	O.D.	Wall	I.D.
2	3.80	0.39	3.02	3.95	0.42	3.12	3.96	0.45	3.06	3.96	0.48	3.00
4	4.80	0.42	3.96	5.00	0.45	4.10	5.00	0.48	4.04	5.00	0.52	3.96
6	6.90	0.44	6.02	7.10	0.48	6.14	7.10	0.51	6.08	7.10	0.55	6.00
8	9.05	0.46	8.13	9.05	0.51	8.03	9.30	0.56	8.18	9.30	0.60	8.10
10	11.10	0.50	10.10	11.10	0.57	9.96	11.40	0.62	10.16	11.40	0.68	10.04
12	13.20	0.54	12.12	13.20	0.62	11.96	13.50	0.68	12.14	13.50	0.75	12.00
14	15.30	0.57	14.16	15.30	0.66	13.98	15.65	0.74	14.17	15.65	0.82	14.01
16	17.40	0.60	16.20	17.40	0.70	16.00	17.80	0.80	16.20	17.80	0.89	16.02
18	19.50	0.64	18.22	19.50	0.75	18.00	19.92	0.87	18.18	19.92	0.96	18.00
20	21.60	0.67	20.26	21.60	0.80	21.00	22.06	0.92	20.22	22.06	1.03	21.00
24	25.80	0.76	24.28	25.80	0.89	24.02	26.32	1.04	24.22	26.32	1.16	24.00
30	31.74	0.88	29.98	32.00	1.03	29.94	32.40	1.20	30.00	32.74	1.37	30.00
36	37.96	0.99	35.98	38.30	1.15	36.00	38.70	1.36	39.98	39.16	1.58	36.00
42	44.20	1.10	42.00	44.50	1.28	41.94	45.10	1.54	42.02	45.58	1.78	42.02
48	50.50	1.26	47.98	50.80	1.42	47.96	51.40	1.71	47.98	51.98	1.96	48.06
54	56.66	1.35	53.96	57.10	1.55	54.00	57.80	1.90	54.00	58.40	2.23	53.94
60	62.80	1.39	60.02	63.40	1.67	60.06	64.20	2.00	60.20	64.82	2.38	60.06
72	75.34	1.62	72.10	76.00	1.95	72.10	76.88	2.39	72.10			
84	87.54	1.72	84.10	88.54	2.22	84.10						

Pipe Size	Class E 500 Ft. 217 PSIG			Class F 600 Ft. 260 PSIG			Class G 700 Ft. 304 PSIG			Class H 800 Ft. 347 PSIG		
	O.D.	Wall	I.D.	O.D.	Wall	I.D.	O.D.	Wall	I.D.	O.D.	Wall	I.D.
2												
4												
6	7.22	0.58	6.06	7.22	0.61	6.00	7.38	0.65	6.08	7.38	0.69	6.00
8	9.42	0.66	8.10	9.42	0.71	8.00	9.60	0.75	8.10	9.60	0.80	8.00
10	11.60	0.74	10.12	11.60	0.80	10.00	11.84	0.86	10.12	11.84	0.92	10.00
12	13.78	0.82	12.14	13.78	0.89	12.00	14.08	0.97	12.14	14.08	1.04	12.00
14	15.98	0.90	14.18	15.98	0.99	14.00	16.32	1.07	14.18	16.32	1.16	14.00
16	18.16	0.98	16.20	18.16	1.08	16.00	18.54	1.18	16.18	18.54	1.27	16.00
18	20.34	1.07	18.20	20.34	1.17	18.00	20.78	1.28	18.22	20.78	1.39	18.00
20	22.54	1.15	20.24	22.54	1.27	20.00	23.02	1.39	20.24	23.02	1.51	20.00
24	26.90	1.31	24.28	26.90	1.45	24.00	27.76	1.75	24.26	27.76	1.88	24.00
30	33.10	1.55	30.00	33.46	1.73	30.00						
36	39.60	1.80	36.00	40.04	2.02	36.00						
42												
48												
54												

Stainless Steel, Hastelloy "C"* and Titanium Pipe ▫

Pipe	Size	1/2	3/4	1	1 1/4	1 1/2	2	2 1/2	3	3 1/2	4	5	6
Sched	Out. Dia.	.840	1.050	1.315	1.660	1.900	2.375	2.875	3.500	4.000	4.500	5.563	6.625
5S (a)	I.D.	.710	.920	1.185	1.530	1.770	2.245	2.709	3.334	3.834	4.334	5.345	6.407
	Wall	.065	.065	.065	.065	.065	.065	.083	.083	.083	.083	.109	.109
Sched 10S (a)	I.D.	.674	.884	1.097	1.442	1.682	2.157	2.635	3.260	3.760	4.260	5.295	6.357
	Wall	.083	.083	.109	.109	.109	.109	.120	.120	.120	.120	.134	.134
Sched 40S	I.D.	.622	.824	1.049	1.380	1.610	2.067	2.469	3.068	3.548	4.026	5.047	6.065
	Wall	★.109	★.113	★.133	★.140	★.145	★.154	★.203	★.216	★.226	★.237	H.258	★.280
Sched 80S	I.D.	.546	.742	.957	1.278	1.500	1.939	2.323	2.900	3.364	3.826	4.813	5.761
	Wall	▲.147	▲.154	▲.179	▲.191	▲.200	▲.218	▲.276	▲.300	▲.318	▲.337	▲.375	▲.432

Pipe	Size	8	10	12	14	16	18	20	22	24
Sched	Out. Dia.	8.625	10.750	12.750	14.000	16.000	18.000	20.000	22.000	24.000
5S (a)	I.D.	8.407	10.482	12.438	13.688	15.670	17.670	19.634	21.624	23.563
	Wall	.109	.134	.156	.156	.165	.165	.188	.188	.218
Sched 10S (a)	I.D.	8.329	10.420	12.390	13.624	15.624	17.624	19.564	21.564	23.500
	Wall	.148	.165	.180	.188	.188	.188	.218	.218	.250
Sched 40S	I.D.	7.981	1.020	12.000						
	Wall	★.322	★.365	■.375						
Sched 80S	I.D.	7.625	9.750	11.750						
	Wall	▲.500	▲.500	▼.500						

* A registered trademark of Union Carbide Corp.

Carbon Steel and PVC ▫ Pipe

Pipe	Size	1/2	3/4	1	1 1/4	1 1/2	2	2 1/2	3	3 1/2	4	5	6
	Out. Dia.	.840	1.050	1.315	1.660	1.900	2.375	2.875	3.500	4.000	4.500	5.563	6.625
Standard	I.D.	.622	.824	1.049	1.380	1.610	2.067	2.469	3.068	3.548	4.026	5.047	6.065
	Wall	.109	.113	.133	.140	.145	.154	.203	.216	.226	.237	.258	.280
Extra Heavy	I.D.	.546	.742	.957	1.278	1.500	1.939	2.323	2.900	3.364	3.826	4.813	5.761
	Wall	.147	.154	.179	.191	.200	.218	.276	.300	.318	.337	.375	.432
Double Extra Heavy	I.D.	.252	.434	.599	.896	1.100	1.503	1.771	2.300	2.728	3.152	4.063	4.897
	Wall	.294	.308	.358	.382	.400	.436	.552	.600	.636	.674	.750	.864
Sched. 10	I.D.												
	Wall												
Sched. 20	I.D.												
	Wall												
Sched. 30	I.D.												
	Wall												
Sched. 40	I.D.	.622	.824	1.049	1.380	1.610	2.067	2.469	3.068	3.548	4.026	5.047	6.065
	Wall	★.109	★.133	★.133	★.140	★.145	★.154	★.203	★.216	★.226	★.237	★.258	★.280
Sched. 60	I.D.												
	Wall												
Sched. 80	I.D.	.546	.742	.957	1.278	1.500	1.939	2.323	2.900	3.364	3.826	4.813	5.761
	Wall	▲.147	▲.154	▲.179	▲.191	▲.200	▲.218	▲.276	▲.300	▲.318	▲.337	▲.375	▲.432
Sched. 100	I.D.												
	Wall												
Sched. 120	I.D.										3.624	4.563	5.501
	Wall										.438	.500	.562
Sched. 140	I.D.												
	Wall												
Sched. 160	I.D.	.466	.614	.815	1.160	1.338	1.689	2.125	2.624		3.438	4.3135.1896.8138.500	
	Wall	.187	.218	.250	250	.281	.343	.375	438		.531	.625	.718

Pipe	Size	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	4
	Out. Dia.	8.625	10.750	12.750	14.000	16.000	18.000	20.000	22.000	24.000	26.000	28.000	30.000	32.000	34.000	36.000	42.(
Standard	I.D.	7.981	10.20	12.000	13.250	15.250	17.250	19.250	21.250	23.250	25.250	27.250	29.250	31.250	33.250	35.250	41.:
	Wall	.322	.365	.375	.375	.375	.375	.375	.375	.375	.375	.375	.375	.375	.375	.375	■.3
Extra Heavy	I.D.	7.625	9.750	11.750	13.000	15.000	17.000	19.000	21.000	23.000	25.000	27.000	29.000	31.000	33.000	35.000	41.(
	Wall	.500	.500	.500	.500	.500	500	.500	.500	.500	.500	.500	.500	.500	.500	.500	■.5
Double Extra Heavy	I.D.	6.875	8.750	10.750													
	Wall	.875	1.000	1.000													
Sched. 10	I.D.				13.500	15.500	17.500	19.500	21.500	23.500	25.376	27.376	29.376	31.376	33.376	35.376	
	Wall				.250	.250	.250	.250	.250	.250	.312	.312	.312	.312	.312	.312	
Sched. 20	I.D.	8.125	10.250	12.250	13.376	15.376	17.376	19.250	21.250	23.250	25.000	27.000	29.000	31.000	33.000	35.000	41.(
	Wall	.250	.250	.250	.312	.312	.312	★.375	★.375	★.375	▲.500	▲.500	▲.500	▲.500	s.500	s.500	s.5
Sched. 30	I.D.	8.071	10.136	12.090	13.250	15.250	17.124	19.000	21.000	22.876		26.750	28.750	30.750	32.750	34.750	40.:
	Wall	.277	.307	.330	★.375	★.375	.438	▲.500	▲.500	.562		.625	.625	.625	.625	.625	■.6
Sched. 40	I.D.	7.981	10.020	11.938	13.124	15.000	16.976	18.814		22.626							
	Wall	★.322	★.365	.406	.438	▲.500	.562	.593		.687							
Sched. 60	I.D.	7.813	9.750	11 626	12.814	14.688	16.500	18.376	20.250	22.064							
	Wall	.406	s.500	.562	.593	.656	.750	.812	.875	.968							
Sched. 80	I.D.	7.625	9.564	11.376	12.500	14.314	16.126	17.938	19.750	21.564							
	Wall	▲.500	.593	.687	.750	.843	.937	1.031	1.125	1.218							
Sched. 100	I.D.	7.439	9.314	11.064	12.126	13.938	15.688	17.438	19.250	20.938							
	Wall	.593	.718	.843	.937	1.031	1.156	1.281	1.375	1.531							
Sched. 120	I.D.	7.189	9.064	10.750	11.814	13.564	15.250	17.000	18.750	20.376							
	Wall	.718	8.43	1.000	1.093	1.218	1.375	1.500	1.625	1.812							
Sched. 140	I.D.	7.001	8.750	10.500	11.500	13.124	14.876	16.500	18.250	19.876							
	Wall	.812	1.000	1.125	1.250	1.438	1.562	1.750	1.875	2.062							
Sched. 160	I.D.		10.126	11 188	12.814	14.438	16.064	17.750	19.314								
	Wall	.906	1.125	1.312	1.406	1 593	1.781	1 968	2.125	2.343							

Notes:
- ★ Wall thickness identical with thickness of "Standard Weight" pipe.
- ▲ Wall thickness identical with thickness of "Extra Heavy" pipe.
- ■ These do not conform to American Standard B36.10.
- ▫ These materials are generallly available in Schedules 40 and 80 only.
- (a) Wall thickness of Schedule 5S and 10S does not permit threading in accordance with the American Std. for Pipe Threads (ASA No. B2.1)

Pipe Weight Formula For Steel Pipe

(Pounds per foot)
10.68 (D-t)t
D - Outside Diameter
t - Wall Thickness

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Appendix C

Related Calculations

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Appendix C

Related Calculations

Correction Factor For Liquid Filled Manometers

When using liquid filled manometers, the value of h_w that is needed for the Annubar flow equations is dependent on the density of the liquid in the manometer and the density of fluid transmitting the pressure. Figure C.1 shows the two most common methods of connecting manometers to Annubars.

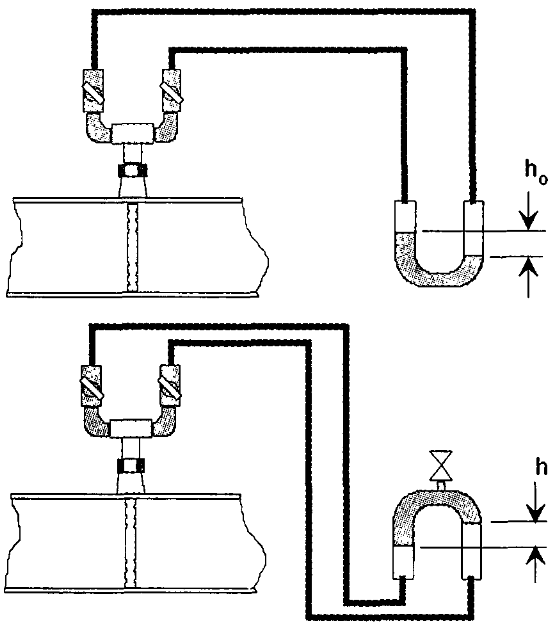

Figure C.1

In the top diagram of Figure C.1, the fluid in the manometer must be more dense than the fluid in the pipeline. Table 2.9 has been formulated for this type of manometer connection where the fluid in the pipeline is gas and the fluid in the manometer is mercury. The bottom diagram is used generally when a liquid is flowing in the pipeline. The valve can be left open to the atmosphere or closed with compressed air or gas applied to the top of the manometer.

To explain how to derive h_w, let

- h = Pressure difference in terms of the height of a column of the fluid flowing in the pipeline, inches.
- h_o = Height of the observed liquid in manometer, inches.
- h_w = Inches of water at 68°F.
- ρ = Density of the fluid in the pipeline
- ρ_o = Density of the liquid in the manometer
- ρ_b = Density of the fluid used to transmit the pressure
- ρ_s = Density of water at 68°F, (62.320 lb/ft3)

Then, $$h\rho = (h_0\rho_0 - h_0\rho_b) = h_0(\rho_0 - \rho_b) \tag{C.1}$$

or,

$$h = h_0\left[\frac{(\rho_0 - \rho_b)}{\rho}\right] \tag{C.2}$$

For use in the flow equations, it is necessary to have the value of differential pressure expressed in the equivalent inches of water at 68°F. To evaluate h and h_o in terms of h_w,

$$h_\rho = h_w\rho_s \tag{C.3}$$

or,

$$h = h_w\frac{\rho_s}{\rho} \tag{C.4}$$

Combining equation (C.4) with equation (C.2), gives

$$h_w = h_0\left(\frac{\rho_0 - \rho_b}{\rho_s}\right) \tag{C.5}$$

It is interesting to note that equation (C.5) does not contain the density of the flowing fluid (ρ); although, when the temperature of the fluid in the pipeline equals the temperature of the manometer, $\rho = \rho_b$. Also, a broader definition should be given to ρ_b, namely, ρ_b is the density of the fluid in the low-column side of the manometer.

For example, if the valve in the bottom diagram of Figure C.1 were open, the right-hand tube would have a column of air, of height h, in excess of that in the left-hand tube. To illustrate the magnitude of this effect, assume water is flowing in the pipe and $\rho_0 = \rho_s = 62.320$ lbm/ft³, and for air, $\rho_b = 0.076$ lbm/ft³. Then equation (C.5),

$$h_w = h_o\frac{62.320 - 0.076}{63.320} = 0.9988h_o$$

shows that the air in the low-liquid side of the manometer affects the value of h_w by over 0.1 percent for each atmosphere of pressure. Sometimes this correction is known as the "air-leg" effect.

Another example would be for water flow with mercury as the fluid in the manometer. If both water and mercury are at 68°F, then $\rho_b = \rho_s = 62.320$ lbm/ft^3 and $\rho_o = 845.64$ lbm/ft^3. Equation (C.5) becomes,

$$h_w = h_o \frac{845.64 - 62.320}{62.320} = 12.569 h_o$$

All of the above equations were shown for "U-tube" type manometers. Equation (C.5) would apply just the same if manometers of the pot or cistern type were used.

Ideal and Real Specific Gravity

The real specific gravity of a gas is defined as the ratio of the density of the gas to the density of air while both gas and air are at the same pressure and temperature. The fact that the temperature and pressure were not stated has resulted in small variances in specific gravity determination. It has been common practice to determine the specific gravity at near atmospheric pressure and temperature and assume that this specific gravity holds true for all other pressures and temperatures. This assumption has neglected compressibility effects.

These compressibility effects have led to defining the term "ideal specific gravity", which is the ratio of the molecular weight of the gas to the molecular weight of air. As long as no chemical reactions occur which would change the composition (molecular weight) of the gas, the ideal specific gravity remains constant regardless of the pressure and temperature. The molecular weight of air is 28.9644.

The relationship between ideal specific gravity and real specific gravity is established as follows:

The equation of state can be written as:

$$PV = \mathrm{MZRT}$$

or

$$PV = \frac{g_c W\,\mathrm{ZRT}}{g} \qquad where, M = \frac{g_c W}{g} \tag{C.6}$$

or $$P = \frac{g_c}{g}\frac{W\,\mathrm{ZRT}}{V}$$

$$P = \gamma \frac{g_c\,\mathrm{ZRT}}{g} \qquad where, \gamma = \frac{W}{V} \tag{C.7}$$

Since $g = \dfrac{\rho g}{g_c}$ then equation (C.7) can be written:

$$P = \frac{\rho g}{g_c}\frac{g_c\,\mathrm{ZRT}}{g} = \rho\,\mathrm{ZRT} \tag{C.8}$$

$$\rho = \frac{P}{\mathrm{ZRT}} \tag{C.9}$$

Now since the real specific gravity is defined as:

$$G = \frac{\rho_g}{\rho_a}$$

It can be written as:

$$G = \frac{\dfrac{P_g}{Z_g R_g T_g}}{\dfrac{P_a}{Z_a R_a T_a}}$$

or

$$G = \frac{P_g Z_a R_a T_a}{P_a Z_g R_g T_g} \tag{C.10}$$

The gas constant R is defined as the Universal Gas Constant divided by the molecular weight.

$$R = \frac{1545.32}{\mathrm{Mol.Wt.}}$$

Equation (C.10) can be written as:

$$G = \frac{P_g Z_a \dfrac{1545.32}{\text{Mol. Wt. of Air}} T_a}{P_a Z_g \dfrac{1545.32}{\text{Mol. Wt. of Air}} T_g}$$

or

$$G = \frac{P_g Z_a T_a}{P_a Z_g T_g} \times \frac{\text{Mol. Wt. of Gas}}{\text{Mol. St. of Air}} \tag{C.11}$$

Now since the ideal specific gravity is

$$G_f = \frac{\text{Mol. Wt. of Gas}}{\text{Mol. Wt. of Air}}$$

Equation (C.11) can be written as:

$$G = \frac{P_g Z_a T_a}{P_a Z_g T_g} G_f \tag{C.12}$$

Equation (C.12) gives the relationship between real specific gravity and ideal specific gravity. As can be seen, if both the gas and air are at the same pressure and temperature, the difference between real and ideal specific gravities depends upon the respective compressibilities factors.

The following nomenclature is for the above equations:

P = Pressure in psia

V = Volume in cu. ft.

M = Mass

R = Universal Gas Constant = $\frac{1545.32}{\text{Mol. Wt.}}$

T = Temperature in degrees Rankine

Z = Compressibility Factor (Deviation from Boyle's Law)

W = Weight

g_c = Standard Gravitational Constant, 32.1740 ft/sec²

g = Actual gravitational constant for location

γ = Specific Weight

ρ = Density

G = Real specific gravity

G_f = Ideal specific gravity

Derivation of Annubar Flow Equations

The Annubar flow equations listed in Chapter 2 of this handbook are all derived from the hydraulic equation. The hydraulic equation for volumetric flow is given in equation (1.9), while the hydraulic equation for mass flow is given in equation (1.10). The following shows how the Annubar flow equations are developed from the hydraulic equations.

Problem:

Derive the volumetric flow rate in GPM for liquids where the differential pressure is measured in inches of water at 68°F, the pipe diameter is measured in inches.

Solution:

The following definitions and conversion factors are required.

1 Gallon = 231 in³ = 0.13368 ft³

1 ft³ = 7.48052 Gallons

1" H_2O at 68°F (h_w) at standard gravity
= 0.036065 lbf/in² (psi)

g = local gravity constant

g_c = standard gravity constant, 32.1740 ft/sec²

ρ = Density lbm/ft³

dP = P_1-P_2 = differential pressure, lbf/ft²

D = Diameter of pipe, inch

A = Area of pipe, ft²

K = Annubar Flow Coefficient

Q = Volumetric Flow

Beginning with equation (1.9)

$$Q = KA\sqrt{\frac{2g(P_1 - P_2)}{\rho}} = KA\sqrt{2g\frac{dP}{\rho}} \qquad (1.9)$$

The units can be checked as follows:

$$Q = Ft^2\sqrt{\frac{Ft(lbf/Ft^2)}{Sec^2(lbm/Ft^3)}} = \frac{Ft^3}{Sec}$$

Note: In the above units conversion, lbf is set equal to lbm. This is only true at standard gravity. The gage location factor described later corrects for locations where the local gravity does not equal the standard gravity.

Substituting units leads to:

$$Q = K\left[\frac{60Sec}{Min}\right]\left[\frac{7.48052Gal}{Ft^3}\right]\left[\frac{Ft^3}{144In^2}\right]\left[\frac{\pi D^2 In^2}{4}\right]$$

$$\sqrt{\frac{2\left[32.1740\frac{Ft}{Sec^2}\right]h_w\left[.036065\frac{lbf}{In^2}\right]\left[144\frac{In^2}{Ft^2}\right]}{\rho\frac{lbm}{Ft^3}}}$$

$$Q = GPM = 44.751KD^2\sqrt{\frac{h_w}{\rho}} \qquad (C.13)$$

We can now define the density of any fluid by referencing that fluid to water at 60°F.

$$\rho = \rho_{60}G_f$$

where ρ_{60} = density of water at 60°F
= 62.3707 lbm/Ft³

and g_f = flowing specific gravity of the fluid

$$Q = GPM = 44.751KD^2\sqrt{\frac{h_w}{62.3707G_f}}$$

$$GPM = 5.6664KD^2\sqrt{\frac{h_w}{G_f}} \qquad (C.14)$$

If a liquid-filled manometer is used to measure the differential pressure of the Annubar, a correction factor (F_M) must be applied. This correction factor is described in detail at the beginning of this appendix. If the pipe temperature is different from the temperature at which the internal diameter (D) was measured, a factor (F_{AA}) must be applied to account for the area change. Likewise, if the Annubar is operating at a location where the gravity constant is not equal to the standard gravity constant, a correction factor (F_1) must be applied. In some cases (as with the original Diamond-shaped Annubar, and some other devices) a Reynolds Number Factor, F_{RA}, is applied to the equation. With these four factors applied, equation (C.14) becomes:

$$GPM = 5.6664KD^2F_{RA}F_MF_{AA}F_1\sqrt{\frac{h_w}{\rho}} \qquad (C.15)$$

This equation is identical to the first Annubar flow equation of Chapter 2.

Use of Annubar Flow Equations with Densitometers

The Annubar flow equations of Section 2 are established for the most common types of instrumentation used today. However, new and different instrumentation is being used more and more. As an example, densitometers are being developed to a high degree of accuracy. These instruments measure the density of the fluid directly. Therefore, eliminating the need to determine the density of the fluid from the measured pressure and temperature. As long as the densitometer determines the density in lbm/ft^3, the equations of Section 2 are correct whenever an Annubar and densitometer are used together. For flowing fluids whose density varies with time, integration of the densitometer signal and the Annubar's differential pressure will give the total flow of the fluid over that period of time.

Use of Annubar Flow Equations with Temperature Integrators

The gas volumetric flow equations at standard conditions of Section 2 are already established for use with pressure integrators. The equation as written will give the correct results whether the pressure is constant or the pressure is integrated over a period of time. However, the equations are **not** correct if temperature integrators are used. The F_{NA} constants were calculated assuming the temperature to be 60°F. If, in fact, the temperature was constant but different than 60°F, the flowing temperature factor F_{tf} was used to calculate the correct flowrate.

For those applications where the pressure, temperature, and differential pressure are to be integrated, the following equation should be used:

$$Q_S = C'\sqrt{\frac{h_w P_f}{T_f}}$$

where T_f is the flowing tmperature in degrees Rankine.

h_w is the differential pressure in inches of water at 68°F.

P_f is the flowing pressure in PSIA

and C' is defined as follows:

$$C' = F_{NA} K D^2 F_{RA} Y_A F_{pb} F_{tb} F_g F_{pv} F_m F_{AA} F_l$$

Please note that C' does **not** contain the flowing temperature factor. The following F_{NA} factors should be used to obtain the standard volumetric flowrates listed below:

Standard Rate of Flow Q_S	Units Conversion Factor F_{NA}
SCFM	128.52
SCFM	7711.4
SCFD	185070

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DS-7300 (02/97)

CEMS – DP TRANSMITTER

ORDERING INFORMATION

TABLE 5-6. Model 3051C Differential, Gage, and Absolute Pressure Transmitters. — = Not Applicable • = Applicable

Model	Transmitter Type (Select One)			CD	CG	CA
3051CD	Differential Pressure Transmitter			•	—	—
3051CG	Gage Pressure Transmitter			—	•	—
3051CA	Absolute Pressure Transmitter			—	—	•
Code	**PRESSURE RANGES (URL) (Select One)** Model 3051CD	Model 3051CG	Model 3051CA	**CD**	**CG**	**CA**
0	Not Applicable	Not Applicable	0–0.167 to 0–5 psia (0–8.6 to 0–260 mmHga)	—	—	•
1	0–0.5 to 0–25 inH_2O (0–0.12 to 0–6.22 kPa)	Not Applicable	0–0.3 to 0–30 psia (0–2.07 to 0–206.8 kPa)	•	—	•
2	0–2.5 to 0–250 inH_2O (0–0.62 to 0–62.2 kPa)	0–2.5 to 0–250 inH_2O (0–0.62 to 0–62.2 kPa)	0–1.5 to 0–150 psia (0–10.34 to 0–1034.2 kPa)	•	•	•
3	0–10 to 0–1,000 inH_2O (0–2.48 to 0–248 kPa)	0–10 to 0–1,000 inH_2O (0–2.48 to 0–248 kPa)	0-8 to 0-800 psia (0–55.16 to 0–5515.8 kPa)	•	•	•
4	0–3 to 0–300 psi (0–20.7 to 0–2070 kPa)	0–3 to 0–300 psig (0–20.7 to 0–2070 kPa)	0–40 to 0–4,000 psia (0–275.8 to 0–27580 kPa)	•	•	•
5	0–20 to 0–2,000 psi (0–138 to 0–13800 kPa)	0–20 to 0–2,000 psig (0–138 to 0–13800 kPa)	Not Applicable	•	•	—

Code	Output	CD	CG	CA
A	4–20 mA with Digital Signal Based on *HART* Protocol	•	•	•
M(1)	Low-Power, 1–5 V dc with Digital Signal Based on *HART* Protocol (See Option C2 for 0.8–3.2 V dc)	•	•	•

Code	MATERIALS OF CONSTRUCTION Process Flange Type	Flange Material	Drain/Vent	Flange Adapters	CD	CG	CA
5	*Coplanar*	Plated CS	SST	Plated CS	•	•	•
2	*Coplanar*	SST	SST	SST	•	•	•
3(2)	*Coplanar*	*Hastelloy C*	*Hastelloy C*	*Hastelloy C*	•	•	•
4	*Coplanar*	*Monel*	*Monel*	*Monel*	•	•	•
8(2)	*Coplanar*	Plated CS	*Hastelloy C*	Plated CS	•	•	•
7(2)	*Coplanar*	SST	*Hastelloy C*	SST	•	•	•
0	Alternate Flange–See Options H2, H3, H4, H7, F1, F2, G1, G2, FA, FB, FC, FD, or S5				•	•	•

Code	Isolating Diaphragm	CD	CG	CA
2	316L SST	•	•	•
3(2)	*Hastelloy C-276*	•	•	•
4	*Monel*	•	•	•
5	Tantalum (Available on Model 3051CD and CG, Ranges 2–5 only. Not available on Model 3051CA)	•	•	—
6	Gold-plated *Monel*	•	•	•
7	Gold-Plated SST	•	•	•
Code	**O-ring**	**CD**	**CG**	**CA**
A	Glass-filled TFE	•	•	•
B	Graphite-filled TFE (for use with Isolating Diaphragm Option Code 6, Gold-plated Monel)	•	•	•
Code	**Fill Fluid**	**CD**	**CG**	**CA**
1	Silicone	•	•	•
2	Inert fill (Halocarbon)	•	•	—

Code	Housing Material	Conduit Entry Size	CD	CG	CA
A	Polyurethane-covered Aluminum	½–14 NPT	•	•	•
B	Polyurethane-covered Aluminum	M20 x 1.5 (CM20)	•	•	•
C	Polyurethane-covered Aluminum	PG 13.5	•	•	•
D	Polyurethane-covered Aluminum	G ½	•	•	•
J	SST	½–14 NPT	•	•	•
K	SST	M20 x 1.5 (CM20)	•	•	•
L	SST	PG 13.5	•	•	•

(1) Not available with hazardous locations certification Option Codes I1, N1, E4, and K6.

(2) Meets NACE material recommendations per MR 01-75.

Annubar
Thermocouple or RTD

2 red
2 black
1 yellow
1 white

ODH 8 9/16"
OUR [illegible]