TESCOM

FLOW FORMULAS

FOR COMPUTING GAS AND LIQUID FLOW THROUGH REGULATORS AND VALVES

Definitions:

C_V: Flow coefficient for regulators and valves that expresses flow capabilities of a unit at full open condition. For **liquids**, this coefficient is defined as the flow of water at 60˚ F in gallons per minute at a pressure drop of one psig. For **gases**, this coefficient is defined as the flow of air at standard conditions in standard cubic feet per minute for each psig of inlet pressure.

S_L: Specific gravity of liquids relative to water, both at standard temperature of 60˚ F. (Specific gravity of water = 1.0 @ 60˚ F.)

S_g: Specific gravity of a gas relative to air; equals the ratio of the molecular weight of the gas to that of air. (Specific gravity of air = 1.0 @ 60˚ F.)

P: Line pressure (psia).

P_1: Inlet pressure expressed in psia.

P_2: Outlet pressure expressed in psia.

ΔP: Differential pressure (P_1 - P_2).

psia: Absolute pressure which is gauge pressure (PSIG) plus 14.7 (atmospheric pressure).

Q_L: Liquid flow in gallons per minute (GPM).

Q_g: Gas flow in standard cubic feet per minute (SCFM). (At standard conditions of 60˚ F. and 14.7 psia.)

Q: Volume flow rate in cubic feet per minute (CFM).

M: Mass flow rate in poinds per minute (lbs/min).

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Process Management

FORMULAS AND EXAMPLES:*

1. **Liquid Flow Formulas:**

$$C_V = \frac{Q_L\sqrt{S_L}}{\sqrt{\Delta P}} \quad \therefore \quad Q_L = \frac{C_V\sqrt{\Delta P}}{\sqrt{S_L}}$$

Example: Determine liquid flow (assume water) through a regulator in gallons per minute with the following conditions:

Given:

P_1 = 1000 psia.

P_2 = 600 psia.

S_L = 1.0

C_V = .08

$$Q_L = \frac{C_V\sqrt{\Delta P}}{\sqrt{S_L}} = \frac{0.8\sqrt{1000\text{-}600}}{\sqrt{1}} = \frac{0.8 \times 20}{1}$$

= 16 GPM (Water)

2. **Gaseous Flow Formulas:***

a. $C_V = \dfrac{Q_g \times 2\sqrt{S_g}}{P_1}$ Use when P_1 equals or is greater than 2 x P_2 . (Referred to as critical flow)

Example: Determine C_V required for a regulator when inlet pressure (P_1) is equal or greater than two times outlet pressure (P_2) and the following items are known:

Given:

P_1 = 1000 psia

P_2 = 400 psia

Q_g = 400 SCFM

S_g = 1.0 (assume air in this example)

$$C_V = \frac{Q_g \times 2\sqrt{S_g}}{P_1} = \frac{400 \times 2}{1000} = .8\ C_V$$

*Caution: When sizing components for flow applications, attention must also be directed to the size of plumbing. When flow requirements are at low pressures, the plumbing may be the flow limiting item rather than the regulator or valve.

b. $C_V = \dfrac{Q_g \times \sqrt{S_g}}{\sqrt{\Delta P \times P_2}}$ Use when P_1 is less than 2 x P_2 or P_2 is greater than one-half of inlet pressure. Note: This is referred to as sub-critical flow.

2. (continued) . . .

Example: Determine maximum flow capability through the same regulator (example in a.) using the C_V factor when the following conditions exist:

Given:

P_1 = 1000 psia

P_2 = 600 psia

C_V = 0.8

S_g = 1.0 (assume air in this example)

Solve formula for Qg:

$$Qg = \frac{Cv\sqrt{\Delta P \times P_2}}{\sqrt{Sg}}$$

$$= \frac{.8\sqrt{1000\text{-}600 \times 600}}{\sqrt{1}} = \frac{392}{1}$$

$$Qg = \underline{\underline{392}}$$

3. **Convert flow from CFM to SCFM**

$$Q_g = \frac{Q \times P}{14.7}$$

Example: Convert gas flow expressed in cubic feet per minute (CFM) to units of standard cubic feet per minute (SCFM).

Given:

Q = 20 CFM

P = 294 psia

$$Qg = \frac{Q \times P}{14.7} = \frac{20 \text{ CFM} \times 294 \text{ psia}}{14.7 \text{ psia}}$$

$$= \underline{\underline{400 \text{ SCFM}}}$$

4. **Convert mass flow to volume flow (SCFM) of air.**

$$Qg \text{ (Air)} = \frac{M \text{ (any gas)} \times 13.36}{S_g \text{ (any gas)} \times \sqrt{\dfrac{1}{S_g \text{ (any gas)}}}}$$

Example: Convert mass flow (lb/min) of any gas to volume flow (SCFM) of air

Given: M (H_e) = 1 lb. min, Sg (H_e) = .138

$$Qg = \frac{M \times 13.36}{S_g \times \sqrt{\dfrac{1}{S_g}}} = \frac{1 \times 13.36}{.138 \times \sqrt{\dfrac{1}{.138}}}$$

$$= \underline{\underline{35.96 \text{ SCFM (Air)}}}$$

TABLES

A. Approximate multipliers to use when converting flow (GPM) of water to various liquids:

Crude Oil	1.015 to 1.11
Gasoline	1.15
Hydraulic Oil-Mineral Base	1.12
Hydraulic Oil-Phosphate Ester Base	.95
Hydraulic Oil-Standard Mil 5606	1.10
Hydraulic Oil-Water Glyol Base	.98
Kerosene	1.10
Water	1.00

Example: Determinemaximum flow of kerosene through a regulator if maximum water flow capability is 5 GPM.

Kerosene flow = 5 GPM (water) x 1.10 (kerosene multiplier) = 5.5 GPM

B. Approximate mulitpliers to use when converting flow (SCFM) of air to various gases:

Air	1.000
Ammonia	1.295
Argon	.852
Arsine	.609
Carbon Dioxide	.810
Helium	2.690
Hydrogen	3.790
Hydrogen Chloride	.888
Nitrogen	1.015
Oxygen	.951
Silane	.915

Example: Determine maximum flow of helium through a regulator if the maximum air flow capability is 300 SCFM.

Helium flow = 300 SCFM (air) x 2.69 (helium multiplier) = 807 SCFM

C. Approximate specific gravities (S_L) for various liquids:

Crude Oil	.81 to .97
Gasoline	.75
Hydraulic Oil-Mineral Base	.80
Hydraulic Oil-Phosphate Ester Base	1.10
Hydraulic Oil-Standard Mil 5606	.83
Hydraulic Oil-Water Glycol Base	1.05
Kerosene	.82
Water	1.00

To convert the flow from water (specific gravity of 1.0) to a liquid having a specific gravity other than 1.0 use the following formula:

$$Q_L \text{ (any liquid)} = Q_L \text{ (water)} \sqrt{\frac{1}{S_L \text{ (any liquid)}}}$$

D. Approximate specific gravities (S_g) for various gases:

Air	1.000
Ammonia	.596
Argon	1.379
Arsine	2.695
Carbon Dioxide	1.529
Helium	.138
Hydrogen	.070
Hydrogen Chloride	1.268
Nitrogen	.967
Oxygen	1.105
Silane	1.195

To convert the flow from air (specific gravity of 1.0) to a gas having a specific gravity other than 1.0 use the following formula:

$$Q_g \text{ (any gas)} = Q_g \text{ (air)} \sqrt{\frac{1}{S_g \text{ (any gas)}}}$$

CGA Compressed Gas Cylinder Valve Outlets and Connections:

GAS	CGA Valve Outlet and Conn.	GAS	CGA Valve Outlet and Conn.	GAS	CGA Valve Outlet and Conn.	GAS	CGA Valve Outlet and Conn.
Acetylene	510	2-2 Dimethyl Propane	510	“Genetron 152A”		Nitrogen	580
Air (Breathing)	346	Ethane	350	(1,1-Difluoroethane)	660	Nitrogen (6000 psig)	677
Air (Industrial)	346	Ethyl Acetylene	510	Germane	350	Nitrogen Dioxide	660
Allene	510	Ethyl Chloride	300	Helium	580	Nitrogen Trioxide	660
Ammonia, Anyhdrous	705	Ethylene	350	Hexafluoroacetone	660	Nitrosyl Chloride	660
Ammonia (U.H.P)	660	Ethylene Oxide	510	Hydrogen	350	Nitrous Oxide	326
Argon	580	Fluorine	679	Hydrogen Bromide	330	Oxygen	540
Argon (6000 psig)	677	“Freon 12”		Hydrogen Chloride	330	Ozone	660
Arsine	350	(Dichlorodifluoromethane)	660	Hydrogen Fluoride	660	Perfluorobutene-2	660
Boron Trichloride	660	“Freon 13”		Hydrogen Iodide	330	Perfluorophropane	660
Boron Trifluoride	330	(Chlorotrifluoromethane)	320	Hydrogen Selenide	660	Phosgene	660
Bromine Pentafluoride	670	“Freon 13B1”		Hydrogen Sulfide	330	Phosphine	350
Bromine Trifluoride	670	(Bromotrifluoromethane)	320	Iodine Pentafluoride	670	Phosphorus Pentafluoride	330
1-3 Butadiene	510	“Freon 14”		Isobutane	510	Propane	510
Butane	510	(Tetrafluoromethane)	320	Isobutylene	510	Propylene	510
Butenes	510	“Freon 22”		Krypton	580	Silane (High Pressure)	350
Carbon Dioxide	320	(Chlorodifluoromethane)	660	“Manufactured Gas B”	350	Silane (Low Pressure)	510
Carbon Monoxide	350	“Freon 114” (1,2		Methane	350	Silicon Tetrafluoride	330
Carbonyl Fluoride	660	Dichlorotetrafluorethane)	660	Methyl Acetylene	510	Sulfur Dioxide	660
Carbonyl Sulfide	330	“Freon 116”		Methyl Bromide	320	Sulfur Hexafluoride	668
Chlorine	660	(Hexafluoroethane)	320	3-Methyl Butene-1	510	Sulfur Textrafluoride	330
Chlorine Trifluoride	670	“Freon C318”		Methyl Chloride	660	Sulfuryl Fluoride	330
Chlorotrifluoroethylene	660	(Octafluorocyclobutane)	660	Methyl Mercaptan	330	Trimethylamine	705
Cyanogen	660	“Genetron 21”		Monoethylamine	705	Vinyl Bromide	290
Cyclopropane	510	(Dichlorofluoromethane)	660	Monomethylamine	705	Vinyl Chloride	290
Deuterium	350	“Genetron 23” (Fluoroform)	320	Natural Gas	350	Vinyl Floride	350
1,1-Difluoroethylene	350	“Genetron 115”		Neon	590	Vinyl Methyl Ether	290
Dimethylamine	705	(Monochloropentafluoroethane)	660	Nickel Carbonyl	320	Xenon	580
Dimethyl Ether	510			Nitric Oxide	660		