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Common Equivalents & Conversions

WARNING

Don't become a casualty!

Beware of confined spaces where there is insufficient oxygen to support life. Types of confined spaces include:

A. Pits and deep depressions, sewers

B. Above-ground confined spaces such as air separation cold boxes and similar insulated cavities, silos, furnace boxes, combustion chambers, etc.

C. Tanks on railroad cars and highway vehicles, storage tanks, mixing tanks

D. Reaction kettles, stills, receivers, steam drums

E. Acetylene generators and gas holders

Where atmospheric air is not deliberately provided, or where breathing equipment is not available, Tank Entry Procedures as published and provided by this company or similarly detailed procedures published by other interested organizations must be rigidly followed.

All data set forth herein is provided for general information only and is based on generally accepted tests and on published data from standard technical reference works. The accuracy or completeness of any such information, test or data is not warranted in any way.

Approximate Common Equivalents

1 inch	=	25 millimeters
1 foot	=	0.3 meter
1 yard	=	0.9 meter
1 mile	=	1.6 kilometers
1 sq inch	=	6.5 sq cm
1 sq foot	=	0.09 sq meter
1 sq yard	=	0.8 sq meter
1 acre	=	0.4 hectare+
1 cu inch	=	16 cu cm
1 cu foot	=	0.03 cu meter
1 quart (lq)	=	1 liter+
1 gallon	=	0.004 cu meter
1 ounce (avdp)	=	28 grams
1 pound (avdp	=	0.45 kilogram
1 horsepower	=	0.75 kilowatt
1 millimeter	=	0.04 inch
1 meter	=	3.3 feet
1 meter	=	1.1 yards
1 kilometer	=	0.6 mile
1 sq centimeter	=	0.06 cu inch
1 cu meter	=	35 cu feet
1 cu meter	=	1.3 cu yards
1 cubic meter	=	250 gallons
1 liter+	=	1 quart
1 gram	=	0.035 oz (avdp)
1 kilogram	=	2.2 lbs (avdp)
1 kilowatt	=	1.3 horsepower

+ common term not used in S1
* exact
Source: NBS Special Pub. 304.

Conversions Accurate to Parts Per Million

inches x 25.4	=	millimeters
feet x 0.3048"	=	meters
yards x 0.9144	=	meters
miles x 1.609.34	=	kilometers
sq inches x 6.4516*	=	sq centimeters
sq feet x 0.0929030	=	sq meters
sq yards x 0.836127	=	sq meters
acres x 0.404686	=	hectares
cu inches x 16.3871	=	cu centimeters
cu feet x 0.0283168	=	cu meters
cu yards x 0.764555	=	cu meters
quarts (lq) x 0.946353	=	liters
gallons x 0.00378541	=	cu meters
ounces (avdp) x 28.3495	=	grams
pounds (avdp) x 0.453592	=	kilograms
horsepower x 0.745700	=	kilowatts
millimeters x 0.03937701	=	inches
meters x 3.28084	=	feet
meters x 1.09361	=	yards
kilometers x 0.621371	=	miles
sq centimeters x 0.155000	=	sq inches
sq meters x 10.7639	=	sq feet
sq meters x 1.19499	=	sq yards
hectares x 2.47104	=	acres
cu cm x 0.0610237	=	cu inches
cu meters x 35.3147	=	cu feet
cu meters x 1.30795	=	cu yards
liters x 1.05669	=	quarts (lq)
cu meters x 264.172	=	gallons
grams x 0.0352740	=	ounces (avdp)
kilograms x 2.20462	=	pounds (avdp)
kilowatts x 1.34102	=	horsepower

Table of Contents

Page No.

Table of Contents

Page No.

Physical Properties of Selected Gases

Name of Gas	Oxygen	Nitrogen	Argon	Helium	Methane
Chemical Symbol	O_2	N_2	Ar	He	CH_4
Molecular Weight	31.9988	28.0134	39.948	4.0026	16.043
Color	None	None	None	None	None
Odor	None	None	None	None	None
Taste	None	None	None	None	None
Spec. Gravity (Air=1) 70°F. 1 Atm.	1.105	0.9669	1.395	0.13796	.5539
Density lb Per cu ft 70°F 1 Atm.	0.08281	0.07245	0.1034	0.01034	.0415
Spec Vol. cu ft per lb 70°F 1 Atm.	12.076	13.803	9.671	96.71	24.096
Density Sat'd Vapor, lb per cu ft 1 Atm.	0.27876	0.2874	0.35976	1.0434	.1134
Normal Boiling Point °F	-297.33	-320.36	-302.55	-452.1	-258.7
Heat of Vaporization BTU per Pound	91.7	85.6	70.1	9	223.3
Critical Pressure Atmospheres, Abs.	50.14	33.54	48.34	2.26	666.88
lb per sq in, Abs.	736.9	492.9	710.4	33.2	
Critical Temp. °F	-181.08	-232.40	-188.12	-450.31	-116.67
Triple Point Pressure Atmosphere, Abs.	0.00145	0.1238	0.68005	None	
lb per sq in, Abs.	0.0213	1.189	9.994		1.7032
Triple Point Temp. °F	-361.83	-346.01	-308.8	None	-296.45
Specific Heat Const. Press	0.2199 @77°F	0.2488 @77°F	0.1244 @77°F	1.2404 @77°F	.5339 @80°F
Ratio Specific Heats	1.396 @80.3°F	1.4014 @70°F	1.6665 @86°F	1.6671 @77°F	1.305 @80°F
Coeff. Viscosity, Micropoises @77°F	206.39	177.96	226.38	198.5	112
Thermal Conductivity, 32°F BTU/(sq ft)(Hr.)(°F/ft)	0.0142	0.0139	0.00980	0.08266 @40°F	.0193 @70°F
Ionization Potential, Volts	13.6	14.5	15.7	24.5	
Exitation Potentials: First Resonance Potential, Volts	9.1	6.3	11.56	20.91	
Metastable Potentials, Volts			11.66 11.49	19.77	

* Normal sublimation temperature ** Latent heat of sublimation

Physical Properties of Selected Gases

Acetylene	Hydrogen	Neon	Krypton	Xenon	Air
C_2H_2	H_2	Ne	Kr	Xe	—
26.0382	2.01594	20.183	83.80	131.30	28.96
None	None	None	None	None	None
Sweet	None	None	None	None	None
None	None	None	None	None	None
0.9053	0.0695	0.6958	2.898	4.56	1.0
0.06785	0.005209	0.05215	0.2172	0.3416	0.07493
14.7	192.0	19.175	4.604	2.927	13.3
0.10800	0.083133	0.5963	0.536	0.718	
-118.5*	-423.0	-410.8	-243.8	-162.5	
344.8**	191.7	38.3	46.3	41.4	88.3
60.58	12.98	26.19	54.3	57.64	
890.3	190.8	384.9	798.0	847.1	
+95.32	-399.96	-379.75	-82.8	+61.86	
1.2651	0.071	0.4273	0.7220	0.8064	
18.592	1.04	6.28	10.61	11.85	
-112.99	-434.56	-415.49	-251.28	-169.18	
0.4067 @80°F	3.4202 @77°F	0.2462 @77°F	0.0597 @87°F	0.0382 @77°F	0.2406 @80.3°F
1.234 @77°F	1.405 @77°F	1.642 @68°F	1.701 @87°F	1.666 @68°F	1.4017 @80.3°F
95.5	89.37	313.81 @68°F	251.71	231.02	184.67 @80°F
0.0123 @80°F	0.0973	0.021087	0.00501	0.00293	0.0139
11.6	13.5	21.5	13.9	12.1	
	10.2	16.58	9.98	8.39	
		16.62 16.53	10.51 9.86	9.4 8.28	

Chemical Formula . . . . . CO_2

Molecular Weight 44.01

Color-Vapor and Gas . . . . . None

Solid . . . . . translucent white
Odor . . . . . slight-pungent
Taste . . . . . biting

Specific Gravity (Air-1.0)

Gas at 70°F, atmospheric pressure 1.53

Specific Volume at atmospheric pressure

Gas 60°F . . . . . 8.57 cu ft/lb
Gas 70°F . . . . . 8.74 cu ft/lb

Temperature of Solid at atmospheric pressure . . . . . -109.25°F

Density

Solid: -109.25°F . . . . . 97.6 lb/cu ft
Liquid: +1.7°F 300 psi gauge . . . . . 63.36 lb/cu ft
Liquid: +70°F 839 psi gauge . . . . . 47.35 lb/cu ft

Heat Vaporization

Solid: -109.25°F . . . . . 246.6 BTU/lb

Liquid: +1.7°F 300 psi gauge . . . . . 119.2 BTU/lb

Liquid: +70°F 839 psi gauge . . . . . 63.9 BTU/lb

Specific Heat — gas—varies

(At constant pressure of 1 atmosphere) 70°F . . . . . 0.20 BTU/lb
(At constant volume) . . . . . 0.15 BTU/lb

Viscosity— gas at atmosphere pressure & 70°F . . . . . 0.015 Centipoise

Liquid at 0°F . . . . . 0.14 Centipoise

Critical temperature (highest temperature at which

CO_2 can exist as a liquid . . . . . 87.82°F

Triple Point (temperature pressure combination at which
CO_2 can exist simultaneously as a solid, liquid or gas) . . -69.83°F & 75.13 psia

(Reference: Airco R687 A and data of Plank & Kuprianoff)

Physical State of CO_2 Versus Saturated Vapor Temperature and Pressure

Temperature (°F)	Gauge Pressure (Lb/Sq In)	Specific Volume Cu Ft/ Lb (Liquid or Solid)	(Gas)	Physical State of CO_2
+88.41	1057.0	0.03453	0.0345	Gas Only above this point
+60.0	732.7	0.01970	0.0995	Liquid and Gas
+32.0	490.6	0.0173	0.1663	Liquid and Gas
0.0	291.1	0.01571	0.2905	Liquid and Gas
-20	200.4	0.01498	0.4165	Liquid and Gas
-40	131.2	0.01437	0.6113	Liquid and Gas
-69.83 triple	60.4	0.01360	1.1570	Liquid and Gas
-69.83 point	60.4	0.01059	1.1570	Gas and Solid
-90.0	19.4	0.01040	2.52	Gas and Solid
-109.25	0.0	0.01025	5.69	Gas and Solid
-140.0	23.4*	0.01007	24.5	Gas and Solid

* Inches of mercury vacuum

Property	Condition	Value
International Symbol		N_2O
Molecular Weight		44.013
Vapor Pressure, psia	@ -4°F	262
	@ 32°F	455
	@ 68°F	736
	@ 98°F	1055
Density, gas @ 1 atm, lb/cu ft	@ 32°F	0.1230
	@ 68°F	0.1146
Specific Gravity, gas @ 32°F and 1 atm (air=1)		1.529
Specific Volume, gas @ 1 atm, cu ft/lb	@ 32°F	8.130
	@ 68°F	8.726
Density, saturated vapor, lb/cu ft	@ boiling point	0.194
	@ -4°F and 262 psia	2.997
	@ 68°F and 736 psia	10.051
Density, liquid	@ boiling point and 1 atm	76.6
	@ 70°F	48.3
Specific Gravity, liquid @ 68°F and 736 psia		0.785
Boiling Point @ 1 atm		–127.3°F
Melting Point @ 1 atm		–131.5°F
Triple Point		–131.5 @ 12.74 psia
Critical Temperature		97.7°F
Critical Pressure, psia		1054
Critical Density, lb/cu ft		28.15
Latent Heat of Vaporization, BTU/lb	@ boiling point	161.8
	@ 32°F	107.5
	@ 68°F	78.7
Latent Heat of Fusion at triple point, BTU/lb		63.9
Specific Heat, gas, at 1 atm, BTU/(lb)(°F)	Cp 77°F to 212°F	0.212
	Cp @ 59°F	0.2004
	Cv @ 59°F	0.1538
Ratio of Specific Heats, Cp/Cv @ 59°F and 1 atm		1.303
Solubility in Water at 1 atm, vol/1 vol of water	@ 32°F	1.3
	@ 68°F	0.72
	@ 77°F	0.66
Solubility in Alcohol at 68°F and 1 atm, vol/1 vol of alcohol		3.0
Weight/gal, liquid, lb	@ boiling point	10.23
	@ -4°F and 262 psia	8.35
	@ 68°F and 736 psia	6.54
Viscosity, gas, centipoises	@ 32°F	0.0135
	@ 80°F	0.0149
Thermal Conductivity, gas @ 32°F (BTU)(ft)/(sq ft)(hr)(°F)		0.0083

Nitrous Oxide

	Pounds	Tons	S.C.F. Gas	S.G. Gas	Gallons/Liquid	Cu Ft/Liquid	Liters/Liquid
1 Pound	1	0.0005	8.711	65.158	0.09782	0.01308	0.37023
1 Ton	2000	1	17.422	130.316	195.64	26.12	740.46
1 S.C.F Gas 70°F – 14.7 psia	0.1148	57.4×10^{-6}	1	7.4805	0.01124	0.001502	0.04250
1 Gallon Gas 70°F – 14.7 psia	0.01535	7.675×10^{-6}	0.13371	1	0.00150	0.000210	0.00568
1 Gallon Liquid	10.223	0.005111	89.053	666.17	1	0.133680	3.78533
1 cu ft Liquid	76.474	0.038237	666.17	4983.28	7.48052	1	28.3162
1 Liter Liquid	2.701	0.001350	23.528	176.00	0.264178	0.0353154	1

SCF (Standard Cubic Feet) Nitrous Oxide Gas are measured at 70°F and 14.7 psia. Liquid Nitrous Oxide quantities are measured at -127.2°F and 14.7 psia.

S.G. (Standard Gallons) Nitrous Oxide Gas are measured at 70°F and 14.7 psia.

Methane

	Weight		Gas		Liquid	
	Pounds (Lb)	Kilograms (Kg)	Cubic Feet (SCF)	Cubic Meters (Nm^3)	Gallons (Gal)	Liters (L)
1 Pound	1	0.4536	24.058	0.67986	0.28366	1.0734
1 Kilogram	2.205	1	53.048	1.4991	0.62548	2.3667
1 Ton	2000	907.2	48116	1359.7	567.33	2146.7
1 SCF Gas	0.0414	0.0188	1	0.028259	0.011744	0.044437
1 Nm^3 Gas	1.465	0.6645	35.386	1	0.41557	1.5725
1 Gal Liquid	3.53	1.6	84.925	2.3999	1	3.7839
1 L Liquid	0.9329	0.4231	22.444	0.63425	0.26463	1

SCF (Standard Cubic Foot) gas measured at 1 atmosphere and 70°F (21.1°C). Liquid measured at 1 atmosphere and boiling temperature.

Nm^3 (normal cubic meter) measured at 1 atmosphere and 0°C. All values rounded to nearest 4/5 significant numbers.

Oxygen

	Weight		Gas		Liquid	
	Pounds (Lb)	Kilograms (Kg)	Cubic Feet (SCF)	Cubic Meters (Nm^3)	Gallons (Gal)	Liters (L)
1 Pound	1.0	0.4536	12.076	0.3174	0.1050	0.3977
1 Kilogram	2.205	1.0	26.62	0.6998	0.2316	0.8767
1 SCF Gas	0.08281	0.03756	1.0	0.02628	0.008691	0.0329
1 Nm^3 Gas	3.151	1.4291	38.04	1.0	0.3310	1.2528
1 Gal Liquid	9.527	4.322	115.1	3.025	1.0	3.785
1 L Liquid	2.517	1.1417	30.38	0.7983	0.2642	1.0

Nitrogen

1 Pound	1.0	0.4536	13.803	0.3627	0.1481	0.5606
1 Kilogram	2.205	1.0	30.42	0.7996	0.3262	1.2349
1 SCF Gas	0.07245	0.03286	1.0	0.02628	0.01074	0.04065
1 Nm^3 Gas	2.757	1.2506	38.04	1.0	0.4080	1.5443
1 Gal Liquid	6.745	3.060	93.11	2.447	1.0	3.785
1 L Liquid	1.782	0.8083	24.60	0.6464	0.2642	1.0

SCF (Standard Cubic Foot) gas measured at 1 atmosphere and 70°F.
Liquid measured at 1 atmosphere and boiling temperature.

Nm^3 (normal cubic meter) measured at 1 atmosphere and 0°C.
All values rounded to nearest 4/5 significant numbers.

Argon

	Weight		Gas		Liquid	
	Pounds (Lb)	Kilograms (Kg)	Cubic Feet (SCF)	Cubic Meters (Nm^3)	Gallons (Gal)	Liters (L)
1 Pound	1.0	0.4536	9.671	0.2543	0.08600	0.3255
1 Kilogram	2.205	1.0	21.32	0.5605	0.18957	0.7176
1 SCF Gas	0.1034	0.04690	1.0	0.02628	0.008893	0.03366
1 Nm^3 Gas	3.933	1.7840	38.04	1.0	0.3382	1.2802
1 Gal Liquid	11.630	5.276	112.5	2.957	1.0	3.785
1 L Liquid	3.072	1.3936	29.71	0.7812	0.2642	1.0

Neon

1 Pound	1.0	0.4536	19.175	0.5040	0.09928	0.3758
1 Kilogram	2.205	1.0	42.27	1.1112	0.2191	0.8292
1 SCF Gas	0.05215	0.02366	1.0	0.02628	0.005177	0.019594
1 Nm^3 Gas	1.9840	0.8999	38.04	1.0	0.19714	0.7462
1 Gal Liquid	10.065	4.565	193.2	5.077	1.0	3.785
1 L Liquid	2.661	1.2070	51.03	1.3410	0.2642	1.0

SCF (Standard Cubic Foot) gas measured at 1 atmosphere and 70°F.
Liquid measured at 1 atmosphere and boiling temperature.

Nm^3 (normal cubic meter) measured at 1 atmosphere and 0°C.
All values rounded to nearest 4/5 significant numbers.

Helium

	Weight		Gas		Liquid	
	Pounds (Lb)	Kilograms (Kg)	Cubic Feet (SCF)	Cubic Meters (Nm^3)	Gallons (Gal)	Liters (L)
1 Pound	1.0	0.4536	96.71	2.542	0.9593	3.631
1 Kilogram	2.205	1.0	213.2	5.603	2.115	8.006
1 SCF Gas	0.01034	0.004690	1.0	0.02628	0.009919	0.03754
1 Nm^3 Gas	0.3935	0.17847	38.04	1.0	0.3775	1.4289
1 Gal Liquid	1.0423	0.4728	100.80	2.649	1.0	3.785
1 L Liquid	0.2754	0.1249	26.63	0.6998	0.2642	1.0

Hydrogen

1 Pound	1.0	0.4536	192.00	5.047	1.6928	6.408
1 Kilogram	2.205	1.0	423.3	11.126	3.733	14.128
1 SCF Gas	0.005209	0.002363	1.0	0.02628	0.008820	0.03339
1 Nm^3 Gas	0.19815	0.08988	38.04	1.0	0.3355	1.2699
1 Gal Liquid	0.5906	0.2679	113.41	2.981	1.0	3.785
1 L Liquid	0.15604	0.07078	29.99	0.7881	0.2642	1.0

SCF (Standard Cubic Foot) gas measured at 1 atmosphere and 70°F.
Liquid measured at 1 atmosphere and boiling temperature.
Hydrogen gas values expressed in the stable conditions 75% ortho, 25% pure.

Nm^3 (normal cubic meter) measured at 1 atmosphere and 0°C.
All values rounded to nearest 4/5 significant numbers.
Hydrogen liquid values expressed in the stable para condition.

Krypton

	Weight		Gas		Liquid	
	Pounds (Lb)	Kilograms (Kg)	Cubic Feet (SCF)	Cubic Meters (Nm^3)	Gallons (Gal)	Liters (L)
1 Pound	1.0	0.4536	4.604	0.12098	0.04967	0.1880
1 Kilogram	2.205	1.0	10.147	0.2667	0.10939	0.4141
1 SCF Gas	0.2172	0.09852	1.0	0.02628	0.010773	0.04078
1 Nm^3 Gas	8.266	3.749	38.04	1.0	0.4101	1.5525
1 Gal Liquid	20.13	9.131	92.69	2.436	1.0	3.785
1 L Liquid	5.318	2.412	24.51	0.6441	0.2642	1.0

Xenon

1 Pound	1.0	0.4536	2.927	0.07692	0.03921	0.14840
1 Kilogram	2.205	1.0	6.451	0.16958	0.08642	0.3271
1 SCF Gas	0.3416	0.15495	1.0	0.02628	0.013392	0.05069
1 Nm^3 Gas	13.000	5.897	38.04	1.0	0.5096	1.9291
1 Gal Liquid	25.51	11.572	74.67	1.9623	1.0	3.785
1 L Liquid	6.738	3.056	19.726	0.5185	0.2642	1.0

SCF (Standard Cubic Foot) gas measured at 1 atmosphere and 70°F.
Liquid measured at 1 atmosphere and boiling temperature.

Nm^3 (normal cubic meter) measured at 1 atmosphere and 0°C.
All values rounded to nearest 4/5 significant numbers.

Carbon Dioxide

	Weight			Gas		Liquid		Solid
	Pounds (Lb)	Tons (T)	Kilograms (Kg)	Cubic Feet (SCF)	Cubic Meters (Nm^3)	Gallons (Gal)	Liters (L)	Cubic Feet (Cu Ft)
1 Pound	1.0	0.0005	0.4536	8.741	0.2294	0.11806	0.4469	0.010246
1 Ton	2000.0	1.0	907.2	17,483.0	458.8	236.1	893.9	20.49
1 Kilogram	2.205	0.0011023	1.0	19.253	0.5058	0.2603	0.9860	0.2260
1 SCF Gas	0.1144	—	0.05189	1.0	0.02628	0.013506	0.05113	0.0011723
1 Nm^3 Gas	4.359	0.002180	1.9772	38.04	1.0	0.5146	1.9480	0.04468
1 Gal Liquid	8.470	0.004235	3.842	74.04	1.9431	1.0	3.785	0.08678
1 L Liquid	2.238	0.0011185	1.0151	19.562	0.5134	0.2642	1.0	0.02293
1 Cu Ft Solid	97.56	0.04880	44.25	852.8	22.38	11.518	43.60	1.0

SCF (Standard Cubic Foot) gas measured at 1 atmosphere and 70°F.
Nm^3 (normal cubic meter) gas measured at 1 atmosphere and 0°C.
Liquid measured at 21.42 atmospheres and 1.7°F.
All values rounded to nearest 4/5 significant numbers.
Solid measured at -109.25°F.

Oxygen

1 lb Gaseous Oxygen = 12.08 scf at 14.7 psia and 70°F.

1 ton Gaseous Oxygen = 24,160 scf at 14.7 psia and 70°F.

scf/mo (millions)	tons/day
1	1.38
2	2.76
3	4.14
4	5.52
5	6.90
6	8.28
7	9.66
8	11.04
9	12.42
10	13.80
20	27.59
30	41.39
40	55.19
50	68.98

tons/day	scf/mo (millions)
10	7.25
12.5	9.06
25	18.12
50	36.24
75	54.36
100	72.5

Nitrogen

1 lb Gaseous Nitrogen = 13.80 scf at 14.7 psia and 70°F.

1 ton Gaseous Nitrogen = 27,605 scf at 14.7 psia and 70°F.

scf/mo (millions)	tons/day
1	1.21
2	2.42
3	3.62
4	4.83
5	6.04
6	7.25
7	8.45
8	9.66
9	10.87
10	12.08
20	24.15
30	36.23
40	48.30
50	60.38

tons/day	scf/mo (millions)
10	8.28
12.5	10.35
25	20.70
50	41.41
75	62.11
100	82.82

Hydrogen

1 lb. Gaseous Hydrogen = 192.0 scf at 14.7 psia and 70°F.

1 ton Gaseous Hydrogen = 383,950 scf at 14.7 psia and 70°F.

scf/mo (millions)	tons/day
1	0.087
2	0.174
3	0.26
4	0.35
5	0.43
6	0.52
7	0.61
8	0.69
9	0.78
10	0.87
20	1.74
30	2.60
40	3.47
50	4.34

tons/day	scf/mo (millions)
10	115.2
12.5	144
25	288
50	576
75	864
100	1152

* Based on 30 day month

Mean Specific Heats

$\bar{C}p = H/t - 60$ BTU per lb, per °F

t (°F)	O_2	H_2	H_2O	N_2	CO	CO_2
100	0.2188	3.420	0.4448	0.2482	0.4285	0.2022
200	0.2203	3.434	0.4472	0.2485	0.2488	0.2086
300	0.2221	3.442	0.4499	0.2488	0.2493	0.2145
400	0.2240	3.448	0.4529	0.2493	0.2501	0.2201
500	0.2259	3.452	0.4562	0.2500	0.2511	0.2253
600	0.2279	3.455	0.4597	0.2509	0.2522	0.2301
700	0.2299	3.458	0.4634	0.2520	0.2535	0.2346
800	0.2318	3.462	0.4674	0.2531	0.2549	0.2388
900	0.2337	3.466	0.4715	0.2544	0.2564	0.2428
1000	0.2355	3.470	0.4757	0.2558	0.2580	0.2465
1100	0.2373	3.475	0.4800	0.2572	0.2596	0.2500
1200	0.2390	3.480	0.4844	0.2586	0.2611	0.2533
1300	0.2406	3.487	0.4888	0.2600	0.2627	0.2564
1400	0.2420	3.494	0.4932	0.2614	0.2642	0.2593
1500	0.2434	3.501	0.4976	0.2628	0.2657	0.2620
1600	0.2448	3.510	0.5021	0.2642	0.2672	0.2646
1700	0.2461	3.519	0.5066	0.2656	0.2686	0.2671
1800	0.2473	3.528	0.5111	0.2669	0.2700	0.2694
1900	0.2484	3.538	0.5156	0.2682	0.2713	0.2716
2000	0.2495	3.549	0.5201	0.2695	0.2726	0.2737
2100	0.2506	3.460	0.5245	0.2707	0.2739	0.2757
2200	0.2517	3.572	0.5289	0.2719	0.2751	0.2776
2300	0.2527	3.584	0.5334	0.2732	0.2763	0.2795
2400	0.2536	3.596	0.5375	0.2742	0.2774	0.2813
2500	0.2545	3.608	0.5415	0.2753	0.2784	0.2830
2600	0.2554	3.620	0.5456	0.2764	0.2794	0.2845
2700	0.2562	3.632	0.5496	0.2774	0.2804	0.2860
2800	0.2570	3.644	0.5536	0.2784	0.2814	0.2875
2900	0.2578	3.656	0.5575	0.2793	0.2823	0.2889
3000	0.2585	3.668	0.5614	0.2802	0.2831	0.2902
3100	0.2593	3.680	0.5652	0.2811	0.2840	0.2915
3200	0.2600	3.692	0.5688	0.2819	0.2848	0.2927

Courtesy of AFS Handbook of Cupola Operation

Densities At Various Saturation Pressures

	OXYGEN		NITROGEN		ARGON	
Saturation Pressure PSIG	Liquid Density Lbs/Ft^3	Gas Density SCF/Gal	Liquid Density Lbs/Ft^3	Gas Density SCF/Gal	Liquid Density Lbs/Ft^3	Gas Density SCF/Gal
0	71.17	115.10	50.44	93.11	87.51	112.50
5	70.42	113.72	49.62	91.55	85.77	110.89
10	69.80	112.73	49.00	90.40	84.77	109.60
25	67.86	109.59	47.50	87.63	82.46	106.61
50	65.55	105.86	45.69	84.18	79.90	103.31
75	63.76	102.97	44.19	81.53	77.90	100.71
100	62.43	100.82	42.88	79.12	76.15	98.45
150	59.80	96.57	40.70	75.08	73.16	94.59
200	57.62	93.05	38.76	71.51	70.28	90.87
250	55.60	89.79	36.83	67.95	67.79	87.65

Note: Density of water at 60°F = 62.30 lbs/cu ft

Gas Densities at Liquid Pressures

SCF of GAS / Liter of LIQUID

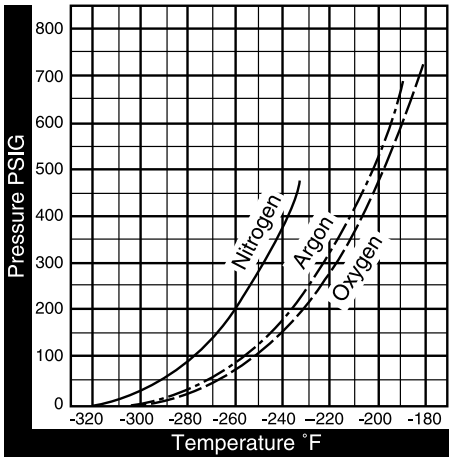
Pressure psig	Argon	Nitrogen	Oxygen	CO_2
0	29.69	24.60	30.36	
25	28.24	23.17	28.89	
50	27.32	22.26	27.97	
75	26.60	21.53	27.25	22.40
100	25.98	20.89	26.63	21.96
125	25.43	20.33	26.09	21.57
150	24.93	19.80	25.59	21.23
175	24.46	19.30	25.12	20.91
200	24.01	18.82	24.67	20.61
225	23.58	18.35	24.24	20.34
250	23.17	17.89	23.83	20.07
275	22.77	17.43	23.43	19.82
300	22.37	16.96	23.03	19.58
325	21.98	16.47	22.64	19.34
350	21.43	15.96	22.25	19.11
375	21.19	15.42	21.86	18.88
400	20.79	14.80	21.47	18.66
425	20.39	14.07	21.08	18.44

Gas Densities at Liquid Pressures

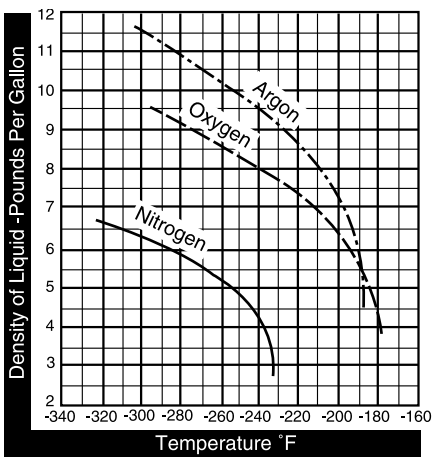
SCF of GAS / Gallon of LIQUID

Pressure psig	Argon	Nitrogen	Oxygen	CO_2
0	112.38	93.11	114.91	
25	106.89	87.70	109.35	
50	103.41	84.25	105.87	
75	100.68	81.49	103.14	84.78
100	98.33	79.07	100.79	83.12
125	96.25	76.95	98.75	81.64
150	94.36	74.94	96.86	80.36
175	92.58	73.05	95.08	79.14
200	90.87	71.23	93.38	78.01
225	89.25	69.45	91.75	76.99
250	87.70	67.71	90.20	75.96
275	86.18	65.97	88.68	75.02
300	84.67	64.19	87.17	74.11
325	83.19	62.34	85.69	73.20
350	81.11	60.41	84.22	72.33
375	80.20	58.36	82.74	71.46
400	78.69	56.02	81.26	70.63
425	77.18	53.25	79.79	69.80

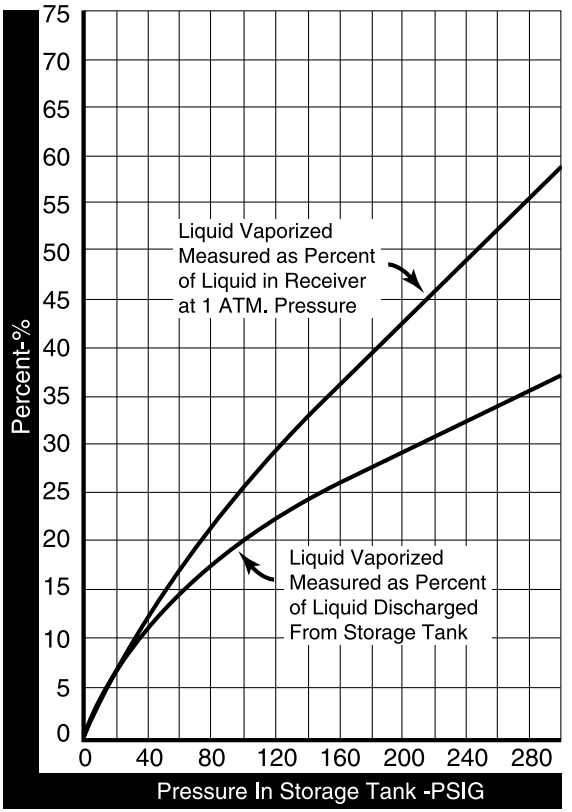
Pressure over liquid oxygen, nitrogen and argon compared with temperature at which liquids boil



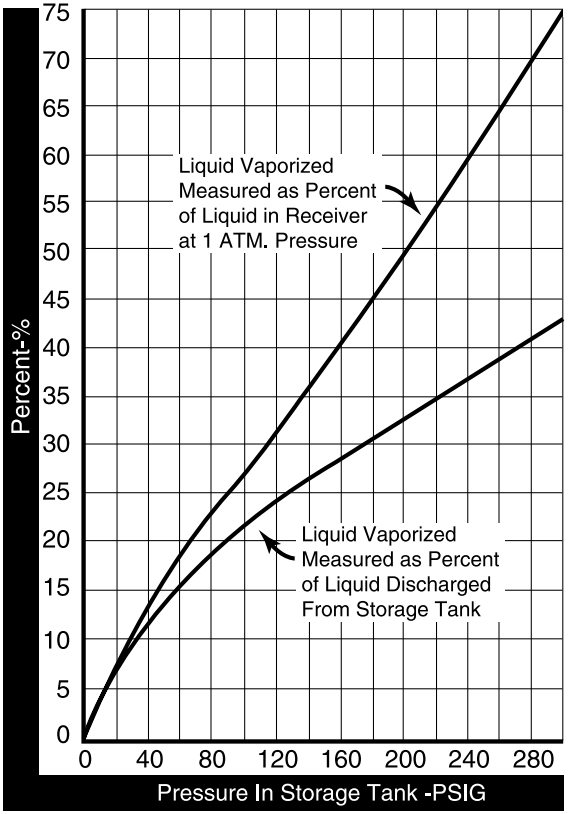
Density-temperature relationships for liquid oxygen, nitrogen and argon



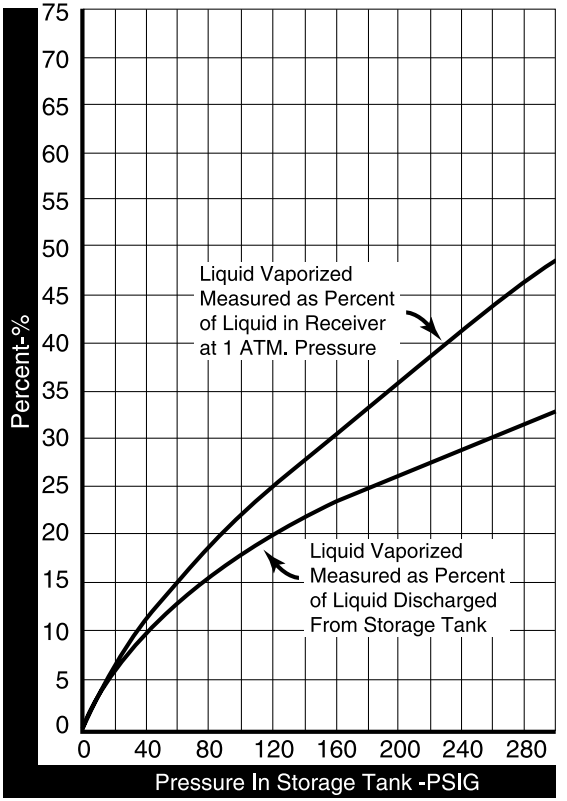
Vapor release from depressurized liquid oxygen



Vapor release from depressurized liquid nitrogen



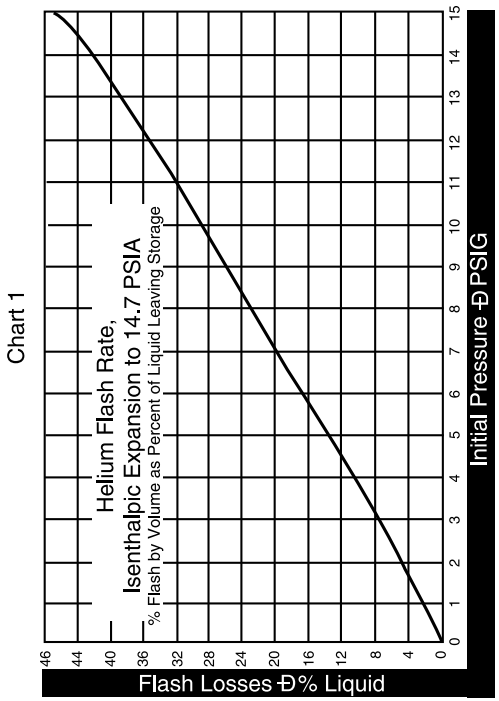
Vapor release from depressurized liquid argon



Vapor release from depressurized liquid helium

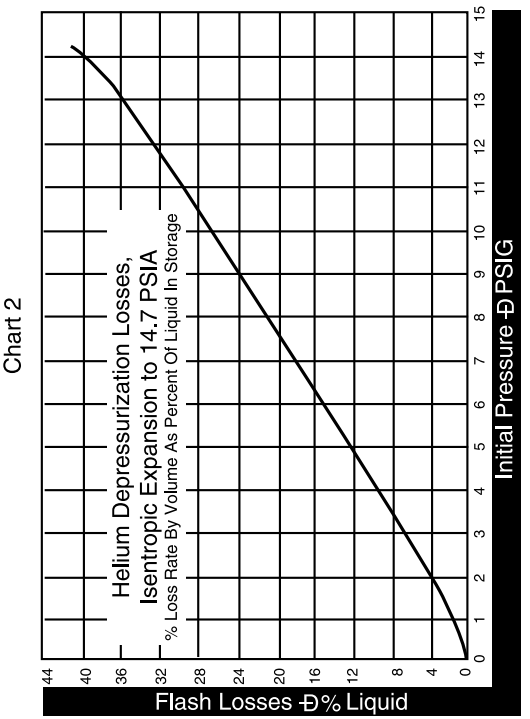
In addition to liquid losses due to container and transfer tube normal heat leak, tube and receiving vessel cool down, boil-off in the container resulting from heat input of the pressurizing gas and saturated vapor equalization, there is a flash loss from the pressure drop in a transfer line and a loss from depressurizing a container after making a partial withdrawal.

For best transfer efficiency, the withdrawal should be started and maintained with as low a pressure as practical. Too low a pressure will require a longer time to make a transfer and thus permit heat leak in the transfer system to become excessive. A balance between effects of heat leak and depressurization generally may be attained by operating in a pressure range of 2 to 3 psig.

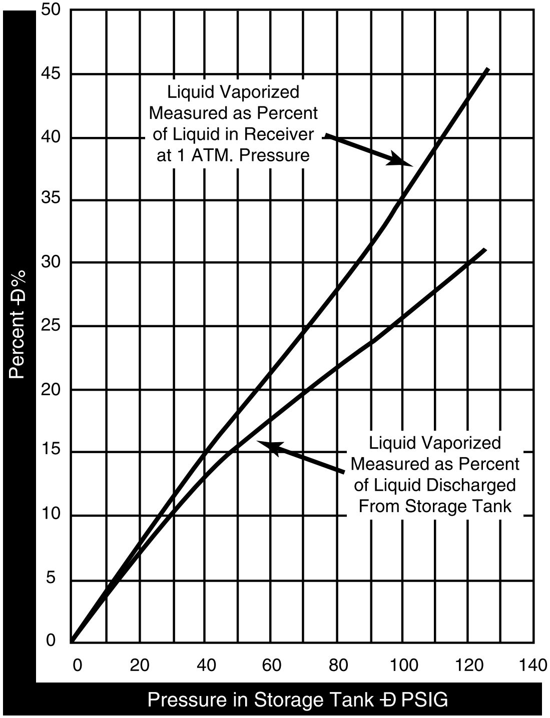


Flash loss due to pressure drop through the transfer line may be estimated by use of Chart 1 “Helium Flash Rate.” Depressurization loss of liquid in the container may be estimated by use of Chart 2 “Helium Depressurization Losses.”

For example: Assume a helium container is discharging at a constant pressure of 5 psig. From Chart 1 the flash loss is approximately 13.8% of the liquid entering the transfer tube. From Chart 2 the loss from depressurizing the container is approximately 12.5% of the liquid remaining in the container.



Vapor release from depressurized liquid hydrogen



Refrigeration Values to +40°F for Expendable Refrigerants

Refrigerant	Refrigerant Temp °F	Pressure psia	Latent Heat BTU/lb	Sensible Heat BTU/lb	Total Heat BTU/lb
Water Ice	32°	14.7	144.0	8.0	152.0
Liquid CO_2 (flashed to snow)	-109°	14.7	113.0*	29.8	149.8
Dry Ice					
Blocks	-109°	14.7	246.3	29.8	276.1
Pellets	-109°	14.7	246.3	29.8	276.1
Liquid Nitrogen					
@ 1 atm	-320°	14.7	85.6	94.0	179.6
@ 5 atm	-288°	73.5	61.0	95.0	156.0

$$\text{Effective Refrigerant Cost} = \frac{\text{Refrigerant Cost Per Pound}}{\text{Total Heat Removed Per Pound}}$$

Water ice has a liquid residue while remaining refrigerants are converted to the gas phase. CO_2 snow is flashed from liquid CO_2 at 314.7 psia storage pressure. Snow yield is 46% by weight. Liquid carbon dioxide is stored at zero degrees and maintained at zero degrees by a mechanical refrigerator. This permits storage of liquid carbon dioxide without loss. Dry ice pellets are manufactured by compressing CO_2 snow in an extrusion machine. Liquid nitrogen losses are present during storage.

* This latent heat value is BTU per pound of liquid CO_2.

Net Positive Suction Head Requirements for Cryogenic Pumps

More pump problems result from incorrect determination of Net Positive Suction Head (NPSH) than from any other single cause.

Liquids at any temperature above their freezing have a corresponding vapor pressure which must be taken into account when planning a pumping system. NPSH can be defined as the difference between the actual pressure and the vapor pressure of the liquid at the suction port of the pump. This is also sometimes referred to as “sub-cooling” or “super pressure.”

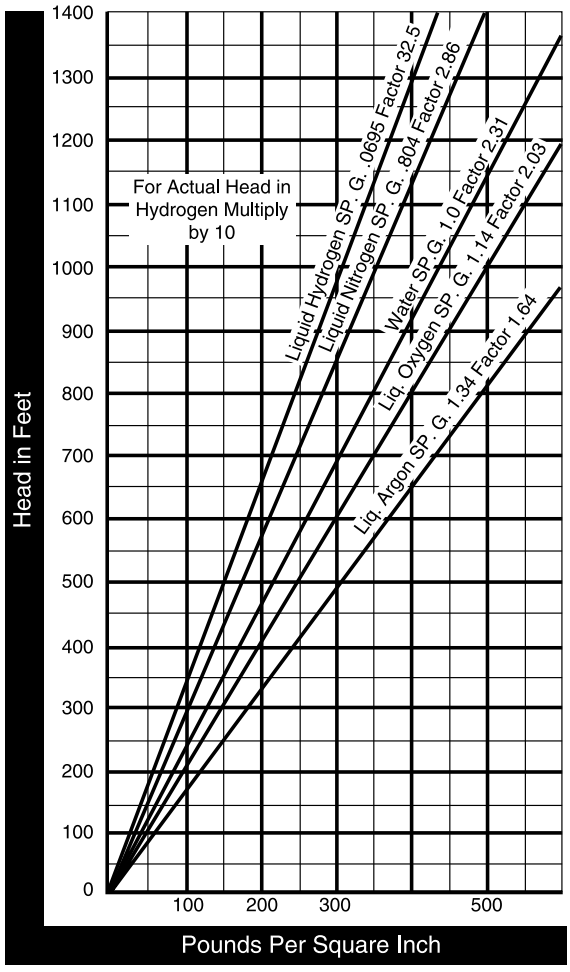
While sitting idle, the liquid in a storage vessel will gradually absorb heat and with all the vents closed, will generate pressures that are directly related to the temperature of the liquid. These pressures are called the “saturated vapor pressures.” This saturated condition exists as long as the liquid is at its boiling point for any given pressure in the vessel. The important point to remember is that no matter what the tank pressure is, any reduction in pressure will cause the saturated liquid to boil.

No cryogenic pump can operate on saturated liquid since in order to establish flow into the pump suction, there must be lower pressure in the pump. This pressure drop causes the saturated liquid to boil, and the resultant vapors enter the pump causing it to “cavitate” and lose prime.

To prevent cavitation, some NPSH must be provided to the pump. The amount of minimum NPSH varies with size, type and make of pump, and is generally indicated on the nameplate. The NPSH can be provided by static head, or elevation of liquid above the pump suction and/or by building an artificial pressure in the supply tank with a pressure building coil. This artificial pressure must be maintained throughout the pumping cycle to insure proper and efficient pump operation.

It is easy to lose, or offset, this “artificial” pressure or liquid head by warming the liquid in the suction line to the pump by heat from the atmosphere. It is possible to have a high “super pressure” in the storage tank so that the liquid is highly “subcooled” and still have saturated liquid at the pump suction. To prevent this, pump suction lines should be short and well insulated.

Head to PSI Conversion



$$PSI = \frac{Ft \times SPG}{2.31} \qquad FT = \frac{PSI \times Water\ (2.31)}{Specific\ Gravity}$$

CONVERSION FORMULAS & FACTORS

Pump Performance with Impeller Diameter &/or Speed Change

Q_1, H_1, bhp_1, D_1 & N_1 = Initial Capacity, Head, Brake Horsepower, Diameter & Speed

Q_2, H_2, bhp_2, D_2 & N_2 = New Capacity, Head, Brake Horsepower, Diameter & Speed

Diameter Change Only	Speed Change Only	Diameter & Speed Change
$Q_2 = Q_1 \left(\frac{D_2}{D_1}\right)$	$Q_2 = Q_1 \left(\frac{N_2}{N_1}\right)$	$Q_2 = Q_1 \left(\frac{D_2}{D_1} \times \frac{N_2}{N_1}\right)$
$H_2 = H_1 \left(\frac{D_2}{D_1}\right)^2$	$H_2 = H_1 \left(\frac{N_2}{N_1}\right)^2$	$H_2 = H_1 \left(\frac{D_2}{D_1} \times \frac{N_2}{N_1}\right)^2$
$bhp_2 = bhp_1 \left(\frac{D_2}{D_1}\right)^3$	$bhp_2 = bhp_1 \left(\frac{N_2}{N_1}\right)^3$	$bhp_2 = bhp_1 \left(\frac{D_2}{D_1} \times \frac{N_2}{N_1}\right)^3$

Temperature

Degrees Fahrenheit = $\frac{9}{5}$ degrees Centigrade + 32

Degrees Centigrade = $\frac{5}{9}$ (degrees Fahrenheit – 32)

Capacity

1 cubic foot per second = 449 gpm
1 million gallons per day = 695 gpm
1 acre foot per day = 449 gpm
1 liter per second = 15.85 gpm

Volume

1 U.S. gallon = 231 cubic inches
= 0.1337 cubic ft
= 3.785 liters
= 0.833 Imperial gal
1 Imperial gallon = 1.2 U.S. gal
1 cubic foot = 7.48 U.S. gal
= 0.0283 cubic meter
1 liter = 0.2642 U.S. gal
1 cubic meter = 35.314 cubic ft
= 264.2 U.S. gal
1 acre foot = 43,560 cubic ft
= 325,829 U.S. gal

Head

1 lb per sq inch = 2.3 feet head of water
= 2.04 inches of mercury
= 0.0703 kg per sq inch
1 foot of water = 0.433 lb per sq inch
1 inch of mercury (or vacuum) = 1.132 foot of water
1 kg per sq cm = 14.22 lb per sq inch
1 atmosphere = 14.7 lb per sq inch
= 34.0 feet of water
= 10.35 meters of water

Weight

1 U.S. gallon of water = 8.33 pounds
1 cubic foot of water = 62.35 pounds
1 kilogram = 2.2 pounds
1 metric ton = 2204.6 pounds

Length

1 mile = 5280 feet
= 1.61 kilometers
1 inch = 2.54 centimeters
1 meter = 3.2808 feet
= 39.3696 inches

$gpm = \frac{\text{Lbs. per hour}}{500 \times \text{Sp. Gr.}}$

$H = \frac{P \times 2.31}{\text{Sp. Gr.}}$

$V = \frac{Q \times 0.321}{A}$

$U = \frac{\text{Diameter (inches)} \times N}{229}$

$h_v = \frac{V^2}{2g}$

$whp = \frac{Q \times H \times \text{Sp. Gr.}}{3960}$

$bhp = \frac{Q \times H \times \text{Sp. Gr.}}{3960 \times e}$

$bhp = \frac{Q \times P}{1715 \times e}$

$T = \frac{bhp \times 5250}{N}$

$N_s = \frac{N\sqrt{Q}}{H^{\frac{3}{4}}} \times \frac{N\sqrt{\sqrt{H}} \times \sqrt{Q}}{H}$

$S = \frac{N\sqrt{Q}}{h_{sv}^{\frac{3}{4}}} \times \frac{N\sqrt{\sqrt{h_{sv}}} \times \sqrt{Q}}{h_{sv}}$

$t_r = \frac{H\left(\frac{1}{e} - 1\right)}{780 \times C}$

gpm = 0.07 x Boiler HP
gpm = 449 x cfs
gpm = 0.0292 x BBL/day
gpm = 0.7 x BBL/hour
gpm = 4.4 x cubic meters/hour

N = Speed in rpm	cfs = Cubic feet per second
N_s = Specific speed in rpm	BBL = Barrel (42 gallons)
S_s = Suction specific speed in rpm	C = Specific heat
Q = Capacity in gpm	Sp. Gr. = Specific gravity
P = Pressure in psi	psi = Pounds per square inch
H = Total head in feet	gpm = Gallons per minute
h_{sv} = Net positive suction head in feet	e = Pump efficiency in decimal
h_v = Velocity head in feet	V = Velocity in feet per second
whp = Water horsepower	D = Impeller diameter in inches
bhp = Brake horsepower	T = Torque in foot pounds
U = Peripheral velocity in feet per sec.	t = Temp. in degrees Fahrenheit
g = 32.16 feet per sec. (acceleration of gravity)	t_r = Temp. rise in degrees Fahrenheit
mgd = Million gallons per day	A = Area in square inches

For lengths of pipe other than 100 feet, the pressure drop is proportional to the length. Thus, for 50 feet of pipe, the air pressure drop is approximately one-half the value given in the table. The pressure drop is also inversely proportional to the absolute pressure and directly proportional to the absolute temperature.

To determine the pressure drop for inlet or average air pressures other than 100 psi and at temperatures other than 60°F, multiply the values given in the table by the formula:

$$\left(\frac{100 + 14.7}{P + 14.7}\right)\left(\frac{460 + t}{520}\right)$$

"P" is the inlet or average gauge pressure in pounds per square inch.

"t" is the temperature in degrees Fahrenheit.

The flow of compressed air in cubic feet per minute at any pressure is inversely proportional to the absolute pressure and directly proportional to the absolute temperature.

To determine the cubic feet per minute of compressed air at any temperature and pressure other than standard conditions, multiply the value of cubic feet per minute of free air by the fomula:

$$\left(\frac{14.7}{14.7 + P}\right)\left(\frac{460 + t}{520}\right)$$

Calculations For Pipe Other Than Schedule 40

To determine the velocity of water, or the pressure drop of water or air, through pipe other than Schedule 40 use the following formulas:

$$v_a = v_{40}\left(\frac{d_{40}}{d_a}\right)^2 \qquad {}^{d}P_a = {}^{d}P_{40}\left(\frac{d_{40}}{d_a}\right)^5$$

"a" refers to velocity or pressure drop through the desired Schedule pipe.

"$_{40}$" refers to the velocity or pressure drop through Schedule 40 pipe as given in the table on the facing page.

CFM Free Air at 60°F and 14.7 psia	CFM Compr. Air at 60°F and 100 psig	Air Pressure Drop In Pounds per Sq Inch per 100 ft of Schedule 40 Pipe For Air at 100 PSIG and 60°F							
		1/4"	**3/8"**	**1/2"**					
1	0.128	0.083	0.018						
2	0.256	0.285	0.064	0.020					
3	0.384	0.605	0.133	0.042	**3/4"**				
4	0.513	1.04	0.226	0.071					
5	0.641	1.58	0.343	0.106	0.027				
						1"			
6	0.769	2.23	0.408	0.148	0.037				
8	1.025	3.89	0.848	0.255	0.062	0.019			
10	1.282	5.96	1.26	0.356	0.094	0.029	**1 1/4"**		
15	1.922	13.0	2.73	0.334	0.201	0.062			
20	2.563	22.8	4.76	1.43	0.345	0.102	0.026	**1 1/2"**	
25	3.204		7.34	2.21	0.526	0.156	0.039	0.019	
30	3.845		10.5	3.15	0.748	0.219	0.055	0.026	
35	4.486		14.2	4.24	1.00	0.293	0.073	0.035	
40	5.126		18.4	5.49	1.30	0.379	0.095	0.044	
45	5.767		23.1	6.90	1.62	0.474	0.116	0.055	**2"**
50	6.408			8.49	1.99	0.578	0.149	0.066	0.019
60	7.690	**2 1/2"**		12.2	2.85	0.819	0.200	0.94	0.027
70	8.971			16.5	3.83	1.10	0.270	0.126	0.036
80	10.25	0.019		21.4	4.96	1.43	0.350	0.162	0.046
90	11.53	0.023		27.0	6.25	1.80	0.437	0.203	0.058
100	12.82	0.029	**3"**		7.69	2.21	0.534	0.247	0.070
125	16.02	0.044			11.9	3.39	0.825	0.380	0.107
150	19.22	0.062	0.021		17.0	4.87	1.17	0.537	0.151
175	22.43	0.083	0.028		23.1	6.60	1.58	0.727	0.205
200	25.63	0.107	0.036		30.0	8.54	2.05	0.937	0.264
225	28.84	0.134	0.045			10.8	2.59	1.19	0.331
250	32.04	0.164	0.055			13.3	3.18	1.45	0.404
275	35.24	0.191	0.066			16.0	3.83	1.75	0.484
300	38.45	0.232	0.078			19.0	4.56	2.07	0.573
325	41.65	0.270	0.090			22.3	5.32	2.42	0.673
350	44.87	0.313	0.104			25.8	6.17	2.80	0.776
375	48.06	0.356	0.119			29.6	7.05	3.20	0.887
400	51.26	0.402	0.134			33.6	8.02	3.64	1.00
425	54.47	0.452	0.151			37.9	9.01	4.09	1.13
450	57.67	0.507	0.168				10.2	4.59	1.26
475	60.88	0.562	0.187				11.3	5.09	1.40
500	64.08	0.623	0.206				12.5	5.61	1.55
550	70.49	0.749	0.248				15.1	6.79	1.87
600	76.90	0.887	0.293				18.0	8.04	2.21
650	83.30	1.04	0.342				21.1	9.43	2.60
700	89.71	1.19	0.395				24.3	10.9	3.00
750	96.12	1.36	0.451				27.9	12.6	3.44
800	102.5	1.55	0.513				31.8	14.2	3.90
840	108.9	1.74	0.576				35.9	16.0	4.40
900	115.3	1.95	0.642				40.2	18.0	4.91
950	121.8	2.18	0.715					20.0	5.47
1000	128.2	2.40	0.788					22.1	6.06
1100	141.0	2.89	0.948					26.7	7.29
1200	153.8	3.44	1.13					31.8	8.63
1300	166.6	4.01	1.32					37.3	10.1
1400	179.4	4.65	1.52						11.8
1500	192.2	5.31	1.74						13.5
1600	205.1	6.04	1.97						15.3
1800	203.7	7.65	2.50						19.3
2000	256.3	9.44	3.06						23.9

PIPE CAPACITIES FLOW — GALLONS PER MINUTE

	Water		70SSU		100SSU		150SSU		200SSU		300SSU		500SSU	
Pipe Size Inches	Gravity	Pressure	Gravity	Pressure	Gravity	Pressure	Gravity	Pressure	Gravity	Pressure	Gravity	Pressure	Gravity	Pressure
3/4	1.42	4.70	0.58	4.21	0.39	4.01	0.25	3.79	0.18	3.64	0.12	3.45	0.068	3.21
1	2.65	9.20	1..04	8.27	0.692	7.85	0.432	7.43	0.324	7.14	0.216	6.75	0.130	5.66
1 1/4	5.30	18.9	3.24	16.9	2.02	16.1	1.30	15.3	0.943	14.7	0.634	13.9	0.389	12.9
1 1/2	8.10	28.4	5.90	25.5	3.74	24.2	2.38	22.9	1.73	20.9	1.17	19.8	0.706	19.4
2	15.60	54.7	11.95	49.0	10.22	46.7	6.55	44.2	4.86	42.4	3.24	40.1	1.94	37.4
2 1/2	25.10	87.4	23.04	78.3	19.50	77.0	13.32	70.5	9.65	67.8	6.55	64.2	3.92	59.8
3	44.50	154	33.2	138	29.5	131	27.1	124	23.2	119	15.7	113	9.22	105.0
4	91.00	317	80.5	284	77	270	72	256	69.8	246	54	233	32.3	217.0
5	164.0	573	139	514	131	489	123	463	116	445	99.1	421	71	392
6	267	930	212	834	202	794	187	751	176	722	159	683	143	570
8	550	1910	469	1,710	436	1,630	401	1,540	379	1,480	350	1,400	312	1,310
10	1,010	3,480	940	3,120	885	2,970	825	2,810	786	2,700	735	2,550	670	2,380
12	1,610	5,590	1,398	5,010	1,305	4,770	1,220	4,519	1,106	4,340	1,085	4,100	995	3,820
14	2,160	7,250	1,880	6,500	1,780	6,190	1,650	5,850	1,580	5,620	1,470	5,320	1350	4,960
16	3,020	10,490	2,610	9,410	2,470	8,760	2,300	8,480	2,180	8,150	2,020	7,700	1840	7,180
18	4,100	14,500	3,580	13,200	3,350	12,400	3,100	13,200	2,920	12,600	2,720	11,000	2500	10,100
20	5,500	19,180	4,850	17,200	4,600	16,400	4,300	15,500	4,100	14,900	3,860	14,100	3580	13,100

1. The flows are based on a loss of head due to friction of fluids in given pipe size for fairly smooth pipe and is considered reasonably conservative. (C = 100)
2. For pitched gravity piping, the loss is one (1) foot per hundred feet of pipe.
3. The pressure piping losses are based on a loss of ten (10) feet per hundred feet of pipe. For short runs and few fittings, use next size smaller pipe; for long runs or many fittings, use a size larger.
4. This chart is designed for rapid sizing of pipe for central coolant systems only. For large complex piping refer to Cameron Hydraulic Data Book.
5. SSU = Standard Sabolt Unit (viscosity).

			Heat of Combustion		Pound Per Pound of Combustible Gas					
			BTU per Pound		Required for Combustion			Products of Combustion		
Name of Gas	Symbol	Mol Weight	Gross	Net	O_2 +	N_2 =	Air	CO_2	H_2P	N_2
Carbon (Solid)	C	12.011	14,093	14,093	2.664	8.863	11.527	3.664	—	8.863
Hydrogen	H_2	2.016	61,100	51,623	7.937	26.407	34.344	—	8.937	26.407
Carbon Monoxide	CO	28.010	4347	4347	0.571	1.900	2.471	1.571	—	1.900
Methane	CH_4	16.043	23,879	21,520	3.990	12.257	17.265	2.744	2.246	13.275
Ethane	C_2H_6	30.070	22,320	20,432	3.725	12.394	16.119	2.927	1.798	12.394
Propane	C_3H_8	44.097	21,661	19,994	3.629	12.074	15.703	2.994	1.634	12.074
Ethylene	C_2H_4	28.054	21,644	20,295	3.422	11.385	14.807	3.138	1.285	11.385
Propylene	C_3H_6	42.081	21,041	19,691	3.422	11.385	14.807	3.138	1.285	11.385
Acetylene	C_2H_2	26.038	21,500	20,776	3.073	10.224	13.297	3.381	0.692	10.224

The Global Measure of Cryogenic Bulk Storage

Chart's VS-01 Series Storage Systems, available in liquid nitrogen, oxygen or argon service are offered in a wide range of sizes for applications requiring Maximum Allowable Working Pressures of 175 and 250 psig (12 and 17 barg) as standard.

Advanced Insulation Technology Provides Longer Holding Times

Our proprietary Composite Super Insulation™ system gives you the competitive edge with high thermal performance, extended hold times, low life-cycle costs and lower weight to reduce operational and installation costs. Chart leads the industry with an innovative, modular piping system designed for performance, durability and low maintenance.

Modular Piping System

Chart's innovative modular piping system provides an Industry Standard Piping Configuration. The advantages include:

- Reduces your life-cycle costs by reducing the number of external piping joints, minimizing the risk of external piping leaks and the cost to repair.
- Simple by design yet robust and able to support a broad range of customer applications.
- Combination Pressure Building/Economizer Regulator for easy pressure adjustment and extended Bonnet Bronze Control Valves for ease of operation.
- Piping modules designed for ease-of-access to all operational control valves with stainless steel interconnecting piping for improved durability.

Model	Gross Capacity Gal	Net Capacity Gal	MAWP* psig	Diameter in	Height in	Weight** (lbs) (175 psi)	Weight** (lbs) (250 psi)	NER*** (%/day in O_2/Ar)	NER (%/day in N_2)
VS 525SC	570	510	– 250	66	105	–	3,300	.55	.89
VS 900SC	940	850	– 250	66	136	–	4,400	.45	.73
VS 1500SC	1,640	1,580	– 250	66	196	–	6,200	.35	.56
VS 3000SC	3,150	3,030	175	250	86	228	11,100	12,800	.25	.40
VS 6000SC	6,010	5,770	175	250	86	383	19,900	21,500	.15	.24
VS 9000SC	9,360	8,990	175	250	114	348	29,400	32,300	.10	.16
VS 11000SC	11,410	10,960	175	250	114	407	35,200	38,700	.10	.16
VS 13000SC	13,470	13,060	175	250	114	466	41,700	45,700	.10	.16
VS 15000SC	15,520	15,060	175	250	114	525	48,000	52,600	.10	.16

* MAWP - Maximum Allowable Working Presure. 400, 500 psig tanks are available upon request.
** Weights are for ASME design.
*** NER = Normal Evaporation Rate

Chart's VS-DSS (Distributor Storage System) Series of vertical bulk storage stations are engineered for superior performance, durability and value. Equipped with our proprietary Composite Super Insulation™ (a light-weight system offering better thermal performance than Perlite), the VS-DSS series provides reduced product losses and a slower rate of pressure rise during periods of non-use. Backing up this performance is a competitive 2-year vacuum warranty.

The modular piping system on our cryogenic tanks was pioneered by Chart, with user-friendly bronze valve manifolds and separate economizer and pressure building regulators coming standard. This means fewer plumbing joints and lower maintenance costs for you.

Available in the 525, 900, 1500, 3000 and 6000 gallon models, the VS-DSS series feature the industry standard thermal performance. The modular plumbing system has been selectively optimized to meet the flow requirements of a complete range of liquid or gas applications. With a comprehensive set of plumbing features, each circuit has been carefully designed to match the demands placed on these vessel sizes. Dual safety relief devices are standard, and tank mounted vaporizers are optional on the 525, 900 and 1500 gallon sizes.

SPECIFICATIONS

Model	VS-DSS 525	VS-DSS 900	VS-DSS 1500	VS-DSS 3000	VS-6000-DSS
Capacity					
Gross (gal)	570	940	1,640	3,150	6,010
Net (gal)	510	850	1,580	3,030	5,770
MAWP (psig)	250	250	250	250	250
Dimensions					
Diameter (in)	66	66	66	86	86
Height (in)	105	136	196	228	383
Weight* (lbs)	3,300	4,400	6,200	12,800	21,500
NER (% /day in O_2/Ar)	.55	.45	.35	.25	.15
(%/day in N_2)	.89	.73	.56	.40	.24
Flow Capacity (SCFH)	9,000	9,000	9,000	18,000	18,000

* Weights are for ASME designs NER = Normal Evaporation Rate

Flow capacity rating down to a 20% contents level with a maximum fall off in tank operating pressure of 15 psig.

$VSCO_2$ Bulk Storage

Our $VSCO_2$ Series of Bulk Carbon Dioxide Storage Tanks continue our pioneering of user-friendly engineered products. This design series offers strength and durability in an all-welded outer container, while maintaining lower life-cycle costs. Utilizing our proprietary Composite Super Insulation™ system along with superior vacuum technology, we are able to offer:

- An ultra-low heat leak - eliminating the need for a costly refrigeration system in most applications.
- No costly down time to refurbish water-soaked or deteriorated foam insulation.

Every $VSCO_2$ pressure vessel is manufactured, tested and stamped in accordance with the latest edition of the ASME Boiler and Pressure Vessel Code, Section VIII, Division I, using SA612 normalized steel. Our $VSCO_2$ Bulk Stations are equipped with an internal cleaning system operated externally, eliminating the need for costly manways.

Product Highlights

- Stainless steel piping for greater strength and durability
- Stainless steel ball valves standard on all fill & process lines
- Minimum number of piping joints, reducing potential piping leaks and maintenance costs
- CGA fill and return fittings with drain valves standard on all models
- High-performance safety system with dual relief valves and rupture disks supplied as standard on all models
- Pressure Building and Vaporizer options available, inquire with factory for more details
- Interchangeable gauge systems with a choice of analog or digital telemetry capable systems are available with flexible stainless steel interconnecting phase lines
- Refrigeration systems including internal coil available as options (vapor space)

$VSCO_2$ Bulk Storage Specifications

SPECIFICATIONS

Model		6 Ton	14 Ton	30 Ton	50 Ton
Capacity					
Net	Tons CO_2	6.4	12.6	29.6	45.8
Gross	Tons CO_2	6.8	13.2	31.1	48.1
Maximum Allowable Working Pressure					
	(psig)	350	350	350	350
Dimensions					
Height	(in)	188	228	287	406
Diameter	(in)	68	86	114	114
Weight*	(lbs)	9,300	17,400	39,600	56,900
NER					
	(%/day in CO_2)	.15	.08	.05	.04

* Tare Weight

ChillZilla® CO_2

The ChillZilla® bulk CO_2 food freezing and dry ice production system increases the refrigeration capacity of the liquid CO_2 by as much as **24%** over traditional bulk tanks. ChillZilla incorporates a patent pending design to lower the saturation pressure of the liquid output without reducing the delivery pressure. With the aid of an external refrigeration system, an internal heat exchanger coil and an insulating baffle, the temperature of the liquid CO_2 is effectively reduced. This system subcools the saturated liquid CO_2 from 300 psig to 120 psig while the electric pressure builder maintains the high tank vapor pressure necessary for consistent CO_2 delivery to the application. The result is an *increase* in refrigeration capacity in the liquid or an *improved* snow yield from 41 to 51%.

Product Highlights

- Reduce liquid CO_2 consumption by as much as 24%
- Reduce bulk tank minimum operating temperature from -40°F to -320°F with stainless steel inner vessel
- T304 stainless steel inner complies with food grade standards
- Improve bulk tank thermal efficiency with vacuum-insulated super insulation system
- Control freezing process more accurately by controlling liquid conditions
- Flexible system control allows lower tank operating pressure to further reduce operating costs
- Reduce deliveries at bulk tank site
- Reduce CO_2 emissions
- Liquid connection: 2" NPS, Python®-Ready

ChillZilla® CO_2 Specifications

SPECIFICATIONS

Model		50 Ton
Capacity		
Net	Tons CO_2	45.8
Gross	Tons CO_2	48.1
Maximum Allowable Working Pressure		
	(psig)	350
Dimensions		
Height	(in)	406
Diameter	(in)	114
Weight*	(lbs)	56,900
NER		
	(%/day in CO_2)	.04

* Tare Weight

The ChillZilla® bulk LN_2 supply management system is engineered to provide consistent liquid nitrogen for optimum equipment performance. Ideally suited for Individually Quick Frozen (IQF), LN_2 immersion freezers and cryobiological storage freezers, the ChillZilla LN_2 system features a Dynamic Pressure Builder™ for precise saturated liquid supply to the freezer regardless of the LN_2 liquid level. The ChillZilla incorporates an insulation baffle to inhibit the mixing of fresh liquid from a trailer load delivery with the liquid supply to the freezer for better liquid supply stability during the refill.

With the aid of a patented high performance two-stage ambient pressure building coil, the heat management of this circuit is optimized for fast pressure recovery and reduced heat transfer to the contents. Coupling these unique features with the temperature monitoring of the liquid supply, a Programmable Logic Controller (PLC), VJ feed valve with an extended VJ pod and extended legs, the ChillZilla LN_2 system automatically provides the optimum liquid nitrogen supply to any liquid application.

Ideally suited for other LN_2 applications with the same demand, like cryogenic rubber and tire deflashing. Optional gas use conversion assembly available.

Product Highlights

- Dynamic Pressure Builder System™ for precise saturated LN_2 supply regardless of liquid level
- Insulation Baffle with dedicated upper fill port for uninterrupted LN_2 supply during transport refill
- High performance two-stage ambient pressure builder vaporizer for maximum efficiency (20 gpm (4 tph) standard)
- PLC controlled with actual LN_2 storage temperature, pressure and level monitoring for precise tank pressure control (PB and Vent) with automatic desaturation capability
- High flow automatic pressure building valve improves response time and performance after a fill along with a tighter operating pressure dead-band
- Extended legs and vacuum insulated pod for increased head pressure aids in dampening LN_2 saturation pressure fluctuations
- Large 1½" vacuum insulated inner supply line provides 20 gpm flow*

** 1½" VIP system of 300' VIP + 5 elbows + 2 valves = 2 psi pressure drop*

SPECIFICATIONS

Model		VS 9000CZ	VS 11000CZ	VS 13000CZ	VS 15000CZ
Capacity					
Net	Gal LN_2	8,990	10,960	13,060	15,060
Gross	Gal LN_2	9,354	11,410	13,470	15,520
Maximum Allowable Working Pressure					
	(psig)	175	175	175	175
Dimensions					
Height	(in)	398	457	516	575
Diameter	(in)	114	114	114	114
Weight*	(lbs)	32,100	37,900	44,300	50,600
NER					
	(%/day in LN_2)	.16	.16	.16	.16

* Tare Weight

VS High Pressure Bulk Stations

Chart's VS High Pressure Bulk Stations are engineered for superior performance in high pressure applications. To support these demands, the VS High Pressure Bulk Station comes standard with a larger pressure-building regulator and coil. For more demanding applications with higher withdrawal rates, a remote pressure-building system is available.

Advanced insulation technology provides longer holding times, and the continuing development of insulation systems has resulted in unsurpassed performance. Our composite insulation is a lightweight system offering superior performance compared to Perlite or Super-Insulation and is easier to maintain, offering longer product hold times.

The standard 400 psig (*27.6 barg*) tank is available in 900 - 15,000 gallon (3,218 - 57,008 liter) models, and the standard 500 psig (*34.5 barg*) tank is available in 900 - 6,000 gallon (3,218 - 21,842 liter) models. Other sizes of both models are available upon request.

Product Highlights

- All welded stainless steel piping modules
- Heavy duty bronze valves with extended bonnets
- Valve bonnet uniformity to reduce spare parts inventory
- Highest grade components for low to zero maintenance
- Separate pressure building and economizer regulators are standard on all 400 and 500 psig (*27.6 and 34.5 barg*) units
- High performance safety system with dual relief valves and rupture disks supplied as a standard
- Inner vessel designed and built to ASME Section VIII Division 1 code

VS High Pressure Specifications

SPECIFICATIONS

Model	VS 900SC	VS 1500SC	VS 3000SC	VS 6000SC	VS 9000SC	VS 11000SC	VS 13000SC	VS 15000SC
Gross Capacity (gal)	940	1,640	3,150	6,010	9,360	11,410	13,470	15,520
Nominal Capacity (gal)	850	1,580	3,030	5,770	8,990	10,960	13,060	15,060
Working Pressure* (psig)	400/500	400/500	400/500	400/500	400	400	400	400
Diameter (in)	66	66	86	86	114	114	114	114
Height (in)	136	196	228	383	348	407	466	525
Weight** (lbs)	5,100/5,800	7,600/8,700	15,100/15,100	27,000/27,100	38,900	46,700	55,100	63,400
Flow Capability* (SCFH)	5,200/3,100	5,900/3,600	6,400/3,800	7,900/4,700	7,500	8,100	8,600	14,400
NER (% /day in O_2/Ar)	.45	.35	.25	.15	.10	.10	.10	.10
(%/day in N_2)	.73	.56	.40	.24	.16	.16	.16	.16

* Higher capacity coil available, refer to factory

** Weights are for ASME designs

NER = Normal Evaporation Rate

An integrated state-of-the-art system, including an HP²™ bulk tank, a multi-function vaporizer and advanced control technology for delivering high-pressure high-performance gas flow. Withthe multi-functional vaporizer, you get pressure building recovery in 10 minutes or less at 95% full. Pressure is easily adjustable to within 50 psi/3.4 bar of tank MAWP. Flow rates up to 12,500 scfh/328 Nm^3H. The rattler valve (attached to the vaporizer) ensures sustained vaporizer performance. The HP²™ bulk tank is available in sizes from 900 gallons/3,406 liters and larger.

Cut Operating Costs

- Reduces deliveries by up to 36%
- Reduces delivery time by up to 33%
- Increases actual storage capacity by 27% or reduces needed tank size
- Reduces service calls and maintenance
- Telemetry ready
- Easy to configure and install

Improve Customer Satisfaction

- Reduces customer downtime by up to 86%... or to zero with optional fill assist unit
- Cuts blow-down and venting losses and increases holding time
- Builds operating pressure in minutes
- Provides precision pressure control and eliminates regulator pressure creep
- Reduces space required to provide the same gas flow rates
- Easy to adjust pressure settings and contents alarms – truly user-friendly
- Supplies warmer outlet gas
- Inner vessel designed and built to ASME Section VIII Division 1 code

GENERAL	
Pressure Building/Recovery Time	10 min or less at 95% full - 150 psi / 10.3 bar to 450 psi / 31 bar
Net Storage Capacity of Tank[1]	95% of gross tank capacity[1]
Pressure Control (Using Pressure Switch)	Adjustable to within 50 psi of MAWP - 3 alerts
Liquid Level Alarms (Using Tank-Tel® Gauge)	Adjustable in 5% increments - 3 alerts
Options	Fill Assist Unit, HP² Retrofit Kits, and Dual Vaporizers

HP²™ TANK (See VS High Pressure)	Net Capacity[1] (gal/liters)	MAWP (psi / bar)
VS-900SC	845 / 3,197	400 / 27.6 or 500 / 34.5
VS-1500SC	1,505 / 5,696	400 / 27.6 or 500 / 34.5
VS-3000SC	3,000 / 11,355	400 / 27.6 or 500 / 34.5
VS-6000SC	5,771 / 21,843	400 / 27.6 or 500 / 34.5
Larger High-Pressure Tanks	Contact Chart	Contact Chart

CONTROL / INSTRUMENTATION[2]	
Power Requirement	110 VAC x 5 Amp
Pressure and Contents Measurement	Tank-Tel - telemetry ready (see Tank-Tel)

PIPING & CONTROL MODULE[2]	
Gas Supply Requirement	Clean Dry Nitrogen or Air (Dew Point -40°F) at 100 psi / 6.9 bar
Ball Valves	2 x Pneumatic Operated
Piping	3/4" Nominal Copper Tubing
Inlet and Outlet Connections	7/8" ODT Compression
Dimensions L x W x H (in / mm)	44 x 26 x 31 / 1,120 x 660 x 790

MULTI-FUNCTION VAPORIZER (Ambient)[2]	3.5 K Model	7.5 K Model	12.5 K Model
Rated Flow Capacity (scfh / Nm^3H)[3]	3,500 / 92	7,500 / 197	12,500 / 328
Design Pressure (psi / bar)	600 / 41	600 / 41	600 / 41
Overall Height (in / mm)	132 / 3,353	132 / 3,353	156 / 3,962
Length / Width (in / mm)	35 x 27 / 889 x 686	35 x 50 / 889 x 1,270	47 x 50 / 1,194 x 1,270
Rattler Valve for Snow and Ice Removal	Optional	Included	Included

Footnotes: Specifications are subject to change without prior notification. **1** - HP² tanks can be filled to 95% of gross capacity. For traditional high-pressure bulk tanks, the recommended fill level is only 75% of gross capacity. **2** - Components used in the HP² Retrofit Kit for converting existing high-pressure tanks to HP² technology. **3** - Flow rate based on nitrogen under standardized conditions with minimum 1" liquid feed and gas return lines.

Pumping 100% of the Liquid 100% of the Time

Chart has engineered the Siphon 100™ bulk storage system to provide an economical, reliable and high performance pumping system for high pressure and liquid cylinder filling. Current cryogenic tank and pumping systems have worked for years, but increased efficiencies are now available using the Siphon 100 with:

- Simple and reliable automatic pump start-up in three minutes with 100% product utilization
- Thermal-siphon design manages heat from pump cool down, keeping storage tank pressure down
- Pump priming at tank pressure of 10 psi (0.69 bar) or less without the necessity for pressure building
- Reduce liquid cylinder and Orca filling losses
- Longer life of high-wear pump parts
- Capability to operate two pumps at once (liquid and HP pump)
- Adapters available to match all standard pumps

The Siphon 100 system combines two revolutionary technologies in cryogenic bulk tanks.

- **Thermal-Siphoning** – improved and patented, the system reduces and efficiently reprocesses the heat of pumping.
- **Composite Insulation** – 30% to 70% more efficient than Perlite in reducing the effects of heat from the atmosphere.

SPECIFICATIONS

Model		1,500	3,000	6,000	9,000	11,000	13,000	15,000
Capacity								
Liquid (Gross)	gallons	1,640	3,150	6,010	9,354	11,410	13,470	15,520
Liquid (Net)	gallons	1,580	3,030	5,770	8,990	10,960	13,060	15,060
Performance								
NER (O_2/Ar)	% per day	.35	.25	.15	.10	.10	.10	.10
(N_2)	% per day	.56	.40	.24	.16	.16	.16	.16
Dimensions & Pressure Ratings								
Diameter	inches	66	86	86	114	114	114	114
Height	inches	240	271	425	398	457	516	575
MAWP	psig	250	175	175	175	175	175	175

Compact Horizontal Bulk Storage

The BulkLite® 1400 is a compact horizontal bulk storage tank designed for economical turnkey installations. The tank can be installed on common precast concrete foundations, asphalt or directly on to class 5 gravel. The integrated forklift channels provide for easy mobility without a crane, further reducing the installation costs. The low profile and low cost installation is ideal for accounts that specify a height restriction and/or pad restriction due to property constraints. The BulkLite is also a good solution for temporary installations. The plumbing is conveniently located on one end of the vessel for easy access in tight locations and it can be filled from a standard transport or an Orca™ MicroBulk delivery system. Note, not designed to be moved with cryogenic product.

SPECIFICATIONS

Model		1400
Capacity		
Gross	gallons	1,400
Net	gallons	1,320
MAWP	psig	250
Performance		
NER (O_2/Ar)	% per day	.28
NER (N_2)	% per day	.45
Dimensions		
Width	inches	72
Height	inches	69
Length	inches	187
Weight	lbs	4,800

Product Highlights

- Compact, horizontal low profile: 69" H x 72" W x 187" L
- Integrated large forklift channels provide for easy mobility and secure mounting for an economical installation
- Forklift channels are 48" center to center (38-¾" min x 57-¼" max) and provide a stable and secure mounting base without the need for a concrete pad
- On-board high-efficiency gas use vaporizer provides up to 2000 SCFH
- Integrated high-efficiency pressure builder supports gas use flows up to 8000 SCFH
- Integrated flat fin pressure builder with PCV-1 (combo regulator) with single pressure adjusting screw for easy changes to the pressure builder and economizer settings
- Durable, ergonomic plumbing with isolation valves for long service life, easy operation and field maintenance
- Low NER is ideal for low usage accounts with longer delivery cycles for low distribution costs
- Liquid withdrawal package option available: 1" vacuum insulated female bayonet, vent connected back pressure regulator and low-range PCV-1 spring for low liquid loss and accurate tank pressure control
- Inner vessel designed and built to ASME Section VIII Division 1 code

The VHR Series high-performance storage system creates a competitive advantage with industry-leading hold times and a stainless steel, low maintenance outer shell. The VHR liquid bulk systems are economical customer stations designed to receive and hold liquid oxygen at a low temperature and pressure. This low-cost storage system is ideal for applications requiring liquid or reserve suppliers, such as hospitals, nursing homes and health care facilities, or as back-up to membrane/PSA systems.

Product Highlights

- Dual relief and rupture disc vent system with a 3-way diverter valve
- Extended stem and packing valves on all liquid lines
- Analog liquid level gauge with low level alarm
- Stainless steel interconnecting piping
- All stainless steel outer vessel eliminates the need for paint and surface maintenance
- Internal product vaporizer saves pad space and reduces maintenance costs
- Super insulation system provides industry leading NER performance and extended product hold times
- Optional Certified lab test reports for medical oxygen service available
- Inner vessel designed and built to ASME Section VIII Division 1 code

SPECIFICATIONS

Model	VHR-120	VHR-260	VHR-400
Capacity - Liquid (gal / liters)			
Net	112 / 424	255 / 964	387 / 1,479
Gross	118 / 447	268 / 1,015	407 / 1,553
Capacity - Gas @ 1 atm of 70°F (SCF / NM^3)			
Nitrogen	10,500 / 280	23,800 / 630	36,100 / 950
Oxygen	12,900 / 340	29,400 / 780	44,600 / 1,180
Argon	12,600 / 340	28,700 / 760	43,600 / 1,150
Dimensions (in / cm)			
Diameter	30 / 76	42 / 107	48 / 122
Height	80 / 203	94 / 239	100 / 254
Weight (lbs / kg)			
Tare	700 / 320	1,700 / 770	2,100 / 950
Nitrogen	1,400 / 640	3,500 / 1,590	4,800 / 2,180
Oxygen	1,710 / 780	4,200 / 1,910	5,800 / 2,630
Argon	1,950 / 890	4,700 / 2,130	6,600 / 2,990
Maximum Pressure (psig / bar)	250 / 17	250 / 17	250 / 17
Gas Delivery Rate (SCFH O_2 / NM^3h O_2)			
Normal*	340 / 10	620 / 18	790 / 22
Peak**	490 / 14	890 / 25	1,140 / 32
Evaporation Rate (% per day of O_2)	1.1%	0.62%	0.62%

* Normal flow rate is for eight hours with a minimum exit temperature of 32°F at an ambient temperature of 68°F.

** Peak flow rate is for one hour with a minimum exit temperature of 32°F at an ambient temperature of 68°F.

Thermax
A Chart Industries Company

Thermax Ambient Air Vaporizers

Free standing or tank mounted, these vaporizers which gasify the liquid product are available in standard sizes ranging from 1700 to 82,900 standard cubic feet per hour and rated to 600 psig*.

Thermax Supergap™ Ambient Vaporizers have become the industry standard for ambient air vaporization. Supergap vaporizers use natural convection of air to vaporize liquefied gases. Finned aluminum tubes absorb heat from the air and transfer that heat to the product gas. The huge four inch gap between fin tips provides room for ice growth allowing for more than 500 hours of continuous operation without defrost, making Supergaps vaporizers ideal for severe climates and long-duration operation. Extended operation requires a vaporizer switching system. In addition to the standard aluminum construction, units are available with stainless steel and other alloy liners for high-pressure and corrosive applications.

** 450 psig when ordered with Mueller flange.*

Product Advantages

- 12-inch fin tube center-to-center spacing
- 4-inch gap between fins
- Standard models rated up to 200 MSCFH
- Aluminum corrosion-resistant construction
- High-strength welded base frame
- Withstands 100 mph winds and Zone 4 seismic forces
- 600 psig standard design pressure on all aluminum units
- Severe thermal cycling design
- Enhanced internal 16-fin heat transfer area, highest in industry
- No-crate shipping design for larger models
- Perimeter frame and legs for unrestricted airflow
- ANSI B31.3, CRN (all provinces), and PED Category IV Module B & D compliant

Chart Part Number	Thermax Model Number	Flow Rate* 8hrs, SCFH, Nitrogen Aluminum	SS Lined	Inlet/Outlet Connection Size (inches)	Dimensions W x D x H (inches)	Weight (Lbs)	Design Pressure
12956561	SG20HF	1,700		3/4 MPT	22 x 22 x 128	135	600
12956579	SG25HF	2,600	2,100	3/4 MPT	22 x 22 x 152	155	600
12956608	SG35HF	3,900	3,100	3/4 MPT	32 x 22 x 152	215	600
12956616	SG50HF	5,200	4,200	3/4 MPT	44 x 22 x 152	275	600
12956587	SG70HF	7,800	6,200	3/4 MPT	48 x 36 x 152	405	600
12956632	SG110HF	11,700	9,400	1 Mueller**	48 x 36 x 213	580	450
12956641	SG140HF	15,600	12,500	1 Mueller**	48 x 48 x 213	760	450
12956659	SG180HF	19,400	15,500	1 Mueller**	48 x 60 x 213	935	450
12956667	SG270HF	29,200	23,400	1-1/2 Mueller**	60 x 72 x 224	1,425	450
12956675	SG360HF	38,900	31,100	1-1/2 Mueller**	75 x 62 x 284	1,890	450
12959631	SG770HF	82,900	68,300	2 Mueller**	98 x 98 x 284	3,875	450

For nominal flow rate: O_2 - multiply by 0.92, Ar - multiply by 1.14.

* Nominal flow rate is based on eight hours continuous service between defrosts, an ambient temperature of 70°, relative humidity 70%, and a 70° approach temperature. Please consult your Chart sales person for ratings for other conditions.

**Mueller Flanges supplied with mating brass flange, bolts, nuts and gaskets.

All tables and information are intended as guides only. Actual performance and dimensions may vary. Thermax does not make any representations or warranties, express or implied, of fitness for a particular purpose. Request a copy of Thermax's Limited Warranty and Remedy for further details. Speak to a Thermax representative for specific design considerations and application criteria.

FLUID	Conversion Data			BTU	Energy Required			
Gallon Liq	Std Cu Ft Per GPM	SCFH Per GPM	GPM at 10,000 SCFH to 70°F	Total BTU per 10,000 SCFH	Kilo Gasoline	Gals/Hr* Steam	Lbs/Hr** Air	CFM***
Argon	112.5	6800	1.47	123,000	36.1	1.0	115	12,300
CO_2	74.04	4440	2.25	171,000	50.2	1.39	160	17,100
Helium	100.8	6040	1.655	67,500	19.8	.55	63	6750
Hydrogen	113.6	6820	1.47	89,000	26.4	.72	84	8900
Nitrogen	93.11	5600	1.787	134,400	39.5	1.09	126	13,400
Oxygen	115.1	6900	1.45	142,000	41.6	1.15	133	14,200
Nitrous Oxide	89.05	5280	1.895	231,000	67.8	1.88	217	23,100
Propane	42	2520	3.97	213,000	62.5	1.73	200	21,300
Methane	84.82	5090	1.96	162,000	47.5	1.31	152	16,200

* Calculated at 85% Thermal Efficiency
** Calculated at 100 psig saturated inlet with outlet at 150°F
*** Calculated at 10° F^3 T thru vaporizer

Laser Assist Gas Supply System

Trifecta® X-Series Gas Supply System is the preferred solution for reliable and continuous laser assist gases for pressures up to 550 psig and flow rates up to 15,000 scfh. Drawing liquid from a standard bulk tank, the Trifecta system boosts the liquid pressure by alternately feeding two liquid cylinders equipped with innovative multi-function pressure building vaporizers.

Product Highlights:

- System utilizes standard low-pressure bulk tank to lower investment and use existing assets.
- No downtime - system maintains pressure and flow when bulk tank is filled and eliminates excessive product losses associated with high-pressure bulk tanks.
- Robust design features streamlined all stainless steel piping with only five control valves and one integrated electronic control system (PLC) for increased durability and reliability.
- Computer-controlled design simplifies installation, start-up and continuous operation.
- Frame assembly features a protective top cover in a compact footprint with an elevated base for improved ventilation.

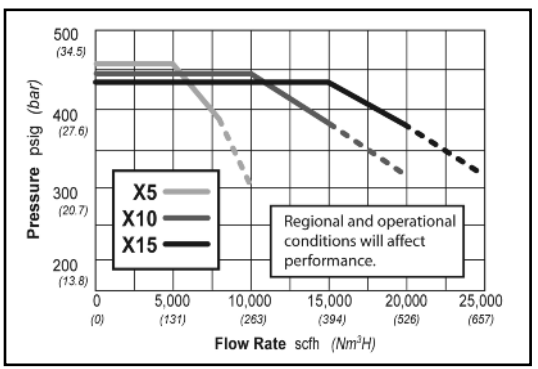
Trifecta® X-Series Specifications

System Requirements

- 15 amp, 110 VAC power, dedicated circuit (230 VAC panel is also available)
- Bulk storage tank with 50 psig minimum pressure
- External vaporizer, minimum 600 psig working pressure, sized for maximum flow rate
- Two piping connections to bulk storage tank (liquid withdrawal, low phase instrument line)
- High-flow pressure regulation
- 100 psig nitrogen gas required for actuated valves (600 MAWP only). All other models use electric solenoid valves

Dimensions

Length	53"	1347 mm
Width	55"	1400 mm
Height	96"	2440 mm
Weight X5	1700 lbs	770 kg
Weight X10	1750 lbs	795 kg
Weight X15	1800 lbs	815 kg

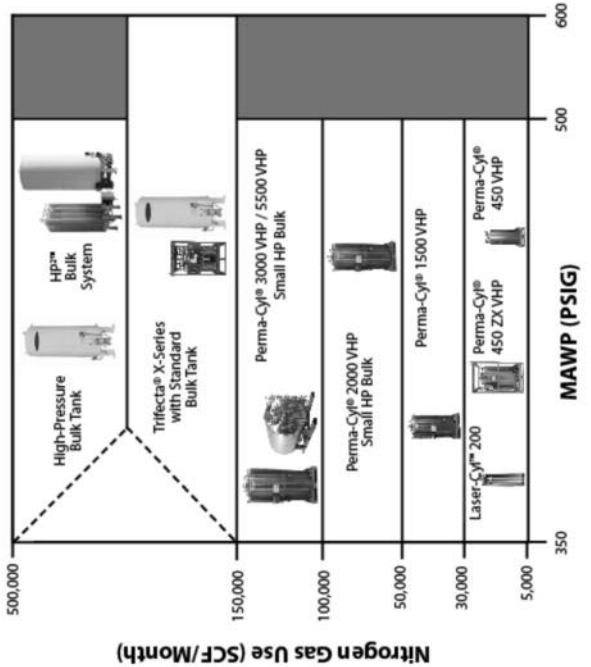


Shown for Inert Service (500 MAWP)

Trifecta Vaporizer Specifications

Trifecta Model	Flow Rate* SCFH, Nitrogen	Thermax Vaporizer Model Number	MAWP (psig)
Trifecta 5K	7,500	SG70HF	600
Trifecta 10K	11,500	SG110HF	600
Trifecta 15K	19,400	SG180HF	600
Trifecta 15K	19,400	SG180-HF-C	700

* Nominal flow rate is based on 8 hours continuous service between defrosts, an ambient temperature of 70°F, relative humidity of 70%, and a 20°F Approach temperature. Please consult your Thermax, Inc. sales person for ratings for other conditions.



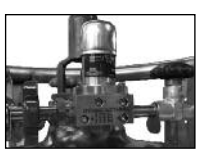
Gas Delivery Option	Maximum Allowable Working Pressure (MAWP)	Maximum Operating Pressure	System Capacity	Maximum Flow Rate	Delivery Mode	Target Application
Units	PSIG / BARG	PSIG / BARG	Gallons or Liters	SCFH / Nm³ per hr	N/A	N/A
HP™	500 / 34	450 / 31	900 - 6,000 Gal	12,500 / 354	Bulk	Multiple lasers, high volume
High-Pressure Bulk Tank	500 / 34	450 / 31	525 - 15,000 Gal	14,400 / 378	Bulk	Multiple lasers, high volume
Trifecta® X15 & Standard Bulk Tank	600 / 41	550 / 98	525 - 15,000 Gal	15,000 / 425	Bulk	Multiple lasers, high volume
Trifecta® X10 & Standard Bulk Tank	600 / 41	550 / 98	525 - 15,000 Gal	10,000 / 283	Bulk	Multiple lasers, medium volume
Trifecta® X5 & Standard Bulk Tank	500 / 34	450 / 31	525 - 15,000 Gal	5,000 / 142	Bulk	Multiple lasers, low volume
Perma-Cyl® 5500 VHP	500 / 34	450 / 31	5,500 Liters	5,000 / 142	MicroBulk	Multiple lasers, low volume
Perma-Cyl® 3000 VHP	500 / 34	450 / 31	3,000 Liters	3,500 / 99	MicroBulk	Three lasers, high volume
Perma-Cyl® 2000 VHP	500 / 34	450 / 31	2,000 Liters	3,500 / 99	MicroBulk	Two lasers, medium volume
Perma-Cyl® 1500 VHP	500 / 34	450 / 31	1,500 Liters	1,350 / 38	MicroBulk	Single laser, medium volume
Perma-Cyl® 450 VHP	500 / 34	450 / 31	450 Liters	575 / 15	MicroBulk	Single laser, low volume
Perma-Cyl® 450 ZX VHP	500 / 34	450 / 31	450 Liters	2,000 / 52.6	MicroBulk	Single laser, low volume
Laser-Cyl™ 200	500 / 34	450 / 31	200 Liters	350 / 9	Package	Single laser, low volume

A durable, user-friendly performer

The Dura-Cyl® series is a premium transportable liquid cylinder for cryogenic service. The patented internal support system design and quality construction makes the Dura-Cyl series the most efficient yet rugged cylinder on the market today.

- Ideal for liquid nitrogen, oxygen, argon, CO_2 or nitrous oxide
- Different sizes, pressures, and features to better meet your needs
- Stainless steel construction
- Thick, dent-resistant outer shell
- Patented durable, inner-vessel support system
- Large diameter handling ring with four supports
- Optional Micrometer Controlled Regulator (MCR) or Liquid Cylinder Control Manifold (LCCM)
- Roto-Tel Liquid Level Gauge System
- Footring and caster base models with round or square caster bases for safe and easy mobility
- Seven-year vacuum warranty

LCCM Models have an integral mounted combination pressure control regulator, isolation valve and a calibrated dome control knob. (MP & HP models only)



MCR Models have a combination pressure control regulator with an exclusive, calibrated micrometer adjusting screw. (MP & HP models only)

SPECIFICATIONS

			FOOTRING					CASTER BASE														
Model	**Size/Pressure**	**160MP**	**160HP**	**180LP**	**180MP**	**180HP**	**200 LP**	**200MP**	**200HP**	**120LP RB**	**230LP RB**	**230MP RB**	**230HP RB**	**230LP SB**	**200 MP SB**	**230HP SB**	**265MP RB**	**265HP RB**	**265MP SB**	**265HP SB**
Capacity																				
Liquid (Gross)	liters	176	176	196	196	196	209	209	209	120	240	240	240	240	240	240	276	276	276	276
Liquid (Net)	liters	165	165	185	185	185	196	196	196	110	230	230	230	230	230	230	265	265	265	265
Gas (N_2)	ft^3	3,685	3,464	–	4,089	3,864	–	4,375	4,072	–	–	5,024	4,734	–	5,024	4,734	5,768	5,438	5,768	5,438
Gas (O_2)	ft^3	4,577	4,348	–	5,086	4,843	–	5,435	5,048	–	–	6,244	5,930	–	6,244	5,930	7,186	6,811	7,186	6,811
Gas (Ar)	ft^3	4,448	4,226	–	4,961	4,709	–	5,290	4,932	–	–	6,073	5,763	–	6,073	5,763	6,982	6,634	6,982	6,634
Gas (CO_2)	ft^3	–	3,382	–	–	3,766	–	–	4,011	–	–	–	4,614	–	–	4,614	–	5,305	–	5,305
Gas (N_2O)	ft^3	–	3,207	–	–	3,574	–	–	3,810	–	–	–	4,378	–	–	4,378	–	5,034	–	5,034
Performance																				
NER (N_2)	% per day	2.0	2.0	1.5	1.9	1.9	1.66	1.85	1.85	2.0	1.5	1.8	1.8	1.5	1.8	1.8	2.0	2.0	2.0	2.0
NER (O_2+Ar)	% per day	1.4	1.4	1.0	1.3	1.3	1.2	1.2	1.2	1.4	1.0	1.2	1.2	1.0	1.2	1.2	1.4	1.4	1.4	1.4
NER (CO_2 - N_2O)	% per day	–	0.5	–	–	0.5	–	–	0.5	–	–	–	0.5	–	–	0.5	–	0.5	–	0.5
Gas Flow (N_2, O_2, Ar)	ft^3/hr	350	350	–	350	350	–	400	400	–	–	400	400	–	400	400	400	400	400	400
Gas Flow (CO_2 or N_2O)	ft^3/hr	–	110	–	–	110	–	–	110	–	–	–	110	–	–	110	–	110	–	110
Dimensions & Pressure Ratings																				
Diameter	in	20	20	20	20	20	20	20	20	20	26	26	26	26	26	26	26	26	26	26
Height	in	59.8	59.8	64.3	64.3	64.3	66.6	66.6	66.6	51	57.2	57.2	57.2	56.8	56.8	56.8	59.9	59.9	59.5	59.5
Tare Weight	lb	290	280	210	260	300	210	280	320	177	296	311	367	325	340	395	330	390	360	418
Relief Valve Setting	psig	230	350	22	220	350	22	230	350	22	22	230	350	22	230	350	230	350	230	350
DOT/CTC Rating		4L200	4L292	4L100	4L200	4L292	4L100	4L200	4L292	4L100	4L100	4L200	4L292	4L100	4L200	4L292	4L200	4L292	4L200	4L292

(1) Pressure building regulator optional on LP models. (2) Gas capacities at DOT4L limits. See manual P/N 106429/12 for details.
(3) Most of the Dura-Cyl models are available with permanently installed CGA fittings for medical applications. Contact Customer Service for details.
(4) Dura-Cyl 120LP is not TC approved. (5) Dimensions are measured from the floor to the top of the sight gauge protector.

RB = Round caster base SB = Square caster base
Note: All caster base models are available with stainless steel casters.
NER = Nominal Evaporation Rate

A stable, efficient performer

Like the Dura-Cyl models, the Cryo-Cyl™ 80HP model is designed and built to meet the rugged demands of the liquid cylinder market. However in contrast, this model is designed specifically for liquid and low to medium gas flow applications. By specifically targeting these applications, we are able to offer this model at an economical value over our premium Dura-Cyl series.

- Ideal for liquid nitrogen, oxygen, argon, CO_2 or nitrous oxide
- Stainless steel construction
- Thicker, dent-resistant outer shell
- Patented durable, inner-vessel support system
- Heavy-duty footring and large diameter handling ring with two supports
- Roto-Tel Liquid Level Gauge System
- Seven-year vacuum warranty

The optional pressure building kit includes a regulator and plumbing components.

On the new Cryo-Cyl HP liquid cylinder, the liquid valve is an extended stem globe valve which allows for less ice build-up on the handle and easier operation.

SPECIFICATIONS

Model	Size / Pressure	80HP
	Part Number	10648610
Capacity(1)(2)		
Liquid (Gross)	(liters)	85
Liquid (Net)	(liters)	80
Gas (N_2)	(ft^3)	1,680
Gas (O_2)	(ft^3)	2,108
Gas (Ar)	(ft^3)	2,049
Gas (CO_2)	(ft^3)	1,640
Gas (N_20)	(ft^3)	1,555
Performance		
NER (N_2)	(% per day)	3.0
NER (O_2 or Ar)	(% per day)	2.0
NER (CO_2 or N_2O)	(% per day)	0.8
Gas Flow (N, O_2, Ar)(3)	(SCFH)	100
Gas Flow (CO_2 or N_2O)	(SCFH)	35
Dimensions & Pressure Ratings		
Relief Valve Setting	(psig)	350
Operating Pressure(4)	(psig)	125
DOT/CTC Rating		4L292
Diameter (Cylinder)	(in)	20
Height (Cylinder)(5)	(in)	39.5
Tare Weight	(lbs)	165

(1) Net gas capacities at DOT 4L limits.
(2) The Cryo-Cyl model is available with permanentaly installed CGA fittings for medical applications. Contact Customer Service for details.
(3) Gas flows of twice the continuous flow rate can be achieved for 1 hr. over an 8 hr. period.
(4) Pressure building regulator range (50-175 psi).
(5) Height dimensions are measured from the floor to the top of the sight gauge protector.

Maximum Versatility

The Mega-Cyl™ series is Chart's line of palletized cylinders designed for easy transport with capacities from 450 to 1000 liters. Engineered with the volume user in mind, it's ideal for construction sites, remote purging operations and back-up systems. Mega-Cyl cylinders are available at 350 psig (*24 barg*) and are specifically designed to optimize distribution costs.

Examine the rugged, maneuverable Mega-Cyl series, and you'll find all the quality features you expect from the industry leader, Chart.

Product Highlights:

- Tough, durable stainless steel construction
- High-performance Super Insulation
- Easily accessible valves and gauges
- Spray header for pump filling on vent tube
- Accurate differential pressure contents gauge (non-electric)

SPECIFICATIONS

Model		450HP	800HP	1000HP
Size/Pressure		10588979	10671262	10752281
Part Number				
Capacity				
Liquid (Gross)	(liters)	450	880	1,056
Liquid (Net)	(liters)	428	800	950
Gas (N_2)	(ft^3)	8,875	19,672	23,363
Gas (O_2)	(ft^3)	11,111	24,320	28,843
Gas (Ar)	(ft^3)	10,812	23,767	28,234
Gas (CO_2)	(ft^3)	8,652	16,255	18,580
Performance				
NER (N_2)	(% per day)	2.1	1.8	1.3
NER (O_2, Ar)	(% per day)	1.4	1.2	0.9
NER (CO_2, N_2O)	(% per day)	0.6	0.5	0.3
Gas Flow (N, O_2, Ar)	(SCFH)	575	880	960
Gas Flow (CO_2 or N_2O)	(SCFH)	195	280	300
Dimensions & Pressure Ratings				
Diameter (cylinder)	(in)	30	42	42
Height (cylinder)	(in)	62	67	76
Base Width (frame)	(in)	34	45	45
Base Depth (frame)	(in)	34	45	45
Height (frame)	(in)	74	95	95
Tare Weight (cyl + frame)	(lbs)	1,275	2,500	2,650
Relief Valve Setting	(psig/barg)	350	350	350
DOT/CTC Rating		4L292	ASME	ASME

* Atmospheric gas based on net volume at 0 psig, CO_2 values and 450 liter models based on DOT4L fill density.
** Customized pallets are available upon request.
*** Weights are approximate and vary with pallet design.

Maximum Efficiency with High Capacity Performance

Laser-Cyl™ is designed specifically for laser applications, as a high-performance option to expensive high-pressure cylinder tanks. The Laser-Cyl delivers optimal pressure up to 500 psig (*34.5 bar*) and continuous flow rates up to 575 SCFH (*15.1 Nm^3/hr*).

Product Highlights:

- Built-in vaporizer coils supply constant pressure gas at continuous flow rates up to 575 SCFH (*15.1 Nm^3*)
- Piping controls located on top of the vessel for easy operation and maintenance
- Differential pressure liquid level gauge accurately displays product level
- Insulation system provides low NER for longer holding time
- Available in 200 and 450 liter sizes with an optional pallet frame

SPECIFICATIONS

Model	Size / Pressure	200VHP	450VHP
	Part Number	10619771	10619659
Capacity			
Liquid (Gross)	(liters)	200	450
Liquid (Net)	(liters)	196	428
Gas (N_2)	(ft^3)	3,521	7,922
Gas (O_2)	(ft^3)	4,674	10,519
Gas (Ar)	(ft^3)	4,552	10,241
Gas (CO_2)	(ft^3)	3,537	7,960
Gas (N_20)	(ft^3)	3,333	7,516
Performance			
NER (N_2)	(% per day)	2.0	2.0
NER (O_2 or Ar)	(% per day)	1.4	1.4
NER (CO_2 or N_2O)	(% per day)	0.5	0.5
Gas Flow (N, O_2, Ar)	(SCFH)	350	575
Gas Flow (CO_2 or N_2O)	(SCFH)	110	180
Dimensions & Pressure Ratings			
Diameter (Cylinder)	(in)	20	30
Height (Cylinder)	(in)	65.8	61.3
Base Width (Frame)	(in)	–	34
Base Depth (Frame)	(in)	–	34
Base Height (Frame)	(in)	–	73.8
Tare Weight	(lbs)	375	1,265*
Relief Valve Setting	(psig)	500	500
DOT/CTC Rating		4L412	4L412

* Weights are approximate and vary with pallet design

M45 Manifold

The M45 Manifold is a convenient, automatic way of increasing the gas delivery rate to any application. The unique changeover valve allows easy manual selection of the primary bank of cylinders. An indicator light shows when the system switches to the reserve bank so replacement cylinders can be ordered.

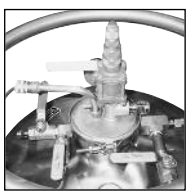
The economizer functions of all tanks still work through the M45 Manifold. Tank pressure and delivery pressure are shown on the manifold, while other features include:

- All stainless steel cabinet can be wall mounted or used with the optional floor stand.
- Hoses are easily mounted to the cabinet
- Takes up to six liquid cylinders

Durability and High Performance

The Ultra Helium Dewar™ is designed and built for reliable transport. They are light, maneuverable and durable, while providing superior thermal performance. The unique nec tube design provides proven support during transportation. The outboard caster base provides maximum stability in a compact design.

Available in sizes ranging from 60 to 500 liters. The Ultra Helium Dewars are suitable for air transport (IATA conforming) with the optional absolute pressure relief valve. All models are 100% nonmagnetic for Magnetic Resonance Imagery (MRI) service.



The controls are conveniently located on the top of the dewar, with nesting fill couplings to accept various standard transfer line sizes. The optional electric pressure builder can quickly increase pressure for liquid transfer while maintaining low heat leak. It has two pre-set ranges (4 or 8 psig/0.3 or 0.6 barg) for efficient liquid helium withdrawal:

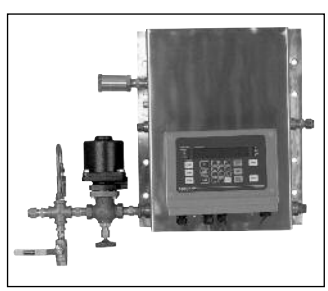
- Maximum durability and lightweight
- Outstanding thermal performance
- Large ball valves for up to 3/4" (19 mm) transfer lines

SPECIFICATIONS

Model	Size	60	100	250	500
	Part Number	10533409	10533417	9923629	11202581
Capacity					
Liquid (Gross)	(liters)	66	110	275	550
Liquid (Net)	(liters)	60	100	250	500
Performance					
NER	(% per day)	1.75	1.25	1.0	1.0
MAWP	(psig)	10	10	10	10
Dimensions & Pressure Ratings					
Diameter	(in)	24	24	32	42
Height	(in)	49.5	56.5	67.4	67.25
Dip Tube Length	(in)	32.5	39.5	54.4	51.5
Tare Weight	(lbs)	184	212	348	470
Main Relief Valve Setting	(psig)	10	10	10	10
Secondary Relief Valve	(psig)	12	12	12	12

Lo-Loss™ Liquid Cylinder Filling System

Lo-loss is an automated filling system that dramatically reduces depressurization (flash) losses during liquid cylinder filling. By maintaining an optimal pressure difference between the bulk tank and liquid cylinder, losses are kept at a minimum without increasing fill times.



New for 2016!

Introducing the Econo-Cyl™ Liquid Cylinder from Chart. The Econo-Cyl offers a thick stainless steel outer jacket, an all-metal shock absorbing footring, color-coded valve handles, and color-coded safeties. Built with our legendary Composite Super Insulation™ and Chart Vacuum Technology®, the Econo-Cyl provides maximum gas utilization for your customers. The most popular models have been streamlined — making them the preferred choice in economical transportable liquid cylinders.

Product Highlights:

- Ideal for liquid nitrogen, oxygen, argon, CO_2 or nitrous oxide
- All stainless steel inner and outer cylinder construction
- Thick, dent-resistant outer shell
- Four handling ring supports with large one-inch pipe size ring
- 4" galvanized casters on 230 models
- Integrated pull handle on 230 square base model
- Color-coded valve handles and name tags for easy identification of the plumbing functions
- Roto-Tel™ Liquid Level Gauge System
- Five-year vacuum warranty

Specifications		Footring		I Caster Base	
MODEL		**180**	**200**	**230 RB**	**230 SB**
	Pressure	HP	HP	HP	HP
PBER	P/N	14880547	14880555	14880563	14880571
CAPACITY(1)(2)					
Liquid (Gross)	(liters)	196	209	240	240
Liquid (Net)	(liters)	185	196	230	230
Gas (N_2)	ft^3 / Nm^3	3864/102	4072/108	4734/124	4734/124
Gas (O_2)	ft^3 / Nm^3	4843/127	5048/133	5930/156	5930/156
Gas (Ar)	ft^3 / Nm^3	4709/124	4932/130	5763/151	5763/151
Gas (CO_2)	ft^3 / Nm^3	3766/99	4011/105	4614/121	4614/121
Gas (N_2O)	ft^3 / Nm^3	3574/94	3810/100	4378/115	4378/115
PERFORMANCE(3)					
NER (N_2)	% per day	1.9	1.85	1.8	1.8
NER (O_2 - Ar)	% per day	1.3	1.2	1.2	1.2
NER (CO_2 - N_2O)	% per day	0.5	0.5	0.5	0.5
Gas Flow(N_2,O_2,Ar)	SCFH/Nm^3/hr	350/9.2	400/10.5	400/10.5	400/10.5
Gas Flow(CO_2,N_2O)	SCFH/Nm^3/hr	110/2.9	110/2.9	110/2.9	110/2.9
DIMENSIONS & PRESSURE RATINGS					
Relief Valve Setting	psig/barg	350/24	350/24	350/24	350/24
DOT Rating		4L292	4L292	4L292	4L292
Diameter(4)	in / cm	20/50.8	20/50.8	26/66.0	26/66.0
Height(5)	in / cm	64/163	67/169	57/145	57/144
Tare Weight	lb / kg	288/130	305/138	360/163	393/178
Full Weight (N_2)	lb / kg	568/257	603/273	703/318	736/333
(O_2)	lb / kg	689/312	732/332	851/386	884/400
(Ar)	lb / kg	775/351	824/373	956/433	989/448
(CO_2)	lb / kg	719/326	764/346	888/402	921/417

(1) Gas capacities at DOT4L limits. See manual for details.
(2) All models are available with permanently installed CGA fittings for medical applications. Contact Customer Service for details.
(3) Ambient conditions: 68°F/20°C and 50% relative humidity
(4) Dimension of square caster base: 27-3/4" W x 28-3/4" D.
(5) Dimensions are measured from the floor to the top of the sight gauge protector.
Note: All caster base models are available with galvanized casters.
RB = Round Base SB = Square Base NER=Nominal Evaporation Rate

Mobile MicroBulk System

Chart's Nomad Series offers a versatile and flexible solution for temporary gas applications and small liquid delivery requirements of oxygen, nitrogen or argon. The Nomad Series comes complete with a 4700 SCFH vaporizer, trailer and gas use connection for immediate use in a wide range of gas applications such as construction sites, welding jobs, or as a backup delivery system. The tank plumbing is designed with pressure building and economizer circuits to match the vaporizer flow rate for maximum efficiency.

Product Highlights:

- Premium Quality Drop-Deck Felling® Trailer
  - 2.5" Lunette Eye/Pintle Hitch or Gooseneck Hitch Option
- High-Performance Ambient Vaporizer
- Robust Field-Proven Internal Tank Support System
- Thermal Efficient Super Insulation System
- Optimized Pressure Builder & Economizer Design
- Low Pressure Road Relief Circuit (CGA-341)
- High Performance Pressure Building Coil
- Stainless Steel Bottle Construction
- Dual Safety System with Diverter Valve
- One-Year Parts & Vacuum Warranty

NOMAD SPECIFICATIONS

Gross Capacity	829 gal / 3,138 L
Net Capacity(1)	746 gal / 2,824 L
MAWP(2)	250 psig / 17.23 barg
Length (overall) - "A" (3)	23 ft / 700 cm
Tank Diameter - "B"	58 in / 147 cm
Height (overall) - "C"	96 in / 243 cm
Trailer Width - "D"	96 in / 243 cm
Total Weight (tare)	9500 lbs / 20,900 kg
Total Weight (gross)(4)	18,000 lbs / 39,600 kg
Vaporizer	4,700 SCFH
NER (%/day) N_2	1.18%
NER (%/day) O_2/Ar	.73%
N_2 Capacity	69,469 SCF
O_2 Capacity	85,835 SCF
Ar Capacity	83,886 SCF
N_2, O_2 & Ar Flow Rate	4,700 SCFH

(1) Based on 10% Ullage
(2) Inner: ASME Section VIII Division 1
(3) Consult factory for trailer specifications
(4) When filled with Argon

MicroBulk Medical Skid

The Microbulk Medical Skid is a turnkey package designed to comply with all the necessary codes for a safe and economical Medical MicroBulk installation. The standard skid is designed to accept standard FlexFill™ piping MicroBulk tanks ranging in size from 1000 liters up to 3000 liters for oxygen and nitrogen service. The skid design allows for an easy vessel upgrade at the customer site without the need to replace the entire skid.

Product Advantages

- Designed in accordance with NFPA* 99 & CGA M-1
- Available in Perma-Cyl® tank sizes from 1000 to 3000 liters
- High flow capable, up to 2000 SCFH**
- Utilizes a WIKA analog gauge with adjustable low level alarm set point
- Maintains residual liquid level in Perma-Cyl tanks for no-loss fill & purity integrity
- Optional external PB and process vaporizer packages available
- Integrates with most alarm facility panels
- Suitable for outdoor installations
- Skid Dimensions: 84" wide x 95.5" long x 90.25" high

* National Fire Protection Agency
** Standard Cubic Feet per Hour

The Perma-Cyl® MicroBulk storage system allows users to enjoy the benefits of on-site gas delivery. What makes the Perma-Cyl design revolutionary is:

- The first fill-at-site solution for packaged or cylinder gas users
- Fast filling capable
- Single hose no-loss/low-loss filling
- Automatic fill shutoff when used with Orca delivery system
- Extended holding times
- Telemetry ready with Cyl-Tel® gauge

When filled by an Orca™ MicroBulk Delivery System, the Perma-Cyl vessel is designed to have an actual fill-time of three minutes or less with little or no loss under normal conditions. The vessel will allow liquid to be held for long periods without venting, limiting product losses during periods of nonuse.

Features

- Very low NER/product loss
- Designed for very fast, automatic fills utilizing the Orca delivery system
- Unique auto shut-off feature allows remote filling with optional wall box and hose
- Heavy gauge, stainless steel outer shell
- Cyl-Tel gauge standard on 300L and larger, optional on 230L

DESCRIPTION	230L MP,LCCM Sq/Rd Base w/casters	230L HP,LCCM Sq/Rnd Base w/casters	265L MP,LCCM Sq/Rnd Base w/casters	265L HP,LCCM Sq/Rnd Base w/casters	450L MP Plate Base	450L HP Plate Base	450L VHP Plate Base	700L HP Plate Base	1000L HP/VHP Plate Base	1500L HP/VHP Pallet Base	2000L HP/VHP Pallet Base	3000L HP/VHP Pallet Base	3000L HP/VHP Horizontal Forklift Base	5500L VHP Pallet Base
CAPACITY (Liters)														
Gross	240	240	278	278	450	450	450	688	1,056	1,550	2,042	2,911	2,911	5,434
Kg	230	230	265	265	420	420	645	950	1,455	1,945	2,707	2,707	2,707	5,110
MAWP														
psig	230	350	230	350	250	350	500	350	350/500	350/500	350/500	350/500	350/500	500
bar	15.9	24.1	15.9	24.1	17.2	24.1	34.5	24.1	24.1/34.5	24.1/34.5	24.1/34.5	24.1/34.5	24.1/34.5	34.5
MAXIMUM PRE-SET OPERATING PRESSURE														
psig	125	300	125	300	125	300	450	300	300/450	300/450	300/450	300/450	300/450	450
bar	8.6	20.7	8.6	20.7	8.6	20.7	31.0	20.7	20.7/31.0	20.7/31.0	20.7/31.0	20.7/31.0	20.7/31.0	31.0
DESIGN SPEC	DOT	DOT	DOT	DOT	ASME	DOT/ASME	DOT/ASME	ASME	ASME	ASME	ASME	ASME	ASME	ASME
STORAGE CAPACITY														
Nitrogen														
SCF	5,024	4,734	5,769	5,769	10,332	8875/10332	7922/10332	15,860	24,350	35,790	47,847	66,592	66,592	125,000
Nm³	142	134	192	192	272	271/272	271/272	449	689	1,013	1,257	1,750	1,750	3,540
Oxygen														
SCF	6,244	5,930	7,186	7,186	12,760	11124/12760	11124/12760	19,600	30,070	44,220	59,089	82,239	82,239	154,900
Nm³	177	168	189	189	336	315/336	315/336	554	850	1,250	1,553	2,161	2,161	4,386
Argon														
SCF	6,073	5,763	6,982	6,982	12,478	10812/12478	10812/12478	19,160	29,400	43,220	57,786	80,425	80,425	151,700
Nm³	172	163	183	183	328	306/328	306/328	542	832	1,223	1,519	2,115	2,115	4,296
Carbon Dioxide														
SCF	N/A	4,615	N/A	5,306	N/A	8312/8200	8312/8200	12,608	19,960	29,340	38,048	52,954	N/A	N/A
Nm³	N/A	130.7	N/A	150.3	N/A	235/232	235/232	357	564	830	1,000	1,390	N/A	N/A
THERMAL PERFORMANCE (NER%/DAY)														
N_2	1.8%	1.8%	2.0%	2.0%	1.9%/1.6%	1.6%	1.9%/1.6%	1%	1%	1%	1%	1%	1%	.7%
O_2-Ar	1.12%	1.12%	1.4%	1.4%	1.2%/1.0%	1.0%	1.2%/1.0%	.62%	.62%	.62%	.62%	.62%	.62%	.43%
CO_2	N/A	1.6%	N/A	.7%	.6%/.5%	N/A	.6%/.5%	.3%	.3%	.3%	.3%	.3%	N/A	N/A
GAS DELIVERY RATE (LIN/LAR/LOX)														
SCF/H	400	400	400	400	575	575	575	660	960	1,350	1,350/2,000	1,350/2,000	2,000	3,500/6,000
Nm³/h	10.5	10.5	10.5	10.5	15.1	15.1	15.1	18.6	25.2	35.4	35.4/52.4	35.4/52.4	52.4	99/141
GAS DELIVERY RATE (CO_2)														
SCF/H	N/A	133	N/A	133	192	192	192	220	320	450	450/667	450/667	N/A	N/A
Nm³/h	N/A	3.8	N/A	3.8	5.4	5.4	5.4	6.2	9.0	12.7	12.7/17.5	12.7/17.5	N/A	N/A
DIMENSIONS														
Diameter														
In	26	26	26	26	30	30	30	42	42	48	48	59	59	80
mm	660	660	660	660	762	762	762	1,067	1,067	1,219	1,219	1,499	1,499	2,032
Height														
In	61.9/62	61.9/62	64.6/64.8	64.6/64.8	69	69	69	62.5	82	92/91	118.5/119.5	122/122.5	71	119
mm	1,570/1,575	1,570/1,575	1,641/1,646	1,641/1,646	1,753	1,753	1,753	1,588	2,083	2,337/2,311	3,010/3035	3,098/3,112	1,803	3,023
Tare Weight														
Lbs	300	340	340	340	605	688	812	1,250	1500/1750	2200/2500	2600/2950	3300/4250	3800/4250	9100
Kg	136	154	154	154	274	312	368	567	680/794	998/1134	1179/1338	1497/1928	1724/1928	4128

Perma-Cyl® with FlexFill™

The FlexFill™ Piping Option is a top and bottom fill circuit that replaces the top float assembly so the driver can control the tank pressure while filling the Perma-Cyl® MicroBulk Storage System. FlexFill uses technology adopted from our LNG fueling system which allows it to safely go liquid full. Once the Orca™ meter senses a flow rate reduction, the pump is automatically shut down. This patented automatic dispensing system simulates the same process drivers have used for years to safely fill Perma-Cyl storage tanks with a single hose.

Features

- Allows top & bottom filling for accurate pressure control in Perma-Cyl tank during refill
- Provides the same safe, single hose, no-loss, auto-shut off fill with the Orca delivery system as the top fill float design
- Backward compatible - works with new and existing Orca delivery units without modifications
- Available on 1000 HP/VHP, 1500 HP/VHP, 2000 HP/VHP, 3000 HP/VHP, and 5500 VHP models

Mixed Gas Skid

Chart's improved Mixed Gas Skid is a prefabricated blending system that provides a reliable source of high-precision mixed gas in a safe and secure package. The system includes options that make it flexible and capable of handling a wide range of gas blends required in welding and other applications. The Mixed Gas System's design simplicity provides higher interconnecting piping integrity, faster start up time, and reduced installation costs. This system also features all the advantages of Chart's MicroBulk Solutions.™

Product Highlights:

- Provides a turnkey solution: two vessels, pressure control manifolds, a mixer, and an emergency HP cylinder mixed gas reserve (HP bottles not included)
- Prefabricated system reduces installation time and costs
- On-site filling using the Orca™ MicroBulk Delivery System
- Two standard size skid packages to select from
- Transported by pallet jack, forklift or overhead crane
- Thermco® world class mixer provides high quality and proven reliability
- Gas mixer supports two gas sources and a mixed gas output of 0-50% CO_2 in argon
- Provides a regulated source of pure argon gas
- Excellent solution for emergency back-up or temporary requirements
- Gas connection ½" FPT

The mixed gas skid is offered in two sizes with both consisting of a primary and a secondary gas supply, regulating manifolds, and a mixer all installed and connected for immediate installation.

SKID PACKAGES

Skid Package	Skid Dimensions/Weight	Primary Gas Source	Second Gas Source	Emergency Back Up	Materials
Small Skid	72" L x 72" W x 93" H 183 cm x 183 cm x 236 cm 900 lbs. (409 Kg)	Perma-Cyl® 450 HP DOT	Perma-Cyl® 230 HP R8	4 Bottle High-Pressure Manifold (HP bottles not included)	Welded steel powder coated painted frame
Large Skid	84" L x 95" W x 93" H 213 cm x 241 cm x 236 cm 1200 lbs. (545 Kg)	Perma-Cyl® 1000 HP	Perma-Cyl® 450 HP DOT	8 Bottle High-Pressure Manifold (HP bottles not included)	Welded steel powder coated painted frame

Other Gas Combinations available upon request including tri-mixes. Option without Thermco mixer available upon request.

MIXER® Thermco® Model 8500 CA50X1100

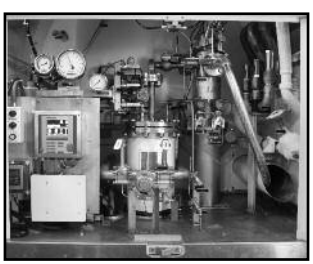
Model	Range	Flow Capacity	Accuracy
8500 CA50X1100	0-50% CO_2 in Argon	0-750 SCFH (0-20.1 Nm³/hr)	+/- 1.5% CO_2

The HL models incorporate an external pump for oxygen service or an innovative submerged pump for inert service. The submerged pump eliminates cool down time and completes a Perma-Cyl® tank fill in 3 to 15 minutes without product loss under normal conditions.

Features:

- Fast on-site filling of Perma-Cyl storage system
- Filling of small bulk tanks
- Instantaneous push-button delivery of product
- Simple valves to operate
- "Smart" flow metering system reduces required operator training
- NIST*/California Weights and Measures approved delivery metering system
- Special delivery hose minimizes contamination, cool down and pressure loss
- Electronic pump speed control allows driver to safely optimize delivery rate
- Vessel designed with robust inner support system for rugged road conditions
- Stainless steel plumbing with bronze valves for long service life and reliability
- Low-maintenance submerged pump for instant starts and continuous delivery

** NIST is the National Institute of Standards and Technology*



Back view
of Orca truck

SPECIFICATIONS		1650	2000	2800	3300	4400
Gross Capacity	(gal/ltrs)	1,726/6,534	2,144/8,116	2,880/10,902	3,399/12,867	4,654/17,617
MAWP	(psig/bar)	50/3.4	50/3.4	50/3.4	50/3.4	50/3.4
Length	(in/cm)	192/488	200/508	244/620	273/693	344/874
Diameter	(in/cm)	80/203	80/203	80/203	80/203	80/203
Height	(in/cm)	87/221	87/221	87/221	87/221	87/221
Tare Weight*	(lbs/cm)	7,700/3,493	8,500/3,856	9,400/4,264	10,500/4,763	12,200/5,534

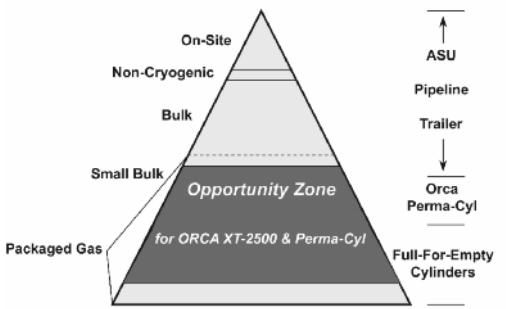
** For MC338 tank only. For CGA-341 tank, lower operating pressure, refer to factory for weights and dimensions.*

Design: ASME SEC VIII, Div. I / DOT MC-338 / CGA-341

Orca™ XT Series

Designed for smaller markets or as a starter system, the XT Series delivers product efficiently from an innovative Pulse Technology process. This pump-less design uses a high-pressure pulse tank that integrates with the low-pressure main tank for a low-loss and low cost delivery solution. The XT Series' pulse pressure design benefits larger deliveries from the main tank. Pulse transfer technology works in harmony with Chart Perma-Cyl® storage vessels and small bulk tanks.

Gas Distribution Pyramid



SPECIFICATIONS		2000	2500
Gross Capacity	(gal/ltrs)	2,026 / 7,671	2,489 / 9,422
MAWP	(psig/bar)	217 / 15 (main)	217 / 15 (main)
Length	(in/cm)	234 / 594	270 / 686
Diameter	(in/cm)	72 / 183	72 / 183
Height	(in/cm)	78 / 198	78 / 198
Tare Weight*	(lbs/kg)	10,900 / 4,944	11,600 / 5,262
** For MC338 tank only. For CGA-341 tank, lower operating pressure, refer to factory for weights and dimensions.*			
Design: ASME SEC VIII, Div. I / DOT MC-338 / CGA-341			

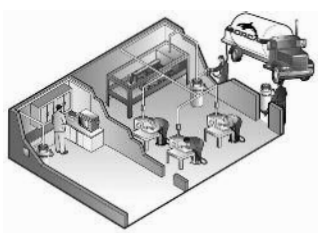
Orca™ ST Series

The Orca™ ST MicroBulk Delivery System incorporates an external pump for oxygen service or an innovative submerged pump for inert service. The submerged pump eliminates cool down time and completes a Perma-Cyl® tank fill in 3 to 15 minutes without product loss under normal conditions.

SPECIFICATIONS		4100
Gross Capacity	(gal/ltrs)	4,250 / 16,088
MAWP	(psig/bar)	38 / 2.6
Length	(in/cm)	338 / 859
Diameter	(in/cm)	80 / 203
Height	(in/cm)	133 / 338
Tare Weight*	(lbs/kg)	17,100 / 7,756
** For MC338 tank only. For CGA-341 tank, lower operating pressure, refer to factory for weights and dimensions.*		
Design: ASME SEC VIII, Div. I / DOT MC-338 / CGA-341		

**ST model also available in 6800 gallons upon request.

Chart Exclusive - "Smart" flow metering system monitors flow electronically with no moving parts in meter section. (Standard on all HL, XT and ST models.)



Carbo Series Bulk CO_2 Systems

Serving a variety of markets and usage requirements, Carbo Series bulk CO_2 systems meet the unique demands of every customer.

Carbo Series systems eliminate run-outs, allowing your focus to be on customer sales rather than operations. One Carbo Series bulk system meets all of your CO_2 requirements. The vessel requires no employee handling, continuously supplying CO_2 for a variety of applications.

Product Advantages

- **Stationary, automatic system** 100% stainless steel vessel construction, permanently installed and self-contained with no electricity required for dispense.
- **Maximizes limited space** One system replaces all of your high-pressure cylinders, using less than 3 square feet of floor space.
- **Sized to match usage needs** Available in a variety of sizes, the Carbo Series systems will meet the unique demands of your business.

Carbo Series Specifications

SPECIFICATIONS								
Model	220	300	450	550	750	750HF	1000HF	
DIMENSIONS								
Diameter	20 in	20 in	20 in	22 in	26 in	26 in	30 in	
Height (with legs)§	46 in	55.625 in	71.875 in	72.9 in	73.875 in	73.875 in	72.5 in (no legs)	
DESIGN CRITERIA								
Code	ASME*	ASME*	ASME*	ASME*	ASME*	ASME*	ASME*	
MAWP	300 psig	300 psig	300 psig	300 psig	300 psig	300 psig	300 psig	
Insulation Type	SI †	SI †	SI †	SI †	SI †	SI †	SI †	
CAPACITY								
Net Volume	25.5 gal	32 gal	48 gal	62 gal	82 gal	82 gal	118 gal	
Storage Capacity at 125 psig	221 lb	299 lb	477 lb	584 lb	789 lb	789 lb	1000 lb	
PERFORMANCE								
Minimum Usage (No Venting)Δ	1.0 lb/day	2.0 lb/day	2.5 lb/day	2.5 lb/day	3.0 lb/day	3.0 lb/day	3.0 lb/day	
CO_2 Gas Delivery (Continuous)@	1.0 lb/hr	1.0 lb/hr	5.5 lb/hr	6.5 lb/hr	10 lb/hr	15 lb/hr^	30 lb/hr	
Peak Flow Rate$	1.5 lb/hr	3.0 lb/hr	10 lb/hr	10 lb/hr	15 lb/hr	40 lb/hr^	50 lb/hr@	

§ Height without legs, subtract 6 in, @ 12 consecutive hours at room temperature, ^ Can achieve flows up to 40 lb/hr, for 12 consecutive hours continuous use. At these higher flow rates, gas supply temperatures from the tank will be lower than freezing (32°F). Additional external vaporization should be added to achieve gas temperatures above freezing (32°F). * ASME Boiler and Pressure Vessel Design Section VIII, Div. 1, † Super Insulation/High Vacuum, $ Four consecutive hours at room temperature, Δ No loss in normal applications

Dispensing draft beer with a mixed gas blend of Carbon Dioxide (CO_2) and Nitrogen (N_2) helps ensure the correct presentation and flavor. Quality draft beer requires a precise, consistent supply of Nitrogen and Carbon Dioxide. Chart's GeN$_2$® Nitrogen Generator coupled with a Carbo-Mizer® Bulk CO_2 tank is the ideal system to provide the correct blended gas mix. This system provides a reliable, uninterrupted flow of individual or mixed gas and eliminates the need to change out smaller high pressure cylinders. The GeN$_2$ system brings industry leading technology to the nitrogen generator for dependable, accurate, and cost effective operation.

GeN$_2$® Nitrogen Generator

Product Advantages

- Proven, continuous flow rate, rotary PSA system provides quick response to surge demands and eliminates the need for a large capacity N_2 storage tank
- Heavy duty compressor has a long lifecycle and is easy to maintain
- Integrated, small five gallon surge tank reduces footprint and simplifies installation
- Double hinged doors allow easy access for maintenance
- Sleek, modern look blends with site decor
- Self-diagnostic system helps service technicians identify scheduled maintenance or repairs

N_2 Purity	99.8% (< 0.2% O_2)
N_2 output	> 7 slpm avg (14.8 scfh)
Kegs per hour	9 (sustained)
External Tank Size	None
Internal Tank Size	5 gal
pints/min	19 (sustained)
N_2 outlet on unit	Yes
Maintenance Access	Service panel w/ latch
Compressor	Durr Technik Oil-Free
Compressor Warranty	3 yr / 5000 hr
Blender	McDantim
# of blends	2 (70% CO_2 & 25% CO_2 Standard)
Blend outlet pressure	~ 60 psi_g
Case Size	44"H x 26" W x 17" D
Case Weight	160 lbs
***Pints/min and kegs/hour assume 70% CO_2 blend, 25 psi_g keg pressure, and a leak-free beer system**	

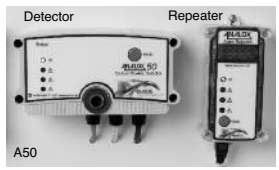
The VLCD bulk CO_2 delivery system is an affordable alternative for transporting liquid CO_2. Ideal for start-up installations, hot shot deliveries and remote operations, the VLCD provides easy delivery to Chart bulk CO_2 systems. The system is mounted in a secure mobile pallet base with all the interconnecting piping and controls that are easily accessible by the driver. Heat management of the liquid CO_2 is controlled with a vacuum-insulated jacket for long hold times in periods of non-use and external pressure building systems for fast pressurerecovery.

**Optional: Small accurate deliveries are performed with our exclusive FlowCom® meter system and a convenient ticket printer.*

Specifications	950		1900	
Capacity	950 lbs	431 kg	1,900 lbs	864 kg
Design Criteria				
MAWP	350 psig	24 barg	350 psig	24 barg
Dimensions				
Length	43 in	1,092 mm	65 in	1,651 mm
Width	34 in	864 mm	46 in	1,168 mm
Height	71.25 in	1,810 mm	77 in	1,956 mm
Tare Weight	1,150 lbs	522 kg	2,350 lbs	1,066 kg
Full Weight	2,180 lbs	989 kg	4,250 lbs	1,932 kg

CO_2 Monitoring System

The Analox CO_2 Monitoring System is a precision instrument that provides continuous, accurate monitoring of CO_2 levels to ensure a safe working environment for your employees, suppliers and yourself. A proven system with over 80,000 units installed worldwide. The A50 is comprised of one detector (with visual and audible alarms) to be mounted in the area where CO_2 is stored and one alarm repeater for remote mounting. The AX60 is designed for sites needing multiple placements of alarm and sensor units which are connected to a central display.



A50

AX60

Product Advantages

- Relay on Alert 1 - Leak Alert (Set at 1.5% CO_2)
- Relay on Alert 2 - No Entry Alert (Set at 3% CO_2)
- Bright 10 LED visual and loud 80 dB audible alarms
- Detector housing designed to withstand splash environments (IP 65)
- 15 year CO_2 sensor warranty, 2 year electronics warranty
- Plug-in cables for fast and easy installation
- AX60 - same detector as A50, but modular (5 year system warranty)

VaporMan 125®

VaporMan 125® is a CO_2 vaporizer and manifold combination intended for use with the Carbo-Max series Beverage Systems tanks and CO_2 configured Perma-Cyl® tanks. The VaporMan 125 consists of one 2 fin parallel style vaporizer and one 2 fin series style vaporizer, connected together. The unit also includes a manifold for connecting a single tank or multiple tanks in pairs. The vaporizers and manifold are mounted to a stainless steel pedestal, which is attached to a 27" x 27" x 3/8" stainless steel base plate.

Product Advantages

- Compact design, less than 2-1/2 ft square and 4 feet tall
- Cost effective, compared to larger traditional ambient vaporizers
- Easy to attach to bulk CO_2 tanks, using the manifold connections

Extend product shelf life and improve package integrity with our liquid nitrogen (LN_2) dosing systems. Designed for easy interchangeability to various packaging lines, our dosers provide continuous operation at all fill speeds, including high speed lines. Engineered options are available to meet your packaging specifications.

CryoDoser®

The CryoDoser is the premier liquid nitrogen (LN_2) dosing system utilizing advanced cryogenic technology and PLC programming. Three sensors detecting line speed, timing, and bottle presence allow the system to detect all line speeds, including high speeds, to dispense a precise dose of LN_2 into every container every time.

UltraDoser®

The UltraDoser is the multi-purpose liquid nitrogen (LN_2) dosing system utilizing advanced cryogenic technology and PLC programming. Chart engineers designed an ultra-efficient system for low to medium production line speeds to dispense a precise dose of LN_2 into every container every time. The LN_2 gasifies and is either trapped in the container to add rigidity or escapes with oxygen to inert the headspace.

Inerter™

The Inerter is a large volume liquid nitrogen (LN_2) dosing system for full container and high-volume headspace inerting applications. Chart engineers designed an ultra-efficient system to dispense a precise dose of LN_2 into every container every time to displace the oxygen in the container.

SPECIFICATIONS

Doser Selection Guide	CryoDoser	UltraDoser		Inerter		
Model (Non-Aseptic)	**2K**	**2K**	**500S**	**150S**	**2K**	**500S**	**150S**
Package/Container							
LN_2 Volume/Head Space	Medium	Small	Small	Small	Large	Large	Large
Body							
Arm/Head Type	Flexible	Rigid	Rigid	Rigid	Rigid	Rigid	Rigid
Quick Service Auto Defrost	Yes						
Head Pressure	0.9 psi	0.45 psi	0.45 psi	0.45 psi	≥3 psi	≥3 psi	≥3 psi
Controller							
Discrete Dosing (cpm)	2000	2000	500	150	2000	500	150
Dose Duration (ms)	5.5-1000	5.5-1000	15-1000	20-1000	5.5-1000	15-1000	20-1000
PLC Platform	Allen-Bradley or Siemens	Allen-Bradley or Siemens	Siemens	Siemens	Allen-Bradley or Siemens	Siemens	Siemens
Encoder Compatible	Yes	Yes			Yes		
Line Speed Auto Detect	Yes	Yes			Yes		
Electronic Dose Targeting	Yes	Yes	Yes		Yes	Yes	
Fixed Delay Mode	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Container Speed Comp. Mode	Yes	Yes	Yes		Yes	Yes	
Multiple Languages	Yes	Yes			Yes		
Ethernet Ready	Yes	Yes			Yes		
Recipe Storage	Yes	Yes			Yes		
MicroDose™ Technology	Yes	Yes			Yes		
RemoteDose™ Web Tech.	Option	Option			Option		
SoftDose™ Technology	Option	Option	Option	Option	Option	Option	Option
Electric Dosing System	Yes	Yes	Option	Option	Option	Option	Option
Heated Purge Option	Option	Option	Option	Option	Option	Option	Option

chartdosers.com
ditchthewidget.com

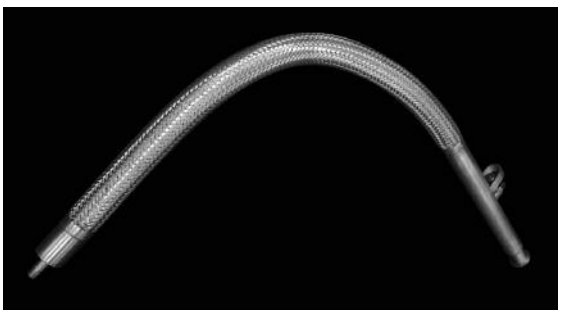
Modular Vacuum Insulated Pipe - MVIP Pro®

MVIP Pro® Vacuum Insulated Pipe accomodates pressures up to 150 psi and is suitable for liquid nitrogen (LN_2) and liquid argon (LAR) applications.

The MVIP Pro system offers pre-engineered standard modular sections for flexible configuration and easy, low-cost installation. Bayonet connections eliminate the need for cutting or field welding. Modules can be reused and reconfigured if your facility layout changes or expands. Internal bellows offer improved protection while accommodating a greater than 400ºF temperature differential between the interior and exterior.

Modules Available

- Straight modules
- Flex modules
- Valve modules
- Cryovent modules
- Drop modules or Gas Traps
- Adapter modules
- (2) Tee modules (F x M x M) and (F x M x F)
- Elbow modules
- Bayonet connections to adapt to any existing VIP system



MVIP Pro Flex Pipe

MVIP Pro Rigid Pipe

MVIP Python®

Python® Vacuum Insulated Pipe products provide thermal performance that far exceeds conventional foam insulation materials, take only a fraction as much space, and require no additional protection against moisture or vapors. Python piping is adapt- able, reusable and easy to install. Available in 1⁄2" Outer Diameter Tube (ODT), 1", 2" and 3" Nominal Pipe Sizes (NPS).

Installed costs are comparable to most conventional mechanical insulation systems. Typical delivery on small projects is next day from stock. Installation service can be provided from one of our many loca- tions worldwide.

Python piping is designed for temperatures down to -350° F and pressures up to 500 psi. Python systems can be modi ed and adapted to many applica-

tions such as liquid nitrogen, liquid argon, lique ed natural gas (LNG) and liquid carbon dioxide. Python piping is ideal for highly temperature-sensitive piping systems found in the petrochemical, energy, manufacturing, and food and beverage industries around the world.

Modules Available

- Straight modules
- Flex modules
- Valve module kit
- Cryovent modules
- Adapter modules
- Tee module kit
- Elbow module kit
- Straight insulation kit
- End transitions are standard butt weld joints for the inner pipe

Python 1/2" Tube (No joint welding required)

Python 1", 2" or 3" Pipe

MVIP Select®

To meet complex application requirements, MVIP Select®Vacuum Insulated Pipe ffers custom engineered, built-to-order vacuum insulated pipe systems. Chart's experienced staff is available to guide you through design and price trade-offs to create your best total value while meeting precise system requirements.

Chart's staff can design, build and install cryogenic system solutions of all levels of complexity. Sales engineers, field technicians, customer service representatives, project managers, project engineers, staff engineers and designers are at your service to create the optimal system to meet your unique specifications and installation needs.

Five Major Pipe Design Platforms in Stainless Steel or Invar

- Invar
- Internal bellows
- External bellows
- Helium Lines
- Custom Python®

C-Flex Vacuum Insulated Transfer Hoses

Super flexible vacuum insulated liquid nitrogen transfer hoses are used in a wide variety of applications including tool connections and custom OEM applications. The coaxial bellowed construction allows for optimal flexibility. The use of lightweight stainless steel reduces cool-down loss to an absolute minimum.
C-Flex hoses are protected by a stainless steel spiral wrap or a braided outer cover.

Features

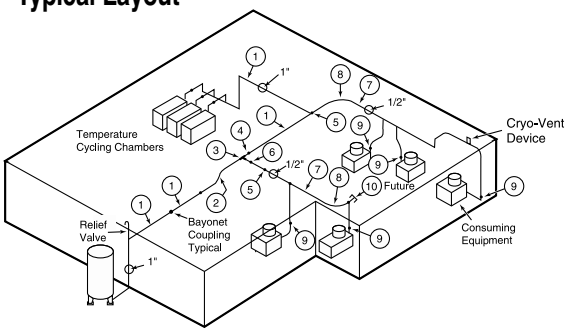
- Custom Manifolds Available
- High Pressure Requirements
- Minimal Cool Down & Steady State Losses
- Integrated pump out

C-Flex Hose	04S	06S	08S	08B
Inner Diameter (ID)	1/4"	3/8"	1/2"	1/2"
Outer Diameter (OD)	1.25"	1.65"	1.90"	1.80"
Minimum Flexible Bend Radius	7"	8"	10"	10"
Minimum Static Bend Radius	5"	6"	8"	7"
Maximum Operating Pressure	150 psi	150 psi	150 psi	150 psi

S: Spiral wrap outer covering **B:** Braided outer covering
C-Flex hoses are available in standard or custom lengths up to 60 feet.

- Multi-layer super insulation with vacuum jacket for lowest product loss
- Optional invar inner eliminates expansion bellows
- Accessories for instant liquid at use points
- Reusable bayonet couplings for easy installation and system modifications

Typical Layout



1	1" Rigid Section	6	1/2" Vacuum Jacketed Valve
2	1" Flexible Section	7	1/2" Rigid Section
3	1" x 1/2" Reducing Tee	8	1/2" Flexible Section
4	1" Vacuum Jacketed Valve	9	1/2" Extended Packing Cryogenic Valve
5	1" x 1/2" Reducer	10	1/2" Capped Bayonet

Vacuum Insulated Pipe
Customized size and length permits engineering or contractor personnel to design and install a liquid distribution center to fit any application.

Bayonet Couplings
Provide a positive metal to metal interference fit at cryogenic temperatures. Interchangeable for easy assembly or removal for system expansion.

Flexible Sections
Protected by stainless steel, interlocking guards to allow direction and elevation change while maintaining structural integrity.

Accessories
Standard accessories such as the cryovent device to keep the line flooded, phase separator for single phase flow at the use points, and vacuum jacketed or non-jacketed valves provide optimum utilization of cryogenic piping.

Specify Chart Vacuum Insulated Pipe (VIP) and System components for state-of-the-art technology, lowest product loss (see chart) and instant liquid at use points. From design assistance and custom manufacturing to installation at your site, Chart provides total cryogenic distribution systems. This single source responsibility assures you of a trouble-free system guaranteed to perform as expected.

Rigid Engineered-to-Order VIP Construction Details

Inner Pipe Size	Vacuum Jacket Pipe Size	Wt/ft	Cooldown Wt/ft	Heat Leak Btu/hr/ft	Bayonet Heat BTU/hr
1/2"	2"	1.9 lb	0.54 lb	.35	7.5
1"	3"	3.4 lb	0.87 lb	.50	11.8
1-1/2"	3"	4.4 lb	1.28 lb	.67	15.4
2"	3-1/2"	5.2 lb	1.61 lb	.81	17.9
3" +	Consult Factory				

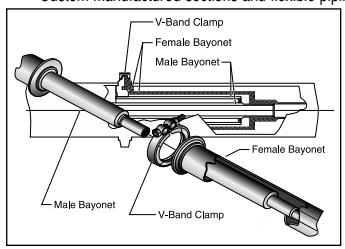
Flexible Engineered-to-Order VIP Construction Details

SS Inner Flex I.D.	SS Outer Flex I.D.	SS Outer Flex O.D.	Minimum Bend Radius	Weight Per Foot	Cooldown Weight/Foot	Heat Leak BTU hr/ft
1/2" Nom	2" Nom	2.80"	17"	2.75 lb	.45 lb	.50
1" Nom	2-1/2" Nom	3.32"	21"	3.50 lb	1.00 lb	1.00
1-1/2" Nom	3" Nom	3.87"	23"	4.65 lb	2.00 lb	1.35
2" Nom	4" Nom	4.92"	28"	6.00 lb	2.25 lb	1.65
3"+	Consult Factory					

Stainless steel braid cover is standard on the inner flex and optional for the outer vacuum jacket flex.

Chart vacuum insulated pipe utilizes multi-layer super insulation for lowest heat leak. When used to replace copper or conventionally insulated lines, investment payback can be extremely fast.

Custom manufactured sections and flexible piping allow easy system planning and installation — no special tools are required.



Bayonet couplings provide positive metal-to-metal interference fit at cryogenic temperatures. With these re-usable couplings, pipe sections and components can be easily assembled or removed for system modification or expansion.

Liquid Nitrogen Storage Container

The Lab Series of cryogenic dewars earned their name from their worldwide acceptance in laboratories and medical offices. These high-efficiency, super-insulated dewars are the most convenient, economical way to store and dispense liquid nitrogen. Many lab units can be fitted with pouring spouts, pressurized dispensing devices or dippers to aid in the transfer of liquid nitrogen.

Accessories:

- Transfer Hose
- Phase Separator
- Pour Spout
- Swivel Dipper
- Rigid Dipper
- Spare Corks
- Discharge Device
- Roller Base
- Cryo Gloves

Cryo-Cyl Series

Cryo-Cyl units can be used to supply liquid through a transfer hose to your application. A convenient pressure and liquid level gauge monitors the operation of the cylinder.

SPECIFICATIONS

Model		LAB 4	LAB 5	LAB 10	LAB 20	LAB 30	LAB 50
Net Capacity	(liters)	4	5	10	20	32	50
Performance							
Static Evaporation Rate*	(liters/day)	0.19	0.15	0.18	0.18	0.22	0.49
Unit Dimensions							
Neck opening	(in)	1.4	2.18	2.18	2.18	2.5	2.5
Usable height	(in)	7.8	10.5	13.5	13.7	14.9	22
Overall height	(in)	16.8	18.2	21.5	24.5	24	30.5
Outside diameter	(in)	7.3	8.8	10.3	14.5	17	17
Internal diameter	(in)	5.5	6.5	8.3	11.4	14	14
Weight empty	(lbs)	6	8	12	19	25	31
Weight full	(lbs)	13	17	31	55	82	120

* Static evaporation rate and static holding time are nominal. Actual rate and holding time will be affected by the nature of container use, atmospheric conditions, and manufacturing tolerances.

Self-Contained PSA Oxygen Generators

For unique applications, AirSep offers a range of completely self-contained oxygen generators equipped with air compressors. With the exception of the Centrox, these generators require no special installation. Simply connect the oxygen outlet to your oxygen distribution system and the power cord to a grounded electrical outlet. Turn the unit on and set your desired oxygen flow.

AIRSEP®
A Chart Industries Company


Centrox


Topaz Series


Workhorse Series


Onyx Series


Regalia

Model	Product Flow			Product Pressure		
	SCFH*	Nm^3/Hr*	LPM*	psig	kPa	barg
Workhorse-8	8	0.21	3.8	9	62	0.62
Workhorse-12	12	0.31	5.7	9	62	0.62
Workhorse-15	15	0.39	7.1	7	48	0.48
Workhorse Profile-15	15	0.39	7.1	7	48	0.48
Workhorse Profile-23	23	0.60	10.8	7	48	0.48
Onyx	12	0.31	6	9	62	0.62
Onyx Plus	17	0.44	8	20	138	1.37
Onyx Ultra	21	0.55	10	20	138	1.37
Topaz	12	0.31	6	9	62	0.62
Topaz Plus	17	0.44	8	20	138	1.37
Topaz Ultra	21	0.55	10	20	138	1.37
Dual Topaz Plus	38	1.0	18	20	138	1.37
Regalia	21	0.55	10	7	48	0.48
Reliant	17	0.44	8	50	345	3.5
Centrox	32	0.84	15	50	345	3.5

*SCF (Standard cubic foot) gas measured at 1 atmosphere and 70°F.
* Nm^3 (Normal cubic meter) gas measured at 1 atmosphere and 0°C.
* LPM (Liters per minute) gas measured at 1 atmosphere and 21°C.

Standard PSA Oxygen Generators

AirSep SeQual brand and Alpha-Series Oxygen Generators produce from 8 to 5,500 cubic feet of oxygen per hour at up to 95% oxygen concentration. When electricity and a source of compressed air is supplied, these dependable machines can provide oxygen for practically any application.


AS-J


AS-A


Quad Series


ATF Series

Model	Product Flow			Product Pressure		
	SCFH*	Nm^3/Hr*	LPM*	psig	kPa	barg
ATF-8	8	0.21	3.8	9	62	0.62
ATF-12	12	0.31	5.7	9	62	0.62
ATF-15	15	0.39	7.1	7	48	0.48
ATF-23	23	0.60	10.8	7	48	0.48
ATF-25	25	0.65	12	14	97	0.96
ATF-32	32	0.84	15	14	97	0.96
Quad-60	60	1.57	28	7	48	0.48
Quad-100	100	2.62	47	15	103	1.03
Quad-130	130	3.41	60	15	103	1.03
AS-A	20 – 25	0.53 – 0.66	9 – 11	45 – 50	310 – 345	3.0 – 3.4
AS-B	45 – 55	1.18 – 1.45	21 – 25	45 – 55	310 – 379	3.0 – 3.7
AS-D	80 – 90	2.10 – 2.37	37 – 42	45 – 55	310 – 379	3.0 – 3.7
AS-D+	80 – 100	2.10 – 2.63	37 – 47	45 – 65	310 – 448	3.0 – 4.4
AS-E	160 – 195	4.21 – 5.13	75 – 92	45 – 65	310 – 448	3.0 – 4.4
AS-G	250 – 320	6.57 – 8.41	117 – 151	45 – 65	310 – 448	3.0 – 4.4
AS-J	450 – 600	11.83 – 15.77	212 – 283	45 – 65	310 – 448	3.0 – 4.4
AS-K	750 – 900	19.72 – 23.66	353 – 424	45 – 65	310 – 448	3.0 – 4.4
AS-L	1,000 – 1,300	26.29 – 34.18	471 – 613	45 – 65	310 – 448	3.0 – 4.4
AS-N	1,500 – 1,800	39.43 – 47.32	707 – 849	45 – 65	310 – 448	3.0 – 4.4
AS-P	2,000 – 2,300	52.58 – 60.46	943 – 1,085	45 – 65	310 – 448	3.0 – 4.4
AS-Q	2,500 – 2,800	65.72 – 73.61	1,179 – 1,321	45 – 65	310 – 448	3.0 – 4.4
AS-R	3,000 – 3,700	78.86 – 97.27	1,415 – 1,746	45 – 65	310 – 448	3.0 – 4.4
AS-W	4,000 – 4,600	105.15 – 120.93	1,887 – 2,170	45 – 65	310 – 448	3.0 – 4.4
AS-Z	5,000 – 5,500	131.45 – 144.59	2,359 – 2,595	45 – 65	310 – 448	3.0 – 4.4

*SCF (Standard cubic foot) gas measured at 1 atmosphere and 70°F.
* Nm^3 (Normal cubic meter) gas measured at 1 atmosphere and 0°C.
* LPM (Liters per minute) gas measured at 1 atmosphere and 21°C.

Mini Pack PSA Oxygen Generators

Designed specifically for applications with fixed flow and pressure characteristics, the reduced size oxygen receiver feature of our Mini Pack Oxygen Generators offers a quick start-up and a significantly smaller footprint than comparable systems that utilize a standard, separate receiver. Simply connect the unit's inlet to a suitable compressed air source, the oxygen outlet to the application, and the power cord to an appropriate electrical source.

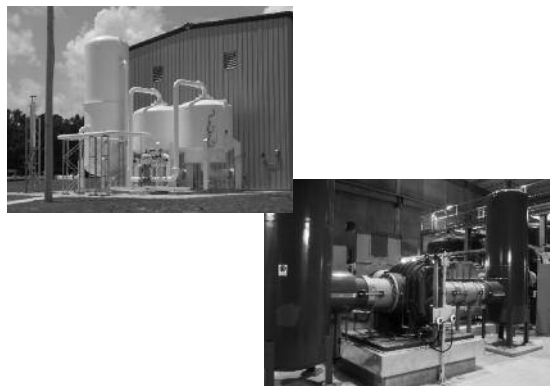
AS-A, AS-B and AS-D Mini Pack Generators

Model	Product Flow			Product Pressure		
	SCFH*	Nm^3/Hr*	LPM*	psig	kPa	barg
AS-A Mini Pack	20 – 25	0.53 – 0.66	9 – 11	45 – 50	310 – 345	3.0 – 3.4
AS-B Mini Pack	45 – 55	1.18 – 1.45	21 – 25	45 – 55	310 – 379	3.0 – 3.4
AS-D Mini Pack	80 – 90	2.10 – 2.37	37 – 42	45 – 55	310 – 379	3.0 – 3.4

*SCF_3 (Standard cubic foot) gas measured at 1 atmosphere and 70°F.
* Nm^3 (Normal cubic meter) gas measured at 1 atmosphere and 0°C.
* LPM (Liters per minute) gas measured at 1 atmosphere and 21°C.

VPSA Oxygen Tonnage Plants

AirSep offers custom-engineered VPSA Oxygen Systems designed to the specific requirements of installation, with capacities from 2,000 SCFH (53 Nm^3/hr) to 120,000 SCFH (3,155 Nm^3/hr).
AirSep's high-efficiency, rugged 2-bed VPSA oxygen process design offers extremely low energy consumption, on-line efficiency of 99%, easy operation, and long-term equipment life of 25 years or more.
AirSep also offers containerized VPSA plants up to 4,000 SCFH (105 Nm^3/hr).



Sample Specifications (Generally Available in 1,000 SCF Increments)		
Model	**Capacity**	**VPSA Building Dimensions**
ASV2000	2,000 SCFH (53 Nm^3/hr)	32 x 24 x 20 ft (9.8 x 7.3 x 6.1 m)
ASV10000	10,000 SCFH (263 Nm^3/hr)	42 x 24 x 20 ft (12.8 x 7.3 x 6.1 m)
ASV20000	20,000 SCFH (526 Nm^3/hr)	58 x 33 x 25 ft (17.7 x 10.1 x 7.6 m)
ASV50000	50,000 SCFH (1,314 Nm^3/hr)	80 x 55 x 30 ft (24.4 x 16.8 x 9.1 m)
ASV120000	120,000 SCFH (3,155 Nm^3/hr)	90 x 60 x 30 ft (27.4 x 18.3 x 9.1 m)

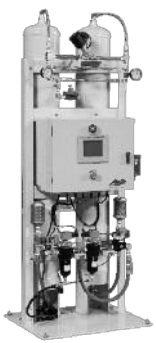
All AirSep VPSA Oxygen Systems have a guaranteed power consumption of:
1.08 kWh ±5% per 100 SCFH of total flow, nominal 93% oxygen at 3 psig product pressure at maximum plant capacity.
.41 kWh ±5% per Nm^3 of total flow, nominal 93% oxygen at .21 barg product pressure at maximum plant capacity.
Note: Specifications subject to change without notice.

Membrane & PSA Nitrogen Generators

AirSep manufactures both 2-bed PSA Nitrogen Generators, as well as expandable, cabinet-mounted Modular PSA and Membrane Nitrogen Generators. Standard PSA Nitrogen Generators are available with capacities of 360 (9.46 Nm^3/hr) to 37,000 SCFH (972.7 Nm^3/hr) and may be placed on an existing foundation or skid-mounted as a turnkey plant with compressor(s), dryer(s), and pre-filtration.

PSA technology is ideal for applications that require 99-5 – 99.995% concentration, while membrane based generators produce 95.0 – 99.0% nitrogen. When electricity and a source of compressed air is supplied, these dependable machines can provide nitrogen for practically any use. For special applications, an optional purifier can be added to increase nitrogen concentration to 99.999% (10 PPM oxygen).

N2-AS-K



N2-AS-D+

Standard or Custom-Designed Systems

Standard oxygen and nitrogen plants are available in either low pressure power-optimized or high pressure cost-optimized designs. Low pressure oxygen plants generate nominal 93% oxygen at up to 15 psig (105 kPa or 1.03 barg) and consume approximately 400 kWh[1] per ton of oxygen. High pressure plants generate nominal 93% oxygen at up to 65 psig (448 kPa or 4.4 barg) without the use of an oxygen compressor. They consume approximately 750 kWh[1] per ton oxygen. Nitrogen plants generally produce 99.5% – 99.999% nitrogen at up to 85 psig (586 kPa or 5.8 barg). An optional oxygen or nitrogen compressor delivers the gas at pressures up to 3,000 psig (20,685 kPa or 206 barg) for specialty applications or to fill cylinders. Containerized plants are also available.

Unskidded Package Plant

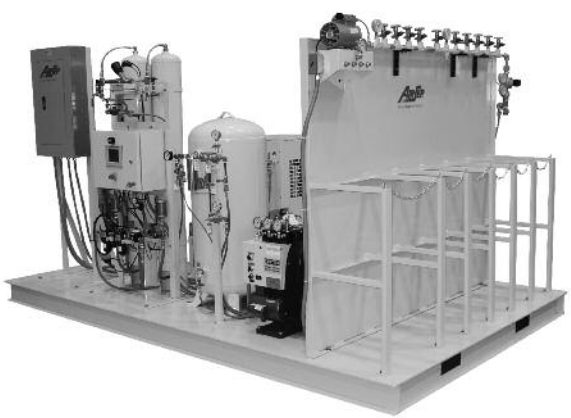
Containerized High Purity Packaged Plant

[1] Power consumption based on per ton (2,000 lb) of total product generated.

Cylinder Refilling Systems

AirSep Oxygen and Nitrogen Cylinder Refilling Plants enable customers to fill cylinders for existing needs or to supply others. AirSep manufacturers a complete line of turnkey oxygen and nitrogen cylinder refilling plants — with capacities from 8-100s of cylinders per day. Complete plants include a feed air compressor, feed air dryer, oxygen or nitrogen generator, oxygen or nitrogen compressor, and a cylinder filling rack. The oxygen or nitrogen compressor delivers the gas at up to 2,200 psig (15,169 kPa or 151 barg) to a high pressure manifold capable of filling up to 10 cylinders at a time.

These cylinder refilling plants operate automatically and generate either 99.5 – 99.999% nitrogen or oxygen that meets the United States and European Pharmacopoeia Oxygen 93 Percent (93% ±3%) Monograph. For special applications, an optional high purity module can be added to the plant, to increase oxygen concentration to 99%.



Cylinder Refilling Plant

Length Conversion Factors

Length	Multiply units in left column by proper factor below								
	in	ft	yd	mile	mm	cm	m	km
1 inch	1	0.0833	0.0278	—	25.40	2.540	0.0254	—
1 foot	12	1	0.3333	—	304.8	30.48	0.3048	—
1 yard	36	3	1		914.4	91.44	0.9144	—
1 mile	—	5280	1760	1	—	—	1609.3	1.609
1 millimeter	0.0394	0.0033	—	—	1	0.100	0.001	—
1 centimeter	0.3937	0.03281	0.0109	—	10	1	0.01	—
1 meter	39.37	3.281	1.094	—	1000	100	1	0.001
1 kilometer	—	3281	1094	0.6214	—	—	1000	1

(1 micron = 0.001 millimeter)

Courtesy of Ingersoll-Rand Company

Area Conversion Factors

Area	Multiply units in left column by proper factor below						
	sq in	sq ft	acre	sq mile	sq cm	sq m	hectare
1 sq inch	1	0.0069	–	–	6.452	–	–
1 sq foot	144	1	–	–	929	0.0929	–
1 acre	–	43,560	1	0.0016	–	4047	0.4047
1 sq mile	–	–	640	1	–	–	259
1 sq centimeter	0.1550	–	–	–	1	0.0001	–
1 sq meter	1550	10.76	–	–	10,000	1	–
1 hectare	–	–	2471	–	–	10,000	1

Courtesy of Ingersoll-Rand Company

Volume Conversion Factors

Volume	Multiply units in left column by proper factor below							
	cu in	cu ft	cu yd	cu cm	cu meter	liter	U.S. gal	Imp gal
1 cu inch	1	–	–	16.387	–	0.0164	–	–
1 cu foot	1728	1	0.0370	28,317	0.0283	28.32	7.481	6.229
1 cu yard	46,656	27	1	–	0.7646	764.5	202	168.2
1 cu centimeter	0.0610	–	–	1	–	0.001	–	–
1 cu meter	61,023	35.31	1.308	1,000,000	1	999.97	264.2	220.0
1 liter	61.023	0.0353	–	1000	0.001	1	0.2642	0.2200
1 U.S. gallon	231	0.1337	–	3785.4	–	3.785	1	0.8327
1 Imperial gallon	227.4	0.1605	–	4546.1	–	4.546	1.201	1

Courtesy of Ingersoll-Rand Company

Weight Conversion Factors

Weight	Multiply units in left column by proper factor below						
	grain	oz	lb	ton	gram	kg	metric ton
1 grain	1	–	–	–	0.0648	–	–
1 ounce	437.5	1	0.0625	–	28.35	0.02835	–
1 pound	7000	16	1	0.0005	453.6	0.4536	–
1 ton	–	32,000	2000	1	–	907.2	0.9072
1 gram	15.43	0.0353	–	–	1	0.001	–
1 kilogram	–	35.274	2.205	–	1000	1	0.001
1 metric ton	–	35,274	2205	1.102	–	1000	1

Courtesy of Ingersoll-Rand Company

Density Conversion Factors

Density	Multiply units in left column by proper factor below				
	lb/cu in	lb/cu ft	lb/gal	g/cu cm	g/liter
1 pound/cu in	1	1728	231	27.68	27,680
1 pound/cu ft	–	1	0.1337	0.0160	16.019
1 pound/gal	0.00433	7.481	1	0.1198	119.83
1 gram/cu cm	0.03613	62.43	8.345	1	1000
1 gram/liter	–	0.06243	0.008345	0.001	1

Courtesy of Ingersoll-Rand Company

Pressure Conversion Factors

Pressure	Multiply units in left column by proper factor below							
	lb/sq in	lb/sq ft	int atm	kg/cm²	mm Hg @ 32°F	in Hg @ 32°F	ft water at 39.2°F	KPa
1 pound/sq in	1	144	–	0.0703	51.713	2.0359	2.307	6.895
1 pound/sq ft	0.00694	1	–	–	0.3591	0.01414	0.01602	0.0479
1 int atmosphere	14.696	2116.2	1	1.0333	760	29.921	33.9	101.325
1 kilogram/sq cm	14.223	2048.1	0.9678	1	735.56	28.958	32.81	98.06
1 millimeter mercury – (1000 microns) 1 torr (torricelli)–	0.0193	2.785	–	–	1	0.0394	0.0446	0.1333
1 inch mercury	0.4912	70.73	0.0334	0.0345	25.400	1	1.133	3.386
1 foot water	0.4335	62.42	–	0.0305	22.418	0.8826	1	2.989
1 kilopascal 0.01 bars 1000 N/sq meters	.1450	20.89	0.009869	0.01020	7.502	0.3025	0.3346	1

Courtesy of Ingersoll-Rand Company

Energy Conversion Factors

Energy	Multiply units in left column by proper factor below					
	ft-lb	BTU	g-cal	Joule	kw-hr	hp-hr
1 foot-pound	1	0.001285	0.3240	1.3556	–	–
1 BTU	778.2	1	252.16	1054.9	–	–
1 gram-calorie	3.0860	0.003966	1	4.1833	–	–
1 int Joule	0.7377	0.000948	0.2390	1	–	–
1 int kilowatt-hour	2,655,000	3412.8	860,563	–	1	1.3412
1 horsepower-hour	1,980,000	2544.5	641,700	–	0.7456	1

Courtesy of Ingersoll-Rand Company

Specific Energy Conversion Factors

Specific Energy	Multiply units in left column by proper factor below				
	absolute Joule/g	Int Joule/g	cal/g	int cal/g	BTU/lb
1 absolute Joule/gram	1	0.99984	0.23901	0.23885	0.42993
1 int Joule/gram	1.000165	1	0.23904	0.23892	0.43000
1 calorie/gram	4.1840	4.1833	1	0.99935	1.7988
1 int calorie/gram	4.1867	4.1860	1.00065	1	1.8000
1 BTU/lb	2.3260	2.3256	0.55592	0.55556	1

Courtesy of Ingersoll-Rand Company

Power Conversion Factors

Power (rate of energy use)	Multiply units in left column by proper factor below								
	hp	watt	kw	BTU/min	BTU/hr	ft-lb/sec	ft-lb/min	g-cal/sec	metric hp
1 horsepower	1	745.7	0.7457	42.41	2544.5	550	33,000	178.2	1.014
1 watt	–	1	0.001	0.0569	3.413	0.7376	44.25	0.2390	0.00136
1 kilowatt	1.3410	1000	1	56.88	3412.8	737.6	44,254	239	1360
1 BTU per minute	–	–	–	1	60	12.97	778.2	4.203	0.0239
1 metric hp	0.9863	735.5	0.7355	41.83	2509.6	542.5	32,550	175.7	1

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Refrigeration	Multiply units in left column by factor below					
	BTU (IT)/min	BTU (IT)/hr	kg cal/hr	ton (US) comm	ton (Brit) comm	frigorie/hr
1 ton (US) comm	200	12,000	3025.9	1	0.8965	3025.9
1 ton (Brit) comm	223.08	13,385	3375.2	1.1154	1	3375.2
1 frigorie/hr	0.06609	13.9657	1	0.0003305	0.0002963	1

BTU is Internal Steam Table BTU (IT). 1 frigorie = 1 kg cal (NOT IT).
One ton of refrigeration is the heat required to melt one ton (2000 lbs) of ice at 32°F to water at 32°F during 24 hours.

Courtesy of Ingersoll-Rand Company

Velocity

Multiply	*By*	*To Obtain*
Feet per minute	0.01136	Miles per hour
	0.01829	Kilometers per hour
	0.5080	Centimeters per second
	0.01667	Feet per second
Feet per second	0.6818	Miles per hour
	1.097	Kilometers per hour
	30.48	Centimeters per second
	0.3048	Meters per second
	0.5921	Knots
Knots	1.0	Nautical miles per hour
	1.6889	Feet per second
	1.1515	Miles per hour
	1.8532	Kilometers per hour
	0.5148	Meters per second
Meters per second	3.281	Feet per second
	2.237	Miles per hour
	3.600	Kilometers per hour
Miles per hour	1.467	Feet per second
	0.4470	Meters per second
	1.609	Kilometers per hour
	0.8684	Knots

Flow Rate

1 SCFH = .472 liters/minute

Thermal Conductivity

Multiply	*By*	*To Obtain*
BTU/(hr)(ft^2)(°F/ft)	0.00413	Cal/(sec)(cm^2)(°C/cm)
	12.0	BTU/(hr)(ft^2)(°F/in)
	0.0173	Watts/(cm^2)(°C/cm)

Temperature

Degrees Fahrenheit = 1.8 (degrees Celsius) + 32
Degrees Kelvin = degrees Celsius = 273.16
Degrees Rankine = degrees Fahrenheit + 459.69

Temperature Conversion

	°K	°C	°F	°R
	0	–273.15	-459.7	0
He	4.216	–268.93	-452.1	7.6
	10	–263.15	-441.7	18.0
	20	–253.15	-423.7	36.0
H_2	20.27	–252.88	-423.2	36.5
Ne	27.17	–245.98	–410.8	48.9
	30	–243.15	–405.7	54.0
	40	–233.15	–387.7	72.0
	50	–223.15	–369.7	90.0
	60	–213.15	–351.7	108.0
	70	–203.15	–333.7	126.0
N_2	77.395	–195.76	–320.36	139.3
	80	–193.15	–315.7	144.0
Ar	87.29	–185.86	–302.55	157.1
	90	–183.15	–297.7	162.0
O_2	90.19	–182.96	–297.33	162.4
	100	–173.15	–279.7	180.0
	110	–163.15	–261.7	198.0
Kr	119	–153.25	–243.8	215.9
	120	–153.15	–243.7	216.0
	130	–143.15	–225.7	234.0
	140	–133.15	–207.7	252.0
	150	–123.15	–189.7	270.0
	160	–113.15	–171.7	288.0
Xe	164.6	–108.55	–163.4	296.3
	170	–103.15	–153.7	306.0
	180	–93.15	–135.7	324.0
	190	–83.15	–117.7	342.0
	200	–73.15	–99.7	360.0
	210	–63.15	–81.7	378.0
	220	–53.15	–63.7	396.0
	230	–43.15	–45.7	414.0
	240	–33.15	–27.7	432.0
	250	–23.15	–9.7	450.0
	260	–13.15	8.3	468.0
	270	–3.15	26.3	486.0
	280	6.85	44.3	504.0
	290	16.85	62.3	522.0
	300	26.85	80.3	540.0
	310	36.85	98.3	558.0
	320	46.85	116.3	576.0
	330	56.85	134.3	594.0
	340	66.85	152.3	612.0
	350	76.85	170.3	630.0
	360	86.85	188.3	648.0
	370	96.85	206.3	666.0
	380	106.85	224.3	684.0
	390	116.85	242.3	702.0
	400	126.85	260.3	720.0

Boiling points of indicated gases are at one atmosphere pressure.

Decimal Equivalents

Decimal Equivalents

Inch Fractions	Decimal Equivalent	Millimeter Equivalent
1/32	.03125	.794
1/16	.0625	1.588
3/32	.09375	2.381
1/8	.125	3.175
5/32	.15625	3.969
3/16	.1875	4.763
7/32	.21875	5.556
1/4	.250	6.350
9/32	.28125	7.144
5/16	.3125	7.938
3/8	.375	9.525
11/32	.34375	8.731
13/32	.40625	10.319
7/16	.4375	11.113
15/32	.46875	11.906
1/2	.500	12.700
17/32	.52125	13.494
9/16	.5625	14.288
19/32	.59375	15.081
5/8	.625	15.875
21/32	.65625	16.669
11/16	.6875	17.463
23/32	.71875	18.256
3/4	.750	19.050
25/32	.78125	19.844
13/16	.8125	20.638
27/32	.84375	21.431
7/8	.875	22.225
29/32	.90625	23.019
15/16	.9375	23.813
31/32	.96875	24.606

Absolute Zero— The lowest temperature attainable. All molecular activity is considered to cease. Its value is -459.7°F (-273.15°C)

Coefficient of Viscosity— A measure of the tendency of a fluid to resist shear. The unit for viscosity is the poise which is defined as the resistance (in dynes per square centimeter of its surface) to one layer of fluid to the motion of a parallel layer one centimeter away and with a relative velocity of one cm per second.

Critical Pressure— The pressure under which a substance may exist as a gas in equilibrium with the liquid at the critical temperature.

Critical Temperature— The temperature above which a gas cannot be liquified by pressure alone.

Cryogenics— The science which involves very low temperatures, usually regarded as below -150°F.

Density— Mass per unit volume.

Dew Point— The temperature at which liquid first condenses when a vapor is cooled.

Dielectric Constant— The specific inductive capacitance of a material. It is equal to the ratio of the capacitances of two condensers of identical size, one using the particular dielectric, the other using air or a vacuum as the dielectric.

Joule-Thomson Effect— The change in temperature resulting from expansion of a gas or vapor through an orifice or other restriction. In general, a lowering of temperature or cooling effect is the usual result of such an expansion.

Latent Heat of Fusion— The heat required to convert a unit mass of substance from the solid state to the liquid state at a given pressure (and temperature).

Latent Heat of Sublimation— The heat required to convert a unit mass of substance from the solid state to the gaseous state.

Latent Heat of Vaporization— The heat required to convert a unit mass of substance from the liquid state to the gaseous state at a given pressure (and temperature).

Liquified Gases— Usually applied to the liquid form of substances which under normal conditions of temperature and pressure are found as gases. Liquid oxygen is an example.

Molecular Weight— The sum of the atomic weights of all the atoms in a molecule. The atomic weight is the relative weight of the atom, on the basis of carbon isotope C^{12}.

Normal Boiling Point— The temperature at which a liquid boils when under a total pressure of one atmosphere.

Normal Sublimation Temperature— The temperature at which a solid sublimes under a total pressure of one atmosphere.

Specific Heat— The ratio of the heat capacity of a body to the heat capacity of water at some reference temperature.

Specific Gravity— The ratio of the mass of a body to the mass of an equal volume of air (for gases) at a specified temperature. It is dimensionless. For liquids and solids, it is the ratio of the mass of a body to the mass of an equal volume of water.

Specific Heat Ratio— Ratio of specific heat at constant pressure to the specific heat at constant volume at a particular temperature.

Specific Volume— The volume occupied by one unit weight of a substance.

Superconductivity— The phenomenon by which some substances suddenly lose all electrical resistance when their temperatures are reduced. These transitions occur at temperatures lower than that of liquid hydrogen.

Thermal Conductivity— The property of a material that describes the rate at which heat will be conducted through a unit area of material for a given driving force. It is dependent on the material and upon its temperature.

Triple Point— The particular condition under which a substance can be present in any or all phases (gaseous, liquid, or solid).

Vapor Pressure— The pressure exerted by a vapor in equilibrium with the liquid phase of the same substance.

Miscellaneous Physical Constants

Constant	Numerical Value	Units
Avogadro's Number	6.0228×10^{23}	Molecules/gram mole
Boltzmann Constant	1.38048×10^{-16}	Erg/°C
Electronic Charge	4.80239×10^{-10}	Absolute esu
e	2.718282	—
Gas-Law Constant R	1.987	Cal/(gm-mole) (°K) or BTU/(lb-mole) (°K)
	82.05	(cm^3) (atm)/(gm-mole) (°K)
	0.08205	(liter) (atm)/(gm-mole) (°K)
	10.731	(ft^3) (lb)/(in2)(lb-mole) (°R)
	0.7302	(ft^3) (atm)/(lb-mole) (°R)
Loge 10	2.30258	—
Mechanical Equivalent of heat	4.182	Joule/cal
Pi	3.14159*	—
Planck Constant	6.6254×10^{-27}	erg sec

* Approximate value, since Pi is an irrational number

Notes