Innovation. Experience. Performance.™

DATA BOOK

for Cryogenic Gases and Equipment

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.

Common Equivalents & Conversions

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

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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			11.66	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

Nitrous Oxide

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 Conversion Data

	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

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

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 Conversion Data

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.
Liquid measured at 21.42 atmospheres and 1.7°F.
Solid measured at -109.25°F.

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

Tonnage Conversion Factors*

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

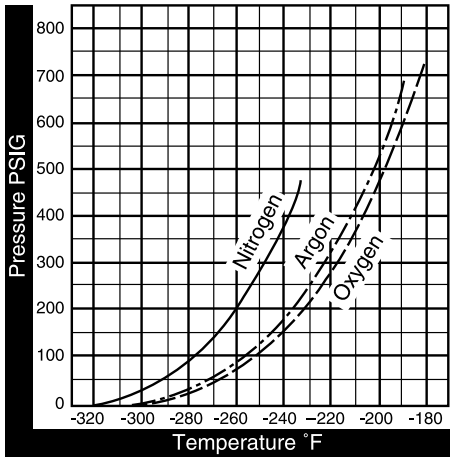
Densities At Various Saturation Pressures

	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

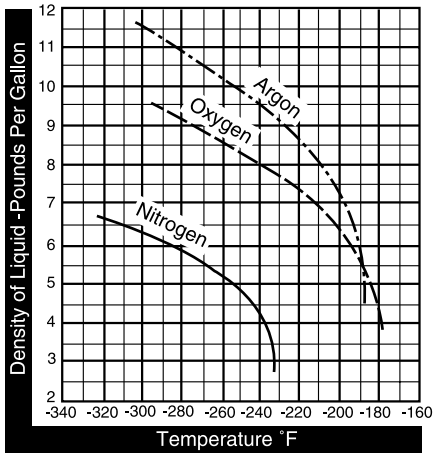
Note: Density of water at 60°F = 62.30 lbs/cu ft

Comparison Charts

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

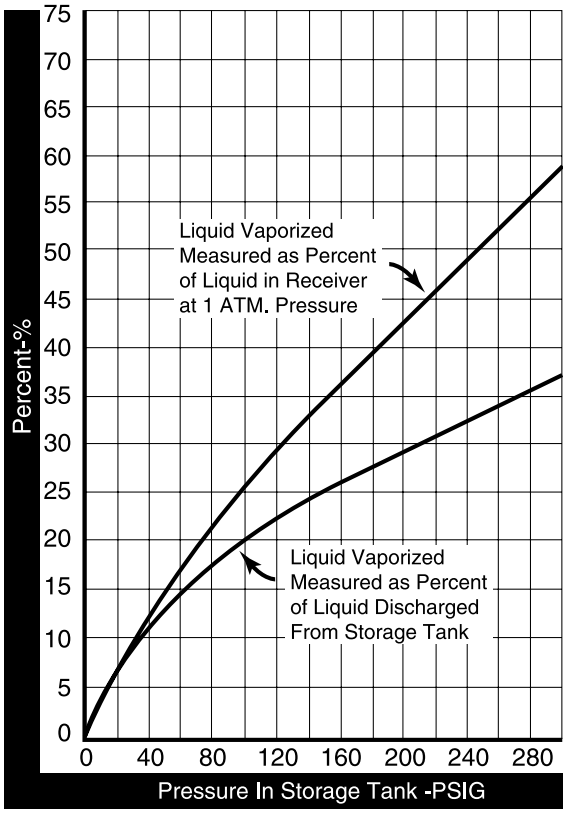


Density-temperature relationships for liquid oxygen, nitrogen and argon

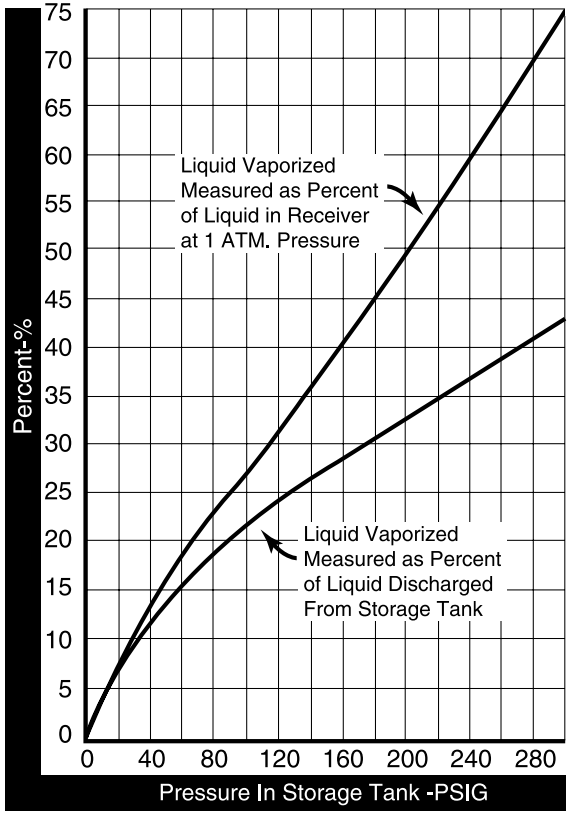


Vapor Release Charts

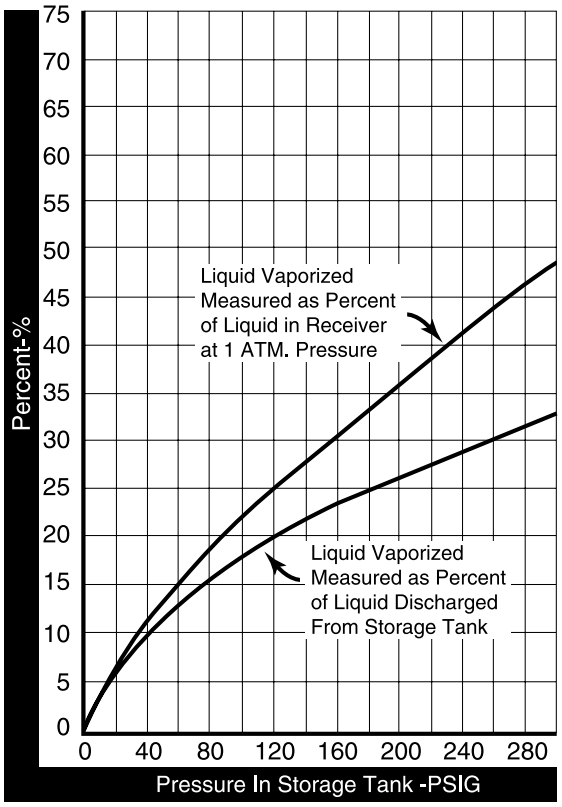
Vapor release from depressurized liquid oxygen



Vapor release from depressurized liquid nitrogen



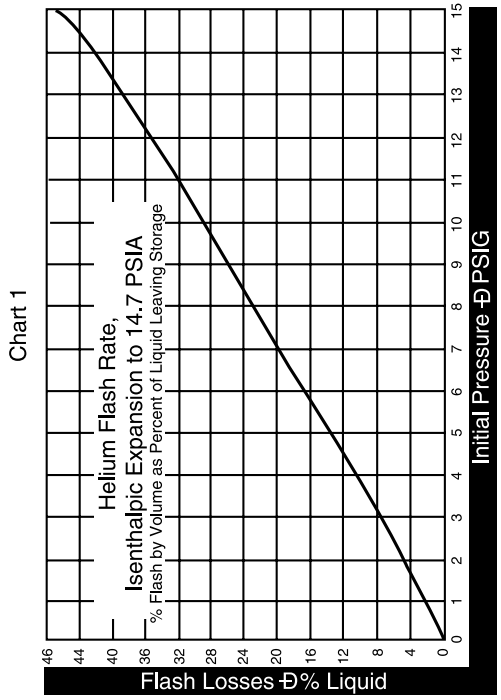
Vapor release from depressurized liquid argon



Vapor release from depressurized liquid helium

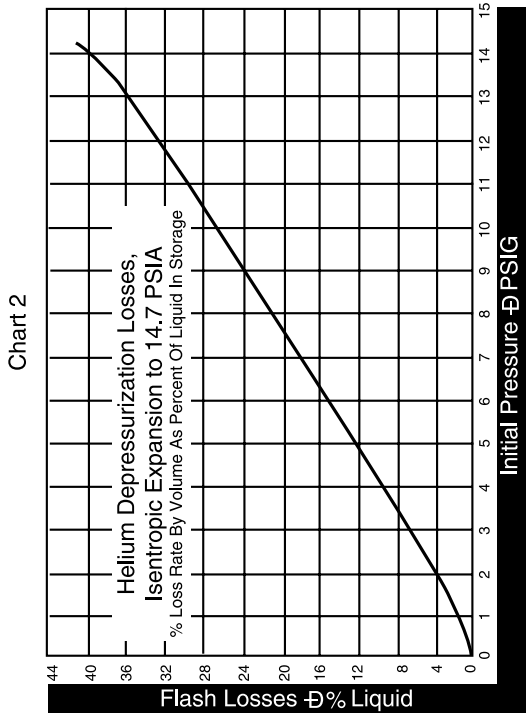
In addition to liquid losses due to container and transfer tube normal heat leak, tube and receiving vessel cool down, boil-off in the container resulting from heat input of the pressurizing gas and saturated vapor equalization, there is a flash loss from the pressure drop in a transfer line and a loss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

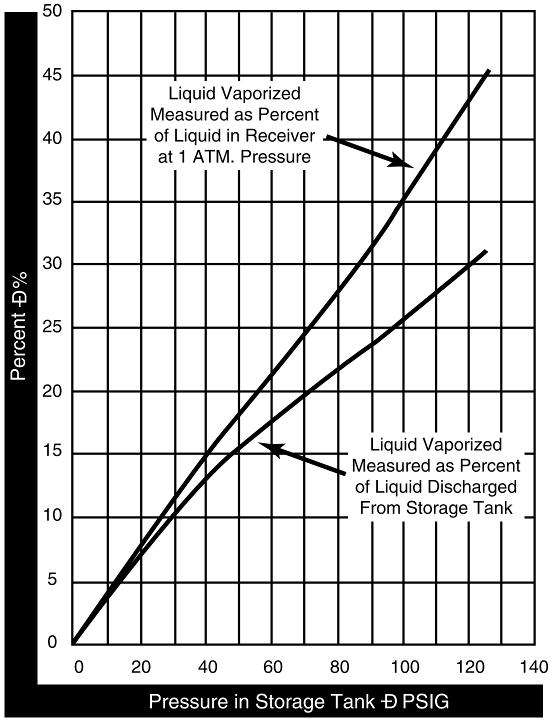


Flash loss due to pressure drop through the transfer line may be estimated by use of Chart 1 “Helium Flash Rate.” Depressurization loss of liquid in the container may be estimated by use of Chart 2 “Helium Depressurization Losses.”

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.”

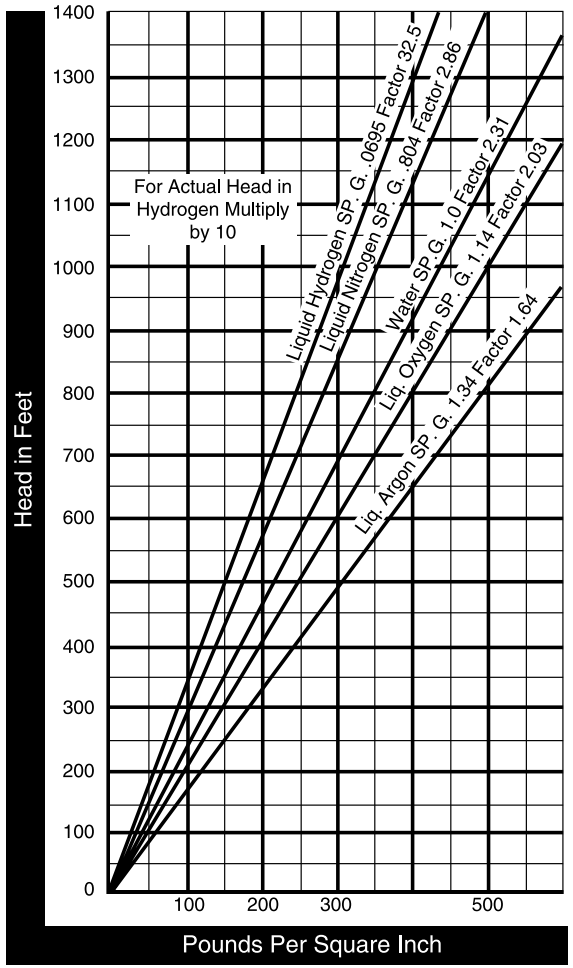
While sitting idle, the liquid in a storage vessel will gradually absorb heat and with all the vents closed, will generate pressures that are directly related to the temperature of the liquid. These pressures are called the “saturated vapor pressures.” This saturated condition exists as long as the liquid 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



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

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

Pipe Size Inches	Water		70SSU		100SSU		150SSU		200SSU		300SSU		500SSU	
	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

The leader in cryogenic bulk tankage for over 40 years, Chart now offers the new VS Series Bulk Tanks that can be used in liquid nitrogen, oxygen or argon service. Other tanks are available for liquid CO_2 and N_2O applications. As a global leader, Chart offers equipment designed for ASME, AD Merkblatter and other international codes. Both 175 and 250 psig tanks (*12 and 17 bar*) are available as standards, with other pressures available upon request.

Advanced Insulation Technology Provides Longer Holding Times

Chart's 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 holding times.

Modular Piping System

Nothing comes close to our new heavy-duty modular piping system for performance and low maintenance. The features and benefits include:

- 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
- Combination pressure building and economizer regulator for easy pressure adjustment
- Standard level pressure gauge is the telemetry-ready Tank-Tel® electronic gauge
- Optional level gauges include ITT Barton Model 288A with alarm contacts or Tank-Tel gauge with DataQuest Telemetry

Model	Gross Capacity Gal	Nominal Capacity Gal	Working Pressure* psig	Diameter in	Height in	Weight*** (lbs) (175 psi)	Weight*** (lbs) (250 psi)	NER** (% / day)
VS 525NS	540	491	– 250	66	102	–	3,800	.55
VS 900NS	929	845	– 250	66	134	–	5,100	.45
VS 1500NS	1,585	1,509	– 250	66	188	–	7,000	.33
VS 3000NC	3,158	3,037	175 250	86	228	12,600	13,500	.25
VS 6000NC	6,075	5,841	175 250	86	382	22,200	24,500	.15
VS 9000NC	9,447	9,084	175 250	114	347	33,000	36,800	.10
VS 11000NC	11,480	11,145	175 250	114	406	39,500	44,100	.10
VS 13000NC	13,513	13,119	175 250	114	465	46,700	52,100	.10
VS 15000NC	15,545	15,093	175 250	114	525	53,700	59,900	.10

* 400 and 500 psig tanks are available upon request.
** (NER) = Nominal Evaporation Rate
*** Weights are for ASME designs

Pumping 100% of the Liquid 100% of the Time

With a continuing commitment to cryogenic systems, Chart has produced the Siphon 100 System to give you the most economical, reliable and highest performing 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:

- Faster pump priming of 3 minutes or less
- Simpler and more reliable pump start-up for automatic pump operation
- Utilization of all tank's product liquid by allowing tank to be pumped virtually empty
- Priming at 10 psi or less without the necessity for pressure building
- Reduced product losses
- Longer life of high-wear pump parts
- Can operate two pumps at once
- Adapters available to match most pumps

Chart's Siphon 100 system is the combination of 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 Super-Insulation or Perlite in reducing the heat from the atmosphere.

SPECIFICATIONS

Model		2,000	3,000	6,000	9,000	11,000	13,000	15,000
Capacity								
Liquid (Gross)	gallons	2,416	3,158	6,075	9,447	11,480	13,513	15,545
Liquid (Net)	gallons	2,301	3,037	5,841	9,084	11,145	13,119	15,093
Gas (O_2)	1000 x scf	265	349	672	1,045	1,282	1,509	1,737
Gas (Ar)	1000 x scf	259	341	657	1,022	1,253	1,475	1,697
Gas (N_2)	1000 x scf	214	282	543	845	1,037	1,221	1,405
Performance								
NER (O_2)	% per day	.25%	.25%	.15%	.10%	.10%	.10%	.10%
Dimensions & Pressure Ratings								
Diameter	inches	86	86	86	114	114	114	114
Height	inches	228	271	423	398	457	516	575
Working Pressure	psig	175	175	175	175	175	175	175
Empty Weight	lbs x 1000	12.0	14.4	23.7	34.9	41.4	49.7	57.0

VS-CO_2 Bulk Storage

Our VS-CO_2 Series of Bulk Carbon Dioxide Storage Tanks continues the pioneering of user-friendly engineered products that we are accustomed to designing. This design series offers the strength and durability of an all-welded outer container, while maintaining lower life-cycle costs. Utilizing our composite 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 VS-CO_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 VS-CO_2 Bulk Stations are equipped with an internal cleaning system operated externally, eliminating the need for costly manways.

Simplified Plumbing Layout

- Stainless steel piping for greater strength and durability
- Stainless steel ball valves standard on all fill & process lines
- Minimal number of piping joints, reducing potential piping leaks and maintenance costs
- CGA fill and return fittings with drain valves standard on all models
- Optimum piping design results in flexible equipment connection
- Dual regulator pressure-bleed system standard, eliminating any safety concerns
- 6-Ton and 14-Ton Bulk Stations equipped with two liquid and two vapor connections
- 30-Ton and 50-Ton Bulk Stations equipped with three liquid and two vapor connections
- 6-Ton equipped with capped refrigerant lines and internal coil (*available as option on all other models*)

VS-CO_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)	9,400	17,400	39,600	56,900

* Tare Weight

Chart's VS-DSS Series of vertical bulk storage stations are engineered for superior performance, durability and value. Equipped with Super Insulation, a light-weight system offering better thermal performance than Perlite, VS-DSS Models provide reduced product losses and a slower rate of pressure rise during periods of non-use, while backing up this performance with a competitive 2-year 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.

Now available in the 525, 900, 1500, 3000 and 6000 gallon models, these new DSS Models feature 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. While including a comprehensive set of plumbing features, each circuit has been carefully designed to match the demands placed on these vessel sizes. To improve your flexibility at time of purchase, dual safety-relief devices are now standard, along with tank mounted vaporizers on the 900 and 1500 gallon sizes. These DSS Models also can be configured to meet your particular needs, which results in a complete design that makes the DSS Series the ideal choice for your small bulk applications.

SPECIFICATIONS

Model	VS-DSS 525	VS-DSS 900	VS-DSS 1500	VS-DSS 3000	VS-6000-DSS
Capacity					
Gross (gal)	540	929	1,585	3,158	6,075
Nominal (gal)	491	845	1,509	3,037	5,841
MAWP (psig)	250	250	250	250	250
Dimensions					
Diameter(in)	66	66	66	86	86
Height (in)	102	134	188	228	382
Weight* (lbs)	4,000	5,100	6,900	13,500	24,500
NER (% /day in O_2)	.55	.45	.35	.25	.15
Flow Capability (SCFH)	9,000	9,000	9,000	18,000	18,000

* Weights are for ASME designs NER = Nominal Evaporation Rate

Flow capability rating down to 15% contents level with a maximum fall off in tank operating pressure of 15 psi.

VS High Pressure Bulk Stations

The High Pressure Bulk Tank Line is used in liquid nitrogen, oxygen or argon service and utilizes many of the standard VS Series Tank features and functions. These HP Tanks are engineered for superior performance, durability and value, with the standard 400 psig (*27.6 bar*) storage tank designed to ASME code and available in 900 - 15,000 gallon models. All of the tanks come with mounted pressure-building coils, and other sizes are available upon request.

The standard 500 psig (*34.5 bar*) storage tank is also designed to ASME code and is available in 900 - 6000 gallon models, all coming with mounted pressure-building coils. Other sizes of 500 psig (*34.5 bar*) tanks are available upon request.

Remote pressure-building coil options for both 400 and 500 psig (*27.6 and 34.5 bar*) with withdrawal rates of 60,000 and 1000,000 scfh (*1,699 and 2,832 Nm³/hr*) are available upon request. 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.

Features and benefits include:

- 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
- Combination pressure building and economizer regulators are standard on all 400 psig (*27.6 bar*) units
- Separate pressure building and economizer regulators are standard on all 500 psig (*34.5 bar*) units

VS High Pressure Specifications

SPECIFICATIONS

Model		VS 900NS	VS 1500NS	VS 3000NC	VS 6000NC	VS 9000NC	VS 11000NC	VS 13000NC	VS 15000NC
Gross Capacity	(gal)	929	1,585	3,158	6,075	9,447	11,480	13,513	15,545
Nominal Capacity	(gal)	845	1,509	3,037	5,841	9,084	11,145	13,119	15,093
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)	134	188	228	382	347	406	465	525
Weight**	(lbs)	6,000/6,700	8,400/9,500	6,400/3,800	29,700/33,000	44,800	53,700	62,700	72,200
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)	.45	.33	.25	.15	.10	.10	.10	.10

* Higher capacity coil available, refer to factory

** Weights are for ASME designs

NER = Nominal Evaporation Rate

A durable, user-friendly performer

Chart's Dura-Cyl® liquid cylinders provide the longest holding time, lowest evaporation rate, highest gas withdrawal rate and best life cycle cost.

- Ideal for liquid nitrogen, oxygen, argon, CO_2 or nitrous oxide
- Different sizes and pressures to better meet your needs
- Stainless steel construction, inside and out
- Patented durable inner vessel support system
- Heavy-duty footring and large diameter handling ring
- Combination Pressure Control Regulator

The Dura-Cyl liquid cylinder's LCCM integrally mounted pressure control manifold eliminates all plumbing fittings and permits field adjustable operating pressure with a calibrated knob.

The Dura-Cyl liquid cylinder's MCR uses a combination pressure building and economizer regulator. The calibrated adjusting screw gives a quick and accurate way to adjust the container's operating pressure. A retrofit kit of the regulator is also available.

SPECIFICATIONS

Model	Size/Pressure	160MP	160HP	180MP	180HP	200MP	200HP	230MP	230HP	265MP	265HP
Capacity											
Liquid (Gross)	liters	176	176	196	196	209	209	240	240	276	276
Liquid (Net)	liters	165	165	185	185	196	196	230	230	265	265
Gas (N)	ft^3	3,685	3,464	4,099	3,864	4,375	4,072	5,024	4,734	5,769	5,438
Gas (O2)	ft^3	4,577	4,348	5,096	4,843	5,435	5,048	6,244	5,930	7,186	6,811
Gas (Ar)	ft^3	4,448	4,226	4,961	4,709	5,290	4,932	6,073	5,763	6,982	6,634
Gas (CO_2)	ft^3	–	3,382	–	3,766	–	4011	–	4614	–	5,305
Gas (N_2O)	ft^3	–	3,207	–	3,574	–	3810	–	4378	–	5,034
Performance											
NER (N)	% per day	2%	2%	1.9%	1.9%	1.85%	1.85%	1.8%	1.8%	2.0%	2.0%
NER (CO_2 - N_2O)	% per day	–	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
Gas Flow (CO_2 or N_2O)	ft^3/hr	–	110	–	110	–	110	–	110	–	110
Dimensions & Pressure Ratings											
Diameter	in	20	20	20	20	20	20	26	26	26	26
Height	in	59.6	59.6	63.5	63.5	65.8	65.8	52.9	52.9	57.8	57.8
Empty Weight	lb	250	280	260	300	280	320	300	340	340	360
Relief Valve Setting	psig	230	350	230	350	230	350	230	350	230	350
DOT/CTC Rating		4L200	4L292	4L200	4L292	4L200	4L292	4L200	4L292	4L200	4L292

A stable, efficient performer

Chart's Cryo-Cyl® LP liquid cylinder product line is designed specifically for low pressure liquid applications.

- Ideal for laboratories and hospitals where liquid nitrogen is used
- Rugged, oversized canisters offer low center of gravity making them safer and easier to handle
- Attractive polished stainless steel outer jacket
- Optional pressure building regulator kit turns any Cryo-Cyl LP liquid cylinder into a pressure building unit
- Pressure building circuit on the inside of each cylinder
- Extended stem liquid valve
- Super Insulation provides lowest NER
- Optional stainless steel casters make the Cryo-Cyl LP liquid cylinder a non-magnetic cylinder ideal for MRI service

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

On the new Cryo-Cyl LP 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	80*	120*	180	230RB*	230SB**
Capacity						
Liquid (Gross)	(liters)	85	120	196	240	240
Liquid (Net)	(liters)	80	110	185	230	230
Performance						
NER (N)	(% per day)	3.0%	2.0%	1.5%	1.5%	1.5%
NER (O_2 or Ar)	(% per day)	2.0%	1.4%	1.0%	1.0%	1.0%
Dimensions & Pressure Ratings						
Diameter	(inches)	20	20	20	26	26
Height	(inches)	39.5	51	63.5	54.8	54.8
Empty Weight	(lbs)	165	165	210	275	311
Relief Valve Setting	(psig)	350	22	22	22	22
DOT/CTC Rating		4L292	4L100	4L100	4L100	4L100

*Round caster base

**Square caster base

Maximum Versatility

The Mega-Cyl® Liquid Cylinder introduces Chart's line of palletized cylinders, designed for easy transport, with a capacity of up to 1000 liters. Engineered with the volume user in mind, it's ideal for construction sites, remote purging operations and back-up systems. The Mega-Cyl liquid cylinder is available in all pressures for a variety of services up to 350 psig (*24.1 bar*) and is specifically designed to optimize distribution costs.

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

Quality Features include:

- Tough, durable stainless-steel construction
- High performance Super Insulation
- Easily accessible valves and gauges
- Spray header for pump filling

SPECIFICATIONS

Model		450MP	450HP	800HP	1000HP
Size/Pressure					
Capacity					
Liquid (Gross)	(liters)	450	450	880	1,056
Liquid (Net)	(liters)	428	428	800	950
Gas (N)	(ft^3)	9,589	8,875	19,672	23,363
Gas (O_2)	(ft^3)	11,474	11,111	24,320	28,843
Gas (Ar)	(ft^3)	11,003	10,812	23,767	28,234
Gas (CO_2)	(ft^3)	–	8,652	16,255	18,580
Performance					
NER (O_2)	(% per day)	1.4%	1.4%	1.2% .	.9%
Gas Flow (N, O_2, Ar)	(ft^3 / hr)	575	575	880	960
Gas Flow (CO_2 or N_2O)	(ft^3 / hr)	–	195	280	300
Dimensions & Pressure Ratings					
Diameter (cylinder)	(in)	30	30	42	42
Height (cylinder)	(in)	62	62	67	76
Base Width (frame)	(in)	34	34	45	45
Base Depth (frame)	(in)	34	34	45	45
Height (frame)	(in)	74	74	80	80
Tare Weight (cyl + frame)	(lbs)	1,250	1,275	2,500	2,650
Relief Valve Setting	(psig/bar)	250	350	350	350
DOT/CTC Rating		4L212	4L292	ASME	ASME

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

Maximum Efficiency with High Capacity Performance

Designed specifically for laser applications, the Laser-Cyl's liquid cylinder's automatic pressure builder and economizer systems deliver optimal pressure up to 500 psig (*34.5 bar*). The top-mounted valve cluster puts total control at your fingertips. The built-in vaporizer coil supplies gas at continuous flow rates up to 575 SCFH (*15.1 Nm^3*).

The Laser-Cyl liquid cylinder is a high performance option to expensive manifolded high-pressure cylinder banks. The Laser-Cyl 450 product uses a differential pressure liquid level gauge that accurately shows the amount of product in the container. All operational valves are easy to reach, located on the top of the tank.

Quality Features:

- Automatic pressure builder and economizer systems maintain optimal operating pressure
- 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

SPECIFICATIONS

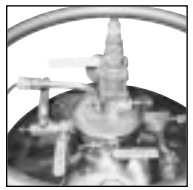
Model	Size / Pressure	200VHP	450VHP
Capacity			
Liquid (Gross)	(liters)	204	450
Liquid (Net)	(liters)	200	428
Gas (N)	(ft^3)	3,588	7,922
Gas (O_2)	(ft^3)	4,770	10,519
Gas (Ar)	(ft^3)	4,642	10,241
Gas (CO_2)	(ft^3)	3,609	7,960
Gas (N_20)	(ft^3)	3,408	7,516
Performance			
NER (N)	(% per day)	1.8%	1.8%
NER (O_2 or Ar)	(% per day)	1.12%	1.12%
NER (CO_2 or N_2O)	(% per day)	0.5%	0.5%
Gas Flow (N, O_2, Ar)	(ft^3/hr)	350	575
Gas Flow (CO_2 or N_2O)	(ft^3/hr)	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

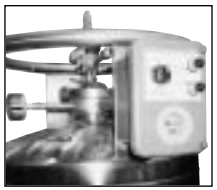
* Weights are approximate and vary with pallet design

Durability and High Performance

Chart's Ultra Helium Dewars are built for reliable transport. They are light, maneuverable and durable, while providing superior thermal performance. The base design and outboard casters provide maximum stability.

Available in sizes ranging from 60 to 1,000 liters, the Ultra Helium Dewars are suitable for air transport with an optional absolute pressure relief valve. The neck tube has a unique, proven support system that allows these dewars to survive constant transportation. All models are nonmagnetic for MRI service.





The controls are conveniently located on the top of the dewar, with nesting fill couplings to accept various standard transfer lines. The optional electric pressure builder can increase pressure quickly for liquid transfer, and has two pre-set ranges (4 & 8 psi) for efficient liquid helium withdrawal:

- Maximum durability and light weight
- Outstanding thermal performance
- Large ball valves for up to 3/4" transfer lines

SPECIFICATIONS

Model	Size	60	100	250*	500	1000
Capacity						
Liquid (Gross)	(liters)	66	110	275	550	1,050
Liquid (Net)	(liters)	60	100	250	500	1,000
Performance						
NER	(% per day)	1.75%	1.25%	1.0%	1.0%	1.0%
MAWP	(psig)	10	10	10	10	10
Dimensions & Pressure Ratings						
Diameter	(in)	24	24	32	42	52
Height	(in)	50.1	59	67.4	70.6	77.4
Dip Tube Length	(in)	35	43.8	54.4	56.4	67.5
Tare Weight	(lbs)	184	212	348	480	1,050
Main Relief Valve Setting	(psig)	10	10	10	10	10
Secondary Relief Valve	(psig)	12	12	12	12	12

*PB optional, Locking casters optional

Laser Assist Gas Supply System

Trifecta® is the preferred solution for reliable and continuous laser assist gases for pressures up to 450 psi 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.

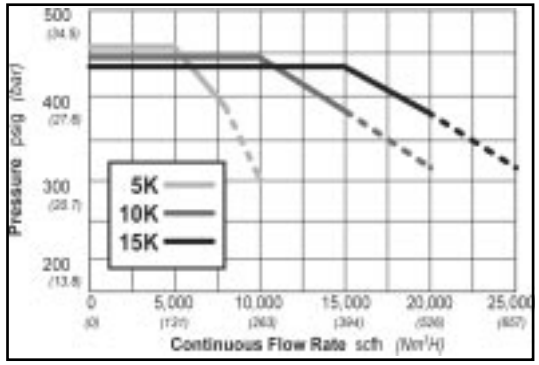
Product Highlights:

- On-site 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 with lower maintenance.
- Tank-Tel and Cyl-Tel monitor systems for user-friendly pressure and level measurement and control.

System Requirements

- 15 amp, 110 VAC power, dedicated circuit
- Bulk storage tank with 50 psig minimum pressure
- External vaporizer, minimum 550 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

DIMENSIONS		
Height	96"	2,440 mm
Length	47"	1,195 mm
Width	55"	1,400 mm
Weight 5K	1,700 lbs.	770 kg
Weight 10K	1,750 lbs.	795 kg
Weight 15K	1,800 lbs.	815 kg



Perma-Cyl®

The Perma-Cyl® liquid cylinder is an innovative design, evolving from proven technology Chart has been using for years on our liquid cylinders. What makes the Perma-Cyl design revolutionary is:

- Fast Fill Capability
- Lo-Loss Fill With Automatic Fill Termination
- Extended Hold Time
- Telemetry Compatibility

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
- The Perma-Cyl 230 is available in a transportable DOT-4L version or the more thermally efficient ASME version
- Unique auto shut-off feature allows remote filling with optional wall box and hose
- Heavy gauge, stainless steel outer shell
- Differential-pressure liquid-level gauge standard, optional Cyl-Tel gauge available

Perma-Cyl Specifications

DESCRIPTION	230L C MP,LCCM Sq Base w/casters	230L C HP,LCCM Rnd Base w/casters	230L C HP,LCCM Sq Base w/casters	265L MP w/casters	300L MP Plate Base	450L HP Plate Base	450L MP Plate Base	450L HP Plate Base	450L VHP Plate Base	700L HP Plate Base	1000L HP Plate Base	1000L VHP Plate Base	1500L HP Pallet Base	1500L VHP Pallet Base	2000L VHP Pallet Base
CAPACITY (Liters)															
Gross	240	240	240	276	330	450	450	450	450	688	1,056	1,056	1,550	1,550	2,042
Net	230	230	230	265	300	420	420	420	420	645	950	950	1,455	1,455	1,945
MAWP															
psig	235	235	350	235	300	350	250	350	500	350	350	500	350	500	500
bar	16.2	16.2	24.1	16.2	20.7	24.1	17.2	24.1	34.5	24.1	24.1	34.5	24.1	34.5	34.5
MAXIMUM PRE-SET OPERATING PRESSURE															
psig	125	300	300	125	250	300	125	300	450	300	300	450	300	450	450
bar	8.6	20.7	20.7	8.6	17.2	20.7	8.6	20.7	31.0	20.7	20.7	31.0	20.7	31.0	31.0
DESIGN SPEC	DOT	DOT	DOT	DOT	ASME	DOT	ASME	ASME	ASME	ASME	ASME	ASME	ASME	ASME	ASME
STORAGE CAPACITY (1)															
Nitrogen															
SCF	5,024	4,734	4,734	5,769	7,380	8,875	10,332	10,332	10,332	15,860	24,350	24,350	35,790	35,790	47,847
Nm³	142	134	134	152	193	271	272	272	272	449	689	689	1,013	1,013	1,257
Oxygen															
SCF	6,244	5,930	5,930	7,186	9,100	11,124	12,760	12,760	12,760	19,600	30,070	30,070	44,220	44,220	59,089
Nm³	177	168	168	189	184	315	336	336	336	554	850	850	1,250	1,250	1,553
Argon															
SCF	6,073	5,763	5,763	6,982	8,850	10,812	12,478	12,478	12,478	19,160	29,400	29,400	43,220	43,220	57,786
Nm³	172	163	163	183	234	306	328	328	328	542	832	832	1,223	1,223	1,519
Carbon Dioxide															
SCF	N/A	N/A	4,500	N/A	N/A	8,312	N/A	8,200	8,200	12,608	19,960	19,960	29,340	29,340	38,048
Nm³	--	--	118	--	--	235	--	232	232	357	564	564	830	830	1,000
THERMAL PERFORMANCE (2) (NER%/DAY)															
N_2	1.8%	1.8%	1.8%	2.0%	1.2%	1.9%	1.6%	1.6%	1.6%	1%	1%	1%	1%	1%	1%
O_2-Ar	1.12%	1.12%	1.12%	1.4%	0.74%	1.2%	1.0%	1.0%	1.0%	0.62%	0.62%	0.62%	0.62%	0.62%	0.62%
CO_2	6%	6%	6%	--	4%	6%	5%	5%	5%	3%	3%	3%	3%	3%	3%
GAS DELIVERY RATE (LIN/LAR/LOX)															
SCF/H	400	400	400	400	500	575	575	575	575	660	960	960	1,350	1,350	2,000(3)
Nm³/h	10.5	10.5	10.5	10.5	14.1	15.1	15.1	15.1	15.1	18.6	25.2	25.2	35.4	35.4	52.4
GAS DELIVERY RATE (CO_2)															
SCF/H	N/A	N/A	133	N/A	N/A	192	192	192	192	220	320	320	450	450	667
Nm³/h	--	--	3.8	--	--	5.4	5.4	5.4	5.4	6.2	9.0	9.0	12.7	12.7	17.5
DIMENSIONS															
Diameter															
in	26	26	26	26	26	30	30	30	30	42	42	42	48	48	48
mm	660	660	660	660	660	762	762	762	762	1,067	1,067	1,067	1,219	1,219	1,219
Height															
In	54.8	52.9	54.8	62	68	68	68	68	68	60	81	81	91	91	117
mm	1,392	1,344	1,392	1,575	1,727	1,727	1,727	1,727	1,727	1,524	2,058	2,058	2,311	2,311	2,970
Tare Weight															
Lbs	300	300	340	340	450	688	605	688	812	1,065	1,750	2,080	2,692	3,200	3,860
Kg	136	136	154	154	204	312	274	312	368	483	794	945	1,221	1,451	1,751

All specifications are subject to change without prior notice
1) Values are based on net capacity at 0 psig (0 bar) for ASME vessels. CO_2 vessels are based on net capacity at 300 psi (20.7 bar). DOT vessels are per code.
2) Values are based on gross capacity
3) Optional 3,500 SCFH (92 Nm³/h) model

Orca MicroBulk Delivery System

Chart's distribution system has been designed to complete an entire fill operation in approximately three minutes - from the moment the driver comes to a stop to the time the flow meter terminates the operation. The Orca mobile utilizes assets more fully, reducing labor costs and serving more customers.

Features:

- Fast on-site filling of Perma-Cylinders
- DOT Liquid Cylinders can be filled on site with scale
- Filling of MicroBulk tanks
- Instantaneous push-button delivery of product
- No complex valves to operate
- "Smart" flow metering system reduces required operator training
- Special delivery hose and purge connector keeps contamination and cooldown to a minimum
- Electronic control allows for fast in-and-out deliveries and invoicing
- Vessel designed for rugged road conditions
- Stainless steel plumbing with bronze valves for additional reliability
- Low-maintenance submerged pump for instant starts and continuous delivery
- Robust inner support system

Orca Specifications

SPECIFICATIONS		Orca HL-2000	Orca HL-2800	Orca HL-3300
**DOT NET Capacity (gal)		1,905	2,559	3,020
MAWP	(psig)	50	50	50
Length	(in)	198	242	271
Diameter	(in)	80	80	80
Height	(in)	87	87	87
Tare Weight*	(lbs)	7,800	8,700	9,800

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

*** For Argon and Nitrogen Service*

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

A "smart" flow metering system monitors flow electronically.

Back view of Orca truck

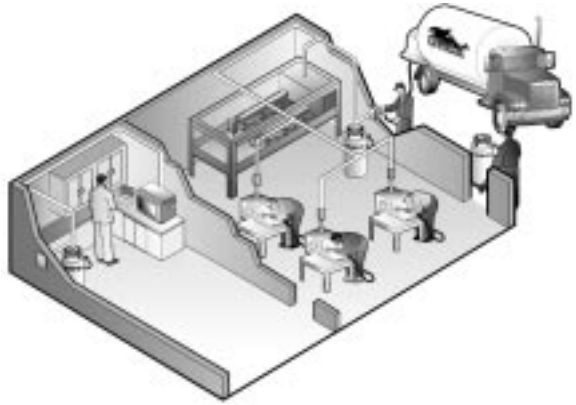


Chart — Your Single Source Supplier of Cryogenic Equipment

Customer needs are the top priority with us. From handling carts to the largest cryogenic vessels, we have the accessories to create an efficient system for you.

Dual Relief Valves

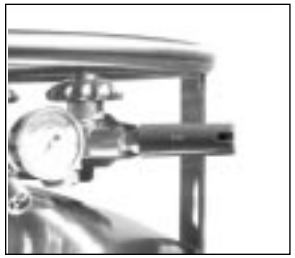
With dual relief valves, one cylinder can be used for both liquid (low pressure) and gas (medium pressure) accounts, which maximizes the flexibility of your liquid cylinders.

Hose

Stainless steel transfer lines that remain flexible during liquid transfer can be coupled with a bronze phase separator.

Muffler

When attached to the vent connection of the liquid cylinder, the Chart muffler can reduce the venting noise during the fill.



Hospital Reserve Kit

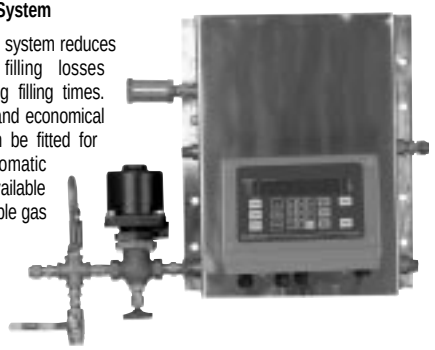
Hospital oxygen applications require a backup supply of oxygen. The Chart hospital reserve kit connects the primary supply (Chart bulk storage tank) with the back-up supply. If the primary supply of oxygen is interrupted, the reserve kit automatically switches to the back-up supply and provides a local and remote warning.

Handling Carts

Chart provides a variety of handling carts, roller bases, and accessories to make the transportation of liquid cylinders safe and easy.

Lo-Loss Filling System

The Chart lo-loss system reduces liquid cylinder filling losses without increasing filling times. This safe, easy and economical filling device can be fitted for manual or automatic operation. It is available as single or multiple gas systems.



M45 Manifold

The M45 Manifold is a convenient, automatic way of increasing the gas delivery rate to any application. The unique changeover value automatically switches from the primary bank of cylinders to the secondary bank when needed. An indicator light shows when this occurs, 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

Vaporizers

Free standing or tank mounted, these vaporizers which gasify the liquid product are available in standard sizes ranging from 250 to 5000 standard cubic feet per hour and rated to 600 psig.

-192°C* Liquid Nitrogen Freezers

The XC and SC series are designed for the user who has small capacity needs, but requires long-term storage and low liquid nitrogen consumption in a convenient lightweight package. By integrating features that users have requested with the widest variety of holding times and storage capacities, MVE Aluminum Freezers are the units of choice.

Accessories:

- Caster Base
- Canister
- Spare Corks
- Level Stick
- Transfer Hose
- Phase Separator
- Square Racks (47/11-6 only)
- Plastic Boxes
- Freezing Tray (34/18 and 47/11-6 only)

** Actual temperature may be ±10°C depending on current atmospheric condition, container history and actual product being stored.*

SPECIFICATIONS

Model		XC Millennium 20	XC 21/6	XC 22/5	XC 32/8	XC 33/22	XC 34/18	XC 43/28	XC 4711-6SQ	XC 47/11-6	XC 47/11-10
Max. Storage Capacity											
No. of canisters		6	9	6	9	6	10	6	6 sq.	6	10
No. of 1/2 cc straws	(10/cane)	720	N/A	2,400	2,520	1,260	2,800	1,260	-	4,500	3,500
No. of 1/2 cc straws	(1 Level Bulk)	1,122	3,870	3,666	3,960	1,764	4,400	1,764	-	6,216	5,000
No. of 1.2 & 2.0 ml vials	(5/cane)	210	N/A	810	855	360	950	360	-	1,320	1,050
No. of Racks	(25 Vials)								750		
Performance											
Liquid nitrogen capacity	(liters)	20.5	21	22.4	32	33.4	34.8	42.2	47.4	47.4	47.4
Static evaporation rate	(liters/day)*	0.09	0.25	0.35	0.35	0.14	0.24	0.14	0.39	0.39	0.39
Normal working duration	(days)**	140	53	40	57	154	90	193	76	76	76
Unit Dimensions											
Neck opening	(in)	2.18	3.5	3.81	3.81	2.75	4	2.75	5	5	5
Overall height	(in)	25.7	17.2	22	21.5	26	25	26.4	26.5	26.5	26.5
Outside diameter	(in)	14.5	18.2	14.5	18.2	18.2	18.25	20	20	20	20
Canister height	(in)	11	5	11	11	11	11	11	-	11	11
Canister diameter	(in)	1.65	2.75	3.09	2.62	2.22	2.6	2.22	-	4	4
Weight empty	(lbs)	23	30	26	30	34	34	36	42	42	42
Weight full	(lbs)	59.5	62.5	66	87	94	95	111	120.4	120.4	120.4

* 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.

** Normal working duration is an arbitrary reference to estimate container performance under normal operating conditions. Actual working time may vary due to current atmospheric conditions, container history, manufacturing tolerances and any individual patterns of use.

SPECIFICATIONS

Model		SC 3/3	SC 8/5	SC 11/7	SC 16/11	SC Millennium 20	SC 20/20	SC 36/32	SC 33/26
Max. Storage Capacity									
No. of canisters		6	6	6	9	6	6	6	6
No. of 1/2 cc straws	(10/cane)	–	–	540	–	540	540	540	540
No. of 1/2 cc straws	(1 Level Bulk)	732	732	732	1098	780	780	780	780
No. of 1.2 & 2.0 ml vials	(5/cane)	–	–	150	–	150	150	150	150
Performance									
Liquid nitrogen capacity	(liters)	3.6	8.4	11.0	16.4	20.5	20.5	36.5	33
Static evaporation rate	(liters/day)*	0.12	0.15	0.15	0.14	.095	0.09	0.10	0.13
Normal working duration	(days)**	19	35	46	74	135	142	224	182
Unit Dimensions									
Neck opening	(in)	2	2	2	2	2.18	2	2	2
Overall height	(in)	16	18.5	21.6	17.5	25.7	25.7	27.2	25.9
Outside diameter	(in)	8.7	10.2	10.2	17.2	14.5	14.5	18.2	18.2
Canister height	(in)	5	5	11	5	11	11	11	11
Canister diameter	(in)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Weight empty	(lbs)	8	12	17	14	23	26	34	34
Weight full	(lbs)	14.4	27	36.6	43	59.5	62.5	100	93.4

* 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.

** Normal working duration is an arbitrary reference to estimate container performance under normal operating conditions. Actual working time may vary due to current atmospheric conditions, container history, manufacturing tolerances and any individual patterns of use.

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
- Pouring Spout
- Swivel Dipper
- Dipper
- Spare Corks
- Pressurized Discharge Device
- Caster Base

Cryo-Cyl Series

The Cryo-Cyl 35 and 50 units operate at 22 psig and can be used to supply liquid through a transfer hose to your application. A convenient pressure and liquid level gauge monitor the operation of the cylinder.

SPECIFICATIONS

Model		LAB 4	LAB 5	LAB 10	LAB 20	LAB 30	LAB 50	SS TRANSFER UNIT
Net Capacity	(liters)	4	5	10	21	32	50	5
Performance								
Static Evaporation Rate	(liters/day)	0.19	0.15	0.18	0.18	0.22	0.49	N/A
Unit Dimensions								
Neck opening	(in)	1.4	2.2	2.2	2	2.5	2.5	6
Usable height	(in)	7.8	10.5	13.5	13.7	14.9	22	14
Overall height	(in)	16.8	18.2	21.5	24.7	24.1	30.7	16.5
Outside diameter	(in)	7.3	8.8	10.3	14.5	17	17	8
Internal diameter	(in)	5.5	6.5	8.3	11.4	14	14	6
Weight empty	(lbs)	6	8	13	19	27	34	11
Weight full	(lbs)	13	17	31	56	84	123	20

-150°C* Liquid Nitrogen Specimen Transport

The MVE Vapor Shipper containers are designed for the safe transportation of biological samples at cryogenic (-150°C) temperatures. Fabricated from durable, lightweight aluminum, they contain a hydro-phobic absorbent that contains the liquid nitrogen. The absorbent also repels moisture and humidity, assuring the maximum holding time.

A protective shipping carton is available for all models, which protects the container from being placed on its side and helps in withstanding the rigors of transportation. These containers can be used to ship your samples with a "non-hazardous" classification throughout the world.

Accessories:

- Shipping Carton
- Canisters
- Spare Corks
- Cryo-Shipper Frame

SPECIFICATIONS

Model	SC 2/1 V	SC 4/2 V	SC 4/3 V	SC 20/12V	XC 20/3V*	MINI MOOVER	CRYO MOOVER	CRYO SHIPPER	CRYO SHIPPER XC
Maximum Storage Capacity									
No. of canisters	1	1	1	6	4 + 1 Center	1	7	1 Rack	-
No. of 1/2 cc straws (10/cane)	-	280	120	540	2,500/2,000*	60	3080	-	-
No. of 1/2 cc straws (1 Level Bulk)	88	440	210	780	3,750/3,000*	88	4,354	-	-
No. of 1/4 cc straws (1 Level Bulk)	182	938	452	6750/6000*	7,410/6,000*	-	8,904	-	-
No. of 1.2 & 2.0 ml vials (5/cane)	-	95	40	150	675/560*	20	945	-	-
No. of 1.2 & 2.0 ml vials (6/cane)	9	106	48	180	840/672*	24	1,134	500	966 (Bulk)
No. of blood bag stored (4R9953)	-	-	-	-	-	-	-	10	10
Performance									
Liquid nitrogen capacity (liters)	1.5	3.6	4.3	12.3	6.8	2.9	4.2	8.5	10
Static evaporation rate (liters/day)	0.19	0.26	0.20	0.09	0.3	0.20	0.35	0.85	0.70
Static holding time (days)	8	14	21	85	23	14	12	10	14
Unit Dimensions									
Neck opening (in)	1.4	2.75	2	2	3.81	1.4	3.8	8.5	8.5
Overall height (in)	13.5	18.4	19.4	25.7	25	19.5	22	21.5	23
Outside diameter (in)	7.25	8.7	8.7	14.5	14.5	7.2	18.3	14.5	15
Canister height (in)	5	11	11	11	11	11	11	-	12.5
Canister diameter (in)	1.2	2.62	1.81	1.5	3.2	1.2	3.1	-	-
Weight empty (lbs)	6	11	13	30	23	8	30.5	24	30
Weight full (lbs)	8.8	18	20.6	52	35	11.6	38	37.5	47

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.

* With center absorbent canister - 3 week holding time; without center absorbent canister - two week holding time, greater storage capacity

Technical Features

The Carbo-Mite system is designed to meet the needs of consumers who use less than 100 lbs of CO_2 per month. Beverage providers who once thought their usage was too small for bulk CO_2 can now enjoy increased fountain profits, enhanced beverage quality, added safety and a continuous flow of CO_2. Features of the Carbo-Mite product include:

- 34" height allows it to fit under most counters
- Easy-to-read gauges for CO_2 contents and tank pressure
- Fully automatic system requires no electricity
- Versatility offers both permanent and portable installation
- Safe, low operating pressure of 125 psi
- Proprietary vacuum-regeneration system for convenient on-site maintenance
- Stainless steel, double-walled, vacuum insulated container

SPECIFICATIONS		CARBO-MITE
Dimensions		
Diameter	(in)	20
Height (with legs add 6 in)	(in)	34
Empty Weight	(lbs)	155
Full Weight	(lbs)	326
Design Criteria		
Code		ASME**
MAWP	(psig)	300
Insulation type		Vacuum with Super Insulation
Capacity		
Net Volume	(gal)	18
Liquid Storage Capacity	(lbs)	171
Performance		
Normal Evaporation Rate (NER)*	(lbs/day)	1.2
Continuous CO_2 Delivery Rate	(lbs/hr)	.75
Peak Flow Rate	(lbs/hr)	1.5
Components		
ASME Relief Valve Setting	(psig)	300
Secondary RV Setting	(psig)	450
Gas Use Connection	(in)	$^1/_4$ x 45° Male Flare
Fill Line Connection	(in)	$^5/_8$ x 45° Male Flare
Vent Connection	(in)	$^1/_2$ OD Tube
Construction		
Inner Vessel Material		Stainless Steel
Outer Vessel Material		Stainless Steel
Liquid Level Gauge		Float/Magnetic

* No loss in normal applications

**ASME Boiler and Pressure Vessel Design Section VIII, Div. I

Technical Features

The Carbo-Charger Bulk CO_2 System is an affordable alternative to high pressure CO_2 cylinders. This system is designed to meet the CO_2 gas requirement of operations using less than 150 pounds of CO_2 per month. Other features include:

- Stainless steel, double-walled, vacuum insulated container
- Proprietary vacuum-regeneration system for convenient, on-site maintenance
- Safe, low operating pressure of 125 psi
- Easy-to-read gauges for CO_2 contents and tank pressure
- Efficient gas withdrawal system supplies CO_2 gas in excess of 3 pounds per hour
- Fully automatic system requires no electricity
- Optional 6" welded uni-body legs

SPECIFICATIONS		CARBO-CHARGER
Dimensions		
Diameter	(in)	20
Height (with legs add 6 in)	(in)	51
Empty Weight	(lbs)	216
Full Weight	(lbs)	522
Design Criteria		
Code		ASME**
MAWP	(psig)	300
Insulation type		Vacuum with Super Insulation
Capacity		
Net Volume	(gal)	32
Liquid Storage Capacity	(lbs)	306
Performance		
Normal Evaporation Rate (NER)*	(lbs/day)	2.0
Continuous CO_2 Delivery Rate	(lbs/hr)	1.0
Peak Flow Rate	(lbs/hr)	3.0
Components		
ASME Relief Valve Setting	(psig)	300
Secondary RV Setting	(psig)	450
Gas Use Connection	(in)	$^1/_{4\,x}\ 45^o$ Male Flare
Fill Line Connection	(in)	$^5/_8$ x 45^o Male Flare
Vent Connection	(in)	$^1/_2$ OD Tube
Construction		
Inner Vessel Material		Stainless Steel
Outer Vessel Material		Stainless Steel
Liquid Level Gauge		Float/Magnetic

* No loss in normal applications

**ASME Boiler and Pressure Vessel Design Section VIII, Div. I

Technical Features

The Carbo-Mizer® Bulk CO_2 System is designed to meet all of your CO_2 gas requirements. One tank provides continuous CO_2 supply for single or multiple applications. Other features include:

- Stainless-steel, double-walled, vacuum-insulated container
- Patented Sure-Fill System ensures a complete fill every time, with no manual venting required
- Proprietary vacuum-regeneration system for convenient, on-site maintenance
- Patented CO_2 impurity removal system
- Stable 6" uni-body legs allow for easy cleaning around unit
- Efficient gas-withdrawal system meets multiple flow requirements
- Easy-to-read gauges for CO_2 contents and tank pressure
- Safe, low operating pressure of 125 psi
- Fully automatic system requires no electricity

SPECIFICATIONS		CARBO-MIZER 450
Dimensions		
Diameter	(in)	20
Height (with legs add 6 in)	(in)	65.8
Empty Weight	(lbs)	273
Full Weight	(lbs)	726
Design Criteria		
Code		ASME**
MAWP	(psig)	300
Insulation type		Vacuum with Super Insulation
Capacity		
Net Volume	(gal)	48
Liquid Storage Capacity	(lbs)	453
Performance		
Normal Evaporation Rate (NER)*	(lbs/day)	2.5
Continuous CO_2 Delivery Rate	(lbs/hr)	5.5
Peak Flow Rate	(lbs/hr)	10.0
Components		
ASME Relief Valve Setting	(psig)	300
Secondary Relief Valve Setting	(psig)	450
Gas Use Connection	(in)	$^1/_4$ x 45° Male Flare
Fill Line Connection	(in)	$^5/_8$ x 45° Male Flare
Vent Connection	(in)	$^1/_2$ OD Tube
Construction		
Inner Vessel Material		Stainless Steel
Outer Vessel Material		Stainless Steel
Liquid Level Gauge		Float/Magnetic

* No loss in normal applications

**ASME Boiler and Pressure Vessel Design Section VIII, Div. I

The Carbo-Max 750 High Flow container is designed to meet the CO_2 gas requirements for high-flow applications. The Carbo-Max 750 product features a proprietary, internal, stainless-steel vaporizer that provides superior CO_2 gas delivery at a rate of over 15 lbs. per hour.

Technical Features

- Stainless-steel, double-walled, vacuum-insulated container
- Proprietary vacuum-regeneration system for convenient, on-site maintenance
- Patented Sure-Fill System guarantees a complete fill every time with no manual venting required
- Safe, low-operating pressure of 140 psi
- Stable 6" uni-body legs meet health department sanitation requirements
- Easy-to-read gauges for CO_2 contents and tank pressure
- Fully-automated system

SPECIFICATIONS		CARBO-MAX 750
Dimensions		
Diameter	(in)	26
Height (with legs add 6 in)	(in)	68
Empty Weight	(lbs)	430
Full Weight	(lbs)	1,201
Design Criteria		
Code		ASME**
MAWP	(psig)	300
Insulation Type		Vacuum with Super Insulation
Capacity		
Net Volume	(gal)	82
Liquid Storage Capacity	(lbs)	771
Performance		
Normal Evaporation Rate (NER)*	(lbs/day)	3.0
Continuous CO_2 Delivery Rate	(lbs/hr)	15.0
Peak Flow Rate	(lbs/hr)	N/A
Components		
ASME Relief Valve Setting	(psig)	300
Secondary RV Setting	(psig)	450
Gas Use Connection	(in)	$^1/_4$ x 45^0 Male Flare
Fill Line Connection	(in)	$^5/_8$ x 45^0 Male Flare
Vent Connection	(in)	$^1/_2$ OD Tube
Construction		
Inner Vessel Material		Stainless Steel
Outer Vessel Material		Stainless Steel
Liquid Level Gauge		Float Type (magnetic)

* No loss in normal application

**ASME Boiler and Pressure Vessel Design Section VIII, Div. I

CO_2 Delivery

For years, Chart has provided the finest CO_2 bulk storage tanks for carbonation applications and we now use that same expertise in developing CO_2 delivery units. All delivery units are equipped with differential pressure meters. This meter has a guaranteed deviation of less than 1%, and has lower maintenance and calibration costs because it contains no moving parts.

Features

- Low CO_2 Evaporation Rate
- All stainless steel plumbing and 3-piece ball valves
- Welded outer jacket for greater moisture resistance and durability
- Optional pressure building unit and combo body units
- Meets DOT Specifications 49, MC-331 standards

CO_2 Delivery Specifications

		2 1/2 Ton	3 Ton	3 3/4 Ton
Capacity				
Gross Capacity	(liters)	2,346	2,815	3,518
Liquid Storage Capacity	(lbs)	5,122	6,146	7,681
Dimensions				
Width	(in)	58	58	58
Height	(in)	67	67	67
Length	(in)	111	129	156
Empty Weight	(lbs)	2,819	3,700	4,400
Full Weight	(lbs)	9,066	10,611	13,044

CO_2 Monitor Systems

The Chart Monitor System provides accurate monitoring of CO_2 levels. It is pre-set to exhibit an alarm when detecting abnormal to dangerously high level of CO_2 concentration in the work environment. Over 70,000 systems have been installed world wide. Monitor Systems are constructed with the highest quality components possible.

Features

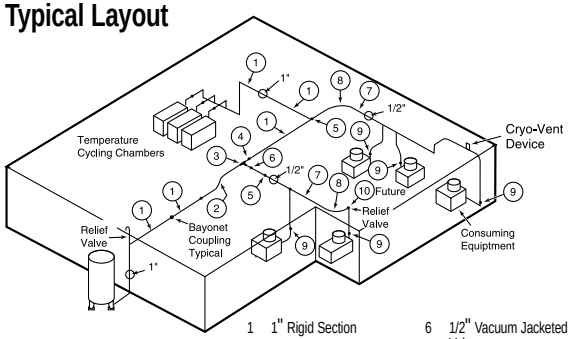
- Patented, gold-plated sensors
- High and low CO_2 alarm
- Three-year product warranty
- Continuous monitoring of CO_2 and temperature
- Digital display: temperature / CO_2%
- Display makes it possible to discover small leakage
- Up to 4 sensors per central unit
- Acoustical/optical signal from central unit and sensors
- Plug-in cables for easy, fast and inexpensive installation
- LED display specifies which sensor reports an alarm or fault
- Activation of a fan or external warning lamp from each sensor possible
- Patented self-calibration, five-year calibration guarantee
- Temperature “high”, “low” indication for coolrooms
- Logico2 program microprocessor
- Approved by UL, TUF and CE
- Gore-Tex® Waterproofing

CO_2 Monitor System Specifications

SPECIFICATIONS	
CO_2 Sensors	
Product	
Operating Principle:	Infrared Technology
Measurement Range-Temperature	0 - 50°C (32 - 122°F)
Measurement Range - CO_2	0 - 3 Vol%
Extended Range - CO_2	3 - 10 Vol%
Gas Sampling Mode	Diffusion
Accuracy	
Temperature	±1°C (±1.8°F)
CO_2	
At Full Operating Temperature Range	±0.05 Vol%
Annual Zero Point Drift	<0.01 Vol.% w/automatic self-calibration
Performance	
Compliance With	89 / 336 / EEC / UL / CE
Sensory Life Expectancy	> 15 years
Dimensions (L x W x H)	7" x 4" x 2"
Power	
Power Input	11 ±3V DC
Outputs	
Digital Interface	RS 485 Serial Port with Logico2 Program
Display	4 digit LCD Display with % CO_2 and Temperature Indication
Filter (Insect protection according to EN S4-7:1994)	Special Gore-Tex® Membranes
CO_2 Central Unit	
Supply	90-260 VAC 50-60Hz
Communication	RS485 100mA, Internal terminated =120 Ohm 0.3 VDC-offset
Acoustic signal-strength	70 dB (1m) max.
Ambient Temperatures	0-40°C
The system is approved by UL, TUF and CE	

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

Typical Layout



1 1" Rigid Section
2 1" Flexible Section
3 1" x 1/2" Reducing Tee
4 1" Vacuum Jacketed Valve
5 1" x 1/2" Reducer
6 1/2" Vacuum Jacketed Valve
7 1/2" Rigid Section
8 1/2" Flexible Section
9 1/2" Extended Packing Cryogenic Valve
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 jacketed or nonjacketed valves provide optimum utilization of cryogenic piping

Specify Chart Cryogenic Pipe 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 Built-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
1/4"	1-1/2"	1.5 lb	0.33 lb	.28	7.5
1/2"	1-1/2"	1.9 lb	0.54 lb	.35	7.5
1"	2-1/2"	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				

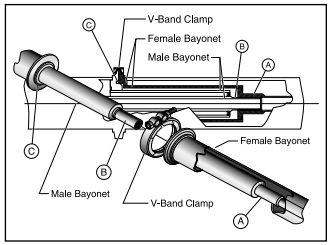
Flexible Built-to-Order VIP Construction Details

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 vacuum jacket flex.

Chart vacuum insulated pipe utilizes multi-layer super insulation for lowest BTU loss. 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.

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 Watts	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

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

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	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	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

	Multiply units in left column by proper factor below					
Energy	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

Courtesy of Ingersoll-Rand Company

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

Flowrate

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

Acknowledgment

Chart thanks AIRCO Welding Products for permission to copy various tables and data from the AIRCO Data Book.

Notes

SPECIFY CHART FOR TOP PERFORMANCE IN...

- ***storage***
- ***distribution***
- ***supply***
- ***handling of cryogenic liquids***

Bulk Storage Systems — horizontal or vertical up to 80,000 gallons

Liquid Cylinders — 80 liters – 1000 liters

Helium Dewars — 30 liters – 1000 liters

Delivery Systems — truck mounted

Biological Cylinders — a wide variety of cryo-biological storage products

CO_2 Beverage — 160 - 750 lbs

Vacuum Insulated Piping — standard or custom ordered sizes

Parts & Accessories — everything to complement cryogenic equipment

chartparts.com

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