LIQUEFIED GAS
PROPELLANT HANDBOOK

DiversifiedCPC INTERNATIONAL

Introduction

An aerosol propellant is defined as an essentially non-toxic material capable of exerting pressure in a sealed container at ambient temperatures. The two basic classes of aerosol propellant include the compressed gas propellants (carbon dioxide, nitrous oxide, and nitrogen) and the liquefied gas propellants (hydrocarbons, fluorocarbons, and ethers).

<table>
<tr><td>Compressed Gas Propellants</td><td>Inert Gases</td><td>Carbon Dioxide
Nitrous Oxide
Nitrogen</td></tr>
<tr><td rowspan="3">Liquefied Gas Propellants</td><td>Hydrocarbons</td><td>Liquefied Petroleum Gases
(Propane, Isobutane, n-Butane)
Isopentane, n-Pentane</td></tr>
<tr><td>Fluorocarbons</td><td>1,1 Difluoroethane (152a)
1,1,1,2 Tetrafluoroethane (134a)</td></tr>
<tr><td>Ethers</td><td>Dimethyl Ether</td></tr>
</table>

Diversified CPC International supplies liquefied gas propellants to domestic and export markets. This brochure is intended to provide basic information regarding liquefied gas propellants.

Advantages that are realized by use of liquefied gas propellants include chemical stability, environmental acceptability and low toxicity. Liquefied gas propellants are high purity, non-corrosive, and the pressure obtained in an aerosol container will remain essentially constant over the duration of use of the product.

Diversified CPC International welcomes inquiries from prospective users of our liquefied gas products.

Important
Please read

Information contained in this brochure is considered to be reliable, however no guarantee or warranty is implied or intended. Nothing contained herein is to be construed as permission or recommendation to practice a patented invention without a license. Information is presented for your consideration and verification. Products listed herein should not be used for food, drug, cosmetic or commercial purposes until you have determined safety and legality of usage.

Product Delivery

Diversified CPC International maintains a substantial fleet of rail tank cars and truck transports for liquefied gas product distribution throughout the United States. All tank cars and transports are dedicated assuring maximum product purity

Various sizes of tank cars and transports are available to meet individual customer requirements. Tank car capacity is 30,500 gallons. Transports are available in capacities of 2,000 through 10,000 gallons.

Tank car shipments can be made within 48 hours of order for all products. Transport deliveries within a 500-mile radius of our terminals normally require a lead lime of 24 to 36 hours.

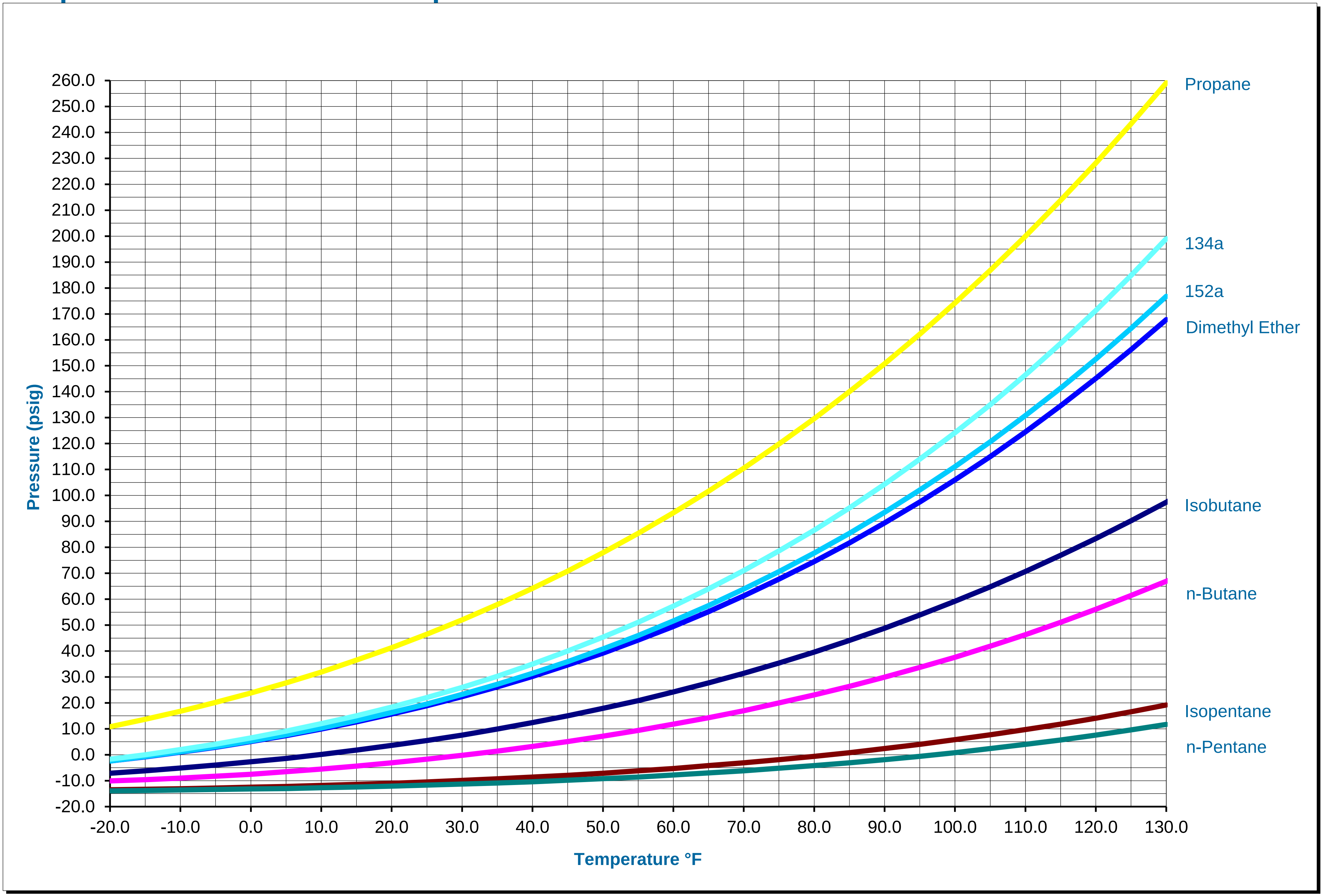
Physical Properties of Liquefied Gases

Figure 1

	A-17	A-31	A-108	Isopentane	n-Pentane	DME	152a	134a
Formula	C_4H_{10}	C_4H_{10}	C_3H_8	C_5H_{12}	C_5H_{12}	CH_3-O-CH_3	CH_3-CHF_2	CF_3-CFH_2
Molecular Weight	58.123	58.123	44.096	72.15	72.15	46.069	66.051	102.03
Vapor Pressure @ 70 °F (psig)	16.9	31.1	109.3	-3.1	-6.2	61.3	63.9	71.0
Vapor Pressure @ 100 °F (psig)	37.5	59.0	172.0	5.8	0.8	106.0	111.1	124.2
Boiling Point @ 1 ATM., °F	31.1	10.9	-43.7	82	97	-12.7	-13	-15.5
Freezing Point @ 1 ATM., °F	-217.0	-255.3	-305.7	-255.8	-201.5	-223	-179	-149.8
Auto Ignition Temperature °F	761	860	842	788	588	662	849	-
Specific Gravity Liquid @ 60 °F	0.584	0.563	0.508	0.624	0.630	0.671	0.922	1.245
Specific Gravity Gas @ 60 °F	2.006	2.006	1.522	2.491	2.491	1.590	2.280	3.523
Density of Liquid lbs./gal. @ 60 °F	4.864	4.699	4.234	5.200	5.255	5.579	7.696	10.384
Vol. of Vapor/lb. @ 60 °F (cu.ft.)	6.54	6.53	8.62	5.27	5.27	8.24	5.74	3.72
Vol. of Vapor/gal. @ 60 °F (cu.ft.)	31.75	30.59	36.35	27.40	27.68	46.12	44.20	38.64
Gas Vol./Liq. Vol. @ 1 ATM. & 60 °F	237.8	229.3	272.7	205.0	207.0	345.0	330.6	289.0
Critical Temperature °F	305.6	274.5	206.1	369.1	385.8	260.3	236.2	213.9
Critical Pressure (psia)	550.6	527.9	616	490.4	488.8	778.9	652.5	587.4
Flash Point °F	-101	-117	-156	-60	-40	-42	-58	Non-Flammable
Spec. Heat of Gas, Cp @ 60 °F, BTU/lb °F	0.395	0.387	0.389	0.384	0.388	0.412	0.240	0.282
Spec. Heat of Liquid, Cp @ 60°F, BTU/lb °F	0.570	0.570	0.620	0.538	0.544	0.566	0.378	0.331
Heat of Vaporization, BTU/lb °F@ BP	165.8	157.2	183.0	147.1	153.6	201.0	140.9	93.4
Net Heat of Comb. of Liquid, 77 °F BTU/lb	19,657	19,589	19,918	19,304	19,495	12,397	4,937	0
Chemical Heat of Comb. (kJ/g)	43.3	42.8	44.0	41.9	42.5	26.5	6.3	0
Viscosity of Liquid, centipoise @100 °F	0.140	0.131	0.084	0.191	0.196	0.115	0.141	0.166
Coefficient of Liquid Expansion @60 °F	0.0011	0.0012	0.0016	0.0009	0.0009	0.0012	0.0014	0.0016
Solubility in water @ 70 °F (%by weight)	0.008	0.008	0.007	Neg.	Neg.	35.0	1.7	0.95
Solubility of water @ 70 °F (%by weight)	0.007	0.008	0.016	0.01	0.009	6.9	0.17	0.095
Surface Tension @ 77 ° F (dynes/cm)	11.9	9.8	7.0	14.5	15.5	11.4	10.0	7.8
Kauri-Butanol Value	20	18	15	N/A	N/A	60	11	9.2
Flammability Limits in Air	1.9 - 8.5	1.8 - 8.4	2.2 - 9.5	1.4 - 7.6	1.5 - 7.8	3.3 - 18.0	3.9 - 16.9	Non-Flammable

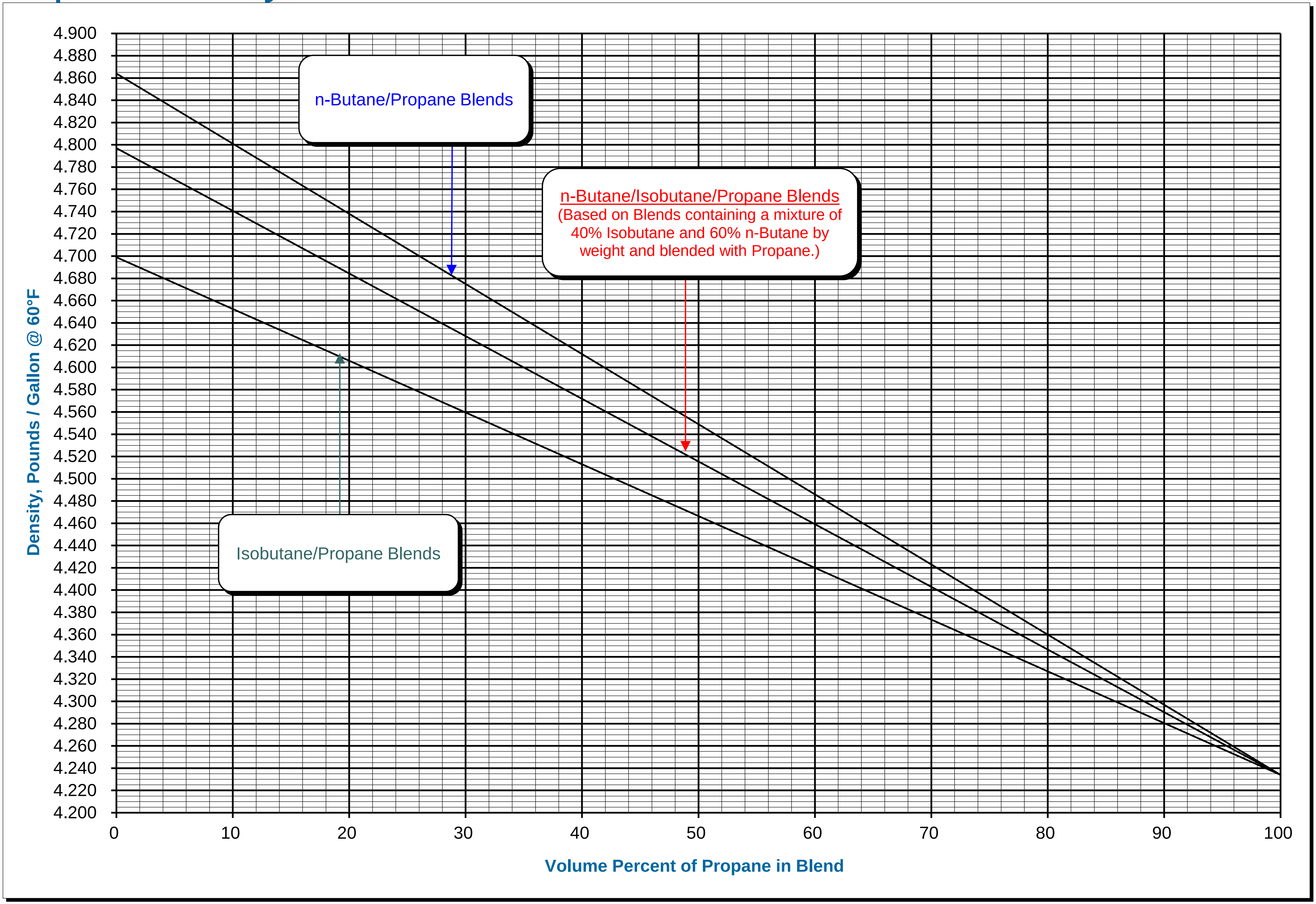
Vapor Pressure of Liquefied Gases

Figure 2



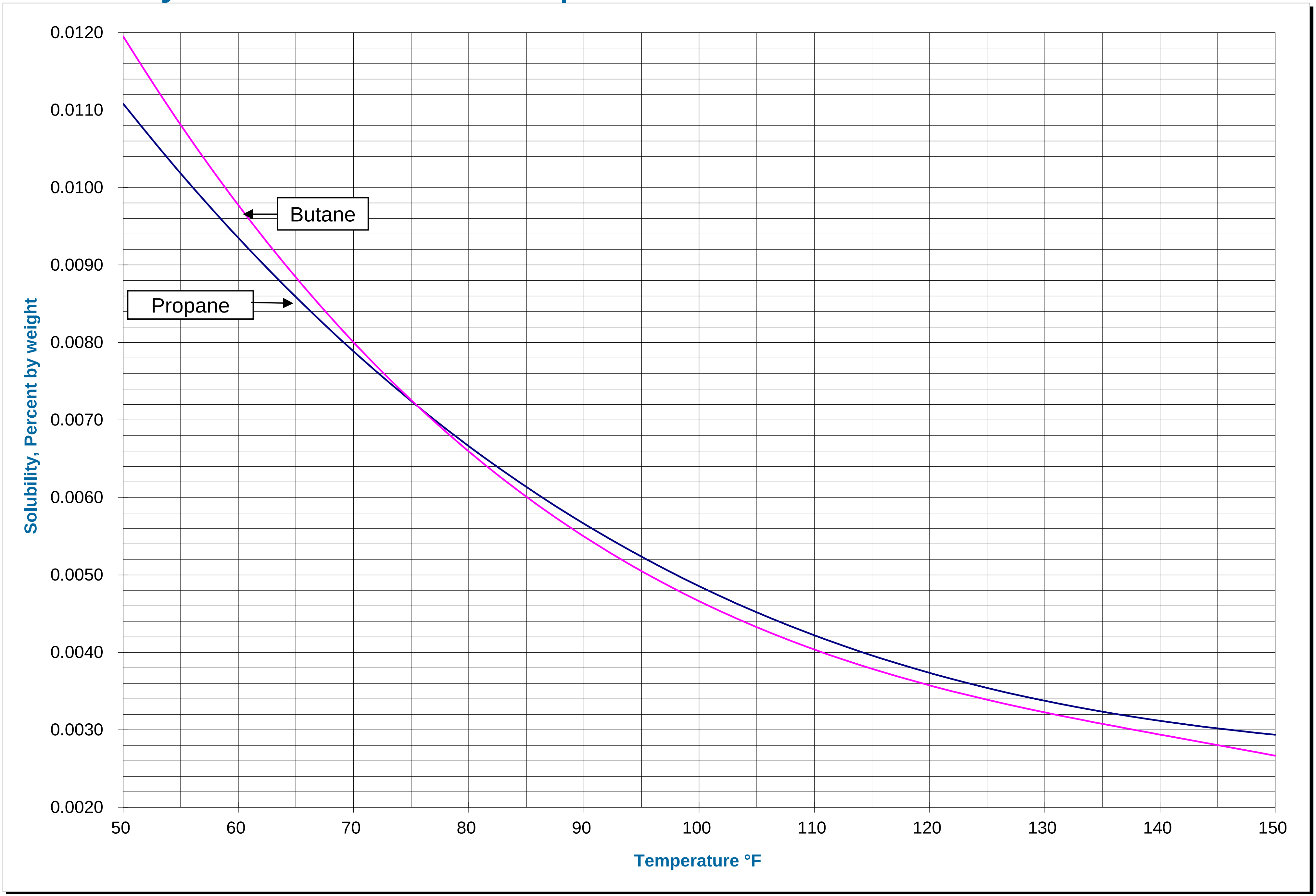
Liquid Density of LP Gas Blends

Figure 3



Solubility of Butane and Propane in Water

Figure 4

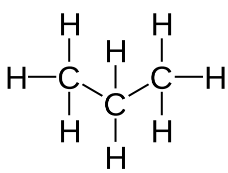
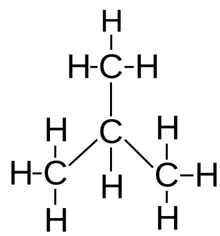
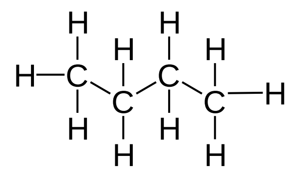


Product Blends

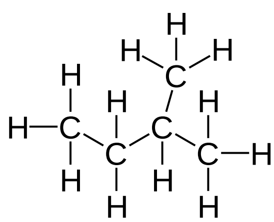
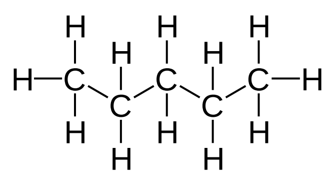
Liquefied Gas Products

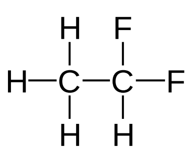
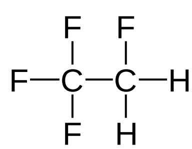
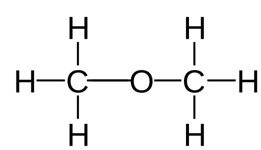
Hydrocarbon

Liquefied Petroleum Gases

 PROPANE	 ISOBUTANE	 N-BUTANE

Pentanes

 ISOPENTANE	 N-PENTANE

Fluorocarbon		Ether
 1,1 DIFLUOROETHANE (152a)	 1,1,1,2 TETRAFLUOROETHANE (134a)	 DIMETHYL ETHER

Diversified CPC International has facilities to provide any blend of Propane, Isobutane, Normal Butane, Isopentane, Normal Pentane, 1,1-Difluoroethane (152a), 1,1,1,2-Tetrafluoroethane (134a), and Dimethyl Ether for desired composition or vapor pressure.

Naming Conventions

Liquefied Petroleum Gas propellants produced and marketed by Diversified CPC International are designated as:

A for propane, isobutane, n-butane, or blends of propane and isobutane, or blends of isobutane and n-butane,

NP for blends of propane and n-butane, and

NIP for blends of propane, isobutane, and n-butane. The ratio of isobutane to n-butane is fixed at 2 to 3 (0.667).

and a number representing the vapor pressure at 70 °F.

The following table cross references the LP Gas propellant designations used by other manufacturers:

LP Gas Propellant Code Cross Reference			
Diversified CPC	Aeropres Corp	Technical Propellants	Phillips
A	A	A	A
NP	AB	BP	BP
NIP	Aeropin	T	BIP

Examples: A-17 is n-butane.

A-24 is a blend of n-butane and Isobutane having a vapor pressure of 24 psig at 70 °F.

A-31 is Isobutane.

A-70 is a blend of Isobutane and Propane having a vapor pressure of 70 psig at 70 °F.

A-108 is Propane.

NP-46 is a blend of n-Butane and Propane having a vapor pressure of 46 psig at 70 °F.

NIP-52 is a blend of n-Butane, Isobutane, and Propane having a vapor pressure of 52 psig at 70 °F such that the ratio of Isobutane and n-butane is fixed at 2/3.

All other propellant blends produced and marketed by Diversified CPC International are designated by the blend components, followed by the components respective weight percentages in parenthesis.

Examples: A31/152a (25/75) is a blend of 25% by weight isobutane and 75% by weight 1,1 Difluoroethane.

A46/DME (45/55) is a blend containing 45% by weight of A-46 and 55% by weight Dimethyl Ether.

Figure 1 provides information on selected physical properties of liquefied gas aerosol propellants.

Figure 2 provides information on vapor pressures of liquefied gas aerosol propellants as a function of temperature.

Figure 3 provides information on the liquid density of Hydrocarbon Propellant Blends.

Solubility data of hydrocarbon propellants in water is given in Figure 4.

Figures 5 through 10 are detailed versions of vapor pressure vs. temperature charts for the more commonly used hydrocarbon propellant blends used by the aerosol industry.

Vapor Pressure Calculation

Vapor pressures resulting from mixtures of the hydrocarbon propellants can, for practical purposes be determined through the application of Raoult's Law, which states the partial pressure of each component is proportional to its molar concentration in the solution. For binary ideal solutions, it is possible to calculate the vapor pressure from the following equation,

$P = p_1 + p_2 = P_1X_1 + P_2X_2$, where P = Total Pressure

p_1 and p_2 = partial pressure of each component
P_1 and P_2 = vapor pressure of each pure component
X_1 and X_2 = mole fraction in the liquid phase

A mole is expressed in terms of standard weight systems, e.g. the g-mol or lb-mol, and the number of moles is found by dividing the weight percentage by the molecular weight. The mole fraction is the number of moles of the component divided by the sum of moles of all components.

Example 1

Propellant	Propane - 16% by wt.	
	Isobutane - 84% by wt.	
	Moles of propane in the mixture	= 16/44.09
		= 0.3629
	Moles of isobutane in the mixture	= 84/58.12
		= 1.4453
	Total number of moles	= 1.8082
	Mole fraction of propane	= 0.2007
	Vapor pressure of propane @ 70 °F	= 124 psia.
	Mole fraction of isobutane	= 0.7993
	Vapor pressure of isobutane @ 70 °F	=45.8 psia.
	Total Pressure (124 x .2007) + (45.8 x .7993)	= 61.5 psia.
		= 46.8 psig.

Conversely, if the vapor pressure of a blend of propane and isobutane is specified as 46 psig at 70 °F then let X be the mole fraction of propane in the blend.

Mole fraction of Isobutane in the blend = 1 -X
Absolute vapor pressure of blend = 46.0 + 14.7 = 60.7 psia
Then from Raoult's Law,
(1 -X) (Vapor pressure of isobutane @ 70° F) + X (vapor pressure of propane @ 70° F)
= vapor pressure of blend @ 70 °F

Substituting the vapor pressures, (1 -X)45.8 + 124X = 60.7
Therefore, 45.8 - 45.8X + 124X = 60.7
Transposing, X (124 - 45.8) = 60.7 - 45.8
Hence X = 14.9/78.2 = 0.19 = mole fraction of propane
and 1 - X = 1 - 0.19 = 0.81 = mole fraction of isobutane
1 mole of mixture contains 0.19 mole of propane = 0.19 * 44.09 = 8.377 lbs.
and 0.81 mole of isobutane 0.81 * 58.12 = 47.077 lbs.
Wt. % Propane in mixture = 15.11

Raoult's law cannot be used for accurate vapor pressure calculations involving blends of dimethyl ether or the fluorocarbon propellants.

A-Blends

Figure 5

Vapor Pressure	Weight% n-Butane	Weight% Isobutane	Weight% Propane	Mole% n-Butane	Mole% Isobutane	Mole% Propane	Liquid Volume % (60 °F) n-Butane	Liquid Volume % (60 °F) Isobutane	Liquid Volume % (60 °F) Propane	Liq. Den. 60°F lb/gl
17	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	4.864
20	80.00	20.00	0.00	80.00	20.00	0.00	79.44	20.56	0.00	4.830
24	50.00	50.00	0.00	50.00	50.00	0.00	49.14	50.86	0.00	4.780
28	25.00	75.00	0.00	25.00	75.00	0.00	24.36	75.64	0.00	4.766
31	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	4.699
32	0.00	99.12	0.88	0.00	98.84	1.16	0.00	99.02	0.98	4.694
33	0.00	98.15	1.85	0.00	97.58	2.42	0.00	97.95	2.05	4.689
34	0.00	97.16	2.84	0.00	96.29	3.71	0.00	96.86	3.14	4.684
35	0.00	96.17	3.83	0.00	95.01	4.99	0.00	95.77	4.23	4.679
36	0.00	95.17	4.83	0.00	93.73	6.27	0.00	94.67	5.33	4.674
37	0.00	94.17	5.83	0.00	92.46	7.54	0.00	93.57	6.43	4.669
38	0.00	93.16	6.84	0.00	91.18	8.82	0.00	92.47	7.53	4.664
39	0.00	92.14	7.86	0.00	89.89	10.11	0.00	91.35	8.65	4.659
40	0.00	91.12	8.88	0.00	88.62	11.38	0.00	90.24	9.76	4.654
41	0.00	90.09	9.91	0.00	87.34	12.66	0.00	89.12	10.88	4.648
42	0.00	89.06	10.94	0.00	86.06	13.94	0.00	88.00	12.00	4.643
43	0.00	88.01	11.99	0.00	84.78	15.22	0.00	86.87	13.13	4.638
44	0.00	86.97	13.03	0.00	83.51	16.49	0.00	85.74	14.26	4.633
45	0.00	85.91	14.09	0.00	82.22	17.78	0.00	84.60	15.40	4.627
46	0.00	84.85	15.15	0.00	80.95	19.05	0.00	83.46	16.54	4.622
47	0.00	83.78	16.22	0.00	79.67	20.33	0.00	82.31	17.69	4.617
48	0.00	82.70	17.30	0.00	78.39	21.61	0.00	81.16	18.84	4.611
49	0.00	81.62	18.38	0.00	77.11	22.89	0.00	80.01	19.99	4.606
50	0.00	80.53	19.47	0.00	75.83	24.17	0.00	78.84	21.16	4.601
51	0.00	79.43	20.57	0.00	74.55	25.45	0.00	77.68	22.32	4.595
52	0.00	78.33	21.67	0.00	73.28	26.72	0.00	76.51	23.49	4.590
53	0.00	77.21	22.79	0.00	71.99	28.01	0.00	75.32	24.68	4.584
54	0.00	76.09	23.91	0.00	70.71	29.29	0.00	74.14	25.86	4.579
55	0.00	74.97	25.03	0.00	69.44	30.56	0.00	72.96	27.04	4.573
56	0.00	73.83	26.17	0.00	68.16	31.84	0.00	71.77	28.23	4.568
57	0.00	72.69	27.31	0.00	66.88	33.12	0.00	70.57	29.43	4.562
58	0.00	71.54	28.46	0.00	65.60	34.40	0.00	69.37	30.63	4.557
59	0.00	70.38	29.62	0.00	64.32	35.68	0.00	68.16	31.84	4.551
60	0.00	69.22	30.78	0.00	63.05	36.95	0.00	66.96	33.04	4.545
61	0.00	68.04	31.96	0.00	61.76	38.24	0.00	65.73	34.27	4.540
62	0.00	66.86	33.14	0.00	60.48	39.52	0.00	64.51	35.49	4.534
63	0.00	65.67	34.33	0.00	59.20	40.80	0.00	63.28	36.72	4.528
64	0.00	64.47	35.53	0.00	57.92	42.08	0.00	62.05	37.95	4.523
65	0.00	63.27	36.73	0.00	56.65	43.35	0.00	60.82	39.18	4.517
66	0.00	62.05	37.95	0.00	55.37	44.63	0.00	59.57	40.43	4.511
67	0.00	60.83	39.17	0.00	54.09	45.91	0.00	58.32	41.68	4.505
68	0.00	59.60	40.40	0.00	52.81	47.19	0.00	57.07	42.93	4.499
69	0.00	58.36	41.64	0.00	51.53	48.47	0.00	55.81	44.19	4.494
70	0.00	57.11	42.89	0.00	50.25	49.75	0.00	54.54	45.46	4.488
71	0.00	55.85	44.15	0.00	48.97	51.03	0.00	53.27	46.73	4.482
72	0.00	54.59	45.41	0.00	47.70	52.30	0.00	52.00	48.00	4.476
73	0.00	53.31	46.69	0.00	46.42	53.58	0.00	50.71	49.29	4.470
74	0.00	52.03	47.97	0.00	45.14	54.86	0.00	49.43	50.57	4.464
75	0.00	50.74	49.26	0.00	43.87	56.13	0.00	48.14	51.86	4.458

Vapor Pressure	Weight% n-Butane	Weight% Isobutane	Weight% Propane	Mole% n-Butane	Mole% Isobutane	Mole% Propane	Liquid Volume % (60 °F) n-Butane	Liquid Volume % (60 °F) Isobutane	Liquid Volume % (60 °F) Propane	Liq. Den. 60°F lb/gl
76	0.00	49.43	50.57	0.00	42.58	57.42	0.00	46.83	53.17	4.452
77	0.00	48.12	51.88	0.00	41.30	58.70	0.00	45.53	54.47	4.446
78	0.00	46.80	53.20	0.00	40.03	59.97	0.00	44.22	55.78	4.440
79	0.00	45.47	54.53	0.00	38.75	61.25	0.00	42.90	57.10	4.433
80	0.00	44.13	55.87	0.00	37.47	62.53	0.00	41.58	58.42	4.427
81	0.00	42.78	57.22	0.00	36.19	63.81	0.00	40.25	59.75	4.421
82	0.00	41.42	58.58	0.00	34.91	65.09	0.00	38.92	61.08	4.415
83	0.00	40.05	59.95	0.00	33.64	66.36	0.00	37.58	62.42	4.409
84	0.00	38.67	61.33	0.00	32.36	67.64	0.00	36.23	63.77	4.402
85	0.00	37.27	62.73	0.00	31.07	68.93	0.00	34.87	65.13	4.396
86	0.00	35.87	64.13	0.00	29.79	70.21	0.00	33.51	66.49	4.390
87	0.00	34.46	65.54	0.00	28.52	71.48	0.00	32.15	67.85	4.383
88	0.00	33.04	66.96	0.00	27.24	72.76	0.00	30.78	69.22	4.377
89	0.00	31.61	68.39	0.00	25.96	74.04	0.00	29.40	70.60	4.371
90	0.00	30.16	69.84	0.00	24.68	75.32	0.00	28.01	71.99	4.364
91	0.00	28.71	71.29	0.00	23.40	76.60	0.00	26.63	73.37	4.358
92	0.00	27.24	72.76	0.00	22.12	77.88	0.00	25.22	74.78	4.351
93	0.00	25.77	74.23	0.00	20.85	79.15	0.00	23.83	76.17	4.345
94	0.00	24.28	75.72	0.00	19.57	80.43	0.00	22.42	77.58	4.338
95	0.00	22.78	77.22	0.00	18.29	81.71	0.00	21.00	79.00	4.332
96	0.00	21.27	78.73	0.00	17.01	82.99	0.00	19.58	80.42	4.325
97	0.00	19.74	80.26	0.00	15.73	84.27	0.00	18.14	81.86	4.318
98	0.00	18.21	81.79	0.00	14.45	85.55	0.00	16.71	83.29	4.312
99	0.00	16.66	83.34	0.00	13.17	86.83	0.00	15.26	84.74	4.305
100	0.00	15.10	84.90	0.00	11.89	88.11	0.00	13.81	86.19	4.298
101	0.00	13.53	86.47	0.00	10.61	89.39	0.00	12.36	87.64	4.291
102	0.00	11.95	88.05	0.00	9.34	90.66	0.00	10.90	89.10	4.285
103	0.00	10.35	89.65	0.00	8.05	91.95	0.00	9.42	90.58	4.278
104	0.00	8.74	91.26	0.00	6.77	93.23	0.00	7.94	92.06	4.271
105	0.00	7.12	92.88	0.00	5.50	94.50	0.00	6.46	93.54	4.264
106	0.00	5.49	94.51	0.00	4.22	95.78	0.00	4.97	95.03	4.257
107	0.00	3.84	96.16	0.00	2.94	97.06	0.00	3.47	96.53	4.250
108	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	4.234

NP-Blends

Figure 6

Vapor	Weight%			Mole%			Liquid Volume % (60 °F)			Liq. Den.
Pressure	n-Butane	Isobutane	Propane	n-Butane	Isobutane	Propane	n-Butane	Isobutane	Propane	60°F lb/gl
31	87.98	0.00	12.02	84.74	0.00	15.26	86.43	0.00	13.57	4.779
32	87.09	0.00	12.91	83.65	0.00	16.35	85.45	0.00	14.55	4.772
33	86.20	0.00	13.80	82.58	0.00	17.42	84.47	0.00	15.53	4.766
34	85.30	0.00	14.70	81.49	0.00	18.51	83.47	0.00	16.53	4.760
35	84.40	0.00	15.60	80.41	0.00	19.59	82.49	0.00	17.51	4.754
36	83.49	0.00	16.51	79.32	0.00	20.68	81.49	0.00	18.51	4.747
37	82.58	0.00	17.42	78.24	0.00	21.76	80.49	0.00	19.51	4.741
38	81.67	0.00	18.33	77.17	0.00	22.83	79.50	0.00	20.50	4.735
39	80.74	0.00	19.26	76.08	0.00	23.92	78.49	0.00	21.51	4.729
40	79.82	0.00	20.18	75.01	0.00	24.99	77.49	0.00	22.51	4.722
41	78.88	0.00	21.12	73.91	0.00	26.09	76.48	0.00	23.52	4.716
42	77.95	0.00	22.05	72.84	0.00	27.16	75.47	0.00	24.53	4.709
43	77.00	0.00	23.00	71.75	0.00	28.25	74.45	0.00	25.55	4.703
44	76.05	0.00	23.95	70.67	0.00	29.33	73.43	0.00	26.57	4.697
45	75.10	0.00	24.90	69.59	0.00	30.41	72.42	0.00	27.58	4.690
46	74.14	0.00	25.86	68.50	0.00	31.50	71.39	0.00	28.61	4.684
47	73.18	0.00	26.82	67.43	0.00	32.57	70.37	0.00	29.63	4.677
48	72.21	0.00	27.79	66.35	0.00	33.65	69.34	0.00	30.66	4.671
49	71.23	0.00	28.77	65.26	0.00	34.74	68.31	0.00	31.69	4.664
50	70.25	0.00	29.75	64.18	0.00	35.82	67.27	0.00	32.73	4.658
51	69.26	0.00	30.74	63.09	0.00	36.91	66.23	0.00	33.77	4.651
52	68.27	0.00	31.73	62.01	0.00	37.99	65.19	0.00	34.81	4.645
53	67.27	0.00	32.73	60.93	0.00	39.07	64.15	0.00	35.85	4.638
54	66.27	0.00	33.73	59.85	0.00	40.15	63.10	0.00	36.90	4.632
55	65.26	0.00	34.74	58.77	0.00	41.23	62.05	0.00	37.95	4.625
56	64.24	0.00	35.76	57.68	0.00	42.32	60.99	0.00	39.01	4.618
57	63.22	0.00	36.78	56.60	0.00	43.40	59.94	0.00	40.06	4.612
58	62.20	0.00	37.80	55.52	0.00	44.48	58.89	0.00	41.11	4.605
59	61.16	0.00	38.84	54.43	0.00	45.57	57.82	0.00	42.18	4.598
60	60.12	0.00	39.88	53.35	0.00	46.65	56.75	0.00	43.25	4.592
61	59.08	0.00	40.92	52.28	0.00	47.72	55.69	0.00	44.31	4.585
62	58.03	0.00	41.97	51.20	0.00	48.80	54.62	0.00	45.38	4.578
63	56.97	0.00	43.03	50.11	0.00	49.89	53.54	0.00	46.46	4.571
64	55.90	0.00	44.10	49.02	0.00	50.98	52.46	0.00	47.54	4.565
65	54.83	0.00	45.17	47.94	0.00	52.06	51.38	0.00	48.62	4.558
66	53.76	0.00	46.24	46.87	0.00	53.13	50.30	0.00	49.70	4.551
67	52.67	0.00	47.33	45.78	0.00	54.22	49.20	0.00	50.80	4.544
68	51.58	0.00	48.42	44.70	0.00	55.30	48.11	0.00	51.89	4.537
69	50.48	0.00	49.52	43.61	0.00	56.39	47.02	0.00	52.98	4.530
70	49.38	0.00	50.62	42.53	0.00	57.47	45.92	0.00	54.08	4.523
71	48.27	0.00	51.73	41.45	0.00	58.55	44.82	0.00	55.18	4.516
72	47.15	0.00	52.85	40.36	0.00	59.64	43.71	0.00	56.29	4.509
73	46.03	0.00	53.97	39.29	0.00	60.71	42.61	0.00	57.39	4.502
74	44.90	0.00	55.10	38.20	0.00	61.80	41.50	0.00	58.50	4.495
75	43.76	0.00	56.24	37.12	0.00	62.88	40.38	0.00	59.62	4.488
76	42.62	0.00	57.38	36.04	0.00	63.96	39.27	0.00	60.73	4.481
77	41.47	0.00	58.53	34.96	0.00	65.04	38.15	0.00	61.85	4.474
78	40.31	0.00	59.69	33.88	0.00	66.12	37.02	0.00	62.98	4.467
79	39.14	0.00	60.86	32.79	0.00	67.21	35.89	0.00	64.11	4.460

Vapor	Weight%			Mole%			Liquid Volume % (60 °F)			Liq. Den.
Pressure	n-Butane	Isobutane	Propane	n-Butane	Isobutane	Propane	n-Butane	Isobutane	Propane	60°F lb/gl
80	37.97	0.00	62.03	31.71	0.00	68.29	34.76	0.00	65.24	4.453
81	36.79	0.00	63.21	30.63	0.00	69.37	33.63	0.00	66.37	4.446
82	35.60	0.00	64.40	29.55	0.00	70.45	32.49	0.00	67.51	4.439
83	34.40	0.00	65.60	28.46	0.00	71.54	31.34	0.00	68.66	4.431
84	33.20	0.00	66.80	27.38	0.00	72.62	30.20	0.00	69.80	4.424
85	31.99	0.00	68.01	26.30	0.00	73.70	29.05	0.00	70.95	4.417
86	30.77	0.00	69.23	25.22	0.00	74.78	27.90	0.00	72.10	4.410
87	29.54	0.00	70.46	24.13	0.00	75.87	26.74	0.00	73.26	4.402
88	28.31	0.00	71.69	23.05	0.00	76.95	25.58	0.00	74.42	4.395
89	27.07	0.00	72.93	21.97	0.00	78.03	24.42	0.00	75.58	4.388
90	25.82	0.00	74.18	20.89	0.00	79.11	23.25	0.00	76.75	4.380
91	24.56	0.00	75.44	19.81	0.00	80.19	22.08	0.00	77.92	4.373
92	23.29	0.00	76.71	18.72	0.00	81.28	20.90	0.00	79.10	4.366
93	22.02	0.00	77.98	17.64	0.00	82.36	19.73	0.00	80.27	4.358
94	20.73	0.00	79.27	16.56	0.00	83.44	18.54	0.00	81.46	4.351
95	19.44	0.00	80.56	15.47	0.00	84.53	17.36	0.00	82.64	4.343
96	18.14	0.00	81.86	14.39	0.00	85.61	16.17	0.00	83.83	4.336
97	16.83	0.00	83.17	13.31	0.00	86.69	14.98	0.00	85.02	4.328
98	15.52	0.00	84.48	12.23	0.00	87.77	13.79	0.00	86.21	4.321
99	14.19	0.00	85.81	11.15	0.00	88.85	12.58	0.00	87.42	4.313
100	12.86	0.00	87.14	10.07	0.00	89.93	11.38	0.00	88.62	4.306
101	11.51	0.00	88.49	8.98	0.00	91.02	10.17	0.00	89.83	4.298
102	10.16	0.00	89.84	7.90	0.00	92.10	8.96	0.00	91.04	4.290
103	8.80	0.00	91.20	6.82	0.00	93.18	7.75	0.00	92.25	4.283
104	7.43	0.00	92.57	5.74	0.00	94.26	6.53	0.00	93.47	4.275
105	6.04	0.00	93.96	4.65	0.00	95.35	5.30	0.00	94.70	4.267
106	4.65	0.00	95.35	3.57	0.00	96.43	4.07	0.00	95.93	4.260
107	3.26	0.00	96.74	2.49	0.00	97.51	2.85	0.00	97.15	4.252

NIP Blends

Figure 7

Vapor Pressure	Weight% n-Butane	Weight% Isobutane	Weight% Propane	Mole% n-Butane	Mole% Isobutane	Mole% Propane	Liquid Volume % (60 °F) n-Butane	Liquid Volume % (60 °F) Isobutane	Liquid Volume % (60 °F) Propane	Liq. Den. 60°F lb/gl
31	55.47	37.00	7.54	54.17	36.13	9.70	54.15	37.39	8.46	4.749
32	54.91	36.63	8.46	53.47	35.67	10.86	53.55	36.98	9.48	4.743
33	54.36	36.26	9.38	52.79	35.21	12.01	52.95	36.56	10.50	4.738
34	53.80	35.89	10.31	52.09	34.75	13.16	52.34	36.14	11.52	4.732
35	53.24	35.51	11.25	51.40	34.28	14.32	51.73	35.71	12.56	4.726
36	52.68	35.13	12.19	50.71	33.82	15.47	51.12	35.29	13.59	4.720
37	52.11	34.76	13.14	50.01	33.36	16.62	50.50	34.87	14.63	4.714
38	51.54	34.37	14.09	49.33	32.90	17.78	49.89	34.44	15.67	4.708
39	50.96	33.99	15.05	48.63	32.44	18.93	49.27	34.02	16.72	4.703
40	50.38	33.61	16.01	47.94	31.98	20.08	48.65	33.59	17.76	4.697
41	49.80	33.22	16.98	47.25	31.52	21.23	48.03	33.16	18.81	4.691
42	49.22	32.83	17.95	46.56	31.06	22.38	47.41	32.73	19.86	4.685
43	48.63	32.44	18.93	45.87	30.60	23.53	46.78	32.30	20.92	4.679
44	48.04	32.04	19.92	45.18	30.13	24.69	46.15	31.86	21.99	4.673
45	47.44	31.64	20.91	44.49	29.67	25.85	45.52	31.43	23.05	4.667
46	46.84	31.24	21.91	43.79	29.21	27.00	44.89	30.99	24.12	4.661
47	46.24	30.84	22.92	43.10	28.74	28.16	44.25	30.55	25.20	4.655
48	45.64	30.44	23.93	42.41	28.28	29.31	43.62	30.11	26.27	4.649
49	45.03	30.03	24.94	41.72	27.82	30.46	42.98	29.67	27.35	4.643
50	44.41	29.62	25.96	41.03	27.36	31.61	42.34	29.23	28.43	4.637
51	43.80	29.21	26.99	40.34	26.90	32.76	41.70	28.78	29.52	4.631
52	43.18	28.80	28.03	39.64	26.44	33.92	41.05	28.34	30.61	4.624
53	42.55	28.38	29.07	38.95	25.98	35.07	40.40	27.89	31.71	4.618
54	41.92	27.96	30.12	38.25	25.52	36.23	39.75	27.44	32.81	4.612
55	41.29	27.54	31.17	37.57	25.06	37.38	39.10	26.99	33.91	4.606
56	40.65	27.12	32.23	36.87	24.60	38.53	38.44	26.55	35.01	4.600
57	40.01	26.69	33.30	36.18	24.13	39.69	37.78	26.09	36.13	4.593
58	39.37	26.26	34.37	35.49	23.67	40.84	37.13	25.63	37.24	4.587
59	38.72	25.83	35.45	34.80	23.21	41.99	36.47	25.18	38.35	4.581
60	38.07	25.39	36.54	34.11	22.75	43.15	35.80	24.72	39.48	4.575
61	37.42	24.96	37.63	33.42	22.29	44.29	35.14	24.26	40.60	4.568
62	36.76	24.52	38.73	32.72	21.83	45.45	34.47	23.80	41.72	4.562
63	36.09	24.07	39.84	32.03	21.36	46.61	33.80	23.33	42.86	4.555
64	35.42	23.63	40.95	31.34	20.91	47.76	33.13	22.88	44.00	4.549
65	34.75	23.18	42.07	30.65	20.44	48.91	32.45	22.41	45.14	4.543
66	34.07	22.73	43.20	29.95	19.98	50.06	31.77	21.94	46.28	4.536
67	33.39	22.27	44.34	29.26	19.52	51.22	31.10	21.47	47.44	4.530
68	32.71	21.82	45.48	28.57	19.06	52.37	30.42	21.00	48.58	4.523
69	32.02	21.36	46.63	27.88	18.60	53.52	29.73	20.53	49.74	4.517
70	31.32	20.89	47.79	27.19	18.13	54.68	29.04	20.05	50.91	4.510
71	30.62	20.43	48.95	26.49	17.68	55.83	28.35	19.58	52.07	4.504
72	29.92	19.96	50.12	25.81	17.22	56.98	27.66	19.10	53.23	4.497
73	29.21	19.48	51.30	25.11	16.75	58.14	26.97	18.62	54.41	4.490
74	28.50	19.01	52.49	24.42	16.29	59.29	26.27	18.14	55.59	4.484
75	27.78	18.53	53.69	23.73	15.83	60.45	25.57	17.66	56.77	4.477
76	27.06	18.05	54.89	23.04	15.37	61.60	24.87	17.17	57.96	4.471
77	26.34	17.57	56.10	22.35	14.91	62.74	24.17	16.69	59.14	4.464
78	25.60	17.08	57.32	21.65	14.45	63.90	23.46	16.20	60.34	4.457
79	24.87	16.59	58.55	20.96	13.98	65.05	22.75	15.71	61.54	4.450

Vapor Pressure	Weight% n-Butane	Weight% Isobutane	Weight% Propane	Mole% n-Butane	Mole% Isobutane	Mole% Propane	Liquid Volume % (60 °F) n-Butane	Liquid Volume % (60 °F) Isobutane	Liquid Volume % (60 °F) Propane	Liq. Den. 60°F lb/gl
80	24.13	16.09	59.78	20.27	13.52	66.21	22.04	15.22	62.74	4.444
81	23.38	15.60	61.02	19.58	13.06	67.36	21.33	14.73	63.94	4.437
82	22.63	15.09	62.28	18.89	12.59	68.52	20.61	14.23	65.16	4.430
83	21.87	14.59	63.54	18.19	12.14	69.67	19.89	13.73	66.38	4.423
84	21.11	14.08	64.80	17.50	11.67	70.82	19.17	13.23	67.60	4.416
85	20.35	13.57	66.08	16.82	11.21	71.97	18.45	12.73	68.82	4.409
86	19.58	13.06	67.37	16.12	10.75	73.12	17.72	12.23	70.04	4.403
87	18.80	12.54	68.66	15.43	10.29	74.28	16.99	11.73	71.28	4.396
88	18.02	12.02	69.96	14.74	9.83	75.43	16.26	11.23	72.52	4.389
89	17.23	11.49	71.28	14.05	9.37	76.59	15.52	10.71	73.76	4.382
90	16.44	10.96	72.60	13.36	8.90	77.74	14.79	10.20	75.01	4.375
91	15.64	10.43	73.93	12.66	8.44	78.89	14.04	9.69	76.26	4.368
92	14.84	9.90	75.27	11.97	7.99	80.04	13.30	9.19	77.51	4.360
93	14.03	9.36	76.62	11.28	7.53	81.20	12.56	8.67	78.77	4.353
94	13.21	8.81	77.97	10.59	7.06	82.35	11.81	8.15	80.05	4.346
95	12.39	8.27	79.34	9.89	6.60	83.50	11.05	7.64	81.31	4.339
96	11.57	7.71	80.72	9.21	6.13	84.66	10.30	7.11	82.59	4.332
97	10.73	7.16	82.11	8.51	5.68	85.82	9.54	6.59	83.87	4.325
98	9.90	6.60	83.50	7.82	5.21	86.96	8.79	6.06	85.15	4.318
99	9.05	6.04	84.91	7.13	4.76	88.12	8.02	5.54	86.44	4.310
100	8.20	5.47	86.32	6.43	4.29	89.27	7.25	5.01	87.74	4.303
101	7.35	4.90	87.75	5.75	3.83	90.42	6.49	4.48	89.03	4.296
102	6.49	4.33	89.19	5.06	3.37	91.57	5.72	3.95	90.33	4.288
103	5.62	3.75	90.63	4.36	2.91	92.73	4.95	3.42	91.64	4.281
104	4.74	3.16	92.09	3.67	2.44	93.89	4.17	2.87	92.96	4.274
105	3.86	2.58	93.56	2.97	1.99	95.04	3.39	2.34	94.27	4.266
106	2.98	1.99	95.04	2.29	1.53	96.18	2.61	1.80	95.59	4.259
107	2.08	1.39	96.53	1.59	1.06	97.35	1.82	1.26	96.92	4.251

A-BLENDS

	A-17	A-24	A-31	A-40	A-46	A-55	A-60	A-67	A-70	A-75	A-80	A-85	A-91	A-108
WEIGHT%														
PRO	0.00	0.00	0.00	8.88	15.15	25.03	30.78	39.17	42.89	49.26	55.87	62.73	71.29	100.00
ISO	0.00	50.00	100.00	91.12	84.85	74.97	69.22	60.83	57.11	50.74	44.13	37.27	28.71	0.00
NOR	100.00	50.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MOLE%														
PRO	0.00	0.00	0.00	11.38	19.05	30.56	36.95	45.91	49.75	56.13	62.53	68.93	76.60	100.00
ISO	0.00	50.00	100.00	88.62	80.95	69.44	63.05	54.09	50.25	43.87	37.47	31.07	23.40	0.00
NOR	100.00	50.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LIQ VOL%														
PRO	0.00	0.00	0.00	9.76	16.54	27.04	33.04	41.68	45.46	51.86	58.42	65.13	73.37	100.00
ISO	0.00	50.86	100.00	90.24	83.46	72.96	66.96	58.32	54.54	48.14	41.58	34.87	26.63	0.00
NOR	100.00	49.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LB/GL	4.864	4.780	4.699	4.654	4.622	4.573	4.545	4.505	4.488	4.458	4.427	4.396	4.358	4.234
SG 60 °F	0.583	0.573	0.563	0.558	0.554	0.548	0.545	0.540	0.538	0.534	0.531	0.527	0.522	0.507

VAPOR PRESSURE (PSIG)

TEMP °F	A-17	A-24	A-31	A-40	A-46	A-55	A-60	A-67	A-70	A-75	A-80	A-85	A-91	A-108
-40	-11.2	-10.6	-10.0	-8.7	-7.8	-6.5	-5.8	-4.7	-4.3	-3.6	-2.8	-2.1	-1.2	1.5
-35	-11.1	-10.2	-9.4	-7.9	-6.9	-5.5	-4.6	-3.5	-3.0	-2.2	-1.3	-0.5	0.5	3.5
-30	-10.8	-9.8	-8.7	-7.1	-6.0	-4.3	-3.4	-2.1	-1.5	-0.6	0.3	1.2	2.3	5.7
-25	-10.5	-9.2	-7.9	-6.1	-4.9	-3.0	-2.0	-0.6	0.1	1.1	2.1	3.1	4.4	8.1
-20	-10.1	-8.6	-7.1	-5.1	-3.7	-1.6	-0.5	1.1	1.8	2.9	4.1	5.2	6.6	10.8
-15	-9.6	-7.9	-6.2	-3.9	-2.4	-0.1	1.2	2.9	3.7	5.0	6.2	7.5	9.0	13.7
-10	-9.0	-7.1	-5.1	-2.6	-1.0	1.6	3.0	4.9	5.8	7.2	8.6	10.0	11.7	16.8
-5	-8.3	-6.1	-4.0	-1.2	0.6	3.4	4.9	7.1	8.0	9.6	11.1	12.7	14.5	20.2
0	-7.5	-5.1	-2.7	0.3	2.3	5.4	7.1	9.4	10.5	12.2	13.9	15.6	17.6	23.8
5	-6.5	-4.0	-1.4	1.9	4.2	7.5	9.4	12.0	13.1	15.0	16.8	18.7	20.9	27.7
10	-5.5	-2.7	0.1	3.7	6.2	9.8	11.9	14.7	16.0	18.0	20.0	22.1	24.5	31.9
15	-4.4	-1.3	1.8	5.7	8.4	12.4	14.6	17.7	19.0	21.2	23.5	25.7	28.3	36.5
20	-3.1	0.2	3.6	7.9	10.7	15.1	17.5	20.9	22.3	24.7	27.2	29.6	32.5	41.3
25	-1.7	1.9	5.5	10.2	13.3	18.0	20.6	24.3	25.9	28.5	31.1	33.8	36.9	46.5
30	-0.2	3.7	7.6	12.7	16.1	21.2	24.0	28.0	29.7	32.5	35.4	38.2	41.6	52.0
35	1.4	5.6	9.9	15.4	19.0	24.6	27.6	31.9	33.8	36.8	39.9	43.0	46.7	57.9
40	3.2	7.8	12.4	18.3	22.2	28.2	31.5	36.1	38.1	41.4	44.7	48.1	52.0	64.2
45	5.1	10.0	15.0	21.4	25.6	32.1	35.6	40.6	42.8	46.3	49.9	53.5	57.8	70.8
50	7.2	12.5	17.9	24.7	29.3	36.2	40.0	45.4	47.7	51.5	55.4	59.2	63.8	77.9
55	9.4	15.1	20.9	28.3	33.2	40.6	44.7	50.5	53.0	57.1	61.2	65.3	70.3	85.4
60	11.8	18.0	24.2	32.1	37.4	45.3	49.7	55.9	58.6	63.0	67.4	71.8	77.1	93.3
65	14.3	21.0	27.7	36.1	41.8	50.3	55.0	61.6	64.5	69.2	73.9	78.7	84.3	101.6
70	17.0	24.2	31.4	40.4	46.5	55.6	60.6	67.7	70.7	75.8	80.9	85.9	92.0	110.5
75	20.0	27.7	35.4	45.0	51.5	61.2	66.6	74.1	77.4	82.8	88.2	93.6	100.0	119.8
80	23.1	31.3	39.6	49.9	56.8	67.1	72.9	80.9	84.4	90.1	95.9	101.7	108.6	129.6
85	26.4	35.2	44.1	55.0	62.4	73.4	79.5	88.1	91.8	97.9	104.0	110.2	117.5	140.0
90	29.9	39.4	48.8	60.4	68.3	80.0	86.5	95.7	99.6	106.1	112.6	119.1	127.0	150.8
95	33.7	43.8	53.9	66.2	74.5	87.0	93.9	103.6	107.8	114.7	121.6	128.6	136.9	162.2
100	37.6	48.4	59.2	72.3	81.1	94.3	101.7	112.0	116.4	123.8	131.1	138.5	147.3	174.2
105	41.9	53.3	64.8	78.7	88.0	102.1	109.9	120.8	125.5	133.3	141.1	148.9	158.2	186.8
110	46.3	58.5	70.7	85.4	95.3	110.2	118.4	130.0	135.0	143.3	151.5	159.8	169.7	200.0
115	51.1	64.0	76.9	92.4	102.9	118.7	127.5	139.7	145.0	153.7	162.5	171.2	181.7	213.8
120	56.1	69.7	83.4	99.9	111.0	127.6	136.9	149.9	155.4	164.7	173.9	183.2	194.3	228.2
125	61.4	75.8	90.2	107.6	119.4	137.0	146.8	160.5	166.4	176.2	186.0	195.8	207.5	243.3
130	66.9	82.2	97.4	115.8	128.2	146.8	157.2	171.6	177.8	188.2	198.5	208.9	221.3	259.1

Figure 8

NP-BLENDS

	NP-31	NP-40	NP-46	NP-50	NP-52	NP-55	NP-60	NP-61	NP-65	NP-70	NP-75	NP-80	NP-85	NP-90
WEIGHT%														
PRO	12.02	20.18	25.86	29.75	31.73	34.74	39.88	40.92	45.17	50.62	56.24	62.03	68.01	74.18
ISO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NOR	87.98	79.82	74.14	70.25	68.27	65.26	60.12	59.08	54.83	49.38	43.76	37.97	31.99	25.82
MOLE%														
PRO	15.26	24.99	31.50	35.82	37.99	41.23	46.65	47.72	52.06	57.47	62.88	68.29	73.70	79.11
ISO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NOR	84.74	75.01	68.50	64.18	62.01	58.77	53.35	52.28	47.94	42.53	37.12	31.71	26.30	20.89
LIQ VOL%														
PRO	13.57	22.51	28.61	32.73	34.81	37.95	43.25	44.31	48.62	54.08	59.62	65.24	70.95	76.75
ISO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NOR	86.43	77.49	71.39	67.27	65.19	62.05	56.75	55.69	51.38	45.92	40.38	34.76	29.05	23.25
LB/GL	4.779	4.722	4.684	4.658	4.645	4.625	4.592	4.585	4.558	4.523	4.488	4.453	4.417	4.380
SG 60 °F	0.573	0.566	0.561	0.558	0.557	0.554	0.550	0.549	0.546	0.542	0.538	0.534	0.529	0.525

VAPOR PRESSURE (PSIG)

TEMP °F	NP-31	NP-40	NP-46	NP-50	NP-52	NP-55	NP-60	NP-61	NP-65	NP-70	NP-75	NP-80	NP-85	NP-90
-40	-9.3	-8.0	-7.2	-6.6	-6.4	-6.0	-5.3	-5.1	-4.6	-3.9	-3.2	-2.5	-1.8	-1.2
-35	-8.8	-7.4	-6.5	-5.8	-5.5	-5.0	-4.3	-4.1	-3.5	-2.7	-1.9	-1.1	-0.3	0.5
-30	-8.3	-6.7	-5.6	-4.9	-4.5	-4.0	-3.1	-2.9	-2.2	-1.3	-0.4	0.5	1.4	2.3
-25	-7.7	-5.8	-4.6	-3.8	-3.4	-2.8	-1.8	-1.6	-0.8	0.2	1.2	2.2	3.2	4.3
-20	-6.9	-4.9	-3.5	-2.6	-2.2	-1.5	-0.4	-0.1	0.8	1.9	3.0	4.2	5.3	6.4
-15	-6.0	-3.8	-2.3	-1.3	-0.7	0.0	1.3	1.5	2.5	3.8	5.0	6.3	7.6	8.8
-10	-5.0	-2.5	-0.9	0.3	0.8	1.6	3.0	3.3	4.4	5.8	7.2	8.6	10.0	11.4
-5	-3.9	-1.2	0.7	1.9	2.5	3.5	5.0	5.3	6.5	8.1	9.6	11.1	12.7	14.2
0	-2.7	0.4	2.4	3.7	4.4	5.4	7.1	7.5	8.8	10.5	12.2	13.9	15.6	17.3
5	-1.3	2.0	4.3	5.7	6.5	7.6	9.4	9.8	11.3	13.2	15.0	16.9	18.7	20.6
10	0.2	3.8	6.3	7.9	8.7	9.9	12.0	12.4	14.0	16.0	18.0	20.1	22.1	24.1
15	1.9	5.8	8.5	10.3	11.1	12.5	14.7	15.1	16.9	19.1	21.3	23.5	25.7	27.9
20	3.7	8.0	10.9	12.8	13.8	15.2	17.6	18.1	20.0	22.4	24.8	27.2	29.6	32.0
25	5.6	10.3	13.4	15.5	16.6	18.1	20.8	21.3	23.4	26.0	28.6	31.2	33.8	36.4
30	7.7	12.8	16.2	18.5	19.6	21.3	24.1	24.7	27.0	29.8	32.6	35.4	38.3	41.1
35	10.0	15.5	19.2	21.6	22.9	24.7	27.8	28.4	30.8	33.9	36.9	40.0	43.0	46.1
40	12.5	18.4	22.4	25.0	26.3	28.3	31.6	32.3	34.9	38.2	41.5	44.8	48.1	51.4
45	15.1	21.5	25.8	28.6	30.1	32.2	35.7	36.5	39.3	42.9	46.4	50.0	53.5	57.1
50	17.9	24.8	29.4	32.5	34.0	36.3	40.1	40.9	44.0	47.8	51.6	55.4	59.3	63.1
55	21.0	28.4	33.3	36.6	38.2	40.7	44.8	45.6	48.9	53.0	57.1	61.3	65.4	69.5
60	24.2	32.1	37.4	41.0	42.7	45.4	49.8	50.7	54.2	58.6	63.0	67.4	71.8	76.2
65	27.6	36.1	41.8	45.6	47.5	50.3	55.0	56.0	59.8	64.5	69.2	73.9	78.7	83.4
70	31.3	40.4	46.5	50.5	52.5	55.6	60.6	61.6	65.7	70.7	75.8	80.8	85.9	91.0
75	35.2	44.9	51.4	55.7	57.9	61.1	66.5	67.6	71.9	77.3	82.7	88.1	93.5	98.9
80	39.3	49.7	56.6	61.2	63.5	67.0	72.8	73.9	78.5	84.3	90.1	95.8	101.6	107.4
85	43.7	54.8	62.2	67.1	69.5	73.2	79.4	80.6	85.5	91.7	97.8	103.9	110.1	116.2
90	48.4	60.1	68.0	73.2	75.8	79.8	86.3	87.6	92.9	99.4	105.9	112.5	119.0	125.6
95	53.3	65.8	74.2	79.7	82.5	86.7	93.6	95.0	100.6	107.6	114.5	121.5	128.4	135.4
100	58.5	71.8	80.7	86.6	89.5	94.0	101.4	102.8	108.7	116.1	123.5	130.9	138.3	145.7
105	64.0	78.1	87.5	93.8	96.9	101.6	109.5	111.0	117.3	125.2	133.0	140.8	148.7	156.5
110	69.8	84.7	94.7	101.4	104.7	109.7	118.0	119.7	126.3	134.6	142.9	151.3	159.6	167.9
115	75.9	91.7	102.3	109.4	112.9	118.2	127.0	128.7	135.8	144.6	153.4	162.2	171.0	179.8
120	82.3	99.1	110.3	117.7	121.5	127.1	136.4	138.2	145.7	155.0	164.3	173.6	182.9	192.3
125	89.1	106.8	118.7	126.5	130.5	136.4	146.2	148.2	156.1	165.9	175.8	185.6	195.5	205.3
130	96.3	115.0	127.5	135.8	139.9	146.2	156.6	158.6	167.0	177.4	187.8	198.2	208.6	218.9

Figure 9

NIP-BLENDS

	NIP-31	NIP-40	NIP-46	NIP-50	NIP-52	NIP-55	NIP-60	NIP-61	NIP-65	NIP-70	NIP-75	NIP-80	NIP-85	NIP-90
WEIGHT%														
PRO	7.50	16.00	21.90	26.00	28.00	31.20	36.50	37.60	42.10	47.80	53.70	59.80	66.10	72.60
ISO	37.00	33.60	31.20	29.60	28.80	27.50	25.40	25.00	23.20	20.90	18.50	16.10	13.60	11.00
NOR	55.50	50.40	46.90	44.40	43.20	41.30	38.10	37.40	34.70	31.30	27.80	24.10	20.30	16.40
MOLE%														
PRO	9.66	20.07	26.99	31.65	33.89	37.41	43.11	44.27	48.94	54.69	60.46	66.22	71.99	77.74
ISO	36.14	31.97	29.17	27.34	26.44	25.02	22.76	22.33	20.46	18.14	15.80	13.53	11.24	8.94
NOR	54.21	47.96	43.85	41.01	39.67	37.57	34.14	33.40	30.60	27.17	23.74	20.25	16.77	13.32
LIQ VOL%														
PRO	8.41	17.75	24.11	28.47	30.58	33.94	39.44	40.57	45.17	50.92	56.78	62.76	68.84	75.01
ISO	37.40	33.58	30.95	29.21	28.34	26.95	24.73	24.30	22.43	20.06	17.63	15.22	12.76	10.24
NOR	54.19	48.67	44.94	42.32	41.07	39.11	35.83	35.13	32.41	29.02	25.59	22.02	18.40	14.75
LB/GL	4.749	4.697	4.661	4.636	4.625	4.606	4.575	4.568	4.542	4.510	4.477	4.443	4.409	4.375
SG 60 °F	0.569	0.563	0.559	0.556	0.554	0.552	0.548	0.547	0.544	0.540	0.536	0.532	0.528	0.524

VAPOR PRESSURE (PSIG)

TEMP °F	NIP-31	NIP-40	NIP-46	NIP-50	NIP-52	NIP-55	NIP-60	NIP-61	NIP-65	NIP-70	NIP-75	NIP-80	NIP-85	NIP-90
-40	-9.6	-8.3	-7.4	-6.9	-6.6	-6.2	-5.5	-5.3	-4.7	-4.0	-3.3	-2.6	-1.9	-1.2
-35	-9.1	-7.6	-6.6	-6.0	-5.7	-5.2	-4.4	-4.2	-3.6	-2.8	-2.0	-1.2	-0.4	0.4
-30	-8.5	-6.8	-5.7	-5.0	-4.7	-4.1	-3.2	-3.0	-2.3	-1.4	-0.5	0.4	1.3	2.2
-25	-7.8	-5.9	-4.7	-3.9	-3.5	-2.9	-1.9	-1.7	-0.9	0.2	1.2	2.2	3.2	4.2
-20	-7.0	-4.9	-3.6	-2.7	-2.2	-1.5	-0.4	-0.2	0.7	1.9	3.0	4.1	5.3	6.4
-15	-6.1	-3.8	-2.3	-1.3	-0.8	0.0	1.2	1.5	2.5	3.8	5.0	6.3	7.5	8.8
-10	-5.1	-2.6	-0.9	0.2	0.8	1.6	3.0	3.3	4.4	5.8	7.2	8.6	10.0	11.4
-5	-4.0	-1.2	0.7	1.9	2.5	3.4	5.0	5.3	6.5	8.1	9.6	11.1	12.7	14.2
0	-2.7	0.3	2.4	3.7	4.4	5.4	7.1	7.4	8.8	10.5	12.2	13.9	15.6	17.3
5	-1.4	2.0	4.2	5.7	6.4	7.6	9.4	9.8	11.3	13.1	15.0	16.8	18.7	20.6
10	0.1	3.8	6.2	7.9	8.7	9.9	11.9	12.3	14.0	16.0	18.0	20.1	22.1	24.1
15	1.8	5.8	8.4	10.2	11.1	12.4	14.6	15.1	16.9	19.1	21.3	23.5	25.7	27.9
20	3.6	7.9	10.8	12.8	13.7	15.2	17.5	18.0	20.0	22.4	24.8	27.2	29.6	32.0
25	5.5	10.3	13.4	15.5	16.5	18.1	20.7	21.2	23.3	25.9	28.6	31.2	33.8	36.4
30	7.6	12.8	16.2	18.4	19.5	21.3	24.1	24.6	26.9	29.8	32.6	35.4	38.3	41.1
35	9.9	15.5	19.1	21.6	22.8	24.7	27.7	28.3	30.8	33.8	36.9	40.0	43.0	46.1
40	12.4	18.3	22.3	25.0	26.3	28.3	31.6	32.2	34.9	38.2	41.5	44.8	48.1	51.4
45	15.0	21.4	25.7	28.6	30.0	32.2	35.7	36.4	39.3	42.8	46.4	50.0	53.5	57.1
50	17.9	24.8	29.4	32.5	34.0	36.3	40.1	40.8	44.0	47.8	51.6	55.4	59.3	63.1
55	20.9	28.3	33.2	36.6	38.2	40.7	44.8	45.6	48.9	53.0	57.1	61.3	65.4	69.5
60	24.1	32.1	37.4	41.0	42.7	45.4	49.7	50.6	54.2	58.6	63.0	67.4	71.8	76.2
65	27.6	36.1	41.8	45.6	47.4	50.3	55.0	56.0	59.8	64.5	69.2	74.0	78.7	83.4
70	31.3	40.4	46.5	50.5	52.5	55.6	60.6	61.6	65.7	70.7	75.8	80.9	85.9	91.0
75	35.2	44.9	51.4	55.8	57.9	61.2	66.5	67.6	72.0	77.4	82.8	88.2	93.6	99.0
80	39.3	49.7	56.7	61.3	63.6	67.1	72.8	73.9	78.6	84.3	90.1	95.9	101.6	107.4
85	43.8	54.8	62.2	67.2	69.6	73.3	79.4	80.6	85.6	91.7	97.8	104.0	110.1	116.3
90	48.4	60.2	68.1	73.4	75.9	79.9	86.3	87.7	93.0	99.5	106.0	112.5	119.1	125.6
95	53.4	65.9	74.3	79.9	82.6	86.8	93.7	95.1	100.7	107.6	114.6	121.5	128.5	135.4
100	58.6	71.9	80.8	86.8	89.6	94.1	101.4	102.9	108.9	116.2	123.6	131.0	138.4	145.7
105	64.1	78.3	87.7	94.0	97.0	101.8	109.6	111.1	117.5	125.3	133.1	140.9	148.8	156.6
110	70.0	84.9	94.9	101.6	104.8	109.9	118.1	119.8	126.5	134.8	143.1	151.4	159.7	168.0
115	76.1	92.0	102.5	109.6	113.0	118.4	127.1	128.9	136.0	144.7	153.5	162.3	171.1	179.9
120	82.6	99.3	110.5	118.0	121.6	127.3	136.5	138.4	145.9	155.2	164.5	173.8	183.1	192.3
125	89.4	107.1	118.9	126.8	130.7	136.7	146.4	148.3	156.3	166.1	175.9	185.8	195.6	205.4
130	96.5	115.2	127.7	136.1	140.1	146.4	156.7	158.8	167.2	177.6	187.9	198.3	208.7	219.0

Figure 10

Aerosol Systems

Aerosol systems can be homogeneous or heterogeneous. In a homogeneous system, the concentrate is completely miscible with the propellant, forming a solution. The system consists of a liquid and vapor phase. Conversely, heterogeneous systems result when part or all of the concentrate are immiscible with the propellant.

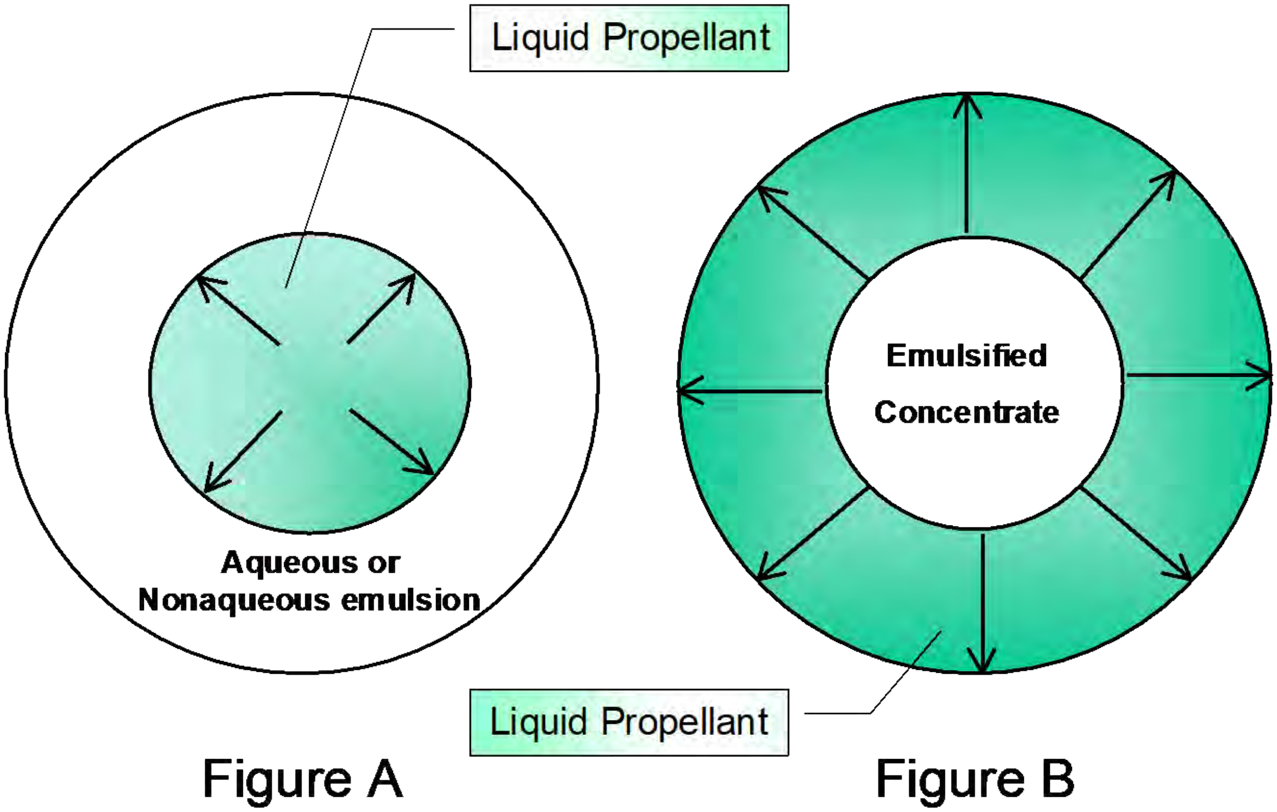
Hydrocarbon propellants are nonpolar in nature and exhibit poor solubility to strong polar compounds such as aqueous systems. Where compatible with the concentrate, a cosolvent such as ethyl alcohol can be used to form a solution system. Solvents and cosolvents usually act as vapor pressure depressants and the resulting vapor pressure is often unpredictable by application of Raoult's Law due to deviations from ideality. This characteristic should be considered when selecting a proper liquefied gas aerosol propellant. The quantity and composition of the liquefied gas aerosol propellant selected can influence the characteristics of the spray from the solution system.

Increasing the quantity and vapor pressure of propellant within an aerosol container will be effective in producing a fine spray that tends to stay suspended in the air (i.e. room deodorant). For directional sprays, such as personal products, it would be desirable to use a smaller quantity of propellant with a lower vapor pressure. Use of vapor tap valves will, in many instances, assist in breaking up the concentrate, resulting in a drier and warmer spray. Adequate allowances should be made to compensate for physical loss of propellant through the vapor tap.

Heterogeneous aerosol systems can be three phase or emulsion type. In the three-phase system the hydrocarbon propellant and concentrate form two separate liquid phases with a vapor phase above. In an emulsion system, one liquid phase is finely dispersed in the other leaving no definite phase boundary between the two. The finely dispersed liquid is also called the discrete phase and the other, the continuous phase.

Emulsion systems may be oil in water or vice versa depending upon whether oil or water forms the discrete phase. An emulsifying agent or surfactant is usually added to form a stable emulsion that can be discharged with uniform composition from the aerosol container.

Depending upon the type of emulsion system, the hydrocarbon liquefied gas aerosol propellant can form either the internal or external phase in the container discharge. If the propellant forms the internal phase (Fig. A), then it must vaporize and pass through the emulsion formulation to escape into the atmosphere. This results in the formation of a foam.



The discharge would be a spray type when the propellant is present in the external phase (Fig. B), in the dispensed droplet. The phase change of the propellant from a liquid to a vapor aids in the breakup of the spray into fine particles or droplets. The propellant from the external phase escapes directly into the atmosphere, leaving behind droplets of the formulation, which form the spray.

In a three-phase system, the active ingredients are present in the aqueous phase with the hydrocarbon propellant floating on top. Part of the propellant vaporizes to fill the headspace. The container pressure obtained would then closely approach the propellant vapor pressure. The discharge from such systems would tend to be wet. Mechanical break up of discharge from such a system is achieved by proper valve selection. Shaking the can may help to disperse the propellant into the concentrate.

Product Safety Information

Toxicity

Hydrocarbon Propellants

Hydrocarbon propellants consist essentially of isobutane, n-butane, propane or mixtures thereof. These products are normally stored as liquefied gases under pressure. When these liquids are released to atmospheric pressure, rapid evaporation occurs resulting in reduced temperatures at the point of evaporation. Exposure of tissue to evaporating liquid can result in freezing. Precautions should be taken to avoid contact of liquid with eyes, skin, or respiratory system. Tissue damaged by exposure to evaporating liquid should be treated as frozen tissue (Frostbite).

Hydrocarbon aerosol propellants are categorized in Underwriters Laboratory Toxicity Classification as Group 5b, indicating a low degree of toxicity. Inhalation of vapor concentrations of 1% gas in air will produce a slight anesthetic effect. Mixtures containing 10% (by volume) gas in air may produce dizziness within an exposure time of 10 minutes. Deliberate inhalation of large concentrations may result in brain damage or death due to asphyxiation. The vapors produce no systemic toxic effects on prolonged or repeated sub acute exposures. Due to low solubility, the materials are rapidly eliminated from the body when inhalation of the gas stops. The effects are not cumulative. Inasmuch as these materials will not remain in a nutrient, oral toxicity has not been investigated. The Food and Drug Administration of the U.S. Department of Health, Education and Welfare considers these materials as substances which are Generally Recognized as Safe for use in contact with human foods. (Reference, Section 184.1, Food Additives Regulations, Code of Federal Regulations Title 21, Food and Drugs.)

Dimethyl Ether

Dimethyl Ether has low acute and chronic toxicity. The main physiological action is that of a weak anesthesia at high-inhaled levels. Weak cardiac sensitization has been observed in animals exposed to Dimethyl Ether at about 200,000 ppm, a circumstance which would likely occur only in gross misuse situations or accidental release of the propellant.

A two-year inhalation study and carcinogenicity bioassay at exposure levels of up to 20,000 ppm showed no compound-related effects in the test animals examined for gross signs, body weight, hematology, urine analysis, blood chemistry, and gross and histopatholigic examination of tissues at any exposure level. Dimethyl Ether showed no signs of carcinogenicity in the study and in separate reproductive studies, Dimethyl Ether has shown no evidence of mutagenicity or teratogenicity.

1, 1 Difluoroethane (152a)

Hydrofluorocarbon 152a has a low order of toxicity on both an acute and chronic basis. The main physiological action of 152a is that of a weak anesthesia at high-inhaled levels. Its 4-hour Approximate Lethal Concentration (ALC) in rats is 383,000 ppm. Its oral Approximate Lethal Dose (ALD) is greater than 1500 mg/kg in rats. Cardiac sensitization occurred in dogs exposed to a concentration of 150,000 ppm in air and an intravenous epinephrine challenge. Effects of repeated exposure include increased urinary fluorides, reduced kidney weight, and reversible kidney changes. The effects of a single, high oral dose include weight loss and lethargy.

Tests in animals demonstrate no carcinogenic activity or developmental effects. Tests in animals for reproductive effects have not been performed. 152a does not produce genetic damage in bacterial cell cultures but has not been tested in animals.

1,1,1,2 Tetrafluoroethane (134a)

The four-hour Approximate Lethal Concentration (ALC) for 134a in rats is 567,000 ppm. Single exposure caused cardiac sensitization at 75,000 ppm, lethargy, narcosis, and increases respiratory rates. Single exposure to near lethal doses caused pulmonary edema. Repeated exposure caused increased adrenals, liver, and spleen weight and decrease uterine and prostrate weight. Repeated dosing of higher concentrations caused temporary tremors and incoordination.

In a two-year inhalation study, 134a, at a concentration of 50,000 ppm, produced an increase in late occurring benign testicular tumors, testicular hyperplasia and testicular weight. The no-effect-level for this study was 10,000 ppm. Animal data show slight fetotoxicity but only at exposure levels producing other toxic effects in the adult animal. Reproductive data on male mice show no change in reproductive performance. Tests have shown that this material does not cause genetic damage in bacterial or mammalian cell cultures, or in animals. In animal testing, this material has not caused permanent genetic damage in reproductive cells of mammals (has not produced heritable genetic damage).

COMPONENT	Dupont AEL (ppm)	OSHA PEL (ppm)	ACGIH TLV (ppm)
PROPANE			
ISOBUTANE			
N-BUTANE		800	800
ISOPENTANE		NE	NE
N-PENTANE		600	600
DME	1000	NE	NE
152a	1000	NE	NE
134a	1000	NE	NE
LPG		1000	1000

Flammability

Safe storage and handling of aerosol propellants, especially flammable aerosol propellants, has always been an important matter for the aerosol industry. Table 1 gives the flammability characteristics of the liquefied gas propellants.

TABLE 1 Flammability Characteristics						
	Flammability Limits in Air, % by Volume		Flash Point	Auto Ignition Temp	Heat of Combustion	Vapor Density at 60 °F
	Lower	Upper	°F	°F	BTU/lb (kJ/g)	Air =1
Propane	2.2	9.5	-156	842	19,918 (44.0)	1.55
Isobutane	1.8	8.4	-117	1010	19,589 (42.8)	2.01
n-Butane	1.9	8.5	-101	761	19,657 (43.3)	2.08
152a	3.9	16.9	-58	849	4,937 (6.3)	3.52
134a	Nonflammable	Nonflammable	-	-	0 (0)	2.28
DME	3.3	18.0	-42	662	12,397 (26.5)	1.59

Addition of other components, such as 134a or water may reduce the flammability of an aerosol product. Valve components of the aerosol package can be selected to alter spray characteristics and contribute to reduction of flammability.

TABLE 2 Flammability of 134a Blends		
	Flammable Component	Maximum Concentration of Flammable Component (wt%)
134a and	Hydrocarbons	3
134a and	Dimethyl Ether	3.5
134a and	152a	12

Nonflammable blends of 134a containing flammable components, may, in the event of a leak or spill, fractionate, i.e., the components may separate, producing compositions that are flammable.

Combustibility of 134a

Although 134a is nonflammable at ambient temperatures and atmospheric pressures, 134a is combustible at pressures above atmospheric and air concentrations greater than 60% by volume. This property of 134a should not pose an explosion hazard from aerosol containers using it as a propellant or during normal aerosol filling operations. However, as is common industry practice, air should be removed from aerosol containers before they are filled with 134a.

Spills and Leaks

Hydrocarbon Propellants have a sweet petroleum odor and 152a, 134a, and Dimethyl Ether have a slight ethereal odor that cannot be detected by smell within the combustible range of gas/air mixtures. Extreme caution must be observed at all points of storage and use to avoid uncontrolled release of materials. All sources of ignition must be eliminated within storage or use areas. Work areas must be properly ventilated to avoid accumulation of combustible gas/air mixtures. Monitoring of storage and work areas, by infrared gas detectors, is recommended. In the event of a large spill or leak, evacuate all personnel to minimize exposure to high concentrations of vapor. Personnel should wear a self-contained breathing apparatus if they must enter an area in which a spill or leak occurred.

Electrical Requirements

Electrical Requirements		
Propellant	**Division 1 Location**	**Division 2 Location**
Hydrocarbons, 152a, or blends with 134a	Group D	Non-Sparking or Group D
Dimethyl Ether and blends with134a, 152a, and/or hydrocarbons	Group C	Non-Sparking or Group C
134a	No rating	No rating

New equipment or existing equipment that requires conversion to explosion-proof service, it should be rated for a Class 1, Group C/D service to permit handling all possible propellant blends.

Global Warming Potentials (GWP) and Atmospheric Lifetime (Years)

Global Warming Potentials (GWPs) are intended as a quantified measure of the globally averaged relative radiative forcing impacts of a particular greenhouse gas. It is defined as the cumulative radiative forcing, including both direct and indirect effects, integrated over a period of time from the emission of a unit mass of gas relative to carbon dioxide (CO2). Direct effects occur when the gas itself is a greenhouse gas. Indirect radiative forcing occurs when chemical transformations involving the original gas produce a gas or gases that are greenhouse gases, or when a gas influences other radiatively important processes such as the atmospheric lifetimes of other gases.

Gas	Atmospheric Lifetime	GWP (100 years)	VOC
Carbon Dioxide[b]	See below[b]	1	
Dimethyl Ether (DME)[a]	0.015	1	Yes
1,1 Difluoroethane (152a)[a]	1.4	124	No
1,1,1,2 Tetrafluoroethane (134a)[a]	14	1,430	No
$C_3 - C_4$ Hydrocarbons [c]	< 1	< 4	Yes

[a] *Intergovernmental Panel on Climate Change IPCC/TEAP (2005).*
[b] *The CO_2 response function used is based upon a revised version of the Bern Carbon cycle model (Bern2.5CC; Joos et al. 2001) using a background CO2 concentration value of 378 ppm. The decay of a pulse of CO2 with time t is given by*

$$a_0 + \sum_{i=1}^{3} a_i \cdot e^{-t/\tau_i}$$

Where a0 = 0.217, a1 = 0.259, a2 = 0.338, a3 = 0.186, τ1 = 172.9 years, τ2 = 18.51 years, and τ3 = 1.186 years.
[c] Indirect GWPs from Collins et al. (2002)

Installation Highlights

Installations of liquefied gas aerosol propellant systems are subject to compliance with Federal, State and Local regulations. We recommend retaining competent consultants to assure proper design, installation and performance of the system. Some salient design and installation recommendations are listed below.

Storage Containers - Design and Construction

Containers must be designed and constructed in accordance with the Rules for Construction of Unfired Pressure Vessels under Section VIII, ASME Boiler and Pressure Vessel Code (current edition), available from American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017.

We recommend a design pressure of 250 psig for liquefied gas aerosol propellant containers to allow storage of products exerting maximum vapor pressures, (Propane). We also recommend installation of a manway to permit internal inspection of the tank interior.

Storage Containers - Accessories

All valves, fittings, and accessories connected directly to the storage tank shall be rated for a minimum working pressure of 250 psig. Materials of fabrication and design of such accessories shall be suitable for handling LP gas. Filling, withdrawal and equalizing connections on the storage tank are to be protected by shutoff valves, excess-flow check valves, backflow check valves and quick closing internal valves used individually or in combination. Excess flow valves must close automatically at the specified vapor or liquid flow rate. All connections leading to the excess flow valve must have flow capacity exceeding rated capacity of the excess flow valve. Back flow check valves shall close when the flow is either stopped or reversed. The container must be protected against excessive pressure build up by installing safety relief valves having direct communication with the vapor side of the container. Safety relief valves shall be capable of unobstructed venting.

Storage Containers - Location

Most authorities follow the recommendations of the National Fire Protection Association Pamphlet #58, LP-Gas Code. However, jurisdictional authorities may specify measures other than the recommendations of Pamphlet #58.

Important: Insurance carriers should be consulted prior to installation of system.

The following minimum isolation from buildings or property lines is normally required.

Water Capacity Per Container	Minimum Distance from Bldg. or Property Line
Less than 125 gallons	None
125 to 500 gallons	10 feet
501 to 2,000 gallons	25 feet *
2,001 to 3,0000 gallons	50 feet

* The above distance requirement may be reduced to not less than 10 feet for a single container of 1,200 gallons water capacity or less, providing such a container is at least 25 feet from any other LP Gas container of more than 125 gallons water capacity.

Containers installed for use cannot be stacked one above the other.

The minimum separation between hydrocarbon propellant tanks and flammable liquid tanks must be 20 feet. Flammable liquid tanks should be diked to prevent release of materials to adjacent hydrocarbon propellant storage areas.

Storage tank area should be kept free of debris and fenced to a minimum of 6-ft. height. Two access gates should be provided. 'No Smoking' and/or 'No Open Flames' signs should be posted on all sides of fenced area. Readily ignitable material, such as weeds and dry grass, should be removed from at least 10-feet of the container; greater distances are desirable.

Storage Containers - Sizing

Selection of storage tank capacity is dependent upon:

1 Production requirements
2 Space availability
3 Economics of delivery system
4 Delivery lead time

Liquefied gas aerosol propellants are commonly delivered by two methods: railroad tank cars and tank transports. In most cases, rail delivery is more economical, due to larger volume deliveries, lower freight costs per gallons shipped, and minimum handling. Tank car capacity is approximately 30,500 gallons. Tank transports are available with capacities of 4,000 through 10,000 gallons.

Selection of tank size should allow for the method of delivery normally used.

Delivery Unit Size	Recommended Storage Tank Capacity
4,000 gal. Transport	12,000 gals.
10,000 gal. Transport	18,000 gals.
33,500 gal. Tank Car	30-45,000 gals. *

* *It is desirable to unload tank cars in one continuous operation. Multiples of storage tanks can be provided to accommodate 30,500-gallon tank car deliveries. Containers should not be filled full of liquid propellants. NFPA Pamphlet #58 may be consulted to determine maximum allowable fill volume at the required temperature.*

Piping and Valves

Piping systems should be designed for maximum pressure of the system, taking into account pump and compressor discharge pressures, and hydrostatic relief valve settings. See note below. We recommend the use of extra heavy pipe (Schedule 80) and forged steel pipefittings. Pipe compounds used on threaded fittings should be resistant to the solvent action of hydrocarbon propellants. Valves listed by Underwriters Laboratories, Inc. are recommended as primary shut off and process valves. Piping between shutoff valves to be protected against hydrostatic pressure conditions by installation of hydrostatic relief valves. Provision should be made for settling of containers, pump pads, thermal expansion / contraction or mechanical damage.

Hoses used for handling should be chemically resistant to liquefied gas aerosol propellants. Hoses subject to container pressure should be designed for a bursting pressure of 1750 psig and tested for a minimum of 700 psig. Transfer hoses used inside buildings should not exceed 6 feet in length. Hoses should not be used where temperatures are likely to exceed 125 °F. Transfer hoses for LP gases must be approved by Underwriters' Laboratories or other equivalent nationally recognized authorities.

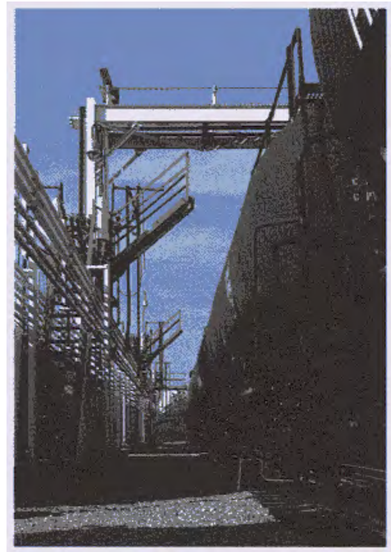
Transfer Systems

Transfer Pumps (Production)

In most applications, liquefied gas aerosol propellants are transferred from storage to production areas in the liquid state at pressures of 50 to 250 psig. Positive displacement pumps, such as vane, gear, rotary and turbine type pumps, are commonly used to transfer liquefied gas propellants to production areas. For flow rates up to 20 gallons per minute, the use of an impeller type pump has been found to be satisfactory. If higher pressures (600 to 800 psig) are required, a second stage liquid pump may be used.

Movement of liquefied gas propellants from the storage container to the production area is subject to interruption by stoppage of the aerosol production line. During these periods of limited or zero demand, it is advisable to provide by-pass relief, returning liquid back to the storage tank, which will permit the continued operation of the transfer pump without developing excessive heat and resultant vapor lock within the pumping system. In addition to the automatic by-pass relief feature, a manually operated by-pass valve is of assistance in establishing liquid flow during production start-up operations. Provision should be made for use of an alternate pump to avoid production down time in the event of mechanical failure. An alternate pump can be permanently installed or retained in maintenance inventory. The system should incorporate a #40 mesh strainer on the pump suction side and a 25-micron filter, with replaceable cartridges on the discharge side. Shut-off valves should be provided both upstream and downstream of the filter to allow isolation when replacing cartridges.

Tank Car Unloading



Tank car unloading into storage tank can best be accomplished by use of a non-lubricated vapor compressor. The system functions by removing vapor from the storage tank and compressing it in the tank car, creating a pressure differential. Transfer rates of 50 to 125 gallons per minute can be anticipated, dependent upon the equipment selected. After unloading liquid, vapor may be recovered from the tank car by reversing direction of vapor flow.

Design of the tank car-unloading riser should consider operator safety and handling ease. Platform type construction with hinged catwalk provides operational advantages. Tank car unloading risers must be equipped with the following safety devices:

(1) An emergency valve with means for manual shutoff and thermal release on liquid hoses at the tank car end of the liquid hose;
(2) Backflow check valves at the riser ends of liquid hose connections;
(3) An emergency valve at each end of the vapor hose with means for manual shutoff and thermal release;
(4) Remote shutoff control.

Emergency shutoff valves must be capable of thermal activation and manual operation from installed and remote locations. Hoses and / or swivel connectors should be capped when not in service. Unloading liquid lines should be fitted with a backflow check valve to prevent inadvertent release of liquid from storage tank. Liquid unloading can be monitored by use of a liquid flow indicator. Unloading risers must be permanently connected to a static electricity ground, with provision for cable attachment to the tank car. Piping to storage tank should be designed to permit tank car unloading without interfering with production.

Transport Unloading

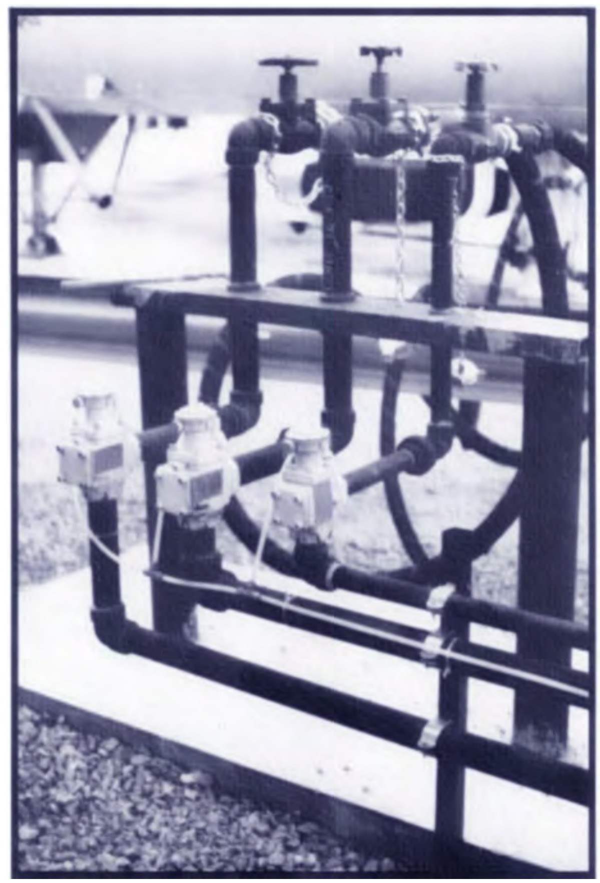
Transports are unloaded by means of a self-contained pumping system or by use of the customer's unloading pump or compressor. Customer installation of unloading pump or compressor allows greater flexibility in receiving propellants by transport. However, it is not uncommon for installations, served exclusively by transport, to rely on the self-contained pumping systems incorporated in dedicated transports. Depending on the pump capacity and restrictions of the delivery system piping, pumping rates of 40 to 140 gallons per minute are considered normal.

The motor carrier normally operates the self-contained pumping system; however, responsible customer personnel must supervise unloading procedures.

Transport unloading risers consist of one liquid line and one vapor balance line between transport and storage container. These risers should be secured firmly by a concrete or steel bulkhead or equivalent anchorage. Liquid and vapor lines connected at the bulkhead should incorporate a shear fitting which will preferentially break away without damaging installations on the plant side, should the transport be inadvertently moved before disconnecting unloading hoses.

Emergency shut-off valves or metal seated backflow check valves capable of thermal activation and manual operation from installed and remote locations must be provided on liquid and vapor lines at the transport-unloading bulkhead. Release of liquid propellant from storage tank, during a transfer emergency, can be prevented by use of backflow check valves installed on liquid lines. Installation of a flow indicator is recommended for monitoring liquid flow. Terminal ends of both liquid and vapor lines on the unloading riser must be provided with shut-off valves and left capped when not in use. Transport unloading installations should be adequately protected against mechanical and malicious damage. Appropriate electrical grounding of delivery and receiving tank is good Industry practice.

Tank Car and Transport Unloading General



1. Tank cars and transports must be attended during unloading.
2. ‘Tank Car Connected' or 'Transport Connected' sign should be posted during unloading.
3. Smoking or open flames should not be permitted in unloading area. Conspicuous warning signs must be posted.
4. Provide fire extinguisher at unloading location (Minimum 12-B, 0 Rating).
5. Personnel responsible for tank car and transport unloading should be instructed regarding safe handling procedures.

Propellant Charging, Pump Rooms and Laboratory

Aerosol Production

Propellants are added to aerosol containers in the propellant charging and pump room. During the process of gassing, some leakage of propellant invariably occurs. However, propellant charging and pump room operations can be kept safe by proper construction and adequate ventilation.

Keeping propellant charging and pump rooms separated a minimum of five feet from the main production building is considered to be the best design. Propellant charging and pump room walls and doors should be capable of withstanding a minimum of 100 pounds per square foot pressure. Deflagration venting panels having a minimum area of 1 square foot per 30 cubic feet of enclosed volume constitutes an important safety feature. They should be designed to vent at a static pressure of no more than 20% of the pressure rating for the main walls. The atmosphere within the propellant charging and pump rooms should be continuously monitored by combustible gas detectors, with appropriate visual and audible indication when activated by released propellant. Safety shutoff valves on propellant supply lines should be interlocked to combustible gas detectors and ventilation system. The propellant supply should be automatically cut off in the event of gas detection or ventilation system failure.

Ventilation of the gassing area is extremely important. Air movement should be non-recirculating and should produce a sweeping flow pattern over the entire floor area of the filling room. There should be no areas in the filling room where insufficient airflow would allow accumulation of flammable vapors.

The required rate of ventilation is determined by the following formula:

$$VR = \frac{(100 - LEL)(V)(R)}{(DL)(LEL)}$$

where,

VR = Required ventilation flow rate, ft^3/min, (m^3/hr.).

LEL = Lower explosive limit for the specific propellant being used, percent by volume. This must be the LEL of the lowest LEL propellant being used. Normally this will be isobutane (Propellant A-31) which is 1.8% at 70 °F (21 °C).

V = Volume of vapor produced per unit volume of liquid propellant being used, ft^3/gal. (m^3/L).

R = Estimated liquid volume of the propellant lost during normal filling operations plus 20 percent for occasional system leaks, gal/min. (L/hr.).

DL = Design level for the maximum percent of the LEL allowable for normal production operations. It is recommended that the design level not exceed 10% of the LEL, i.e. DL = 0.10.

Under no circumstances shall the ventilation rate be less than one air change per minute.

Whenever propellant concentration in the propellant charging and pump rooms reaches 20% of LEL, airflow rate should be increased to 150% of the air flow rate determined above or two air changes per minute, whichever is greater, until the propellant concentration is reduced to normal safe level. Maintaining a slight negative pressure in the propellant charging and pump rooms is recommended to prevent passage of propellant charging and pump rooms atmosphere to other less safe enclosed plant areas. All air from propellant charging and pump rooms should be exhausted at least 10 ft. above roof level. Propellant charging and pump rooms equipment must be properly grounded.

Other safety considerations include the proper design of electrical equipment, sprinkler system, general layout of production and storage areas, and installation of an explosion suppression system. Explosion suppression is a technique by which a flame is detected and suppressed during primary burning stages, preventing development of conditions that could result in an explosion.

Construction of the propellant charging and pump room and other production facilities must comply with local, state and federal regulations. For further information, consult NFPA 30B, Code for the Manufacture and Storage of Aerosol Products. When considering the use of liquefied gas propellants, a thorough examination of existing plant facilities should be conducted to assure compliance with safety standards.

Diversified CPC International provides design and turn-key installations of storage and handling systems and also offers personnel training, plant inspections, and safety audits of propellant storage and handling systems.

Laboratory Handling

Special care must be taken in handling liquefied gas aerosol propellants in the laboratory. The amount of propellants stored in the laboratory should be kept at a minimum. All such containers must be properly capped. Whenever more than a few grams of propellant need to be released, it should always be done under well-ventilated fume hoods, of the one pass type. Cans that need to be punctured to release contents should be adequately grounded. This is especially important for cans containing powders (suspended in propellants), since they are susceptible to buildup of static electricity. Laboratory containers should never be stored full of liquid. To prevent buildup of hydrostatic pressure, part of the liquid in the container should be safely bled out creating a safe volume of vapor space in the container. All laboratory tubing and fittings used for handling propellants should have proper pressure rating and should be constructed of copper or steel. If hoses are used temporarily, it should be ascertained that they are not susceptible to the solvent action of the propellants. When not in use, propellant liquids trapped in tubing should be carefully vented to prevent tube rupture due to hydrostatic pressure buildup. Experiments with propellants should not be conducted near open flames. (Exception: Flame extension tests).

Automatic devices to detect the concentration of gases in the atmosphere are strongly recommended. These devices should give off audible and / or visual alarms and increase ventilation exhaust rates when safe levels of gases are exceeded.

If any container filling of propellant is conducted within a laboratory, it should be treated as a NFPA Class A laboratory unit and all restrictions for a NFPA Class A laboratory are applicable. For Pilot Laboratories, consult NFPA 30B for additional requirements.

Unit Conversion Table

Unit Conversion Table

Linear Measure

Used for measuring distances.

12 inches (“)	= 1 foot
3 feet	= 1 yard
5½ yards	= 1 rod, perch, or pole.
40 rod	= 1 furlong
8 furlongs 1760 yards 5280 feet	= 1 statute mile
3 miles	1 league

Square Measure

Used for computing areas.

144 square inches	= 1 square foot
9 square feet	= 1 square yard
30¼ square yards	= 1 square rod
160 square rods	= 1 acre
640 acres	= 1 square mile

Cubic Measure

Employed for computing volumes.

1726 cubic inches	= 1 cubic foot
27 cubic feet	= 1 cubic yard
144 cubic inches	= 1 board foot
128 cubic feet	= 1 cord
40 cubic feet, merchandise	= 1 shipping ton.

Avoirdupois Weight

The system of weights most commonly used in Great Britain and the United States.

27 1/3 grains	= 1 dram
16 drams 437.5 grains	=1 ounce
16 ounces 7000 grains	= 1 pound
100 pounds	= 1 short hundredweight
112 pounds	= 1 long hundredweight
2000 pounds 20 short hundredweight	= 1 short ton
2240 pounds 20 long hundredweight	= 1 long ton

Dry Measure

The system of units commonly employed for measuring the bulk of “dry commodities" such as grain, vegetables, nuts, and fruit. The dry peck and the dry quart are 16.36 per cent larger than the corresponding liquid measures.

2 pints	= 1quart	= 67.2 cu. In.
8 quarts	= 1peck	= 537.6 cu. In.
4 pecks	= 1 bushel	= 2150.42 cu. In.
105 quarts	= 1 barrel	= 7056.0 cu. In.

Metric Measure
Units Commonly Used

Length	10 millimeters	= 1 centimeter.
	100 centimeters	= 1 meter.
	1000 meters	= 1 kilometer.
Capacity	1000 milliliters	= 1 liter.
	100 liters	= 1 hectoliter.
weight	1000 milligrams	= 1 gram.
	1000 grams	= 1 kilogram.
	1000 kilograms	= 1 metric ton.

Metric Tables

Length	10 millimeters	= 1 centimeter.
	100 centimeters	= 1 meter.
	1000 meters	= 1 kilometer.

Comparison of Metric and Customary (U.S.) Weights and Measures

These tables are based on the U.S. legal standard, which is slightly different from the British standard. Equivalents such as those given here should be used only to the required degree of accuracy. For example, 4 Inches is equal to about 10 centimeters. If greater accuracy is desired, 10.2 centimeters or 102 millimeters may be used.

Length

1 centimeter	= 0.394 inch.
1 inch	= 2.540 centimeters.
1 meter	= 3.281 feet.
1 foot	= 0.305 meter.
1 meter	= 1.094 yards.
1 yard	= 0.914 meter.
1 kilometer	= 0.621 statute mile.
1 statute mile	= 1.609 kilometers.
1 kilometer	= 0.540 nautical mile.
I nautical mile	= 1.853 kilometers.

Unit Conversion Table

Capacity

1 milliliter	= 0.271 U.S. fluid dram.
1 U.S. fluid dram	= 3.697 milliliters.
1 milliliter	= 0.034 U.S. fluid ounce.
1 U.S. fluid ounce	= 29.573 milliliters.
1 liter	= 1.057 U.S. liquid quarts.
1 U.S. liquid quart	= 0.946 liter.
1 liter	= 0.908 U.S. dry quart.
1 U.S. dry quart	= 1.101 liters.
1 liter	= 0.264 U.S. gallon.
1 U.S. gallon	= 3.785 liters.
1 hectoliter	= 2.838 U.S. bushels.
1 U.S. bushel	= 0.3524 hectoliter.

Weight

1 gram	= 15.432 grains.
1 grain	= 0.065 gram.
1 gram	= 0.643 pennyweignt.
1 pennyweight	= 1.555 grams.
1 avoirdupois ounce	= 28.350 grams.
1 gram	= 0.032 troy ounce.
1 troy ounce	= 31.103 grams.
1 kilogram	= 2.205 avoirdupois pounds.
1 avoirdupois pound	= 0.454 kilogram.
1 kilogram	= 2.679 troy pounds.
1 troy pound	= 0.373 kilogram.
1 metric ton	= 0.964 gross or long ton.
1 gross or long ton	= 1.016 metric tons.
1 metric ton	= 1.102 short or net tons.
1 short or net ton	= 0.907 metric ton.

Area

1 square centimeter	= 0.155 square inch.
1 square inch	= 6.452 square centimeters.
1 square meter	= 10.764 square teat.
1 square foot	= 0.0929 square meter.
1 square meter	= 1.196 square yards.
1 square yard	= 0.8361 square meter.
1 square kilometer	= 0.3861 square mile.
1 square mile	= 2.590 square kilometers.
1 hectare	= 2.471 acres.
1 acre	= 0.4047 hectare.

Volume

1 cubic centimeter	= 0.0610 cubic inch
1 cubic inch	= 16.3872 cubic centimeters.
1 cubic meter	= 35.3145 cubic feet.
1 cubic foot	= 0.02832 cubic meter
1 cubic meter	= 1.3079 cubic yards.
1 cubic yard	= 0.7646 cubic meter.
1 liter	= 0.03532 cubic foot.
1 cubic foot	= 28.3162 liters.

Temperature

(°C * 9/5) + 32 = °F
(°F - 32) * 5/9 = °C

Density

1 cu. ft. (U.S.) of water	= 62.37 lb. at 60 °F
1 cu. in. (U.S.) of water	= 0.036 lb. at 60'F.
lbs per gal (U.S.) at 20°C.	= specific gravity at 20/20 °C.* 8.3216
Pounds per gal. (U.S.)	= 0.119826 grams / cc.

Heat Units

1 BTU	= 252 gram calories
	= 1.8 centigrade heat units
	= 10.41 liter·atmospheres
	= 2.930 * 10^{-4} kilowatt hours
1 kilowatt-hours	= 3414 BTU
1 horsepower	= 2545 BTU per hour
	= 0.7457 kilowatts

Pressure

1 Atmosphere	= 14.696 pounds per sq. inch
	= 29.921 Inches of mercury @ 32° F
	= 760 millimeter mercury @ 32 °F
	= 1.033 kilogram per sq. centimeter
	= 1.013 * 10^{-5} Pa = 14.696 psi
1 pound / sq. Inch	= 0.06805 atmospheres
	= 0.07031 kilogram per sq. centimeter
1 kilogram / sq. cm	= 14.223 pounds per sq. inch
	= 0.968 atmosphere
1 Pa	= 1 N/m^2 = 1.451 *10^{-4} psi

Special Conversion Factors

Viscosity

1 centipoise	= 0.01 g./(sec)(cm.)
	= 0.01 poise
	= 2.42 lb/ (hr.) (ft.)
	= 3.60 kg./(hr.) (m)

Thermal Conductivity

1 BTU/(hr)(ft)(°F)	= 1.488 Kcal/(hr)(m)(°C)
	= 241.9 cal/(sec)(cm)(°C)

Heat Transfer Coefficient

1 BTU/(hr)(sq. ft.)(°F)	= 4.883 kcal/(hr)(sq. m)(°C)

Surface Tension

1 dynes/cm	= 6.852 * 10^{-5} lb/ft.

Specific Heat

1 BTU/(lb.)(°F)	= 1.0 cal/(g)(°C)

Values of the Gas Law Constant

R	= 1.9872 cal/(g.mol)(°K)
	= 0.08205 liter-atm./(g. mol) (°K)
	= 0.7302 cubic ft. - atm / (lb mol)(°R)
	= 1.9872 BTU/(lb. mol)(°R)