



SOLSTICE® 454B (R-454B)

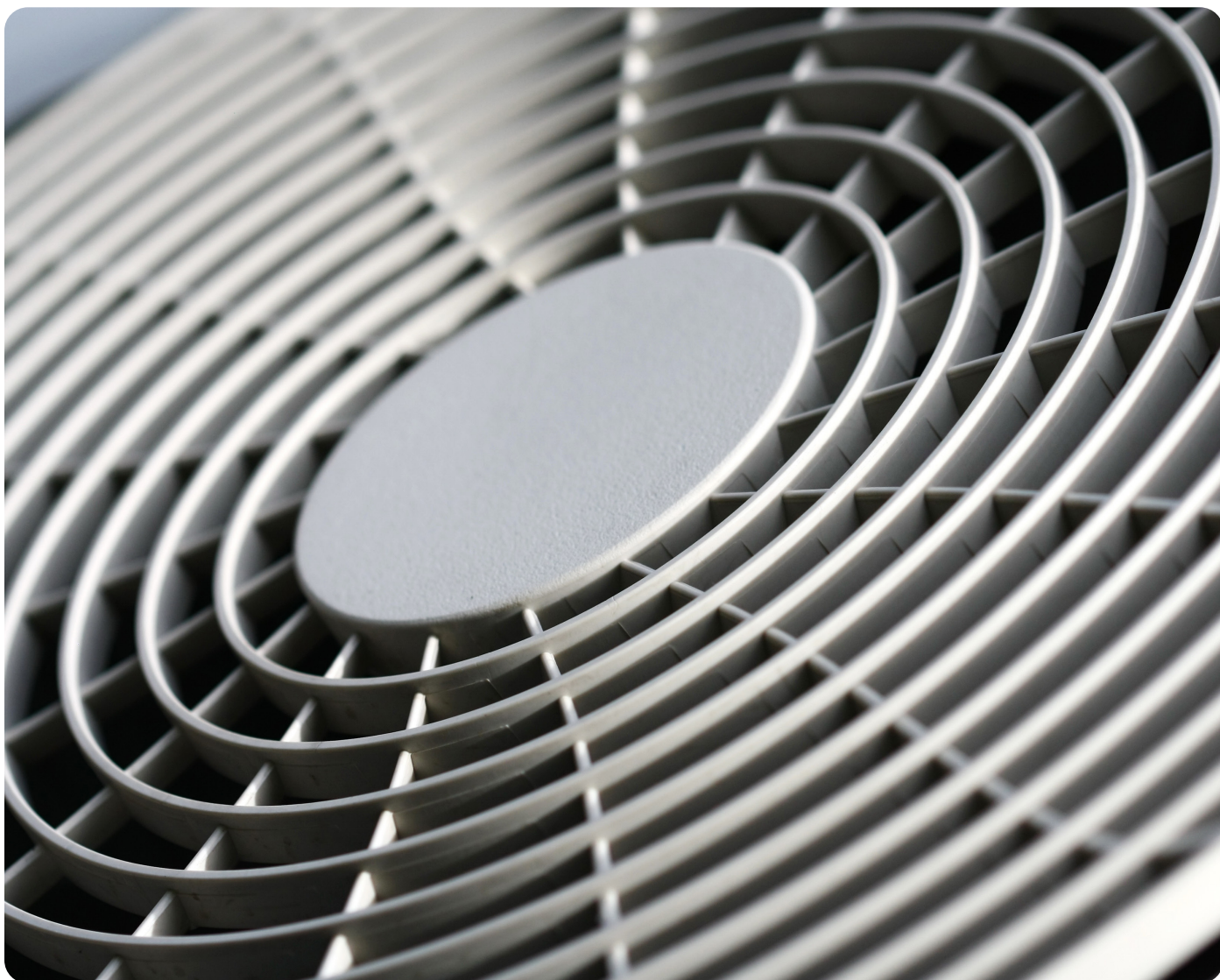


TABLE OF CONTENTS

INTRODUCTION 3

APPLICATIONS 3

EQUIPMENT 3

 Relevant Codes and refrigerant charge limits.....3

 Refrigerant pipe sizing4

 Evaporator and condenser coils5

 Expansion valves.....5

 Pressure regulation valves.....5

 Compressors5

PROPERTIES 5

 Standard Properties.....5

 Thermodynamic Table (English Units)6

 Thermodynamic Table (International Units)8

 Transport Properties (English Units)11

 Transport Properties (International Units)13

 Stability.....15

REGULATORY AND ENVIRONMENTAL 15

STORAGE AND HANDLING 16

CYLINDERS 16

INTRODUCTION

Solstice® 454B (R-454B) is a mildly flammable (A2L) refrigerant having a boiling point of -58.1°F (average of dew and bubble) at 0 psig. R-454B will primarily be used for air conditioning and reversible heating systems, especially in residential and light commercial applications.

The environmental properties of Solstice® 454B (R-454B) include a zero Ozone Depletion Potential (ODP) and a GWP of 467 (AR5).

The properties of R-454B make it an environmentally friendly, safe, easily maintained, energy-efficient, cost-effective and long-term air conditioning solution.

Similar to R-410A, R-454B is a near azeotrope and so has minimal glide.

APPLICATIONS

For applications currently using HFC blends that have become regulated by the Montreal Protocol, Kigali Amendment and the AIM Act, Solstice® 454B (R-454B) provides a practical transition to lowered GWP in long-term refrigeration.

Solstice® 454B (R-454B) has properties very similar to R-410A. With accommodations for the mild flammability of R-454B, it is a good match for equipment previously designed for R-410A. Applications for Solstice® 454B (R-454B) include **(only for new equipment and** subject to regulatory approvals in specific applications):

- Light commercial HVAC
- Residential HVAC
- VRF Systems
- Chillers
- Data centers
- Refrigerated transport

EQUIPMENT

RELEVANT CODES AND REFRIGERANT CHARGE LIMITS

Disclaimer

Codes and regulations are in steady flux. The following interpretations are Solstice's best assessment as of this publication. As manufacturers and code officials acclimate

to new use of A2L refrigerants, expect to see modifications to the codes and their interpretations.

ASHRAE 15 – Safety Standard for Refrigeration Systems

ASHRAE 15 – Safety Standard for Refrigeration Systems is the code generally referred to by local codes such as the International Mechanical Code and the Uniform Mechanical Code. While local jurisdictions may make modifications to the ASHRAE standard to meet local needs, it is by and large the document used to determine safety codes for refrigeration.

Within ASHRAE there are many ways in which an A2L refrigerant such as R-454B can be utilized. A few are highlighted below (see ASHRAE 15 for full details):

- Self-contained commercial occupancy, refrigerant charge < 22lb
 - No restrictions on A2Ls
- >22lb A2L with occupancy other than institutional
 - Calculate EDVC = $RCL \times V_{eff} \times F_{occ}$ (IP)
 - RCL (R-454B) = 0.0031 lb / ft³
 - V_{eff} per ASHRAE 7.2.1 → 7.2.3. Basically, the room volume with some rules
 - F_{occ} = 1
 - For a 15ft x 15ft x 10 ft room this equates to 341lbs

There are some rules about multiple independent circuits that allow more charge when mitigation controls (i.e., leak detection) are used.

ASHRAE also stipulates that a system be “listed” unless used in industrial applications (section 7.7.3). To be listed, a piece of equipment must adhere to UL 60335-2-40 (HVAC) or 60335-2-89 (Refrigeration).

For industrial systems, tables 7-1 and 7-2 in ASHRAE should be followed. These charges will be significantly larger than the commercial systems. It is also important to understand the exceptions (i.e., higher charges) made for industrial and storage coolers and freezers within the code.

ASHRAE 34 – DESIGNATION AND SAFETY CLASSIFICATION OF REFRIGERANTS

ASHRAE 34 provides a system for numbering refrigerants and assigning composition, designating prefixes for refrigerants. Safety classifications based on toxicity and flammability data are included, along with refrigerant concentration limits for the refrigerants. This information is used by the Environmental Protection Agency (EPA) in its refrigerant assessments for the refrigerant Significant New Alternatives Program (SNAP).

EQUIPMENT SAFETY CERTIFICATION (UL)

As noted above, ASHRAE 15 requires UL listing for commercial refrigeration equipment. Due to this, in commercial applications, the UL codes generally drive the maximum refrigerant charge quantities.

The UL standard 60335-2-40 was developed to certify commercial equipment. This standard was developed with the international standard IEC 60335-2-40 as the basis.

The standard includes many sections concerning the manufacture of units. This guide will only relate to the charge limits within the code for A2L refrigerants.

The standard defines several refrigerant mass variables, which are defined as follows (LFL is the lower flammable limit in kg/m³ for the refrigerant used):

- $m_1 = 6 \times \text{LFL}$
- $m_2 = 52 \times \text{LFL}$
- $m_3 = 260 \times \text{LFL}$

Be aware this calculation will provide charges in kg and should be converted to lbs using a “lbs = kg x 2.205” calculation.

REFRIGERANT	m_1 (lb)	m_2 (lb)	m_3 (lb)
Propane	1.1	NA	NA
R454B	8.7	40.3	201
R454C	8.3	33.4	166.8
R455A	12.4	49.4	247.1

Each charge calculation (m_1 , m_2 , m_3) is associated with specific leak-mitigation requirement(s).

The installation location and type of ventilation of the equipment or room also are considered in the charge calculation.

A reading of the UL standard results in the mitigation measures for fixed equipment as listed below. Detailed charges and room areas are expected to be supplied by the manufacturer. The following is for general information only. (refer to UL 60335-2-40 for specifics):

- System charge (or releasable charge) < m_1 :
 - No mitigation required
- System charge > m_1 and < m_2 :
 - For unventilated areas the charge is based on a calculation using LFL, height and area of room or if room area and additional requirements such as continuous (or leak-activated) ventilation are used, the allowable area is increased.
- System charge > m_2 < m_3 – Additional measures such as additional ventilation
- System charge > m_3 : Refer to ASHRAE 15

Note: revisions to the UL standard are being considered that use a “releasable charge” method for charge limits. This may increase the total system charge in certain circumstances.

REFRIGERANT PIPE SIZING

Refrigerant pipe sizes consist of the compressor discharge, condenser return and individual circuit liquid and suction pipes. The correct pipe sizes help to ensure proper oil return and proper pressure drop.

With A2L refrigerants on HVAC systems, the manufacturer is expected to provide line sizes for light-duty split HVAC systems. This is partly to ensure that the refrigerant charge in the system meets the requirements for leak mitigation due to R-454B being an A2L refrigerant.

For built-up systems, line sizes may be needed by the contractor or designer.

The following chart gives comparative suction and liquid pipe sizes for R-454B versus R-410A in air conditioning conditions of +45°F saturated suction temperature. This information shows that R-454B is very close in pressure drop to R-410A systems (it is actually slightly lower in pressure drop for equal line sizes).

As existing R-454B systems are placed into service in systems previously using R-410A,

R-454B systems likely will be able to do this without any pipe-size concerns.

Due to the close performance, it is expected that R-410A line size charts will work well for R-454B systems.

For unique pipe-size situations, please contact Solstice technical support.

Suction sizing comparisons:

CONDITION	LOAD (Btuh)	LINE SIZE H V (in)	PRESSURE DROP (°F)	
			R-454B	R-410A
+45 Suction	6000	1/2 3/8	0.78	0.83
	12000	5/8 1/2	0.79	0.84
110	24000	7/8 5/8	0.59	0.63
Condensing	48000	7/8 5/8	1.94	2.07
100 ft	60000	1-1/8 7/8	0.73	0.79
Equivalent	120000	1-3/8 1-1/8	0.88	0.94
Length (H)*	240000	1-5/8 1-3/8	1.29	1.39
	480000	2-1/8 2-1/8	1.11	1.19

*Plus 10' vertical (V) riser

EVAPORATOR AND CONDENSER COILS

The performance of R-454B in heat exchangers designed for R-410A is expected to have similar performance in comparison to R-410A.

EXPANSION VALVES

The performance of R-454B in expansion valves designed for R-410A is expected to have similar performance in comparison to R-410A.

PROPERTIES

Standard Properties

IP UNITS		
	PROPERTY	
Molecular Weight	62.614	lbm/lb-mol
Boiling Temperature @ 0 Psig	-58.891	F
Critical Temperature	172.587	F
Critical Pressure	763.906	psia
Critical Volume	0.036	ft ³ /lbm
Critical Density	27.658	lbm/ft ³
Saturated Liquid Pressure @ 77°F	227.827	psia
Saturated Vapor Pressure @ 77°F	219.868	psia
Vapor Density @ 0 Psig Boiling Point	0.212	lbm/ft ³
Vapor Density @ 77°F	3.167	lbm/ft ³
Vapor Pressure @ 77°F	219.868	psia
Liquid Density @ 32°F	67.514	lbm/ft ³
Liquid Density @ 77°F	61.468	lbm/ft ³
Liquid Heat Capacity @ 77°F	0.430	Btu/lbm-R
Vapor Heat Capacity @ 77°F	0.343	Btu/lbm-R
Liquid Thermal Conductivity @ 77°F	0.061	Btu/(h-ft-R)
Vapor Thermal Conductivity @ 77°F	0.009	Btu/(h-ft-F)
Liquid Viscosity @ 77°F	0.000077	λbm/ft-sec
Vapor Viscosity @ 77°F	0.000009	λβm/ft-sec

Suction sizing comparisons:

CONDITION	LOAD (Btuh)	LINE SIZE (in)	PRESSURE DROP (°F)	
			R-454B	R-410A
+45 Suction	6000	3/8	0.78	0.1
	12000	3/8	0.79	0.34
110	24000	3/8	0.59	1.17
Condensing	48000	1/2	1.94	0.91
100 ft	60000	1/2	0.73	1.36
Equivalent	120000	5/8	0.88	1.53
Length (H)*	240000	7/8	1.29	0.93
	480000	1-1/8	1.11	0.92

NOTES:

- Refer to equipment manufacturer details for piping practices
- Pressure drop in lines kept below 20F equivalent-saturation temperature change
- Liquid drain line velocity kept below 100fpm
- All sizes indicate outside dimensions type K or L copper tubing
- Equivalent length should include equivalent length for fittings. Refer to ASHRAE guidelines.

PRESSURE REGULATION VALVES

Existing models of pressure-regulating valves are suitable for use with R-454B.

COMPRESSORS

R-454B is now a primary replacement for R-410A. Due to this, compressors are—and will continue to be—available. The components in R-454B (R-32 / R-1234yf) are well-known fluids and should pose no complications for compressor manufacturers. R-454B generally uses POE oil. The exact oil used should be as recommended by the compressor manufacturer.

SI UNITS		
PROPERTY		
Molecular Weight	62.6	g/mol
Boiling Temperature @ 101.325kpa	-50.5	C
Critical Temperature	78.1	C
Critical Pressure	5267	kPA (abs)
Critical Volume	2.257	m³/kg
Critical Density	443.0	kg/m³
Saturated Liquid Pressure @ 25°C	1570.8	kPA (abs)
Saturated Vapor Pressure @ 25°C	1515.9	kPA (abs)
Vapor Density @ 101.325 Kpa Boiling Pt	3.401	kg/m³
Vapor Density @ 25°C	50.724	kg/m³
Vapor Pressure @ 25°C	1515.940	kPA (abs)
Liquid Density @ 0°C	1081.47	kg/m³
Liquid Density @ 25°C	984.63	kg/m³
Liquid Heat Capacity @ 25°C	1.80	KJ/kg-K
Vapor Heat Capacity @ 25°C	1.43	KJ/kg-K
Liquid Thermal Conductivity @ 25°C	106.085	W/m-K
Vapor Thermal Conductivity @ 25°C	15.078	W/m-K
Liquid Viscosity @ 25°C	4.20E+01	µPa-s
Vapor Viscosity @ 25°C	2.34E+01	µPa-s

REFRIGERATION GRADE SPECIFICATIONS	
Molecular Weight	62.6
Assay: Minimum Weight percent of all Fluorocarbons	99.5
Moisture, maximum weight percent	0.00
Non-Volatile Residue, maximum volume percent	0.01
Chloride, maximum weight percent	0.0003
Total Acidity (mg KOH/gm)	0.0015

THERMODYNAMIC TABLE (ENGLISH UNITS)

PRESSURE	LIQUID TEMP	VAPOR TEMP	LIQUID VOLUME	VAPOR VOLUME	LIQUID DENSITY	VAPOR DENSITY	LIQUID ENTHALPY	VAPOR ENTHALPY	LIQUID ENTROPY	VAPOR ENTROPY	LIQUID CV	VAPOR CV	LIQUID CP	VAPOR CP
psig	°F	°F	ft³/lb	ft³/lb	lb/ft³	lb/ft³	Btu/lb	Btu/lb	Btu/lb-F	Btu/lb-F	Btu/lb-F	Btu/lb-F	Btu/lb-F	Btu/lb-F
0	-58.98	-57.5	0.0129	4.5192	77.27	0.22	55.28	192.14	0.182	0.523	0.2193	0.159	0.352	0.2018
5	-48.16	-46.42	0.0131	3.4307	76.21	0.29	59.11	193.52	0.1914	0.5175	0.2185	0.1637	0.3544	0.2088
10	-39.34	-37.53	0.0133	2.7709	75.33	0.36	62.25	194.61	0.1989	0.5133	0.2181	0.1676	0.3567	0.2148
15	-31.82	-29.97	0.0134	2.3268	74.57	0.43	64.95	195.52	0.2053	0.5099	0.2179	0.1709	0.3589	0.2202
20	-25.23	-23.34	0.0135	2.0069	73.89	0.5	67.32	196.28	0.2107	0.5071	0.2178	0.1739	0.361	0.225
25	-19.34	-17.42	0.0136	1.765	73.27	0.57	69.46	196.95	0.2156	0.5046	0.2178	0.1766	0.363	0.2296
30	-14	-12.05	0.0138	1.5755	72.7	0.63	71.41	197.54	0.22	0.5025	0.2179	0.179	0.365	0.2338
35	-9.11	-7.13	0.0139	1.423	72.17	0.7	73.2	198.06	0.2239	0.5006	0.218	0.1812	0.367	0.2378
40	-4.58	-2.57	0.014	1.2974	71.68	0.77	74.87	198.53	0.2276	0.4989	0.2182	0.1833	0.3689	0.2416
45	-0.36	1.68	0.014	1.1921	71.22	0.84	76.44	198.96	0.231	0.4973	0.2183	0.1852	0.3708	0.2453
50	3.6	5.66	0.0141	1.1026	70.78	0.91	77.91	199.35	0.2342	0.4958	0.2185	0.1871	0.3726	0.2488
55	7.34	9.41	0.0142	1.0254	70.36	0.98	79.31	199.71	0.2371	0.4945	0.2187	0.1888	0.3744	0.2523
60	10.87	12.96	0.0143	0.9583	69.95	1.04	80.64	200.04	0.24	0.4932	0.2189	0.1904	0.3762	0.2556
65	14.23	16.34	0.0144	0.8993	69.57	1.11	81.91	200.34	0.2426	0.4921	0.2191	0.192	0.3779	0.2589
70	17.43	19.55	0.0144	0.847	69.2	1.18	83.12	200.62	0.2451	0.491	0.2193	0.1934	0.3797	0.2621
75	20.49	22.63	0.0145	0.8004	68.84	1.25	84.29	200.88	0.2476	0.4899	0.2195	0.1949	0.3814	0.2652
80	23.42	25.57	0.0146	0.7585	68.49	1.32	85.41	201.12	0.2499	0.4889	0.2195	0.1962	0.3832	0.2683
85	26.24	28.41	0.0147	0.7206	68.15	1.39	86.5	201.35	0.2521	0.488	0.2199	0.1975	0.3849	0.2713
90	28.95	31.13	0.0147	0.6863	67.83	1.46	87.54	201.56	0.2542	0.4871	0.2202	0.1988	0.3866	0.2744

PRESSURE	LIQUID TEMP	VAPOR TEMP	LIQUID VOLUME	VAPOR VOLUME	LIQUID DENSITY	VAPOR DENSITY	LIQUID ENTHALPY	VAPOR ENTHALPY	LIQUID ENTROPY	VAPOR ENTROPY	LIQUID CV	VAPOR CV	LIQUID CP	VAPOR CP
psig	°F	°F	ft³/lb	ft³/lb	lb/ft³	lb/ft³	Btu/lb	Btu/lb	Btu/lb-F	Btu/lb-F	Btu/lb-F	Btu/lb-F	Btu/lb-F	Btu/lb-F
95	31.57	33.76	0.0148	0.6549	67.51	1.53	88.56	201.75	0.2562	0.4862	0.2204	0.2	0.3883	0.2773
100	34.1	36.3	0.0149	0.6262	67.2	1.6	89.54	201.94	0.2582	0.4854	0.2206	0.2012	0.39	0.2803
105	36.55	38.75	0.0149	0.5999	66.89	1.67	90.5	202.11	0.2601	0.4846	0.2209	0.2024	0.3917	0.2832
110	38.92	41.13	0.015	0.5755	66.6	1.74	91.43	202.27	0.262	0.4838	0.2211	0.2035	0.3934	0.2862
115	41.22	43.44	0.0151	0.553	66.31	1.81	92.34	202.42	0.2637	0.4831	0.2213	0.2046	0.3951	0.2891
120	43.45	45.68	0.0152	0.5321	66.02	1.88	93.23	202.56	0.2655	0.4824	0.2215	0.2057	0.3968	0.292
125	45.63	47.86	0.0152	0.5126	65.75	1.95	94.09	202.69	0.2672	0.4817	0.2218	0.2067	0.3985	0.2949
130	47.74	49.99	0.0153	0.4944	65.47	2.02	94.93	202.81	0.2688	0.481	0.222	0.2077	0.4003	0.2978
135	49.8	52.05	0.0153	0.4774	65.2	2.09	95.76	202.92	0.2704	0.4803	0.2222	0.2087	0.402	0.3007
140	51.82	54.07	0.0154	0.4614	64.94	2.17	96.57	203.03	0.272	0.4797	0.2225	0.2097	0.4037	0.3036
145	53.78	56.04	0.0155	0.4464	64.68	2.24	97.36	203.13	0.2735	0.4791	0.2227	0.2107	0.4055	0.3066
150	55.69	57.96	0.0155	0.4323	64.42	2.31	98.14	203.22	0.275	0.4785	0.2229	0.2116	0.4072	0.3095
155	57.57	59.83	0.0156	0.419	64.17	2.39	98.9	203.3	0.2764	0.4779	0.2232	0.2126	0.409	0.3124
160	59.4	61.67	0.0157	0.4064	63.92	2.46	99.65	203.38	0.2778	0.4773	0.2234	0.2135	0.4107	0.3154
165	61.19	63.47	0.0157	0.3945	63.68	2.53	100.39	203.45	0.2792	0.4767	0.2236	0.2144	0.4125	0.3184
170	62.95	65.22	0.0158	0.3832	63.43	2.61	101.11	203.52	0.2806	0.4762	0.2239	0.2153	0.4143	0.3214
175	64.67	66.95	0.0158	0.3725	63.19	2.68	101.82	203.58	0.2819	0.4756	0.2241	0.2161	0.4161	0.3244
180	66.36	68.64	0.0159	0.3623	62.96	2.76	102.52	203.63	0.2832	0.4751	0.2244	0.217	0.418	0.3274
185	68.02	70.29	0.0159	0.3526	62.72	2.84	103.21	203.68	0.2845	0.4745	0.2246	0.2178	0.4198	0.3305
190	69.64	71.92	0.016	0.3434	62.49	2.91	103.89	203.73	0.2857	0.474	0.2248	0.2187	0.4217	0.3336
195	71.24	73.52	0.0161	0.3346	62.26	2.99	104.56	203.77	0.287	0.4735	0.2251	0.2195	0.4236	0.3367
200	72.8	75.08	0.0161	0.3262	62.03	3.07	105.22	203.8	0.2882	0.473	0.2253	0.2203	0.4255	0.3398
205	74.35	76.62	0.0162	0.3181	61.81	3.14	105.87	203.83	0.2894	0.4725	0.2256	0.2211	0.4274	0.343
210	75.86	78.14	0.0162	0.3104	61.58	3.22	106.52	203.86	0.2906	0.472	0.2258	0.2219	0.4293	0.3462
215	77.35	79.63	0.0163	0.303	61.36	3.3	107.15	203.88	0.2917	0.4715	0.226	0.2227	0.4313	0.3494
220	78.81	81.09	0.0164	0.2959	61.14	3.38	107.78	203.9	0.2929	0.471	0.2263	0.2235	0.4333	0.3527
225	80.26	82.53	0.0164	0.2891	60.92	3.46	108.4	203.91	0.294	0.4706	0.2265	0.2243	0.4353	0.356
230	81.68	83.95	0.0165	0.2825	60.71	3.54	109.01	203.92	0.2951	0.4701	0.2268	0.2251	0.4373	0.3594
235	83.07	85.35	0.0165	0.2763	60.49	3.62	109.62	203.93	0.2962	0.4696	0.227	0.2258	0.4394	0.3628
240	84.45	86.72	0.0166	0.2702	60.28	3.7	110.21	203.93	0.2972	0.4692	0.2273	0.2266	0.4415	0.3662
245	85.81	88.08	0.0166	0.2644	60.07	3.78	110.81	203.93	0.2983	0.4687	0.2275	0.2274	0.4436	0.3697
250	87.15	89.41	0.0167	0.2587	59.86	3.86	111.39	203.92	0.2994	0.4683	0.2278	0.2281	0.4458	0.3733
255	88.47	90.73	0.0168	0.2533	59.65	3.95	111.97	203.91	0.3004	0.4678	0.228	0.2288	0.448	0.3769
260	89.77	92.02	0.0168	0.2481	59.44	4.03	112.55	203.9	0.3014	0.4674	0.2283	0.2296	0.4502	0.3805
265	91.05	93.3	0.0169	0.243	59.23	4.11	113.12	203.89	0.3024	0.4669	0.2285	0.2303	0.4524	0.3842
270	92.32	94.57	0.0169	0.2381	59.03	4.2	113.68	203.87	0.3034	0.4665	0.2288	0.231	0.4547	0.3879
275	93.57	95.81	0.017	0.2334	58.82	4.28	114.24	203.84	0.3044	0.4661	0.229	0.2318	0.4571	0.3917
280	94.8	97.04	0.0171	0.2288	58.62	4.37	114.79	203.82	0.3054	0.4656	0.2293	0.2325	0.4594	0.3956
285	96.02	98.25	0.0171	0.2244	58.41	4.46	115.34	203.79	0.3063	0.4652	0.2295	0.2332	0.4618	0.3995
290	97.22	99.45	0.0172	0.2201	58.21	4.54	115.89	203.76	0.3073	0.4648	0.2298	0.2339	0.4643	0.4035
295	98.41	100.64	0.0172	0.216	58.01	4.63	116.43	203.72	0.3082	0.4644	0.2301	0.2346	0.4668	0.4076
300	99.59	101.8	0.013	0.2119	57.81	4.72	116.97	203.68	0.3091	0.4639	0.2303	0.2353	0.4693	0.4118
305	100.75	102.96	0.0174	0.208	57.61	4.81	117.5	203.64	0.3101	0.4635	0.2306	0.236	0.4719	0.416
310	101.89	104.1	0.0174	0.2042	57.41	4.9	118.03	203.59	0.311	0.4631	0.2308	0.2367	0.4745	0.4203
315	103.03	105.23	0.0175	0.2005	57.21	4.99	118.55	203.55	0.3119	0.4627	0.2311	0.2374	0.4772	0.4246
320	104.15	106.34	0.0175	0.1969	57.01	5.08	119.07	203.49	0.3128	0.4623	0.2314	0.2381	0.48	0.4291
325	105.26	107.44	0.0176	0.1934	56.81	5.17	119.59	203.44	0.3137	0.4618	0.2316	0.2388	0.4828	0.4336
330	106.35	108.53	0.0177	0.19	56.61	5.26	120.1	203.38	0.3145	0.4614	0.2319	0.2395	0.4856	0.4382
335	107.44	109.61	0.0177	0.1867	56.42	5.36	120.61	203.32	0.3154	0.461	0.2322	0.2402	0.4885	0.443
340	108.51	110.68	0.0178	0.1835	56.22	5.45	121.12	203.26	0.3163	0.4606	0.2325	0.2409	0.4915	0.4478
345	109.57	111.73	0.0178	0.1804	56.02	5.54	121.62	203.19	0.3171	0.4602	0.2327	0.2415	0.4946	0.4527

PRESSURE	LIQUID TEMP	VAPOR TEMP	LIQUID VOLUME	VAPOR VOLUME	LIQUID DENSITY	VAPOR DENSITY	LIQUID ENTHALPY	VAPOR ENTHALPY	LIQUID ENTROPY	VAPOR ENTROPY	LIQUID CV	VAPOR CV	LIQUID CP	VAPOR CP
psig	°F	°F	ft³/lb	ft³/lb	lb/ft³	lb/ft³	Btu/lb	Btu/lb	Btu/lb-F	Btu/lb-F	Btu/lb-F	Btu/lb-F	Btu/lb-F	Btu/lb-F
350	110.62	112.77	0.0179	0.1773	55.82	5.64	122.12	203.13	0.318	0.4598	0.233	0.2422	0.4977	0.4577
355	111.66	113.8	0.018	0.1743	55.63	5.74	122.62	203.05	0.3188	0.4594	0.2333	0.2429	0.5008	0.4629
360	112.69	114.82	0.018	0.1714	55.43	5.83	123.12	202.98	0.3197	0.459	0.2336	0.2436	0.5041	0.4681
365	113.71	115.83	0.0181	0.1686	55.23	5.93	123.61	202.9	0.3205	0.4586	0.2339	0.2442	0.5074	0.4735
370	114.72	116.83	0.0182	0.1658	55.04	6.03	124.1	202.82	0.3213	0.4582	0.2342	0.2449	0.5108	0.479
375	115.72	117.82	0.0182	0.1631	54.84	6.13	124.59	202.74	0.3221	0.4577	0.2345	0.2456	0.5143	0.4846
380	116.71	118.8	0.0183	0.1605	54.64	6.23	125.08	202.65	0.323	0.4573	0.2348	0.2463	0.5178	0.4904
385	117.69	119.77	0.0184	0.1579	54.45	6.33	125.56	202.56	0.3238	0.4569	0.2351	0.2469	0.5215	0.4963
390	118.66	120.74	0.0184	0.1554	54.25	6.43	126.04	202.47	0.3246	0.4565	0.2354	0.2476	0.5252	0.5023
395	119.62	121.69	0.0185	0.1529	54.05	6.54	126.52	202.37	0.3254	0.4561	0.2357	0.2483	0.5291	0.5085
400	120.57	122.63	0.0186	0.1505	53.86	6.64	127	202.28	0.3262	0.4557	0.236	0.2489	0.533	0.5149
405	121.51	123.56	0.0186	0.1482	53.66	6.75	127.47	202.17	0.327	0.4553	0.2363	0.2496	0.5371	0.5214
410	122.45	124.49	0.0187	0.1459	53.46	6.85	127.95	202.07	0.3277	0.4549	0.2366	0.2503	0.5412	0.5281
415	123.38	125.41	0.0188	0.1436	53.26	6.96	128.42	201.96	0.3285	0.4545	0.237	0.251	0.5455	0.535
420	124.3	126.31	0.0188	0.1414	53.07	7.07	128.89	201.85	0.3293	0.454	0.2373	0.2516	0.5499	0.542
425	125.21	127.21	0.0189	0.1392	52.87	7.18	129.36	201.74	0.3301	0.4536	0.2376	0.2523	0.5544	0.5493
430	126.11	128.11	0.019	0.1371	52.67	7.29	129.83	201.62	0.3308	0.4532	0.238	0.253	0.559	0.5568
435	127.01	128.99	0.0191	0.135	52.47	7.4	130.29	201.5	0.3316	0.4528	0.2383	0.2536	0.5638	0.5645
440	127.89	129.87	0.0191	0.133	52.27	7.52	130.76	201.38	0.3324	0.4524	0.2387	0.2543	0.5687	0.5724
445	128.77	130.73	0.0192	0.131	52.07	7.63	131.22	201.26	0.3331	0.452	0.239	0.255	0.5738	0.5806
450	129.65	131.59	0.0193	0.129	51.86	7.75	131.69	201.13	0.3339	0.4515	0.2394	0.2557	0.5791	0.589
455	130.51	132.45	0.0194	0.1271	51.66	7.87	132.15	200.99	0.3346	0.4511	0.2398	0.2564	0.5844	0.5977
460	131.37	133.3	0.0194	0.1252	51.46	7.99	132.61	200.86	0.3354	0.4507	0.2401	0.257	0.59	0.6067
465	132.23	134.13	0.0195	0.1234	51.26	8.11	133.07	200.72	0.3361	0.4503	0.2405	0.2577	0.5958	0.6159
470	133.07	134.97	0.0196	0.1215	51.05	8.23	133.53	200.58	0.3369	0.4498	0.2409	0.2584	0.6017	0.6255
475	133.91	135.79	0.0197	0.1198	50.84	8.35	133.99	200.43	0.3376	0.4494	0.2413	0.2591	0.6079	0.6354
480	134.74	136.61	0.0198	0.118	50.64	8.48	134.45	200.28	0.3384	0.449	0.2417	0.2598	0.6142	0.6457
485	135.57	137.42	0.0198	0.1163	50.43	8.6	134.91	200.13	0.3391	0.4485	0.2421	0.2605	0.6208	0.6563
490	136.39	138.23	0.0199	0.1146	50.22	8.73	135.36	199.97	0.3398	0.4481	0.2425	0.2612	0.6277	0.6673
495	137.2	139.03	0.02	0.1129	50.01	8.86	135.82	199.81	0.3406	0.4476	0.243	0.2619	0.6348	0.6787
500	138.01	139.82	0.0201	0.1112	49.8	8.99	136.28	199.65	0.3413	0.4472	0.2434	0.2626	0.6421	0.6906
505	138.81	140.61	0.0202	0.1096	49.59	9.12	136.74	199.48	0.3421	0.4467	0.2439	0.2633	0.6497	0.7029
510	139.6	141.39	0.0202	0.108	49.37	9.26	137.19	199.3	0.3428	0.4463	0.2443	0.264	0.6577	0.7157
515	140.39	142.16	0.0203	0.1064	49.16	9.39	137.65	199.13	0.3435	0.4458	0.2448	0.2647	0.666	0.729
520	141.18	142.93	0.0204	0.1049	48.94	9.53	138.11	198.95	0.3442	0.4454	0.2453	0.2654	0.6746	0.7429
525	141.95	143.69	0.0205	0.1034	48.72	9.67	138.57	198.76	0.345	0.4449	0.2457	0.2662	0.6835	0.7574
530	142.73	144.45	0.0206	0.1019	48.5	9.82	139.03	198.57	0.3457	0.4444	0.2462	0.2669	0.6929	0.7725
535	143.49	145.2	0.0207	0.1004	48.28	9.96	139.49	198.38	0.3464	0.444	0.2468	0.2676	0.7027	0.7883
540	144.25	145.94	0.0208	0.0989	48.06	10.11	139.95	198.18	0.3472	0.4435	0.2473	0.2684	0.7129	0.8047
545	145.01	146.68	0.0209	0.0975	47.83	10.26	140.41	197.98	0.3479	0.443	0.2478	0.2691	0.7236	0.822
550	145.76	147.41	0.021	0.096	47.61	10.41	140.87	197.77	0.3486	0.4425	0.2484	0.2699	0.7348	0.8401

THERMODYNAMIC TABLE (INTERNATIONAL UNITS)

PRESSURE	LIQUID TEMP	VAPOR TEMP	LIQUID VOLUME	VAPOR VOLUME	LIQUID DENSITY	VAPOR DENSITY	LIQUID ENTHALPY	VAPOR ENTHALPY	LIQUID ENTROPY	VAPOR ENTROPY	LIQUID CV	VAPOR CV	LIQUID CP	VAPOR CP
kPa	°C	°C	m³/kg	m³/kg	kg/m³	kg/m³	kJ/kg	kJ/kg	kJ/kg-K	kJ/kg-K	kJ/kg-K	kJ/kg-K	kJ/kg-K	kJ/kg-K
100	-50.81	-49.87	0.0008	0.2856	1238.54	3.5	128.2	446.77	0.7603	2.1908	0.9185	0.6649	1.4734	0.8438
150	-42.41	-41.42	0.0008	0.195	1214.73	5.13	140.65	451.24	0.8151	2.159	0.914	0.6924	1.4877	0.8849
200	-35.99	-34.97	0.0008	0.1485	1196.04	6.73	150.25	454.5	0.856	2.1368	0.9124	0.7139	1.5013	0.9188
250	-30.73	-29.68	0.0008	0.1201	1180.36	8.32	158.2	457.07	0.889	2.1197	0.912	0.7317	1.5141	0.9483

PRESSURE	LIQUID TEMP	VAPOR TEMP	LIQUID VOLUME	VAPOR VOLUME	LIQUID DENSITY	VAPOR DENSITY	LIQUID ENTHALPY	VAPOR ENTHALPY	LIQUID ENTROPY	VAPOR ENTROPY	LIQUID CV	VAPOR CV	LIQUID CP	VAPOR CP
kPa	°C	°C	m³/kg	m³/kg	kg/m³	kg/m³	kJ/kg	kJ/kg	kJ/kg-K	kJ/kg-K	kJ/kg-K	kJ/kg-K	kJ/kg-K	kJ/kg-K
300	-26.24	-25.15	0.0009	0.1009	1166.67	9.91	165.05	459.17	0.9168	2.1059	0.9123	0.7471	1.5264	0.9748
350	-22.28	-21.18	0.0009	0.087	1154.42	11.49	171.12	460.94	0.941	2.0942	0.9129	0.7607	1.5382	0.9991
400	-18.75	-17.62	0.0009	0.0765	1143.26	13.07	176.59	462.46	0.9625	2.0842	0.9138	0.7729	1.5497	1.0219
450	-15.53	-14.39	0.0009	0.0682	1132.95	14.65	181.6	463.79	0.9819	2.0753	0.9149	0.784	1.5608	1.0435
500	-12.58	-11.42	0.0009	0.0616	1123.34	16.24	186.24	464.96	0.9996	2.0673	0.916	0.7943	1.5717	1.0642
550	-9.85	-8.68	0.0009	0.0561	1114.3	17.83	190.56	466	1.0159	2.0601	0.9173	0.8038	1.5825	1.0841
600	-7.3	-6.11	0.0009	0.0515	1105.74	19.42	194.62	466.93	1.0311	2.0535	0.9186	0.8127	1.5931	1.1034
650	-4.9	-3.71	0.0009	0.0476	1097.59	21.03	198.45	467.76	1.0453	2.0474	0.9199	0.8211	1.6036	1.1222
700	-2.64	-1.44	0.0009	0.0442	1089.8	22.64	202.09	468.51	1.0586	2.0417	0.9212	0.829	1.614	1.1407
750	-0.5	0.71	0.0009	0.0412	1082.32	24.25	205.56	469.2	1.0712	2.0364	0.9226	0.8366	1.6244	1.1589
800	1.53	2.76	0.0009	0.0386	1075.12	25.88	208.88	469.81	1.0832	2.0314	0.924	0.8438	1.6348	1.1768
850	3.48	4.7	0.0009	0.0363	1068.16	27.51	212.07	470.37	1.0946	2.0266	0.9253	0.8508	1.6451	1.1947
900	5.33	6.57	0.0009	0.0343	1061.41	29.16	215.13	470.88	1.1055	2.0221	0.9267	0.8574	1.6555	1.2124
950	7.11	8.36	0.0009	0.0325	1054.86	30.81	218.09	471.33	1.1159	2.0178	0.9281	0.8638	1.6659	1.2301
1000	8.83	10.07	0.001	0.0308	1048.49	32.48	220.95	471.75	1.1259	2.0137	0.9296	0.8701	1.6763	1.2477
1050	10.47	11.73	0.001	0.0293	1042.27	34.16	223.72	472.12	1.1355	2.0097	0.931	0.8761	1.6868	1.2654
1100	12.07	13.32	0.001	0.0279	1036.2	35.84	226.41	472.46	1.1448	2.0059	0.9324	0.882	1.6973	1.2831
1150	13.6	14.86	0.001	0.0266	1030.26	37.55	229.02	472.77	1.1538	2.0022	0.9338	0.8877	1.708	1.301
1200	15.09	16.35	0.001	0.0255	1024.45	39.26	231.56	473.04	1.1624	1.9986	0.9352	0.8933	1.7187	1.3189
1250	16.53	17.8	0.001	0.0244	1018.74	40.98	234.04	473.28	1.1708	1.9952	0.9367	0.8987	1.7296	1.337
1300	17.93	19.2	0.001	0.0234	1013.14	42.72	236.46	473.49	1.179	1.9918	0.9381	0.9041	1.7405	1.3552
1350	19.29	20.56	0.001	0.0225	1007.63	44.48	238.82	473.68	1.1869	1.9885	0.9396	0.9093	1.7516	1.3737
1400	20.62	21.88	0.001	0.0216	1002.21	46.25	241.13	473.84	1.1946	1.9853	0.941	0.9144	1.7629	1.3923
1450	21.91	23.17	0.001	0.0208	996.87	48.03	243.4	473.98	1.2022	1.9822	0.9425	0.9195	1.7743	1.4112
1500	23.16	24.43	0.001	0.0201	991.61	49.82	245.61	474.09	1.2095	1.9792	0.9439	0.9244	1.7859	1.4304
1550	24.39	25.65	0.001	0.0194	986.41	51.64	247.79	474.18	1.2167	1.9762	0.9454	0.9293	1.7976	1.4498
1600	25.58	26.85	0.001	0.0187	981.28	53.47	249.93	474.25	1.2236	1.9732	0.9469	0.9341	1.8096	1.4695
1650	26.75	28.01	0.001	0.0181	976.2	55.31	252.02	474.3	1.2305	1.9703	0.9484	0.9389	1.8218	1.4896
1700	27.89	29.15	0.001	0.0175	971.18	57.17	254.09	474.33	1.2372	1.9675	0.9499	0.9436	1.8342	1.51
1750	29.01	30.27	0.001	0.0169	966.22	59.05	256.12	474.34	1.2437	1.9647	0.9514	0.9482	1.8469	1.5308
1800	30.1	31.36	0.001	0.0164	961.29	60.95	258.11	474.34	1.2502	1.9619	0.9529	0.9528	1.8598	1.552
1850	31.17	32.43	0.001	0.0159	956.41	62.87	260.08	474.31	1.2565	1.9592	0.9544	0.9573	1.873	1.5737
1900	32.22	33.47	0.0011	0.0154	951.57	64.8	262.02	474.27	1.2627	1.9565	0.9559	0.9618	1.8864	1.5957
1950	33.25	34.5	0.0011	0.015	946.77	66.75	263.93	474.21	1.2687	1.9538	0.9574	0.9662	1.9002	1.6183
2000	34.26	35.5	0.0011	0.0146	942	68.73	265.82	474.13	1.2747	1.9512	0.959	0.9706	1.9143	1.6414
2050	35.25	36.49	0.0011	0.0141	937.26	70.72	267.69	474.04	1.2806	1.9486	0.9605	0.9749	1.9288	1.665
2100	36.22	37.46	0.0011	0.0137	932.55	72.74	269.53	473.94	1.2864	1.946	0.9621	0.9793	1.9436	1.6892
2150	37.18	38.41	0.0011	0.0134	927.87	74.77	271.35	473.81	1.2921	1.9434	0.9637	0.9836	1.9588	1.714
2200	38.11	39.34	0.0011	0.013	923.2	76.83	273.15	473.68	1.2977	1.9408	0.9653	0.9878	1.9745	1.7394
2250	39.04	40.26	0.0011	0.0127	918.56	78.92	274.93	473.52	1.3032	1.9383	0.9669	0.9921	1.9905	1.7655
2300	39.95	41.16	0.0011	0.0123	913.93	81.02	276.69	473.36	1.3087	1.9358	0.9685	0.9963	2.007	1.7923
2350	40.84	42.05	0.0011	0.012	909.32	83.15	278.43	473.17	1.3141	1.9333	0.9701	1.0004	2.024	1.8199
2400	41.72	42.93	0.0011	0.0117	904.72	85.3	280.16	472.98	1.3194	1.9307	0.9718	1.0046	2.0415	1.8482
2450	42.58	43.78	0.0011	0.0114	900.14	87.49	281.87	472.76	1.3247	1.9282	0.9734	1.0088	2.0595	1.8774
2500	43.43	44.63	0.0011	0.0111	895.56	89.69	283.57	472.54	1.3299	1.9258	0.9751	1.0129	2.0781	1.9075
2550	44.27	45.46	0.0011	0.0109	890.99	91.93	285.25	472.3	1.335	1.9233	0.9768	1.017	2.0973	1.9386
2600	45.1	46.28	0.0011	0.0106	886.42	94.19	286.92	472.04	1.3401	1.9208	0.9786	1.0211	2.1171	1.9707
2650	45.92	47.09	0.0011	0.0104	881.85	96.48	288.58	471.77	1.3451	1.9183	0.9803	1.0252	2.1376	2.0038
2700	46.72	47.89	0.0011	0.0101	877.29	98.8	290.23	471.49	1.3501	1.9158	0.9821	1.0293	2.1589	2.0381
2750	47.51	48.67	0.0011	0.0099	872.72	101.16	291.86	471.19	1.355	1.9133	0.984	1.0334	2.1808	2.0736

PRESSURE	LIQUID TEMP	VAPOR TEMP	LIQUID VOLUME	VAPOR VOLUME	LIQUID DENSITY	VAPOR DENSITY	LIQUID ENTHALPY	VAPOR ENTHALPY	LIQUID ENTROPY	VAPOR ENTROPY	LIQUID CV	VAPOR CV	LIQUID CP	VAPOR CP
kPa	°C	°C	m³/kg	m³/kg	kg/m³	kg/m³	kJ/kg	kJ/kg	kJ/kg-K	kJ/kg-K	kJ/kg-K	kJ/kg-K	kJ/kg-K	kJ/kg-K
2800	48.29	49.45	0.0012	0.0097	868.15	103.54	293.49	470.88	1.3599	1.9109	0.9858	1.0374	2.2036	2.1103
2850	49.06	50.21	0.0012	0.0094	863.57	105.96	295.1	470.56	1.3647	1.9084	0.9877	1.0415	2.2272	2.1484
2900	49.83	50.96	0.0012	0.0092	858.99	108.41	296.7	470.22	1.3695	1.9059	0.9896	1.0456	2.2518	2.188
2950	50.58	51.71	0.0012	0.009	854.39	110.9	298.3	469.86	1.3743	1.9034	0.9916	1.0497	2.2773	2.2291
3000	51.32	52.44	0.0012	0.0088	849.78	113.42	299.89	469.49	1.379	1.9009	0.9936	1.0538	2.3038	2.2719
3050	52.05	53.16	0.0012	0.0086	845.16	115.99	301.47	469.1	1.3837	1.8984	0.9956	1.0578	2.3315	2.3164
3100	52.77	53.88	0.0012	0.0084	840.52	118.59	303.05	468.7	1.3883	1.8958	0.9977	1.0619	2.3603	2.3628
3150	53.49	54.58	0.0012	0.0082	835.86	121.23	304.62	468.29	1.393	1.8933	0.9999	1.066	2.3904	2.4113
3200	54.19	55.28	0.0012	0.0081	831.18	123.92	306.18	467.85	1.3976	1.8907	1.0021	1.0701	2.4218	2.4619
3250	54.89	55.96	0.0012	0.0079	826.48	126.65	307.74	467.41	1.4021	1.8881	1.0043	1.0743	2.4547	2.5149
3300	55.58	56.64	0.0012	0.0077	821.75	129.43	309.29	466.94	1.4067	1.8855	1.0066	1.0784	2.4892	2.5704
3350	56.26	57.31	0.0012	0.0076	816.99	132.25	310.84	466.46	1.4112	1.8829	1.009	1.0826	2.5253	2.6286
3400	56.93	57.97	0.0012	0.0074	812.2	135.13	312.39	465.96	1.4157	1.8803	1.0114	1.0868	2.5632	2.6897
3450	57.6	58.63	0.0012	0.0072	807.37	138.06	313.94	465.45	1.4202	1.8776	1.0139	1.091	2.6032	2.754
3500	58.26	59.28	0.0012	0.0071	802.51	141.05	315.48	464.91	1.4247	1.8749	1.0165	1.0952	2.6452	2.8217
3550	58.91	59.92	0.0013	0.0069	797.61	144.09	317.03	464.36	1.4291	1.8722	1.0192	1.0995	2.6896	2.8932
3600	59.55	60.55	0.0013	0.0068	792.66	147.19	318.57	463.79	1.4336	1.8695	1.0219	1.1038	2.7364	2.9687
3650	60.19	61.17	0.0013	0.0067	787.67	150.36	320.11	463.2	1.438	1.8667	1.0247	1.1082	2.7861	3.0487
3700	60.82	61.79	0.0013	0.0065	782.63	153.59	321.66	462.59	1.4425	1.8639	1.0276	1.1126	2.8387	3.1336
3750	61.45	62.4	0.0013	0.0064	777.53	156.89	323.2	461.95	1.4469	1.861	1.0306	1.117	2.8946	3.2238
3800	62.06	63.01	0.0013	0.0062	772.38	160.27	324.75	461.3	1.4513	1.8582	1.0337	1.1215	2.9542	3.3201
3850	62.67	63.6	0.0013	0.0061	767.16	163.73	326.31	460.62	1.4558	1.8552	1.0369	1.126	3.0177	3.4225
3900	63.28	64.2	0.0013	0.006	761.87	167.26	327.86	459.92	1.4602	1.8522	1.0402	1.1306	3.0858	3.5323
3950	63.88	64.78	0.0013	0.0059	756.52	170.89	329.43	459.19	1.4647	1.8492	1.0437	1.1352	3.1587	3.65
4000	64.47	65.36	0.0013	0.0057	751.08	174.61	331	458.44	1.4691	1.8461	1.0472	1.14	3.2372	3.7768
4050	65.06	65.93	0.0013	0.0056	745.56	178.43	332.57	457.65	1.4736	1.843	1.0509	1.1448	3.3218	3.9135
4100	65.64	66.5	0.0014	0.0055	739.96	182.36	334.16	456.84	1.4781	1.8398	1.0547	1.1496	3.4134	4.0615
4150	66.22	67.06	0.0014	0.0054	734.25	186.4	335.76	456	1.4826	1.8365	1.0587	1.1546	3.5128	4.2222
4200	66.79	67.61	0.0014	0.0052	728.44	190.56	337.37	455.12	1.4871	1.8331	1.0628	1.1597	3.6212	4.3974
4250	67.35	68.16	0.0014	0.0051	722.51	194.85	338.99	454.21	1.4917	1.8297	1.0671	1.1648	3.7399	4.5892
4300	67.91	68.7	0.0014	0.005	716.46	199.29	340.62	453.26	1.4963	1.8262	1.0716	1.1701	3.8703	4.8001
4350	68.47	69.24	0.0014	0.0049	710.27	203.88	342.28	452.28	1.5009	1.8226	1.0763	1.1755	4.0144	5.0329
4400	69.02	69.77	0.0014	0.0048	703.93	208.65	343.95	451.24	1.5056	1.8189	1.0812	1.1811	4.1746	5.2918
4450	69.56	70.29	0.0014	0.0047	697.43	213.59	345.65	450.16	1.5104	1.815	1.0863	1.1868	4.3536	5.5809
4500	70.1	70.81	0.0014	0.0046	690.75	218.74	347.37	449.03	1.5152	1.811	1.0917	1.1927	4.5552	5.9059
4550	70.64	71.33	0.0015	0.0045	683.87	224.12	349.11	447.84	1.52	1.8069	1.0974	1.1988	4.7838	6.2742
4600	71.17	71.84	0.0015	0.0044	676.76	229.75	350.9	446.58	1.525	1.8027	1.1034	1.2051	5.0457	6.6955
4650	71.69	72.34	0.0015	0.0042	669.4	235.67	352.71	445.26	1.5301	1.7982	1.1098	1.2116	5.3485	7.1812
4700	72.21	72.84	0.0015	0.0041	661.75	241.91	354.58	443.85	1.5352	1.7935	1.1166	1.2184	5.7029	7.748
4750	72.73	73.33	0.0015	0.004	653.77	248.52	356.49	442.36	1.5406	1.7886	1.1239	1.2255	6.1237	8.417
4800	73.24	73.81	0.0015	0.0039	645.41	255.57	358.46	440.76	1.546	1.7834	1.1318	1.233	6.6314	9.2201
4850	73.75	74.29	0.0016	0.0038	636.59	263.12	360.5	439.03	1.5517	1.7779	1.1403	1.2409	7.2563	10.2013
4900	74.25	74.77	0.0016	0.0037	627.24	271.3	362.63	437.16	1.5576	1.772	1.1496	1.2493	8.0448	11.4257
4950	74.75	75.24	0.0016	0.0036	617.22	280.23	364.87	435.11	1.5638	1.7656	1.1598	1.2582	9.0694	12.9977
5000	75.24	75.7	0.0016	0.0034	606.35	290.13	367.25	432.83	1.5704	1.7585	1.1712	1.2679	10.4552	15.0866
5050	75.74	76.15	0.0017	0.0033	594.37	301.31	369.82	430.26	1.5775	1.7507	1.1841	1.2784	12.4296	17.9937
5100	76.22	76.6	0.0017	0.0032	580.85	314.28	372.64	427.28	1.5854	1.7417	1.1991	1.2899	15.4532	22.2994
5150	76.71	77.03	0.0018	0.003	565	330.01	375.87	423.68	1.5944	1.731	1.2171	1.3029	20.6175	29.3237

TRANSPORT PROPERTIES (ENGLISH UNITS)

PRESSURE	LIQUID TEMP	VAPOR TEMP	LIQUID SPEED OF SOUND	VAPOR SPEED OF SOUND	LIQUID THERMAL CONDUCTIVITY	VAPOR THERMAL CONDUCTIVITY	LIQUID VISCOSITY	VAPOR VISCOSITY
psig	°F	°F	ft/s	ft/s	Btu/h-ft-F	Btu/h-ft-F	lb/ft-hr	lb/ft-hr
0	-57.3	77.27	2895.16	610.43	0.091	0.005	0.6835	0.0227
5	-46.42	76.21	2802.97	614.04	0.088	0.005	0.6319	0.0233
10	-37.53	75.33	2726.56	616.45	0.086	0.005	0.5936	0.0238
15	-29.97	74.57	2660.72	618.1	0.085	0.005	0.5633	0.0242
20	-23.34	73.89	2602.52	619.24	0.083	0.006	0.5384	0.0246
25	-17.42	73.27	2550.13	620	0.082	0.006	0.5174	0.025
30	-12.05	72.7	2502.32	620.48	0.081	0.006	0.4992	0.0253
35	-7.13	72.17	2458.23	620.73	0.08	0.006	0.4832	0.0256
40	-2.57	71.68	2417.22	620.81	0.079	0.006	0.469	0.0258
45	1.68	71.22	2378.82	620.73	0.078	0.006	0.4562	0.0261
50	5.66	70.78	2342.65	620.54	0.077	0.006	0.4446	0.0263
55	9.41	70.36	2308.41	620.24	0.076	0.006	0.4339	0.0265
60	12.96	69.95	2275.87	619.86	0.075	0.006	0.4241	0.0267
65	16.34	69.57	2244.83	619.4	0.074	0.006	0.4151	0.0269
70	19.55	69.2	2215.13	618.87	0.074	0.007	0.4066	0.0271
75	22.63	68.84	2186.62	618.29	0.073	0.007	0.3987	0.0273
80	25.57	68.49	2159.2	617.65	0.072	0.007	0.3913	0.0275
85	28.41	68.15	2132.77	616.98	0.072	0.007	0.3843	0.0276
90	31.13	67.83	2107.23	616.26	0.071	0.007	0.3777	0.0278
95	33.76	67.51	2082.51	615.5	0.071	0.007	0.3715	0.0279
100	36.3	67.2	2058.55	614.71	0.07	0.007	0.3656	0.0281
105	38.75	66.89	2035.29	613.89	0.07	0.007	0.3599	0.0282
110	41.13	66.6	2012.68	613.05	0.069	0.007	0.3545	0.0284
115	43.44	66.31	1990.67	612.17	0.069	0.007	0.3494	0.0285
120	45.68	66.02	1969.21	611.28	0.068	0.007	0.3444	0.0286
125	47.86	65.75	1948.28	610.37	0.068	0.007	0.3397	0.0288
130	49.99	65.47	1927.85	609.43	0.067	0.007	0.3352	0.0289
135	52.05	65.2	1907.87	608.48	0.067	0.008	0.3308	0.029
140	54.07	64.94	1888.32	607.51	0.066	0.008	0.3266	0.0292
145	56.04	64.68	1869.18	606.53	0.066	0.008	0.3225	0.0293
150	57.96	64.42	1850.43	605.53	0.066	0.008	0.3186	0.0294
155	59.83	64.17	1832.04	604.52	0.065	0.008	0.3148	0.0295
160	61.67	63.92	1814	603.49	0.065	0.008	0.3111	0.0297
165	63.47	63.68	1796.28	602.46	0.065	0.008	0.3075	0.0298
170	65.22	63.43	1778.88	601.41	0.064	0.008	0.3041	0.0299
175	66.95	63.19	1761.77	600.35	0.064	0.008	0.3007	0.03
180	68.64	62.96	1744.94	599.28	0.063	0.008	0.2974	0.0301
185	70.29	62.72	1728.39	598.2	0.063	0.008	0.2943	0.0302
190	71.92	62.49	1712.09	597.11	0.063	0.008	0.2912	0.0304
195	73.52	62.26	1696.03	596.02	0.062	0.008	0.2882	0.0305
200	75.08	62.03	1680.22	594.91	0.062	0.009	0.2852	0.0306
205	76.62	61.81	1664.62	593.8	0.062	0.009	0.2824	0.0308
210	78.14	61.58	1649.24	592.68	0.062	0.009	0.2796	0.0309
215	79.63	61.36	1634.07	591.55	0.061	0.009	0.2768	0.031
220	81.09	61.14	1619.1	590.42	0.061	0.009	0.2742	0.0312
225	82.53	60.92	1604.32	589.28	0.061	0.009	0.2716	0.0313
230	83.95	60.71	1589.72	588.13	0.06	0.009	0.269	0.0314
235	85.35	60.49	1575.3	586.97	0.06	0.009	0.2665	0.0315
240	86.72	60.28	1561.05	585.81	0.06	0.009	0.264	0.0317

PRESSURE	LIQUID TEMP	VAPOR TEMP	LIQUID SPEED OF SOUND	VAPOR SPEED OF SOUND	LIQUID THERMAL CONDUCTIVITY	VAPOR THERMAL CONDUCTIVITY	LIQUID VISCOSITY	VAPOR VISCOSITY
psig	°F	°F	ft/s	ft/s	Btu/h-ft-F	Btu/h-ft-F	lb/ft-hr	lb/ft-hr
245	88.08	60.07	1546.96	584.65	0.06	0.009	0.2616	0.0318
250	89.41	59.86	1533.02	583.48	0.059	0.009	0.2593	0.0319
255	90.73	59.65	1519.24	582.3	0.059	0.01	0.257	0.0321
260	92.02	59.44	1505.61	581.12	0.059	0.01	0.2547	0.0322
265	93.3	59.23	1492.11	579.93	0.058	0.01	0.2525	0.0323
270	94.57	59.03	1478.75	578.74	0.058	0.01	0.2503	0.0324
275	95.81	58.82	1465.51	577.54	0.058	0.01	0.2481	0.0325
280	97.04	58.62	1452.41	576.34	0.058	0.01	0.246	0.0327
285	98.25	58.41	1439.42	575.14	0.057	0.01	0.2439	0.0328
290	99.45	58.21	1426.55	573.92	0.057	0.01	0.2419	0.0329
295	100.64	58.01	1413.79	572.71	0.057	0.01	0.2399	0.033
300	101.8	57.81	1401.14	571.49	0.057	0.01	0.2379	0.0332
305	102.96	57.61	1388.59	570.27	0.057	0.011	0.2359	0.0333
310	104.1	57.41	1376.14	569.04	0.056	0.011	0.234	0.0334
315	105.23	57.21	1363.79	567.81	0.056	0.011	0.2321	0.0335
320	106.34	57.01	1351.53	566.57	0.056	0.011	0.2303	0.0337
325	107.44	56.81	1339.36	565.33	0.056	0.011	0.2284	0.0338
330	108.53	56.61	1327.28	564.08	0.055	0.011	0.2266	0.0339
335	109.61	56.42	1315.28	562.83	0.055	0.011	0.2248	0.0341
340	110.68	56.22	1303.36	561.58	0.055	0.011	0.223	0.0342
345	111.73	56.02	1291.51	560.33	0.055	0.011	0.2213	0.0343
350	112.77	55.82	1279.74	559.07	0.055	0.012	0.2195	0.0344
355	113.8	55.63	1268.04	557.8	0.054	0.012	0.2178	0.0346
360	114.82	55.43	1256.42	556.53	0.054	0.012	0.2162	0.0347
365	115.83	55.23	1244.85	555.26	0.054	0.012	0.2145	0.0348
370	116.83	55.04	1233.36	553.98	0.054	0.012	0.2128	0.035
375	117.82	54.84	1221.92	552.71	0.054	0.012	0.2112	0.0351
380	118.8	54.64	1210.55	551.42	0.053	0.012	0.2096	0.0352
385	119.77	54.45	1199.23	550.13	0.053	0.012	0.208	0.0354
390	120.74	54.25	1187.96	548.84	0.053	0.013	0.2064	0.0355
395	121.69	54.05	1176.76	547.55	0.053	0.013	0.2048	0.0357
400	122.63	53.86	1165.6	546.25	0.053	0.013	0.2033	0.0358
405	123.56	53.66	1154.5	544.95	0.052	0.013	0.2017	0.0359
410	124.49	53.46	1143.44	543.64	0.052	0.013	0.2002	0.0361
415	125.41	53.26	1132.43	542.33	0.052	0.013	0.1987	0.0362
420	126.31	53.07	1121.47	541.01	0.052	0.013	0.1972	0.0364
425	127.21	52.87	1110.55	539.69	0.052	0.014	0.1957	0.0365
430	128.11	52.67	1099.67	538.37	0.052	0.014	0.1942	0.0367
435	128.99	52.47	1088.84	537.04	0.051	0.014	0.1928	0.0368
440	129.87	52.27	1078.05	535.71	0.051	0.014	0.1913	0.037
445	130.73	52.07	1067.29	534.38	0.051	0.014	0.1899	0.0371
450	131.59	51.86	1056.58	533.04	0.051	0.014	0.1885	0.0373
455	132.45	51.66	1045.9	531.69	0.051	0.015	0.187	0.0374
460	133.3	51.46	1035.26	530.34	0.05	0.015	0.1856	0.0376
465	134.13	51.26	1024.66	528.99	0.05	0.015	0.1842	0.0377
470	134.97	51.05	1014.09	527.63	0.05	0.015	0.1828	0.0379
475	135.79	50.84	1003.55	526.27	0.05	0.015	0.1814	0.0381
480	136.61	50.64	993.05	524.9	0.05	0.015	0.1801	0.0382
485	137.42	50.43	982.58	523.53	0.05	0.016	0.1787	0.0384
490	138.23	50.22	972.14	522.16	0.049	0.016	0.1773	0.0386

PRESSURE	LIQUID TEMP	VAPOR TEMP	LIQUID SPEED OF SOUND	VAPOR SPEED OF SOUND	LIQUID THERMAL CONDUCTIVITY	VAPOR THERMAL CONDUCTIVITY	LIQUID VISCOSITY	VAPOR VISCOSITY
psig	°F	°F	ft/s	ft/s	Btu/h-ft-F	Btu/h-ft-F	lb/ft-hr	lb/ft-hr
495	139.03	50.01	961.73	520.77	0.049	0.016	0.176	0.0388
500	139.82	49.8	951.35	519.39	0.049	0.016	0.1746	0.0389
505	140.61	49.59	941	518	0.049	0.016	0.1732	0.0391
510	141.39	49.37	930.68	516.6	0.049	0.017	0.1719	0.0393
515	142.16	49.16	920.38	515.2	0.049	0.017	0.1706	0.0395
520	142.93	48.94	910.12	513.79	0.049	0.017	0.1692	0.0397
525	143.69	48.72	899.88	512.37	0.048	0.017	0.1679	0.0399
530	144.45	48.5	889.66	510.95	0.048	0.018	0.1666	0.0401
535	145.2	48.28	879.47	509.53	0.048	0.018	0.1652	0.0403
540	145.94	48.06	869.3	508.09	0.048	0.018	0.1639	0.0405
545	146.68	47.83	859.16	506.66	0.048	0.018	0.1626	0.0407
550	147.41	47.61	849.04	505.21	0.048	0.019	0.1613	0.0409
490	138.23	50.22	972.14	522.16	0.049	0.016	0.1773	0.0386

TRANSPORT PROPERTIES (INTERNATIONAL UNITS)

PRESSURE	LIQUID TEMP	VAPOR TEMP	LIQUID SPEED OF SOUND	VAPOR SPEED OF SOUND	LIQUID THERMAL CONDUCTIVITY	VAPOR THERMAL CONDUCTIVITY	LIQUID VISCOSITY	VAPOR VISCOSITY
kPa	°C	°C	m/s	m/s	W/m-K	W/m-K	*Pa-s	*Pa-s
100	-50.81	-49.87	883.657	186.007	0.16	0.01	283.51	9.35
150	-42.41	-41.42	844.282	187.496	0.15	0.01	254.17	9.72
200	-35.99	-34.97	813.596	188.339	0.15	0.01	234.43	10
250	-30.73	-29.68	788.084	188.828	0.14	0.01	219.72	10.23
300	-26.24	-25.15	766.048	189.094	0.14	0.01	208.06	10.42
350	-22.28	-21.18	746.527	189.208	0.14	0.01	198.45	10.59
400	-18.75	-17.62	728.918	189.212	0.13	0.01	190.31	10.75
450	-15.53	-14.39	712.819	189.132	0.13	0.01	183.26	10.89
500	-12.58	-11.42	697.945	188.987	0.13	0.01	177.06	11.02
550	-9.85	-8.68	684.086	188.79	0.13	0.01	171.53	11.13
600	-7.3	-6.11	671.085	188.552	0.13	0.01	166.54	11.24
650	-4.9	-3.71	658.818	188.278	0.13	0.01	162.01	11.35
700	-2.64	-1.44	647.188	187.975	0.12	0.01	157.86	11.45
750	-0.5	0.71	636.115	187.647	0.12	0.01	154.03	11.54
800	1.53	2.76	625.535	187.298	0.12	0.01	150.48	11.63
850	3.48	4.7	615.395	186.93	0.12	0.01	147.17	11.71
900	5.33	6.57	605.648	186.546	0.12	0.01	144.08	11.79
950	7.11	8.36	596.256	186.147	0.12	0.01	141.17	11.87
1000	8.83	10.07	587.187	185.736	0.12	0.01	138.43	11.95
1050	10.47	11.73	578.411	185.313	0.12	0.01	135.83	12.03
1100	12.07	13.32	569.905	184.879	0.11	0.01	133.37	12.11
1150	13.6	14.86	561.647	184.437	0.11	0.01	131.03	12.18
1200	15.09	16.35	553.617	183.986	0.11	0.01	128.8	12.25
1250	16.53	17.8	545.798	183.527	0.11	0.01	126.67	12.33
1300	17.93	19.2	538.176	183.061	0.11	0.01	124.62	12.39
1350	19.29	20.56	530.737	182.588	0.11	0.01	122.67	12.46
1400	20.62	21.88	523.469	182.109	0.11	0.01	120.78	12.53
1450	21.91	23.17	516.36	181.625	0.11	0.01	118.97	12.61
1500	23.16	24.43	509.402	181.135	0.11	0.01	117.23	12.69
1550	24.39	25.65	502.585	180.641	0.11	0.02	115.54	12.78
1600	25.58	26.85	495.9	180.142	0.11	0.02	113.91	12.85
1650	26.75	28.01	489.341	179.638	0.1	0.02	112.34	12.93
1700	27.89	29.15	482.899	179.13	0.1	0.02	110.81	13.01

PRESSURE	LIQUID TEMP	VAPOR TEMP	LIQUID SPEED OF SOUND	VAPOR SPEED OF SOUND	LIQUID THERMAL CONDUCTIVITY	VAPOR THERMAL CONDUCTIVITY	LIQUID VISCOSITY	VAPOR VISCOSITY
kPa	°C	°C	m/s	m/s	W/m-K	W/m-K	*Pa-s	*Pa-s
1750	29.01	30.27	476.568	178.619	0.1	0.02	109.33	13.08
1800	30.1	31.36	470.343	178.103	0.1	0.02	107.89	13.16
1850	31.17	32.43	464.217	177.584	0.1	0.02	106.49	13.23
1900	32.22	33.47	458.185	177.062	0.1	0.02	105.13	13.31
1950	33.25	34.5	452.242	176.536	0.1	0.02	103.8	13.38
2000	34.26	35.5	446.384	176.007	0.1	0.02	102.51	13.46
2050	35.25	36.49	440.606	175.476	0.1	0.02	101.25	13.53
2100	36.22	37.46	434.903	174.941	0.1	0.02	100.02	13.61
2150	37.18	38.41	429.272	174.403	0.1	0.02	98.81	13.68
2200	38.11	39.34	423.709	173.863	0.1	0.02	97.64	13.76
2250	39.04	40.26	418.21	173.32	0.1	0.02	96.48	13.83
2300	39.95	41.16	412.773	172.774	0.1	0.02	95.36	13.91
2350	40.84	42.05	407.393	172.225	0.1	0.02	94.25	13.98
2400	41.72	42.93	402.068	171.674	0.1	0.02	93.17	14.06
2450	42.58	43.78	396.795	171.121	0.1	0.02	92.1	14.14
2500	43.43	44.63	391.571	170.565	0.09	0.02	91.06	14.21
2550	44.27	45.46	386.393	170.006	0.09	0.02	90.03	14.29
2600	45.1	46.28	381.26	169.445	0.09	0.02	89.02	14.37
2650	45.92	47.09	376.169	168.881	0.09	0.02	88.03	14.45
2700	46.72	47.89	371.118	168.315	0.09	0.02	87.05	14.53
2750	47.51	48.67	366.104	167.747	0.09	0.02	86.09	14.61
2800	48.29	49.45	361.127	167.176	0.09	0.02	85.14	14.7
2850	49.06	50.21	356.184	166.603	0.09	0.02	84.2	14.78
2900	49.83	50.96	351.274	166.027	0.09	0.02	83.28	14.86
2950	50.58	51.71	346.394	165.448	0.09	0.02	82.37	14.95
3000	51.32	52.44	341.545	164.867	0.09	0.02	81.47	15.04
3050	52.05	53.16	336.724	164.283	0.09	0.02	80.58	15.13
3100	52.77	53.88	331.93	163.697	0.09	0.02	79.7	15.22
3150	53.49	54.58	327.163	163.108	0.09	0.02	78.83	15.31
3200	54.19	55.28	322.421	162.517	0.09	0.02	77.97	15.4
3250	54.89	55.96	317.702	161.922	0.09	0.03	77.12	15.49
3300	55.58	56.64	313.007	161.325	0.09	0.03	76.28	15.59
3350	56.26	57.31	308.335	160.725	0.09	0.03	75.44	15.69
3400	56.93	57.97	303.684	160.122	0.09	0.03	74.61	15.79
3450	57.6	58.63	299.053	159.515	0.09	0.03	73.79	15.89
3500	58.26	59.28	294.443	158.906	0.09	0.03	72.97	15.99
3550	58.91	59.92	289.853	158.294	0.09	0.03	72.15	16.1
3600	59.55	60.55	285.281	157.678	0.08	0.03	71.35	16.21
3650	60.19	61.17	280.726	157.058	0.08	0.03	70.54	16.32
3700	60.82	61.79	276.19	156.435	0.08	0.03	69.74	16.43
3750	61.45	62.4	271.669	155.808	0.08	0.03	68.95	16.55
3800	62.06	63.01	267.165	155.177	0.08	0.03	68.15	16.67
3850	62.67	63.6	262.675	154.543	0.08	0.03	67.36	16.79
3900	63.28	64.2	258.2	153.904	0.08	0.03	66.57	16.92
3950	63.88	64.78	253.738	153.26	0.08	0.03	65.78	17.05
4000	64.47	65.36	249.288	152.612	0.08	0.03	64.99	17.19
4050	65.06	65.93	244.849	151.959	0.08	0.03	64.2	17.33
4100	65.64	66.5	240.421	151.3	0.08	0.04	63.41	17.47
4150	66.22	67.06	236.001	150.636	0.08	0.04	62.62	17.62
4200	66.79	67.61	231.588	149.966	0.08	0.04	61.83	17.77

PRESSURE	LIQUID TEMP	VAPOR TEMP	LIQUID SPEED OF SOUND	VAPOR SPEED OF SOUND	LIQUID THERMAL CONDUCTIVITY	VAPOR THERMAL CONDUCTIVITY	LIQUID VISCOSITY	VAPOR VISCOSITY
kPa	°C	°C	m/s	m/s	W/m-K	W/m-K	*Pa-s	*Pa-s
4250	67.35	68.16	227.181	149.289	0.08	0.04	61.03	17.93
4300	67.91	68.7	222.778	148.605	0.08	0.04	60.23	18.1
4350	68.47	69.24	218.377	147.914	0.08	0.04	59.42	18.27
4400	69.02	69.77	213.975	147.215	0.08	0.04	58.61	18.46
4450	69.56	70.29	209.571	146.506	0.08	0.04	57.78	18.65
4500	70.1	70.81	205.16	145.788	0.08	0.04	56.95	18.85
4550	70.64	71.33	200.741	145.059	0.08	0.04	56.11	19.06
4600	71.17	71.84	196.308	144.317	0.08	0.05	55.26	19.28
4650	71.69	72.34	191.86	143.561	0.08	0.05	54.39	19.52
4700	72.21	72.84	187.389	142.789	0.08	0.05	53.5	19.77
4750	72.73	73.33	182.892	142	0.08	0.05	52.59	20.04
4800	73.24	73.81	178.36	141.189	0.08	0.05	51.65	20.34
4850	73.75	74.29	173.787	140.352	0.08	0.05	50.68	20.66
4900	74.25	74.77	169.162	139.485	0.08	0.06	49.68	21.01
4950	74.75	75.24	164.478	138.579	0.08	0.06	48.62	21.4
5000	75.24	75.7	159.717	137.623	0.08	0.06	47.5	21.84
5050	75.74	76.15	154.86	136.602	0.08	0.07	46.29	22.34
5100	76.22	76.6	149.885	135.49	0.08	0.07	44.96	22.95
5150	76.71	77.03	144.752	134.235	0.08	0.08	43.44	23.71

TOXICITY

R-454B is classified as Class A or lower-toxicity refrigerant by ASHRAE 34. ASHRAE 34 has established a Workplace Occupational Exposure Level (OEL) of 850 ppm for R-454B. Anyone who uses or handles R-454B should carefully review the SDS and product label prior to use.

STABILITY

The thermal- and chemical-stability testing of R-454B was conducted in sealed glass tubes by accelerating their aging through elevated temperatures (AHRI Project 9016-1 “Materials Compatibility and Lubricants Research For Low GWP Refrigerants: Chemical Stability of Low GWP Refrigerants with Lubricants”).

Solstice conducted sealed-tube thermal-stability tests at 1750°C for two weeks. After exposure, tube contents were analyzed using analytical methods such as the following:

- High-performance liquid chromatography (HPLC) to quantify inorganic anion concentrations
- Gas chromatography mass spectrometry (GC-MS) to identify and quantify volatile components
- Titration to measure lubricant acidity (TAN)

The results showed no signs of decomposition of refrigerant and oil after two weeks of exposure at 1750°C. As the basic components of R-454B showed no signs of concern in thermal-stability testing, it is expected for R-454B to exhibit similar results.

REGULATORY AND ENVIRONMENTAL

Environmental characteristics of the components of Solstice® 454B (R-454B) are presented in the table below:

CHEMICAL NAME	CAS NUMBER	CONCENTRATION %	OZONE DEPLETION	US EPA CAA VOC STATUS	ACGIH TLV	OSHA PEL	WEEL (AIHA) TWA 8 HRS	WEEL (AIHA) TWA 8 HRS	US DOT HAZARD CLASS	TSCA INVENTORY STATUS
Difluoromethane	75-10-5 754-12-1	68.9	0	Exempt	None	None	1000ppm	454BA is US	Not RCRA Waste	Listed
2,3,3,3-Tetrafluoroprop-1-ene	66711-86-2	31.1	0	Exempt	None	None	500ppm	DOT class 2.1	Not RCRA Waste	Listed

STORAGE AND HANDLING

Solstice® 454B should be stored in a cool, well-ventilated area. The material only should be stored in an approved cylinder. Please consult Solstice's Technical Service Department prior to storage of the material in anything other than its original shipping cylinder to ensure the new container meets all safety requirements. The container and its fittings should be protected from physical damage. The container should not be punctured or dropped, or exposed to open flames, excessive heat or direct sunlight. The container's valves should be closed tightly after use and when the container is empty.

CYLINDERS

- Solstice® 454B (R-454B) is available in disposable jugs. Other package sizes include refillable 100lb cylinders as well as ½ and one-ton tanks.
- Connections are reverse-thread 1/4" flare fittings for the disposables.
- Other sizes generally use left-handed reverse-thread 5/8" flare fittings.



For More Information Visit

solstice.com

Solstice Advanced Materials Inc.

115 Tabor Rd. | Morris Plains, NJ 07950

