Designation: D7265 – 23

Standard Specification for Hydrogen Thermophysical Property Tables[1]

This standard is issued under the fixed designation D7265; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 The thermophysical property tables for normal hydrogen are for use in the calculation of the pressure-volume-temperature (PVT), thermodynamic, and transport properties of hydrogen for process design and operations, particularly as they relate to hydrogen fuel cell applications. Tables are provided for gaseous hydrogen at temperatures between 50 K and 500 K at pressures to 500 MPa. These tables were developed by the National Institute of Standards and Technology from a Standard Reference Database product REFPROP, version 10.0[2].

1.2 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

D4150 Terminology Relating to Gaseous Fuels

3. Applicability

3.1 These tables apply directly only to pure gaseous hydrogen. However, it is expected that they may find substantial use in mathematical models and tables for the thermophysical properties of mixtures containing hydrogen.

4. Terminology

4.1 *Definitions*—For definitions of general terms used in D03 Gaseous Fuels standards, refer to Terminology D4150.

5. Tables

5.1 The tabulated thermophysical properties are:

ρ, molar density ($mol \cdot L^{-1}$)
V, molar volume ($L^{-1} \cdot mol$)
H, molar enthalpy ($J \cdot mol^{-1}$)
S, molar entropy ($J \cdot K^{-1} \cdot mol^{-1}$)
C_v, constant volume molar heat capacity ($J \cdot K^{-1} \cdot mol^{-1}$)
C_p, constant pressure molar heat capacity ($J \cdot K^{-1} \cdot mol^{-1}$)
c, speed of sound ($m \cdot s^{-1}$)
η, viscosity (μPa·s)
λ, thermal conductivity ($mW \cdot m^{-1} \cdot K^{-1}$)

5.2 These tables were produced by equations from a computer package, "NIST Standard Reference Database 23; Reference Fluid Thermodynamic and Transport Properties Database (REFPROP): Version 10.0." A wide selection of units (SI units, engineering units, chemical units) is available with this program.

6. Additional Information

6.1 The Reference States for enthalpy and entropy have been updated in this version of the Standard.

6.2 Reference state properties are required to calculate certain of the thermodynamic properties (enthalpy, entropy, etc.) from an equation of state formulation.

6.3 The reference state properties used to generate the tables in this specification are: enthalpy, H, and entropy, S, at 298.15 K and 0.101325 MPa (H = 10018 J⁄mol and S = 186.266 J/(mol K)). The molar mass of hydrogen is 2.0159 g/mol.

6.4 Two new tables have been added at 35 Mpa (350 Bar) and 70 Mpa (700 Bar). These are the most common fuel pressures used for vehicles using hydrogen fuel cells.

7. Keywords

7.1 hydrogen gas tables; thermodynamic properties of hydrogen; transport properties of hydrogen

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[1] This specification is under the jurisdiction of ASTM Committee D03 on Gaseous Fuels and is the direct responsibility of Subcommittee D03.08 on Thermophysical Properties.

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[2] Lemmon, E.W., Bell, I.H., Huber, M.L., McLinden, M.O. NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties-REFPROP, Version 10.0, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, 2018.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

TABLE 1 Hydrogen Thermophysical Property Tables

T (K)	ρ (mol·L^{-1})	V (L^{-1}·mol)	H (J·mol^{-1})	S (J·mol^{-1}·K^{-1})	C_v (J·mol^{-1}·K^{-1})	C_p (J·mol^{-1}·K^{-1})	c (m·s^{-1})	λ (mW·m^{-1}·K^{-1})	η (μPa·s)
				0.1 MPa					
50	0.242470	4.1243	3641.7	142.90	12.543	21.131	584.75	37.766	2.4059
55	0.219970	4.5461	3747.3	144.91	12.579	21.113	613.42	40.905	2.6017
60	0.201340	4.9668	3852.9	146.75	12.643	21.137	640.40	43.986	2.7904
65	0.185650	5.3866	3958.8	148.44	12.740	21.204	665.79	47.025	2.9728
70	0.172240	5.8057	4065.0	150.02	12.871	21.312	689.70	50.040	3.1496
75	0.160660	6.2244	4171.9	151.49	13.037	21.460	712.26	53.046	3.3215
80	0.150540	6.6426	4279.7	152.88	13.235	21.643	733.56	56.059	3.4888
85	0.141630	7.0605	4388.4	154.20	13.462	21.858	753.75	59.089	3.6520
90	0.133720	7.4781	4498.3	155.46	13.712	22.098	772.95	62.146	3.8114
95	0.126650	7.8955	4609.4	156.66	13.981	22.359	791.27	65.237	3.9674
100	0.120300	8.3127	4721.9	157.81	14.264	22.635	808.85	68.365	4.1202
105	0.114550	8.7298	4835.8	158.92	14.556	22.921	825.77	71.531	4.2701
110	0.109330	9.1467	4951.1	160.00	14.852	23.212	842.14	74.735	4.4172
115	0.104560	9.5635	5067.9	161.04	15.150	23.506	858.02	77.974	4.5619
120	0.100200	9.9802	5186.2	162.04	15.446	23.798	873.50	81.242	4.7041
125	0.096183	10.397	5305.9	163.02	15.738	24.086	888.61	84.534	4.8441
130	0.092478	10.813	5427.0	163.97	16.023	24.368	903.41	87.845	4.9821
135	0.089049	11.230	5549.6	164.89	16.300	24.643	917.93	91.167	5.1181
140	0.085865	11.646	5673.5	165.79	16.568	24.908	932.21	94.493	5.2522
145	0.082901	12.063	5798.6	166.67	16.825	25.164	946.27	97.819	5.3846
150	0.080135	12.479	5925.1	167.53	17.073	25.410	960.13	101.14	5.5154
155	0.077549	12.895	6052.7	168.37	17.309	25.645	973.80	104.44	5.6446
160	0.075124	13.311	6181.5	169.19	17.535	25.869	987.30	107.73	5.7723
165	0.072846	13.728	6311.4	169.98	17.750	26.082	1000.6	110.99	5.8985
170	0.070703	14.144	6442.3	170.77	17.954	26.285	1013.8	114.23	6.0235
175	0.068682	14.560	6574.2	171.53	18.147	26.477	1026.9	117.45	6.1471
180	0.066774	14.976	6707.1	172.28	18.330	26.659	1039.8	120.63	6.2695
185	0.064969	15.392	6840.8	173.01	18.503	26.831	1052.6	123.77	6.3908
190	0.063259	15.808	6975.4	173.73	18.666	26.994	1065.3	126.89	6.5109
195	0.061637	16.224	7110.7	174.43	18.821	27.147	1077.8	129.96	6.6299
200	0.060096	16.640	7246.8	175.12	18.966	27.292	1090.2	133.00	6.7480
205	0.058630	17.056	7383.6	175.80	19.103	27.428	1102.6	136.01	6.8650
210	0.057234	17.472	7521.1	176.46	19.231	27.556	1114.8	138.97	6.9810
215	0.055903	17.888	7659.2	177.11	19.352	27.676	1126.9	141.90	7.0961
220	0.054633	18.304	7797.8	177.75	19.465	27.789	1138.9	144.80	7.2104
225	0.053419	18.720	7937.0	178.37	19.572	27.895	1150.8	147.65	7.3238
230	0.052258	19.136	8076.8	178.99	19.672	27.994	1162.6	150.47	7.4363
235	0.051146	19.552	8217.0	179.59	19.765	28.087	1174.4	153.26	7.5481
240	0.050081	19.968	8357.6	180.18	19.852	28.174	1186.0	156.01	7.6591
245	0.049059	20.384	8498.7	180.77	19.934	28.255	1197.6	158.73	7.7693
250	0.048078	20.799	8640.2	181.34	20.010	28.331	1209.0	161.42	7.8788
255	0.047136	21.215	8782.0	181.90	20.081	28.402	1220.4	164.07	7.9876
260	0.046229	21.631	8924.2	182.45	20.148	28.468	1231.7	166.70	8.0957
265	0.045357	22.047	9066.7	182.99	20.209	28.529	1242.9	169.29	8.2032
270	0.044518	22.463	9209.5	183.53	20.267	28.587	1254.1	171.86	8.3100
275	0.043709	22.879	9352.5	184.05	20.320	28.640	1265.1	174.40	8.4162
280	0.042928	23.295	9495.9	184.57	20.370	28.689	1276.1	176.91	8.5218
285	0.042175	23.710	9639.4	185.08	20.416	28.735	1287.0	179.39	8.6268
290	0.041449	24.126	9783.2	185.58	20.458	28.777	1297.9	181.85	8.7313
295	0.040746	24.542	9927.2	186.07	20.498	28.817	1308.6	184.29	8.8351
300	0.040067	24.958	10071	186.55	20.534	28.853	1319.3	186.70	8.9385
305	0.039411	25.374	10216	187.03	20.568	28.886	1329.9	189.09	9.0413
310	0.038775	25.790	10360	187.50	20.599	28.917	1340.5	191.45	9.1435
315	0.038160	26.205	10505	187.96	20.628	28.946	1351.0	193.80	9.2453
320	0.037564	26.621	10650	188.42	20.654	28.972	1361.4	196.12	9.3466
325	0.036986	27.037	10795	188.87	20.679	28.996	1371.8	198.43	9.4474
330	0.036426	27.453	10940	189.31	20.701	29.018	1382.0	200.72	9.5478
335	0.035883	27.869	11085	189.75	20.722	29.039	1392.3	202.98	9.6476
340	0.035355	28.284	11230	190.18	20.740	29.057	1402.4	205.24	9.7471
345	0.034843	28.700	11375	190.60	20.758	29.075	1412.5	207.47	9.8461
350	0.034345	29.116	11521	191.02	20.773	29.090	1422.6	209.69	9.9446
355	0.033862	29.532	11666	191.43	20.788	29.105	1432.5	211.89	10.043
360	0.033392	29.948	11812	191.84	20.801	29.118	1442.4	214.08	10.141
365	0.032934	30.363	11957	192.24	20.813	29.130	1452.3	216.25	10.238
370	0.032490	30.779	12103	192.64	20.824	29.141	1462.1	218.41	10.335
375	0.032057	31.195	12249	193.03	20.834	29.151	1471.8	220.55	10.431
380	0.031635	31.611	12395	193.42	20.843	29.160	1481.5	222.69	10.528
385	0.031224	32.026	12540	193.80	20.852	29.168	1491.1	224.81	10.623
390	0.030824	32.442	12686	194.18	20.859	29.175	1500.7	226.91	10.719
395	0.030434	32.858	12832	194.55	20.866	29.182	1510.2	229.01	10.814\
400	0.030054	33.274	12978	194.91	20.873	29.189	1519.6	231.09	10.909
405	0.029683	33.689	13124	195.28	20.878	29.194	1529.0	233.17	11.003
410	0.029321	34.105	13270	195.63	20.884	29.200	1538.4	235.23	11.097