The International Association for the Properties of Water and Steam

Lucerne, Switzerland
August 2007

Revised Release on Viscosity and Thermal Conductivity of Heavy Water Substance

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This release replaces the corresponding release of 1984 and contains 17 pages.

This release has been authorized by the International Association for the Properties of Water and Steam (IAPWS) at its meeting in Lucerne, Switzerland, 26-31 August 2007, for issue by its Secretariat. The members of IAPWS are: Argentina and Brazil, Britain and Ireland, Canada, the Czech Republic, Denmark, France, Germany, Greece, Italy, Japan, Russia, and the United States of America.

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The material contained in this release is identical to that contained in the IAPS Release on Viscosity and Thermal Conductivity of Heavy Water Substance, issued by IAPS in May, 1983 (Revised February 1984), except for some minor revisions to make the information consistent with the equations contained in the Revised Release on the IAPS Formulation 1984 for the Thermodynamic Properties of Heavy Water Substance and the International Temperature Scale of 1990.

This Release contains in the accompanying Appendices the *International Representation of the Viscosity of Heavy Water Substance* (Deuterium Oxide, D_2O) and the *International Representation of the Thermal Conductivity of Heavy Water* (Deuterium Oxide, D_2O), 1982.

The release issued in 1983 was prepared by Working Group II of IAPS under the chairmanship of J. Kestin, Professor of Engineering at Brown University, Providence, RI, USA.

Details of the equations and their background are presented in J. Kestin, J. V. Sengers, B. Kamgar-Parsi, and J. M. H. Levelt Sengers, J. Phys. Chem. Ref. Data **13**, 601 (1984).

Appendix A contains the Recommended Equation for the Viscosity of Heavy Water Substance and tables of values calculated from this equation.

Appendix B contains the Recommended Equation for the Thermal Conductivity of Heavy Water Substance and tables of values calculated from this equation.

<u>Appendix A:</u> International Representation of the Viscosity of Heavy Water Substance (Deuterium Oxide, D_2O) 1982

IAPS Working Group II (on Transport Properties) critically examined the experimental results on the viscosity of liquid and gaseous heavy water and recommended that the values implied by the equation below should be used for this property. This equation represents the said quantity as a function of temperature and density. For conversion to a representation as a function of temperature and pressure, values of density should be computed from the IAPWS (2005) Revised Release on the IAPS Formulation 1984 for the Thermodynamic Properties of Heavy Water Substance.

This material is unchanged from the IAPS Release on Viscosity and Thermal Conductivity of Heavy Water Substance, issued May 2, 1983 and revised February 14, 1984, except for the change in the critical point temperature used for the reference temperature in the equation. Furthermore, the temperatures used here are on the International Temperature Scale of 1990, replacing the values from the International Practical Temperature Scale of 1968

A.1. <u>Nomenclature</u>

T denotes absolute temperature on the International Temperature Scale of 1990

ρ denotes density

p denotes pressure

μ denotes viscosity

A.2. <u>Reference constants</u>

reference temperature:	$T^* = 643.847$ K	(A1)
reference density:	$\rho^* = 358$ kg/m^3	(A2)
reference viscosity:	$\mu^* = 55.2651$ μPa s	(A3)

The two reference constants T^* and ρ^* are close to, but not necessarily identical with, the critical point constants.

A.3. <u>Dimensionless variables</u>

temperature:	$\overline{T} = T/T^*$	(A4)
density:	$\overline{\rho} = \rho/\rho^*$	(A5)
viscosity:	$\overline{\mu} = \mu/\mu^*$	(A6)

A.4. <u>The recommended equation</u>

The viscosity is represented by the equation

$$\overline{\mu} = \overline{\mu_0}(\overline{T}) \times \overline{\mu_1}(\overline{T}, \overline{\rho}) \quad . \tag{A7}$$

The first factor $\overline{\mu_0}$ of the product represents the viscosity in the dilute-gas limit and is given by

$$\overline{\mu_0}(\overline{T}) = \frac{\sqrt{\overline{T}}}{\sum_{i=0}^{3} \frac{A_i}{\overline{T}^i}} \quad , \tag{A8}$$

with coefficients A_i given in Table A1.

Table A1. Coefficients A_i for $\overline{\mu_0}(\overline{T})$

i	A_i
0	1.000000
1	0.940695
2	0.578377
3	-0.202044

The second factor $\overline{\mu_1}$ of the product represents the contribution to viscosity due to increasing density

$$\overline{\mu}_1(\overline{T}, \overline{\rho}) = \exp\left[\overline{\rho} \sum_{i=0}^{5} \left(\frac{1}{\overline{T}} - 1\right)^i \sum_{j=0}^{6} B_{ij} (\overline{\rho} - 1)^j\right] \tag{A9}$$

with coefficients B_{ij} given in Table A2.

Table A2. Coefficients B_{ij} for $\overline{\mu}_1(\overline{T}, \overline{\rho})$

i	j	B_{ij}
0	0	0.4864192
1	0	-0.2448372
2	0	-0.8702035
3	0	0.8716056
4	0	-1.051126
5	0	0.3458395
0	1	0.3509007
1	1	1.315436
2	1	1.297752
3	1	1.353448
0	2	-0.2847572
1	2	-1.037026
2	2	-1.287846
5	2	-0.02148229
0	3	0.07013759
1	3	0.4660127
2	3	0.2292075
3	3	-0.4857462
0	4	0.01641220
1	4	-0.02884911
3	4	0.1607171
5	4	-0.009603846
0	5	-0.01163815
1	5	-0.008239587
5	5	0.004559914
3	6	-0.003886659

Note: Coefficients B_{ij} omitted from the table are identically equal to zero.

A.5. Range of validity of equation

IAPWS endorses the validity of Eq. (A7) for the viscosity in the following range of pressures p and temperatures T:

$0 \text{ MPa} \leq p \leq 100 \text{ MPa}$

$277 \text{ K (melting point)} \leq T \leq 775 \text{ K}$

A.6. Uncertainties

The equation represents the viscosity within an uncertainty of ±1 % to ±5 % as indicated in Figure A1. However, no uncertainties are assigned in the region contained within

$$0.995 < \overline{T} < 1.005\,,$$
$$0.9 < \overline{\rho} < 1.1\,,$$

because critical-point effects on the viscosity are not incorporated in the equation.

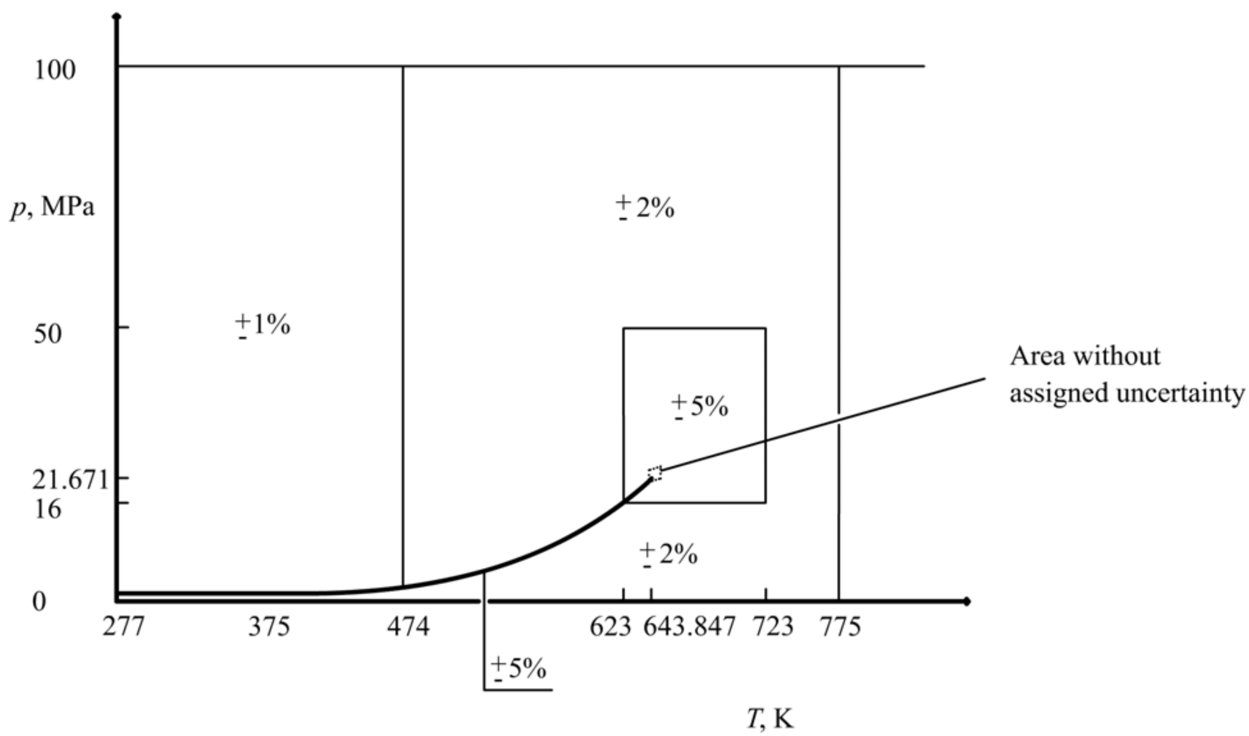

Figure A1. Uncertainties of the representation of the viscosity of heavy water.

A.7. Tables

Three tables are given in this Appendix. Table A3 contains recommended values of viscosity calculated on a grid of temperatures and pressures. Table A4 contains recommended values of viscosity calculated along the saturation line. Table A5 contains values of dimensionless viscosity in terms of $\overline{T}$ and $\overline{\rho}$ quoted to 10 decimal places to serve as an aid in checking computer programs.

Table A3 Values of viscosity obtained from the equations of Appendix A

Viscosity of D_2O/(μPa s)

p MPa	t °C 3.8	25.0	50.0	75.0	100.0	150.0	200.0	250.0
0.1	2085	1095	651.0	443.9	328.7	14.58	16.63	18.72
0.5	2084	1094	651.1	444.1	328.9	210.0	16.46	18.62
1.0	2083	1094	651.2	444.3	329.1	210.2	16.24	18.48
2.5	2078	1094	651.5	444.8	329.6	210.7	152.2	18.08
5.0	2070	1093	652.2	445.7	330.5	211.5	153.0	118.1
7.5	2063	1092	652.8	446.6	331.4	212.3	153.7	119.0
10.0	2056	1091	653.4	447.4	332.3	213.2	154.5	119.8
12.5	2049	1090	654.0	448.3	333.2	214.0	155.3	120.6
15.0	2042	1090	654.6	449.2	334.1	214.8	156.0	121.4
17.5	2035	1089	655.2	450.0	335.0	215.6	156.8	122.2
20.0	2029	1088	655.8	450.9	335.8	216.3	157.5	122.9
22.5	2023	1088	656.4	451.8	336.7	217.1	158.2	123.7
25.0	2017	1087	657.1	452.6	337.6	217.9	158.9	124.4
27.5	2011	1086	657.7	453.5	338.4	218.7	159.6	125.1
30.0	2005	1086	658.3	454.3	339.3	219.4	160.3	125.8
35.0	1995	1085	659.6	456.0	341.0	220.9	161.7	127.2
40.0	1985	1084	660.9	457.6	342.6	222.4	163.0	128.5
45.0	1976	1083	662.1	459.3	344.2	223.8	164.3	129.8
50.0	1967	1083	663.4	460.9	345.9	225.3	165.6	131.0
55.0	1960	1082	664.7	462.5	347.5	226.7	166.9	132.2
60.0	1953	1082	666.1	464.1	349.1	228.1	168.1	133.3
65.0	1947	1082	667.4	465.7	350.6	229.4	169.3	134.4
70.0	1941	1082	668.7	467.3	352.2	230.8	170.5	135.5
75.0	1936	1082	670.1	468.9	353.7	232.1	171.6	136.6
80.0	1932	1082	671.5	470.5	355.2	233.4	172.8	137.6
85.0	1928	1083	672.9	472.0	356.7	234.7	173.9	138.6
90.0	1925	1083	674.3	473.6	358.2	236.0	175.0	139.6
95.0	1923	1084	675.7	475.1	359.7	237.2	176.0	140.6
100.0	1921	1084	677.1	476.6	361.1	238.5	177.1	141.5

Table A3 Continued.

Viscosity of D_2O/(μPa s)

p MPa	*t* °C 300.0	350.0	375.0	400.0	425.0	450.0	475.0	500.0
0.1	20.84	22.97	24.03	25.09	26.15	27.20	28.25	29.29
0.5	20.78	22.94	24.01	25.08	26.15	27.21	28.27	29.32
1.0	20.70	22.90	23.99	25.08	26.16	27.23	28.29	29.34
2.5	20.48	22.80	23.94	25.06	26.17	27.27	28.36	29.44
5.0	20.13	22.66	23.88	25.06	26.23	27.37	28.49	29.60
7.5	19.81	22.56	23.85	25.10	26.31	27.49	28.65	29.79
10.0	94.3	22.53	23.88	25.17	26.43	27.65	28.83	29.99
12.5	95.5	22.60	23.98	25.31	26.60	27.84	29.05	30.23
15.0	96.6	22.92	24.21	25.53	26.82	28.08	29.30	30.49
17.5	97.7	70.2	24.67	25.87	27.13	28.38	29.60	30.79
20.0	98.7	73.5	25.73	26.42	27.55	28.75	29.95	31.12
22.5	99.6	76.1	31.76	27.32	28.13	29.22	30.36	31.51
25.0	100.6	78.2	58.9	29.02	28.95	29.81	30.85	31.95
27.5	101.4	80.0	64.6	33.05	30.16	30.57	31.44	32.45
30.0	102.3	81.6	68.2	42.21	32.02	31.56	32.16	33.03
35.0	103.9	84.3	73.2	57.5	39.26	34.60	34.07	34.48
40.0	105.4	86.6	76.8	64.8	49.44	39.61	36.87	36.40
45.0	106.8	88.7	79.7	69.6	57.4	46.12	40.70	38.91
50.0	108.2	90.5	82.1	73.2	63.0	52.5	45.29	41.99
55.0	109.4	92.2	84.3	76.1	67.2	57.9	50.1	45.49
60.0	110.7	93.7	86.1	78.5	70.5	62.2	54.6	49.16
65.0	111.8	95.2	87.8	80.6	73.3	65.7	58.5	52.8
70.0	112.9	96.5	89.3	82.5	75.6	68.7	62.0	56.2
75.0	114.0	97.7	90.7	84.1	77.7	71.2	64.9	59.3
80.0	115.0	98.8	92.0	85.7	79.5	73.4	67.5	62.1
85.0	116.0	99.9	93.2	87.0	81.1	75.4	69.8	64.5
90.0	116.9	101.0	94.4	88.3	82.6	77.1	71.8	66.8
95.0	117.9	101.9	95.4	89.5	83.9	78.6	73.5	68.7
100.0	118.7	102.9	96.4	90.6	85.2	80.0	75.2	70.5

Table A4 Values of viscosity of D_2O along the saturation line

t °C	p MPa	μ(liq) μPa s	μ(vap) μPa s
3.8	0.0006610	2086	9.60
10.0	0.001028	1678	9.76
20.0	0.002001	1246	10.03
30.0	0.003706	971.3	10.32
40.0	0.006556	784.5	10.63
50.0	0.01113	650.9	10.94
60.0	0.01822	551.6	11.27
70.0	0.02883	475.5	11.60
80.0	0.04427	415.7	11.94
90.0	0.06614	367.8	12.28
100.0	0.09635	328.7	12.62
110.0	0.13719	296.4	12.97
120.0	0.19133	269.4	13.31
130.0	0.26178	246.5	13.65
140.0	0.35197	226.9	13.99
150.0	0.46571	210.0	14.33
160.0	0.60718	195.3	14.67
170.0	0.78094	182.4	15.00
180.0	0.99193	171.0	15.33
190.0	1.245	160.9	15.66
200.0	1.547	151.9	15.99
210.0	1.903	143.7	16.32
220.0	2.319	136.4	16.65
230.0	2.802	129.6	16.98
240.0	3.359	123.5	17.31
250.0	3.998	117.8	17.66
260.0	4.725	112.4	18.01
270.0	5.550	107.4	18.39
280.0	6.480	102.7	18.78
290.0	7.525	98.1	19.21
300.0	8.694	93.6	19.68
310.0	9.999	89.2	20.20
320.0	11.451	84.7	20.81
330.0	13.06	79.9	21.54
340.0	14.85	74.8	22.46
345.0	15.81	72.1	23.03
350.0	16.82	69.0	23.7
355.0	17.89	65.6	24.6
360.0	19.02	61.6	25.7
361.0	19.25	60.7	26.0
362.0	19.48	59.7	26.3
363.0	19.72	58.6	26.7
364.0	19.96	57.5	27.1
365.0	20.21	56.3	27.6
366.0	20.45	55.0	28.1
367.0	20.70	53.4	28.7
368.0	20.96	51.6	29.6
369.0	21.21	49.4	30.7
370.0	21.47	46.0	32.7

Table A5 Values of dimensionless viscosity, $\bar{\mu}$, calculated with selected values of $\bar{T}$ and $\bar{\rho}$

$\bar{T}$	$\bar{\rho}$	$\bar{\mu}$
0.4310	3.0900	36.9123166244
0.4310	3.2300	34.1531546602
0.5000	0.0002	0.1972984225
0.5000	3.0700	12.0604912273
0.5000	3.1800	12.4679405772
0.6000	0.0027	0.2365829037
0.6000	2.9500	5.2437249935
0.6000	3.0700	5.7578399754
0.7500	0.0295	0.2951479769
0.7500	2.6500	2.6275043948
0.7500	2.8300	3.0417583586
0.9000	0.0800	0.3685472578
0.9000	0.1630	0.3619649145
0.9000	2.1600	1.6561616211
0.9000	2.5200	2.1041364724
1.0000	0.3000	0.4424816849
1.0000	0.7000	0.5528693914
1.0000	1.5500	1.1038442411
1.0000	2.2600	1.7569585722
1.1000	0.4900	0.5633038063
1.1000	0.9800	0.7816387903
1.1000	1.4700	1.1169456968
1.1000	1.9600	1.5001420619
1.2000	0.4000	0.6094539064
1.2000	0.8000	0.7651099154
1.2000	1.2000	0.9937870139
1.2000	1.6100	1.2711900131

<u>Appendix B:</u> International Representation of the Thermal Conductivity of Heavy Water Substance (Deuterium Oxide, D_2O) 1982

IAPS Working Group II (on Transport Properties) critically examined the experimental results on the thermal conductivity of liquid and gaseous heavy water and recommended that the values implied by the equation below should be used for this property. This equation represents the said quantity as a function of temperature and density. For conversion to a representation as a function of temperature and pressure, values of density should be computed from the IAPWS (2005) Revised Release on the IAPS Formulation 1984 for the Thermodynamic Properties of Heavy Water Substance.

This material is unchanged from the IAPS Release on Viscosity and Thermal Conductivity of Heavy Water Substance, except for the change in the critical point temperature used for the reference temperature in the equation. The temperature used here is for the International Temperature Scale of 1990, replacing the value from the International Practical Temperature Scale of 1968.

B.1. <u>Nomenclature</u>

T denotes absolute temperature on the International Temperature Scale of 1990

ρ denotes density

p denotes pressure

λ denotes thermal conductivity

B.2. <u>Reference constants</u>

reference temperature:	$T^* = 643.847$ K	(B1)
reference density:	$\rho^* = 358$ kg/m^3	(B2)
reference thermal conductivity:	$\lambda^* = 0.742128$ mW/(m K)	(B3)

The two reference constants T^* and ρ^* are close to, but not necessarily identical with, the critical point constants.

B.3. <u>Dimensionless variables</u>

temperature:	$\bar{T} = T/T^*$	(B4)
density:	$\bar{\rho} = \rho/\rho^*$	(B5)
thermal conductivity:	$\bar{\lambda} = \lambda/\lambda^*$	(B6)

B.4. <u>The recommended equation</u>

The thermal conductivity is represented by the equation

$$\overline{\lambda} = [\lambda_o + \Delta\lambda + \Delta\lambda_c + \Delta\lambda_L] \quad , \tag{B7}$$

where

$$\lambda_0 = \sum_{i=0}^{5} A_i \overline{T}^{\,i} , \tag{B8}$$

$$\Delta\lambda = B_0[1-\exp(B_e\ \overline{\rho})] + \sum_{j=1}^{4} B_j \overline{\rho}^{\,j} , \tag{B9}$$

$$\Delta\lambda_c = C_1 f_1(\overline{T}) f_2(\overline{\rho}) \left(1 + [f_2(\overline{\rho})]^2 \left\{ \frac{C_2 [f_1(\overline{T})]^4}{f_3(\overline{T})} + \frac{3.5 f_2(\overline{\rho})}{f_4(\overline{T})} \right\} \right) \quad , \tag{B10}$$

$$\Delta\lambda_L = D_1 [f_1(\overline{T})]^{1.2} \left\{ 1 - \exp\left[-\left(\frac{\overline{\rho}}{2.5} \right)^{10} \right] \right\} \quad , \tag{B11}$$

and

$$f_1(\overline{T}) = \exp(C_{T1}\overline{T} + C_{T2}\overline{T}^{\,2}) , \tag{B12}$$

$$f_2(\overline{\rho}) = \exp[C_{R1}(\overline{\rho}-1)^2] + C_{R2} \exp[C_{R3}(\overline{\rho}-\rho_{r1})^2] , \tag{B13}$$

$$f_3(\overline{T}) = 1 + \exp[60(\tau-1)+20] \quad , \tag{B14}$$

$$f_4(\overline{T}) = 1 + \exp[100(\tau-1)+15] , \tag{B15}$$

where $\tau = \overline{T} / (|\overline{T} - 1.1| + 1.1)$.

Table B1. Coefficients for thermal-conductivity equation

A_0	= 1.00000	C_1	= 35429.6
A_1	= 37.3223	C_2	= 5000.0×10^6
A_2	= 22.5485		
A_3	= 13.0465	C_{T1}	= 0.144847
A_4	= 0.0	C_{T2}	= -5.64493
A_5	= -2.60735	C_{R1}	= -2.80000
		C_{R2}	= -0.080738543
B_e	= -2.50600	C_{R3}	= -17.9430
B_0	= -167.310	ρ_{r1}	= 0.125698
B_1	= 483.656		
B_2	= -191.039	D_1	= -741.112
B_3	= 73.0358		
B_4	= -7.57467		

B.5. Range of validity of equation

IAPWS endorses the validity of Eq. (B7) for the thermal conductivity in the following range of pressures p and temperatures T:

0 MPa ≤ p ≤ 100 MPa

277 K (melting point) ≤ T ≤ 825 K

B.6. Uncertainties

The equation represents the thermal conductivity within an uncertainty of ±2 % to ±10 % as indicated in Figure B1. However, no uncertainties are assigned in the region contained within

$$0.99 < \overline{T} < 1.05,$$
$$0.8 < \overline{\rho} < 1.2,$$

because the actual thermal conductivity diverges at the critical point, while the thermal conductivity calculated from the equation remains finite at the critical point.

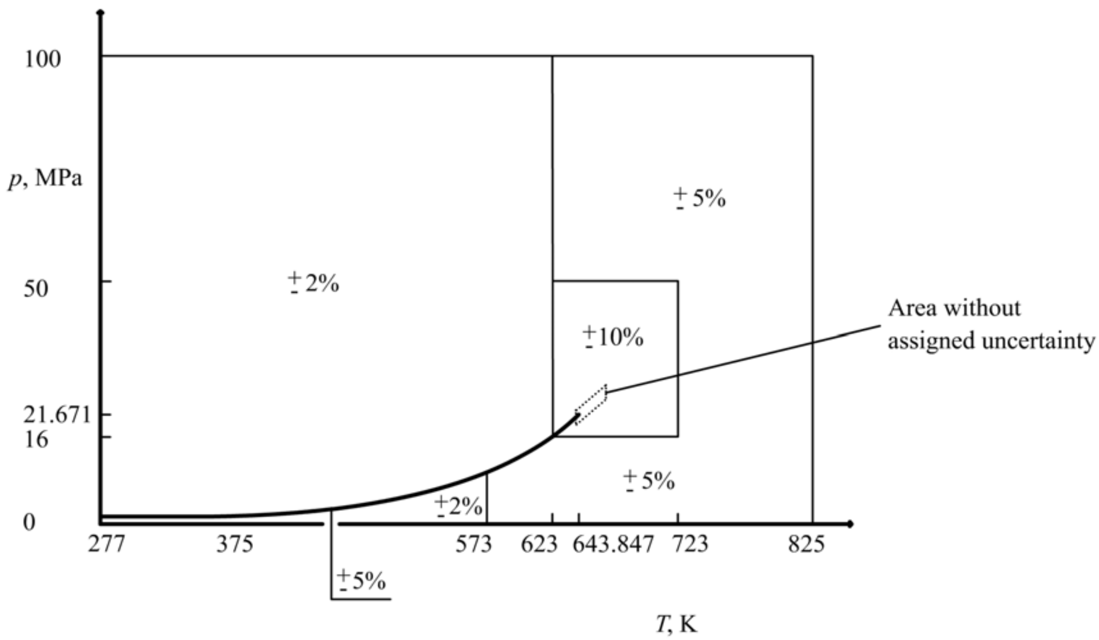

Figure B1. Uncertainties of the representation of the thermal conductivity of heavy water.

B.7. Tables

Three tables are given in this Appendix. Table B2 contains recommended values of thermal conductivity calculated on a grid of temperatures and pressures. Table B3 contains recommended values of thermal conductivity calculated along the saturation line. Table B4 contains values of dimensionless thermal conductivity in terms of $\overline{T}$ and $\overline{\rho}$ quoted to 9 decimal places to serve as an aid in checking computer programs.

Table B2 Values of thermal conductivity obtained from the equations of Appendix B

Thermal Conductivity of D_2O/ mW/(m K)

p MPa	*t* °C 3.8	25.0	50.0	75.0	100.0	150.0	200.0	250.0	300.0
0.1	565	595	618	631	636	29.05	33.77	38.93	44.49
0.5	565	595	618	632	636	625	34.70	39.48	44.85
1.0	565	595	619	632	636	625	36.27	40.29	45.36
2.5	566	596	619	633	637	626	593	43.95	47.33
5.0	567	598	621	634	639	628	595	542	52.9
7.5	569	599	622	635	640	629	596	545	64.3
10.0	570	600	623	636	641	631	598	547	475.5
12.5	572	601	624	638	642	632	600	550	479.6
15.0	573	603	626	639	644	633	602	552	483.6
17.5	575	604	627	640	645	635	604	555	487.4
20.0	576	605	628	641	646	636	605	557	491.1
22.5	578	607	629	642	647	638	607	559	494.7
25.0	579	608	631	644	649	639	609	562	498.1
27.5	580	609	632	645	650	641	610	564	501
30.0	582	610	633	646	651	642	612	566	505
35.0	585	613	635	648	654	645	615	570	511
40.0	587	615	638	651	656	647	619	574	517
45.0	590	618	640	653	658	650	622	578	522
50.0	593	620	642	655	661	653	625	582	527
55.0	596	623	645	658	663	655	628	586	533
60.0	598	625	647	660	665	658	631	590	538
65.0	601	627	649	662	668	660	634	593	542
70.0	604	630	651	664	670	663	637	597	547
75.0	606	632	654	666	672	665	640	600	551
80.0	609	635	656	669	674	668	642	604	556
85.0	611	637	658	671	677	670	645	607	560
90.0	614	639	660	673	679	673	648	610	564
95.0	616	641	662	675	681	675	651	614	568
100.0	619	644	665	677	683	677	653	617	572

Table B2 Continued.

Thermal Conductivity of D_2O/ mW/(m K)

p MPa	*t* °C 350.0	375.0	400.0	425.0	450.0	475.0	500.0	550.0
0.1	50.4	53.5	56.7	59.9	63.3	66.7	70.1	77.2
0.5	50.7	53.8	56.9	60.1	63.5	66.8	70.3	77.3
1.0	51.1	54.1	57.2	60.4	63.7	67.1	70.5	77.5
2.5	52.4	55.2	58.2	61.3	64.6	67.9	71.3	78.2
5.0	55.5	57.8	60.4	63.3	66.3	69.5	72.8	79.6
7.5	60.4	61.5	63.4	65.8	68.5	71.5	74.6	81.2
10.0	68.0	66.7	67.4	69.0	71.3	73.9	76.8	83.1
12.5	80.4	74.3	72.7	73.1	74.7	76.8	79.4	85.2
15.0	103.3	85.6	79.9	78.4	78.8	80.3	82.4	87.7
17.5	393	103.3	89.6	85.0	83.8	84.3	85.8	90.4
20.0	401	136.5	103.0	93.3	89.8	89.1	89.8	93.5
22.5	408	344	122.1	103.9	97.0	94.6	94.3	96.9
25.0	414	370	151.9	117.4	105.7	100.9	99.4	100.6
27.5	420	370	206	135.1	116.1	108.3	105.1	104.7
30.0	425	376	279	158.9	128.6	116.7	111.5	109.1
35.0	436	390	332	227	161.7	137.5	126.7	119.2
40.0	445	403	353	283	205	163.9	145.1	130.8
45.0	453	414	369	314	247	194.7	166.7	143.9
50.0	461	424	382	335	279	226	190.3	158.4
55.0	469	433	394	351	303	253	214	173.9
60.0	476	441	404	364	321	276	237	190.0
65.0	482	449	414	376	337	295	257	206
70.0	488	456	423	387	350	312	275	222
75.0	494	463	431	397	362	326	291	237
80.0	500	470	439	406	373	339	306	251
85.0	506	476	446	414	382	350	319	265
90.0	511	482	453	422	392	361	331	278
95.0	516	488	459	430	400	371	342	290
100.0	521	494	466	437	408	380	352	301

Table B3 Values of thermal conductivity of D_2O along the saturation line

t °C	p MPa	λ(liq) mW/(m K)	λ(vap) mW/(m K)
3.8	0.0006610	564.6	16.53
10.0	0.001028	574.6	16.99
20.0	0.002001	588.7	17.75
30.0	0.003706	600.5	18.53
40.0	0.006556	610.3	19.33
50.0	0.01113	618.2	20.16
60.0	0.01822	624.6	21.01
70.0	0.02883	629.4	21.90
80.0	0.04427	632.9	22.83
90.0	0.06614	635.0	23.80
100.0	0.09635	636.0	24.82
110.0	0.13719	635.8	25.88
120.0	0.19133	634.6	27.01
130.0	0.26178	632.3	28.20
140.0	0.35197	629.0	29.45
150.0	0.46571	624.9	30.79
160.0	0.60718	619.9	32.21
170.0	0.78094	614.1	33.72
180.0	0.99193	607.5	35.35
190.0	1.245	600.1	37.10
200.0	1.547	592.0	39.00
210.0	1.903	583.2	41.08
220.0	2.319	573.7	43.37
230.0	2.802	563.5	45.93
240.0	3.359	552.6	48.80
250.0	3.998	541.1	52.06
260.0	4.725	528.8	55.80
270.0	5.550	515.9	60.07
280.0	6.480	502.4	64.82
290.0	7.525	488.1	69.8
300.0	8.694	473.2	75.2
310.0	9.999	457.7	81.9
320.0	11.451	441.5	90.9
330.0	13.06	424.9	102.8
340.0	14.85	407.9	118.9
345.0	15.81	399.4	129.5
350.0	16.82	391	143
355.0	17.89	385	162
360.0	19.02	382	190
361.0	19.25	383	198
362.0	19.48	385	208
363.0	19.72	388	219
364.0	19.96	393	231
365.0	20.21	399	247
366.0	20.45	409	266
367.0	20.70	424	291
368.0	20.96	447	325
369.0	21.21	483	376
370.0	21.47	548	467

Table B4 Values of dimensionless thermal conductivity, $\bar{\lambda}$, calculated with selected values of $\bar{T}$ and $\bar{\rho}$

$\bar{T}$	$\bar{\rho}$	$\bar{\lambda}$
0.4310	3.0900	762.915707396
0.4310	3.2300	833.912049618
0.5000	0.0002	27.006536978
0.5000	3.0700	835.786416818
0.5000	3.1800	891.181752526
0.6000	0.0027	35.339949553
0.6000	2.9500	861.240794445
0.6000	3.0700	919.859094854
0.7500	0.0295	55.216750017
0.7500	2.6500	790.442563472
0.7500	2.8300	869.672292625
0.9000	0.0800	74.522283066
0.9000	0.1630	106.301972320
0.9000	2.1600	627.777590127
0.9000	2.5200	761.055043002
1.0000	0.3000	143.422002971
1.0000	0.7000	469.015122112
1.0000	1.5500	502.846952426
1.0000	2.2600	668.743524402
1.1000	0.4900	184.813462109
1.1000	0.9800	326.652382218
1.1000	1.4700	438.370305052
1.1000	1.9600	572.014411428
1.2000	0.4000	160.059403824
1.2000	0.8000	259.605241187
1.2000	1.2000	362.179570932
1.2000	1.6100	471.747729424
1.2700	0.3000	145.249914694
1.2700	0.6000	211.996299238
1.2700	0.9500	299.251471210
1.2700	1.3700	409.359675394