The International Association for the Properties of Water and Steam

London, England
September 1998

Revised Release on the IAPS Formulation 1985 for the Thermal Conductivity of Ordinary Water Substance

President:
Dr. Roberto Fernández-Prini
CNEA
Av. Libertador 8250
Buenos Aires-1429
Argentina

Executive Secretary:
Dr. R.B. Dooley
Electric Power Research Institute
3412 Hillview Avenue
Palo Alto, California 94304, USA

This release replaces the corresponding release of 1985 and contains 23 pages.

This release has been authorized by the International Association for the Properties of Water and Steam (IAPWS) at its meeting in London, United Kingdom, 6 - 12 September 1998, for issue by its Secretariat. The members of IAPWS are: Argentina, Canada, the Czech Republic, Denmark, France, Germany, Italy, Japan, Russia, the United Kingdom, and the United States of America.

Further information about this release and other releases issued by IAPWS can be obtained from the Executive Secretary of IAPWS.

The material contained in this release is identical to that contained in the Release on the IAPS Formulation 1985 for the Thermal Conductivity of Ordinary Water Substance, issued by IAPS in September, 1984, except for some minor revisions to make the information consistent with the equations contained in the Release on the IAPWS Formulation 1995 for the Thermodynamic Properties of Ordinary Water Substance for General and Scientific Use, the 1997 Revised Release on the IAPS Formulation 1985 for the Viscosity of Ordinary Water Substance, and the International Temperature Scale of 1990. The material in the IAPS Formulation 1985 for the Thermal Conductivity of Ordinary Water Substance, in turn, was essentially identical to that contained in the Release on Thermal Conductivity of Water Substance, issued by IAPS in December 1977.

The original experimental data have been collected in the document "Available Input of the Thermal Conductivity of Water Substance," K. Scheffler, M. Rosner, and M. Reimann (Institut A für Thermodynamik, Technische Universität, München, revised ed. 1977).

Contents of this Release

Appendix A. Critically Evaluated Experimental Data.

Table A.I. Reduced to a Uniform Grid

This material is unchanged from the Release on the IAPS Formulation 1985 for the Thermal Conductivity of Ordinary Water Substance.

Table A.II. Reduced to the Saturation Line

The saturation pressures in this table have been revised to conform with the Release on the IAPWS Formulation 1995 for the Thermodynamic Properties of Ordinary Water Substance for General and Scientific Use.

Appendix B. Recommended Interpolating Equation for Industrial Use.

This material has been revised to conform to the Release on the IAPWS Formulation 1997 for the Thermodynamic Properties of Water and Steam for Industrial Use and the ITS-90 temperature scale.

Appendix A

Table A.I. Critically-Evaluated Experimental Data Reduced to a Uniform Grid

This material is unchanged from the Release on the IAPS Formulation 1985 for the Thermal Conductivity of Ordinary Water Substance.

Upper value: Thermal conductivity of water or steam, λ in mW K^{-1} m^{-1}

Lower value: Uncertainty in the thermal conductivity, $\pm\Delta\lambda$ in mW K^{-1} m^{-1}

Pressure, p, in MPa

Temperature, t, in °C

The points enclosed by parentheses represent extrapolations in the fluid phase outside the range of reliable experimental data.

The point shown in italics represents an extrapolation into a region where the equilibrium phase is a solid.

The isotherms and isobars represented by this table are not smooth. This reflects the trends existing in the experimental data used in its construction.

Table A.II. Critically-Evaluated Experimental Data Reduced to the Saturation Line

The saturation pressures in this table have been calculated from the Release on the IAPWS Formulation 1995 for the Thermodynamic Properties of Ordinary Water Substance for General and Scientific Use. The experimental values of the thermal conductivity have not been revised, but are identical to values in the IAPS Formulation 1985 for the Thermal Conductivity of Ordinary Water Substance.

Thermal conductivity of saturated liquid, λ', in mW K^{-1} m^{-1}. Thermal conductivity of saturated vapor, λ'', in mW K^{-1} m^{-1}. $\pm\Delta\lambda'$, $\pm\Delta\lambda''$ uncertainty in the above values in mW K^{-1} m^{-1}. Pressure, p, in MPa. Temperature, t, in °C.

Table A.I Critically Evaluated Experimental Data Reduced to a Uniform Grid

p/MPa	Temperature/°C											
	0	25	50	75	100	150	200	250	300	350	375	400
0.1	*563*	610	643	664	25.0	28.9	33.3	38.1	43.3	49.0	52.0	54.9
	11	9	9	10	0.5	0.6	0.7	0.8	0.9	1.0	1.0	1.1
0.5	563	610	643	664	680	688	34.1	38.7	43.7	49.1	52.6	55.5
	11	9	9	10	10	10	1.0	1.2	1.3	1.5	1.6	1.7
1	564	611	643	666	681	689	35.9	39.5	44.3	49.5	53.0	56.0
	11	9	9	10	10	10	1.4	1.2	1.3	1.5	1.6	1.7
2.5	566	611	644	666	682	690	668	43.8	46.5	50.9	54.7	56.9
	11	9	9	10	10	10	10	1.4	1.4	1.5	1.6	1.7
5	567	613	645	668	683	691	671	625	52.7	54.1	56.5	58.6
	11	12	12	13	13	13	13	12	1.6	1.9	1.7	1.8
7.5	570	614	647	669	685	694	673	628	63.6	59.6	60.5	62.7
	11	12	12	13	13	13	13	12	1.9	1.8	1.8	1.9
10	571	615	648	669	686	695	675	631	557	68.2	65.3	66.9
	11	12	13	13	13	13	13	12	11	2.0	2.1	2.0
12.5	571	616	649	672	687	697	678	634	562	81.2	73.6	72.4
	11	12	13	13	13	13	13	12	11	2.4	2.2	2.2
15	573	617	650	673	689	700	680	638	566	107.5	84.8	79.9
	11	12	13	13	13	14	13	12	11	6.7	2.5	2.4
17.5	573	618	651	674	691	701	682	639	571	452	104.2	90.0
	11	12	13	13	13	14	13	12	11	13	3.1	2.7
20	574	619	653	676	691	703	684	641	576	465	144.0	104.9
	11	12	13	13	13	14	13	12	11	14	4.7	3.1
22.5	574	620	654	678	692	705	686	646	581	476	478	124.1
	11	12	13	13	13	14	13	12	11	14	39	4.6
25	577	621	655	679	694	707	689	648	588	482	400	166.4
	11	12	13	13	13	14	13	13	11	14	14	6.7
27.5	578	622	656	680	696	708	690	651	589	490	413	240.8
	11	12	13	13	13	14	13	13	11	14	14	8.4
30	578	623	658	681	697	710	692	653	593	498	426	337
	11	12	13	13	13	14	13	13	11	15	13	12
35	580	625	660	684	700	714	696	660	601	511	453	384
	11	12	13	13	14	14	13	13	12	15	13	12
40	583	626	662	686	702	717	700	664	608	526	471	399
	11	12	13	13	14	14	14	13	12	15	14	16
45	584	629	664	690	705	721	704	670	615	537	486	425
	11	12	13	13	14	14	14	13	12	16	14	12
50	586	630	666	692	708	724	708	673	621	547	498	444
	11	12	13	13	14	14	14	13	12	44	40	36
55	589	633	667	694	710	726	712	678	629	558	510	461
	11	12	13	13	14	14	14	13	12	45	41	37
60	590	635	670	697	713	729	715	682	634	566	525	476
	11	12	13	13	14	14	14	13	12	45	42	38
65	592	638	673	699	715	733	718	688	639	574	535	489
	11	12	13	14	14	14	14	13	12	46	43	39
70	597	639	674	702	718	735	721	691	645	582	546	499
	11	12	13	14	14	14	14	13	12	47	44	40
75	599	641	675	705	720	738	725	696	648	589	554	511
	12	12	13	14	14	14	14	13	13	47	44	41
80	599	645	677	707	723	739	729	699	653	598	564	521
	12	12	13	14	14	14	14	14	13	48	45	42
85	601	646	680	706	726	742	732	702	659	604	571	532
	12	12	13	14	14	14	14	14	13	48	46	43
90	604	648	681	710	728	745	735	707	665	611	578	544
	12	13	13	14	14	14	14	14	13	49	46	44
95	608	650	685	713	731	748	739	711	669	615	586	553
	12	13	13	14	14	15	14	14	13	49	47	44
100	609	650	686	716	735	749	742	715	672	624	594	561
	12	13	13	14	14	15	14	14	13	50	47	45

Table A-1 (continued)

p/MPa	Temperature/°C									
	425	450	475	500	550	600	650	700	750	800
0.1	57.9	60.6	63.8	67.1	73.1	79.9	86.4	93.4	100.5	107.5
	1.2	1.2	1.3	1.3	1.5	2.4	2.6	2.8	3.0	3.2
0.5	58.5	61.4	64.5	67.7	74.0	80.5	87.2	93.8	100.9	108.0
	1.8	1.8	1.9	2.0	2.2	3.2	3.5	3.8	4.0	4.3
1	58.6	61.7	64.7	68.0	74.3	81.0	87.7	94.3	101.4	108.6
	1.8	1.9	1.9	2.0	2.2	3.2	3.5	3.8	4.1	4.3
2.5	59.6	62.6	65.6	68.7	75.1	81.5	88.8	95.3	102.4	109.5
	1.8	1.9	2.0	2.1	2.3	3.3	3.6	3.8	4.1	4.4
5	60.9	64.0	66.4	69.3	75.4	81.5	91.4	95.7	103.6	109.6
	1.8	1.9	2.0	2.1	2.3	3.3	3.7	3.8	4.1	4.4
7.5	64.0	66.7	69.5	73.3	80.0	87.3	96.4	101.0	108.1	112.4
	1.9	2.0	2.1	2.2	2.4	3.5	5.3	4.0	4.3	4.5
10	67.4	69.4	72.1	75.6	82.5	89.4	97.5	102.9	111.2	118.1
	2.0	2.1	2.2	2.3	2.5	3.6	4.6	4.1	5.1	5.2
12.5	72.0	74.1	76.1	79.4	85.0	90.7	97.9	102.9	109.9	116.3
	2.2	2.2	2.3	2.4	2.6	3.6	3.9	4.1	4.4	4.7
15	77.8	78.4	79.3	82.4	87.5	93.4	100.3	105.6	112.7	118.0
	2.3	2.4	2.4	2.5	2.6	3.7	4.0	4.2	4.5	4.7
17.5	84.8	84.0	84.2	85.7	90.2	96.2	102.5	106.0	114.4	119.7
	2.5	2.5	2.5	2.6	2.7	3.8	4.1	4.2	4.6	4.8
20	93.7	90.8	90.1	91.6	94.9	98.6	105.5	109.3	116.8	122.7
	2.8	2.7	2.7	2.7	3.0	3.9	4.2	4.4	4.7	4.9
22.5	105.9	98.6	95.9	96.0	98.1	102.6	107.6	112.1	119.2	123.7
	3.2	3.0	2.9	2.9	2.9	4.1	4.3	4.5	4.8	4 9
25	120.6	108.3	102.8	101.5	102.3	105.7	110.7	114.5	121.5	126.2
	3.6	3.2	3.1	3.0	3.1	4.2	4.4	4.6	4.9	5.0
27.5	139.2	120.3	111.1	107.3	106.1	108.7	113.0	118.0	123.4	127.8
	6.3	3.6	3.3	3.2	3.2	4.3	4.5	4.7	4.9	5.1
30	175.0	133.8	119.4	114.1	110.6	112.3	116.2	119.9	125.7	130.2
	8.1	4.0	3.6	3.4	3.3	4.5	4.6	4.8	5.0	5.2
35	260.5	176.3	144.3	129.7	121.1	119.8	122.7	125.1	130.0	134.6
	7.8	5.5	4.3	3.9	3.6	4.8	4.9	5.0	5.2	5.4
40	331	233.2	178.9	152.9	133.9	129.2	129.5	131.8	135.8	139.3
	11	7.2	5.5	4.6	4.0	5.2	5.2	5.3	5.4	5.6
45	365	287	219.0	180.1	148.2	138.5	136.4	137.7	141.1	144.5
	11	12	7.9	5.4	4.4	5.5	5.5	5.5	5.6	5.8
50	381	325	263	211	164	150	145	145	146	149
	30	26	21	17	13	12	12	12	12	12
55	401	354	297	244	184	162	154	152	153	155
	32	28	24	20	15	13	12	12	12	12
60	423	366	322	277	207	176	164	159	159	161
	34	29	26	22	16	14	13	13	13	13
65	438	387	332	299	228	191	175	168	166	167
	35	31	26	24	18	15	14	13	13	13
70	453	406	355	322	253	205	186	178	173	173
	36	32	28	26	21	16	15	14	14	14
75	467	421	376	327	269	218	198	186	180	178
	37	34	30	26	22	17	16	15	14	15
80	480	435	393	346	298	235	209	(196)	(190)	(185)
	38	35	31	28	34	19	17	16	15	15
85	488	448	410	366	312	246	222	(206)	(196)	(194)
	39	36	33	29	33	20	18	17	16	15
90	500	460	424	385	308	259	233	(215)	(205)	(201)
	40	37	34	31	25	21	19	17	16	16
95	510	473	434	396	322	273	243	(226)	(214)	(207)
	41	38	35	32	26	22	19	18	17	17
100	519	484	445	412	338	288	255	(236)	(221)	(215)
	42	39	36	33	27	23	20	19	18	17

Table A.II Critically Evaluated Experimental Data Reduced to the Saturation Line

t	p	λ'	$\pm\Delta\lambda'$	λ''	$\pm\Delta\lambda''$
0.01	0.000 611 7	565	11	16.7	0.5
10	0.001 228	584	12	17.4	0.5
20	0.002 339	602	12	18.1	0.5
30	0.004 247	617	12	19.0	0.6
40	0.007 385	631	13	19.7	0.6
50	0.012 35	642	13	20.4	0.6
60	0.019 95	652	13	21.2	0.6
70	0.031 20	660	13	22.2	0.7
80	0.047 41	669	13	23.1	0.7
90	0.070 18	675	14	24.0	0.7
100	0.1014	679	14	25.0	0.8
110	0.1434	681	14	25.7	0.8
120	0.1987	685	14	26.8	0.8
130	0.2703	686	14	28.7	0.9
140	0.3615	686	14	29.7	0.9
150	0.4762	686	14	31.0	0.9
160	0.6182	682	14	31.9	1.3
170	0.7922	678	14	33.6	1.3
180	1.003	674	13	35.2	1.3
190	1.255	670	13	37.2	1.2
200	1.555	664	13	38.8	1.4
210	1.908	654	13	40.5	1.7
220	2.320	643	13	43.2	1.3
230	2.797	632	13	45.3	1.4
240	3.347	626	12	47.9	1.4
250	3.976	615	12	51.0	1.5
260	4.692	602	12	54.2	1.6
270	5.503	590	12	57.7	1.7
280	6.417	577	11	61.3	1.8
290	7.442	564	11	67.3	2.8
300	8.588	547	11	73.2	3.8
310	9.865	532	11	79.8	4.3
320	11.284	512	10	88.3	4.8
330	12.858	485	10	99.1	5.9
340	14.601	455	14	116.7	7.9
350	16.529	447	14	138	11
360	18.666	425	23	174	15
370	21.044	418	36	293	55
371	21.297	429	38	331	62
372	21.554	450	42	377	83
373	21.814	520	50	464	141

Appendix B: Recommended Interpolating Equation for Industrial Use

This material has been revised to conform to the Release on the IAPWS Formulation 1997 for the Thermodynamic Properties of Water and Steam for Industrial Use and the ITS-90 temperature scale.

B.1. Nomenclature

T denotes absolute temperature on the International Temperature Scale of 1990

ρ denotes density[1]

λ denotes thermal conductivity

B.2. Reference constants

Reference temperature[2]: $T^* = 647.26$ K (1)

reference density: $\rho^* = 317.7$ kg m^{-3} (2)

reference thermal conductivity: $\lambda^* = 1$ W m^{-1} K^{-1} (3)

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

B.3. Dimensionless variables

Temperature: $\bar{T} = T/T^*$ (4)

density: $\bar{\rho} = \rho/\rho^*$ (5)

thermal conductivity: $\bar{\lambda} = \lambda/\lambda^*$ (6)

B.4. Range of validity of equation

IAPWS endorses the validity of Eq. (8) for the thermal conductivity in the following range of pressures p and temperatures t

$p \le 100$ MPa for $0\ ^\circ\text{C} \le t \le 500\ ^\circ\text{C}$

$p \le 70$ MPa for $500\ ^\circ\text{C} < t \le 650\ ^\circ\text{C}$

$p \le 40$ MPa for $650\ ^\circ\text{C} < t \le 800\ ^\circ\text{C}$ (7)

---

[1] To reproduce the values given in Appendix D. the density should be computed with the aid of the IAPWS Industrial Formulation 1997 (IAPWS-IF97). If another density formulation is used. a relative departure of $\Delta\rho/\rho$ induces at most a relative departure of $\pm\Delta\lambda/\lambda = 2\Delta\rho/\rho$ outside the near-critical region.

[2] The reference temperature differs from that given in the Release on the IAPS Formulation 1985 for the Thermal Conductivity of Ordinary Water Substance because of conversion to the ITS-90 temperature scale.

B.5. Interpolating equation

The values appearing in Tables A.I and A.II may be reproduced within the stated tolerances by the use of the following empirical interpolating equation which is recommended for industrial use. This equation yields a finite value of the thermal conductivity at the critical point instead of the theoretically-justified infinity.

The interpolating equation for industrial use is defined by

$$\overline{\lambda} = \overline{\lambda}_0 (\overline{T}) + \overline{\lambda}_1(\overline{\rho}) + \overline{\lambda}_2(\overline{T},\overline{\rho}) \tag{8}$$

The function $\overline{\lambda}_0 (\overline{T})$ represents the thermal conductivity of steam in the ideal-gas limit and has the form

$$\overline{\lambda}_0(\overline{T}) = \sqrt{\overline{T}} \sum_{k=0}^{3} a_k \overline{T}^k \tag{9}$$

with the coefficients a_k given in Table B.I. The function $\overline{\lambda}_1 (\overline{\rho})$ is defined by

$$\overline{\lambda}_1(\overline{\rho}) = b_0 + b_1\overline{\rho} + b_2 \exp \left\{ B_1(\overline{\rho} + B_2)^2 \right\} \tag{10}$$

with coefficients b_i and B_i given in table B.II. The function $\overline{\lambda}_2 (\overline{T} , \overline{\rho})$ is defined by

$$\begin{aligned} \overline{\lambda}_2(\overline{T},\overline{\rho}) &= \left(\frac{d_1}{\overline{T}^{10}} + d_2 \right) \overline{\rho}^{9/5} \exp[C_1(1 - \overline{\rho}^{14/5})] \\ &+ d_3 S \overline{\rho}^{Q} \exp\left[\left(\frac{Q}{1+Q} \right) \left(1 - \overline{\rho}^{1+Q} \right) \right] + d_4 \exp\left(C_2 \overline{T}^{3/2} + \frac{C_3}{\overline{\rho}^5} \right) \end{aligned} \tag{11}$$

Here Q and S are functions of

$$\Delta\overline{T} = | \overline{T} - 1 | + C_4, \tag{12}$$

where:

$$Q = 2 + \frac{C_5}{\Delta \bar{T}^{3/5}} \tag{13}$$

$$S = \begin{cases} \dfrac{1}{\Delta \bar{T}} & \text{for } \bar{T} \geq 1 \\ \dfrac{C_6}{\Delta \bar{T}^{3/5}} & \text{for } \bar{T} < 1 \end{cases} \tag{14}$$

The coefficients d_i and C_i are given in Table B.III.

B.6. Remarks

Users should be aware of the fact that the above equation is subject to exponential underflows which most computers set to zero; this causes no errors in the final result.

The equation adopted in this Appendix is not the only possible, relatively simple, empirical interpolation formula. An alternative form has been proposed in Engineering Sciences Data Item No. 78039 (Engineering Sciences Data Unit, London, 1978), Appendix A.4.

Table B.I. Coefficients a_k for $\overline{\lambda}_0$ ($\overline{T}$)

a_0 = 0.010 281 1
a_1 = 0.029 962 1
a_2 = 0.015 614 6
a_3 = -0.004 224 64

Table B.II Coefficients b_i and B_i for $\overline{\lambda}_1$ ($\overline{\rho}$)

b_0 = -0.397 070
b_1 = 0.400 302
b_2 = 1.060 000

B_1 = -0.171 587
B_2 = 2.392 190

Table B.III Coefficients d_i and C_i for $\overline{\lambda}_2$ ($\overline{T}$, $\overline{\rho}$)

d_1 = 0.070 130 9
d_2 = 0.011 852 0
d_3 = 0.001 699 37
d_4 = -1.0200

C_1 = 0.642 857
C_2 = -4.117 17
C_3 = -6.179 37
C_4 = 0.003 089 76
C_5 = 0.082 299 4
C_6 = 10.0932

Appendix C: Recommended Interpolating Equation for General and Scientific Use

This material has been revised to conform to the Release on the IAPWS Formulation 1995 for the Thermodynamic Properties of Ordinary Water Substance for General and Scientific Use, the 1997 Revised Release on the IAPS Formulation 1985 for the Viscosity of Ordinary Water Substance and the ITS-90 temperature scale.

C.1. Nomenclature

T denotes temperature on the International Temperature Scale of 1990

ρ denotes density[3]

p denotes pressure

λ denotes thermal conductivity

C.2. Reference constants

Reference temperature[4]: $T^* = 647.226$ K (15)

reference density: $\rho^* = 317.763$ kg m^{-3} (16)

reference pressure: $p^* = 22.115 \times 10^6$ Pa (17)

reference thermal conductivity: $\lambda^* = 0.4945$ W m^{-1} K^{-1} (18)

The three reference constants, T^*, ρ^*, p^* are close to but not identical with the critical constants.

C.3. Dimensionless variables

Temperature: $\bar{T} = T/T^*$ (19)

density: $\bar{\rho} = \rho/\rho^*$ (20)

pressure $\bar{p} = p/p^*$ (21)

(symmetrized) compressibility: $$\bar{\chi}_T = \bar{\rho}\left[\frac{\partial \bar{\rho}}{\partial \bar{p}}\right]_{\bar{T}} \quad (22)$$

thermal conductivity: $\bar{\lambda} = \lambda/\lambda^*$ (23)

---

[3]To reproduce the values given in Appendix E, the density should be computed with the aid of the IAPWS Formulation 1995 for General and Scientific Use.

[4]The reference temperature differs from that given in the Release on the IAPS Formulation 1985 for the Thermal Conductivity of Ordinary Water Substance because of conversion to the ITS-90 temperature scale.

C.4. Range of validity of equation

IAPWS endorses the validity of Eq. (25) for the thermal conductivity in the following range of pressures p and temperatures t

$p \le 400$ MPa for $0\ ^\circ\text{C} \le t \le 125\ ^\circ\text{C}$

$p \le 200$ MPa for $125\ ^\circ\text{C} < t \le 250\ ^\circ\text{C}$

$p \le 150$ MPa for $250\ ^\circ\text{C} < t \le 400\ ^\circ\text{C}$

$p \le 100$ MPa for $400\ ^\circ\text{C} < t \le 800\ ^\circ\text{C}$ (24)

C.5. Interpolating equation

The values appearing in Tables A.I and A.II may also be reproduced within the stated tolerances by the following alternative equation which incorporates in it the present-day understanding of the nature of the critical anomaly in thermal conductivity. In particular, the thermal conductivity becomes infinite at the critical point.

The interpolating equation for scientific use is defined by

$$\bar{\lambda} = \bar{\lambda}_0\,(\bar{T}) \cdot \bar{\lambda}_1\,(\bar{T}, \bar{\rho}) + \bar{\lambda}_2\,(\bar{T}, \bar{\rho}). \tag{25}$$

The factor $\bar{\lambda}_0\ (\bar{T}\ )$ represents the thermal conductivity of steam in the ideal gas limit and has the form

$$\bar{\lambda}_0(\bar{T}) = \frac{\sqrt{\bar{T}}}{\sum_{i=0}^{3} \frac{L_i}{\bar{T}^i}} \tag{26}$$

with coefficients L_i given in Table C.I. The factor $\bar{\lambda}_1\ (\bar{T}, \bar{\rho}\ )$ is

$$\bar{\lambda}_1(\bar{T}, \bar{\rho}) = \exp\left[\bar{\rho} \sum_{i=0}^{4} \sum_{j=0}^{5} L_{ij} \left(\frac{1}{\bar{T}} - 1\right)^i (\bar{\rho} - 1)^j\right] \tag{27}$$

with coefficient L_{ij} given in Table C.II. The additive term $\bar{\lambda}_2\ (\bar{T}, \bar{\rho})$ in (25) which accounts for an enhancement of the thermal conductivity in the critical region is defined by

$$\bar{\lambda}_2(\bar{T},\bar{\rho}) = \frac{0.001\ 384\ 8}{\bar{\mu}_0(\bar{T})\cdot\bar{\mu}_1(\bar{T},\bar{\rho})}\left(\frac{\bar{T}}{\bar{\rho}}\right)^2\left(\frac{\partial\bar{p}}{\partial\bar{T}}\right)^2_{\bar{\rho}}\bar{\chi}_T^{0.4678}\,\bar{\rho}^{1/2}$$

$$\times\ \exp[-18.66(\bar{T}-1)^2-(\bar{\rho}-1)^4]\ , \qquad (28)$$

where the functions $\bar{\mu}_0(\bar{T})$ and $\bar{\mu}_1(\bar{T},\bar{\rho})$ are those defined in Appendix B.5 of the 1997 Revised Release on the IAPS Formulation 1985 for the Viscosity of Ordinary Water Substance.

C.6. Remarks

To produce the values given in Appendix E, the density, the isothermal compressibility as well as the partial derivative $(\partial p/\partial T)_\rho$ should be calculated with the aid of the Release on the IAPWS Formulation 1995 for the Thermodynamic Properties of Ordinary Water Substance for General and Scientific Use. Alternatively, for industrial use, these quantities can be calculated using the IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam with only a small change in results. If another density formulation is used, a relative departure $\pm\Delta\rho/\rho$ induces, at most, a relative departure $\pm\Delta\lambda/\lambda = 2\Delta\rho/\rho$, except for the near-critical region.

A further discussion of this equation can be found in Appendix II of the paper "Representative Equations for the Thermal Conductivity of Water Substance," J. V. Sengers, J. T. R. Watson, R. S. Basu, B. Kamgar-Parsi, and R. C. Hendricks, Journal of Physical and Chemical Reference Data 13 (1984), pp. 893-933.

Table C.I. Coefficients L_i for $\bar{\lambda}_0$ ($\bar{T}$)

L_0	=	1.000 000
L_1	=	6.978 267
L_2	=	2.599 096
L_3	=	-0.998 254

Table C.II. Coefficients L_{ij} for $\bar{\lambda}_1$ ($\bar{T}$, $\bar{\rho}$)

j	L_{0j}	L_{1j}	L_{2j}	L_{3j}	L_{4j}
0	+1.329 304 6	+1.701 836 3	+5.224 615 8	+8.712 767 5	-1.852 599 9
1	-0.404 524 37	-2.215 684 5	-10.124 111	- 9.500 061 1	+0.934 046 90
2	+0.244 094 90	+1.651 105 7	+4.987 468 7	+4.378 660 6	0.0
3	+0.018 660 751	-0.767 360 02	- 0.272 976 94	- 0.917 837 82	0.0
4	-0.129 610 68	+0.372 833 44	- 0.430 833 93	0.0	0.0
5	+0.044 809 953	-0.112 031 60	+0.133 338 49	0.0	0.0

Appendix D

The thermal conductivities in these tables have been recalculated to conform to the revised equations of Appendix B.

Table D.I Values of the Thermal Conductivity of Ordinary Water Substance Obtained with the Aid of the Recommended Interpolating Equation for Industrial Use, Calculated Over a Uniform Grid

Thermal conductivity, λ, in mW K^{-1} m^{-1}; Pressure, p, in MPa; Temperature, t, in °C

Values obtained with the aid of the interpolating equation defined in Appendix B and density values based on the 1997 Formulation for Industrial Use.

The point shown in italics represents an extrapolation into a region where the equilibrium phase is a solid. The two points in parentheses have values slightly outside the tolerances given in Table A.I.

(Note: To assist in programming, the tabular entries contain more significant digits than are justified by the tolerances listed in Table A.I.)

Table D.II. Values of the Thermal Conductivity of Ordinary Water Substance Obtained with the Aid of the Recommended Interpolating Equation for Industrial Use, Calculated along the Saturation Line

Thermal conductivity of saturated liquid, λ', and thermal conductivity of saturated vapor, λ'', in mW K^{-1} m^{-1}; Pressure, p, in MPa; Temperature, t, in °C

(Note: To assist in programming, the tabular entries contain more significant digits than are justified by the tolerances listed in Table A.I.I)

Values obtained with the aid of the interpolating equation defined in Appendix B and with saturation pressures and saturation densities based on the 1997 Formulation for Industrial Use.

Table D.I Values of the Thermal Conductivity of Ordinary Water Substance Obtained with the Aid of the Recommended Interpolating Equation for Industrial Use, Calculated over a Uniform Grid

p/MPa	Temperature/°C										
	0	25	50	75	100	150	200	250	300	350	375
0.1	*562.0*	607.5	640.5	663.5	24.8	28.8	33.4	38.3	43.5	49.0	51.8
0.5	562.3	607.7	640.7	663.7	678.0	683.9	34.2	38.8	43.9	49.3	52.1
1	562.6	608.0	641.0	663.9	678.3	684.2	36.1	39.7	44.5	49.8	52.6
2.5	563.4	608.8	641.7	664.7	679.1	685.2	664.2	43.9	46.8	51.5	54.1
5	564.9	610.1	643.0	666.0	680.5	686.9	666.4	619.1	53.0	55.2	57.1
7.5	566.4	611.4	644.3	667.4	681.9	688.5	668.6	622.3	64.0	60.6	61.1
10	567.8	612.7	645.6	668.6	683.2	690.2	670.7	625.5	548.1	68.5	66.4
12.5	569.3	614.1	646.9	669.9	684.6	691.8	672.8	628.5	553.6	81.1	73.7
15	570.8	615.4	648.1	671.2	685.9	693.4	674.9	631.5	558.7	104.1	84.5
17.5	572.2	616.7	649.4	672.5	687.3	695.0	676.9	634.4	563.6	441.9	103.1
20	573.6	617.9	650.6	673.8	688.6	696.5	678.9	637.2	568.3	454.1	145.2
22.5	575.1	619.2	651.9	675.0	689.9	698.1	680.9	640.0	572.9	464.7	477.1
25	576.5	620.5	653.1	676.3	691.2	699.6	682.9	642.7	577.2	474.1	386.9
27.5	577.9	621.8	654.4	677.5	692.5	701.2	684.8	645.4	581.4	482.7	405.8
30	579.3	623.1	655.6	678.8	693.8	702.7	686.7	648.0	585.5	490.6	420.6
35	582.1	625.6	658.0	681.3	696.4	705.7	690.5	653.2	593.2	504.7	443.9
40	584.9	628.1	660.4	683.7	699.0	708.6	694.2	658.1	600.5	517.3	462.4
45	587.6	630.6	662.8	686.1	701.5	711.6	697.8	662.9	607.4	528.7	478.2
50	590.3	633.0	665.2	688.5	704.0	714.4	701.3	667.5	614.0	539.1	492.0
55	593.0	635.5	667.6	690.9	706.5	717.3	704.8	672.0	620.3	548.7	504.4
60	595.7	637.9	669.9	693.2	708.9	720.0	708.1	676.4	626.3	557.7	515.8
65	598.3	640.3	672.2	695.6	711.3	722.8	711.5	680.6	632.1	566.1	526.2
70	600.9	642.6	674.5	697.9	713.7	725.5	714.7	684.8	637.7	574.0	535.9
75	603.5	645.0	676.8	700.2	716.0	728.2	717.9	688.8	643.0	581.5	545.0
80	606.1	647.3	679.0	702.4	718.4	730.8	721.1	692.8	648.2	588.7	553.5
85	608.6	649.6	681.3	704.7	720.7	733.4	724.2	696.6	653.3	595.5	561.5
90	611.1	651.9	683.5	706.9	723.0	736.0	727.2	700.4	658.1	602.0	569.2
95	613.6	654.2	685.7	709.1	725.2	738.5	730.2	704.1	662.8	608.3	576.4
100	616.0	656.4	687.8	711.3	727.5	741.0	733.2	707.7	667.4	614.3	583.4

Table D.I (continued)

p/MPa	Temperature/°C										
	400	425	450	475	500	550	600	650	700	750	800
0.1	54.7	57.7	60.7	63.8	66.9	73.3	79.9	86.7	93.6	100.6	107.7
0.5	55.0	58.0	61.0	64.0	67.2	73.6	80.1	86.9	93.8	100.8	107.9
1	55.4	58.4	61.4	64.4	67.5	73.9	80.4	87.2	94.0	101.0	108.2
2.5	56.8	59.6	62.5	65.5	68.6	74.9	81.4	88.0	94.9	101.8	108.9
5	59.5	62.1	64.8	67.6	70.6	76.7	83.0	89.6	96.3	103.2	110.2
7.5	62.9	65.1	67.5	70.1	72.8	78.7	84.8	91.2	97.8	104.6	111.5
10	67.2	68.6	70.6	72.8	75.3	80.8	86.8	93.0	99.5	106.1	113.0
12.5	72.8	73.0	74.2	76.0	78.2	83.2	88.9	94.9	101.2	107.7	114.4
15	79.9	78.3	78.5	79.7	81.4	85.8	91.1	96.9	103.0	109.4	116.0
17.5	89.6	84.9	83.6	83.9	85.0	88.7	93.6	99.1	105.0	111.2	117.6
20	103.4	93.4	89.8	88.8	89.1	91.9	96.2	101.4	107.0	113.0	119.3
22.5	124.2	104.3	97.2	94.4	93.7	95.4	99.1	103.8	109.2	115.0	121.1
25	160.0	118.9	106.3	101.1	99.0	99.2	102.1	106.4	111.5	117.0	123.0
27.5	232.4	138.9	117.5	108.9	105.0	103.4	105.4	109.2	113.9	119.2	124.9
30	328.1	167.3	131.5	118.0	111.9	108.0	109.0	112.1	116.4	121.4	126.9
35	373.0	253.6	170.8	141.6	128.5	118.6	116.9	118.5	121.8	126.2	131.2
40	398.5	321.1	(225.0)	(173.2)	149.7	131.2	125.9	125.7	127.8	131.4	135.8
45	419.9	354.9	277.9	211.9	175.7	145.9	136.2	133.6	134.3	136.9	140.7
50	438.3	379.4	315.7	251.3	205.5	162.9	147.7	142.3	141.4	143.0	145.9
55	454.4	400.0	343.1	285.4	236.0	181.7	160.3	151.8	149.1	149.4	151.5
60	468.8	417.9	365.2	312.9	264.6	201.8	174.1	162.1	157.2	156.2	157.4
65	481.8	433.9	384.3	335.5	289.8	222.4	188.7	173.0	165.9	163.4	163.6
70	493.7	448.3	401.3	355.1	311.7	242.7	203.8	184.4	175.0	171.0	170.0
75	504.7	461.5	416.8	372.5	330.9	262.0	219.2	196.3	184.5	178.8	176.7
80	514.9	473.7	430.9	388.4	348.2	280.2	234.6	208.5	194.3	187.0	183.7
85	524.5	485.0	443.9	402.9	363.9	297.1	249.6	220.8	204.3	195.3	190.8
90	533.5	495.5	456.0	416.4	378.5	312.7	264.2	233.1	214.5	203.9	198.2
95	542.0	505.4	467.3	429.0	392.1	327.3	278.3	245.3	224.7	212.5	205.6
100	550.0	514.7	477.9	440.8	404.8	341.0	291.7	257.3	235.0	221.3	213.2

Table D.II. Values of the Thermal Conductivity of Ordinary Water Substance Obtained with the Aid of the Recommended Interpolating Equation for Industrial Use, Calculated along the Saturation Line

t °C	p MPa	λ' mW K^{-1} m^{-1}	λ'' mW K^{-1} m^{-1}
0.01	0.000611 7	561.99	16.49
10	0.001 228	581.92	17.21
20	0.002 339	599.47	17.95
30	0.004 247	614.95	18.71
40	0.007 384	628.56	19.48
50	0.012 35	640.46	20.28
60	0.019 95	650.76	21.10
70	0.031 20	659.57	21.96
80	0.047 41	666.96	22.86
90	0.070 18	673.00	23.80
100	0.1014	677.76	24.79
110	0.1434	681.28	25.85
120	0.1987	683.61	26.96
130	0.2703	684.80	28.15
140	0.3615	684.87	29.42
150	0.4761	683.86	30.77
160	0.6181	681.80	32.22
170	0.7921	678.71	33.77
180	1.003	674.60	35.42
190	1.255	669.49	37.19
200	1.555	663.38	39.10
210	1.907	656.28	41.14
220	2.319	648.18	43.34
230	2.797	639.08	45.72
240	3.347	628.97	48.32
250	3.976	617.81	51.16
260	4.692	605.58	54.30
270	5.503	592.25	57.81
280	6.416	577.75	61.79
290	7.442	562.01	66.37
300	8.588	544.95	71.75
310	9.865	526.47	78.24
320	11.284	506.46	86.35
330	12.858	484.81	96.96
340	14.600	461.44	111.75
350	16.529	436.45	134.53
360	18.666	411.93	176.63
370	21.043	418.09	309.47
371	21.296	432.57	346.99
372	21.553	462.02	403.69
373	21.813	534.96	507.03

Appendix E

The thermal conductivities in these tables have been recalculated to conform to the revised equations of Appendix C.

Table E.I Values of the Thermal Conductivity of Ordinary Water Substance Obtained with the Aid of the Recommended Interpolating Equation for General and Scientific Use, Calculated Over a Uniform Grid

Thermal conductivity, λ, in mW K^{-1} m^{-1}; Pressure, p, in MPa; Temperature, t, in °C

Values obtained with the aid of the interpolating equation defined in Appendix C and density values as well as the values of the thermodynamic derivatives based on the Release on the IAPWS Formulation 1995 for the Thermodynamic Properties of Ordinary Water Substance for General and Scientific Use.

The point shown in italics represents an extrapolation into a region where the equilibrium phase is a solid.

(Note: To assist in programming, the tabular entries contain more significant digits than are justified by the tolerances listed in Table A.I.)

Table E.II. Values of the Thermal Conductivity of Ordinary Water Substance Obtained with the Aid of the Recommended Interpolating Equation for General and Scientific Use, Calculated along the Saturation Line

Thermal conductivity of saturated liquid, λ', and thermal conductivity of saturated vapor, λ'', in mW K^{-1} m^{-1}; Pressure, p, in MPa; Temperature, t, in °C

Values obtained with the aid of the interpolating equation defined in Appendix C with saturation pressures and saturation densities as well as the values of the thermodynamic derivatives based on the IAPWS Formulation 1995 for the Thermodynamic Properties of Ordinary Water Substance for General and Scientific Use.

(Note: To assist in programming, the tabular entries contain more significant digits than are justified by the tolerances listed in Table A.II.)

Table E.I. Values of the Thermal Conductivity of Ordinary Water Substance Obtained with the Aid of the Recommended Interpolating Equation for General and Scientific Use, Calculated Over a Uniform Grid

p/MPa	Temperature/°C										
	0	25	50	75	100	150	200	250	300	350	375
0.1	*561.1*	607.2	643.6	666.8	25.08	28.86	33.28	38.17	43.42	48.97	51.83
0.5	561.3	607.4	643.8	667.0	679.3	682.1	34.93	39.18	44.09	49.45	52.26
1	561.6	607.6	644.0	667.2	679.6	682.4	37.21	40.52	44.96	50.07	52.80
2.5	562.4	608.3	644.7	668.0	680.4	683.4	664.1	45.16	47.82	52.06	54.53
5	563.8	609.4	645.9	669.2	681.8	685.1	666.3	622.5	53.85	55.99	57.87
7.5	565.2	610.6	647.0	670.5	683.1	686.8	668.5	625.7	63.12	61.05	62.00
10	566.5	611.7	648.2	671.7	684.5	688.4	670.6	628.8	550.7	68.09	67.34
12.5	567.9	612.8	649.4	673.0	685.9	690.1	672.7	631.8	556.2	79.12	74.67
15	569.3	614.0	650.5	674.2	687.2	691.8	674.9	634.8	561.4	100.8	85.52
17.5	570.7	615.1	651.7	675.5	688.6	693.4	676.9	637.7	566.5	452.2	103.6
20	572.1	616.2	652.8	676.7	689.9	695.1	679.0	640.5	571.3	463.2	141.5
22.5	573.4	617.4	654.0	678.0	691.3	696.7	681.1	643.4	575.9	472.6	439.4
25	574.8	618.5	655.2	679.2	692.6	698.4	683.2	646.1	580.4	481.1	410.9
27.5	576.2	619.7	656.3	680.4	694.0	700.0	685.2	648.9	584.7	488.8	425.9
30	577.5	620.8	657.5	681.7	695.3	701.7	687.2	651.6	588.8	496.0	438.1
35	580.2	623.1	659.8	684.2	698.0	704.9	691.3	656.8	596.8	509.0	457.3
40	582.9	625.3	662.1	686.6	700.7	708.2	695.3	662.0	604.3	520.7	472.9
45	585.6	627.6	664.4	689.1	703.3	711.4	699.2	667.0	611.5	531.5	486.2
50	588.2	629.8	666.7	691.5	706.0	714.6	703.1	671.9	618.3	541.5	498.2
55	590.8	632.1	669.0	694.0	708.6	717.8	707.0	676.8	624.9	550.8	509.1
60	593.3	634.3	671.3	696.4	711.2	721.0	710.9	681.5	631.2	559.6	519.2
65	595.8	636.5	673.5	698.8	713.9	724.1	714.7	686.2	637.3	568.0	528.7
70	598.3	638.7	675.8	701.2	716.4	727.2	718.5	690.7	643.2	575.9	537.6
75	600.7	640.9	678.0	703.6	719.0	730.4	722.2	695.3	648.9	583.4	546.1
80	603.1	643.0	680.3	705.9	721.6	733.5	726.0	699.7	654.4	590.7	554.2
85	605.4	645.1	682.5	708.3	724.1	736.6	729.7	704.2	659.8	597.6	561.9
90	607.7	647.3	684.7	710.6	726.7	739.7	733.4	708.5	665.1	604.3	569.3
95	610.0	649.3	686.8	712.9	729.2	742.7	737.1	712.9	670.3	610.7	576.4
100	612.2	651.4	689.0	715.2	731.7	745.8	740.8	717.1	675.3	617.0	583.2

Table E.I. (continued)

p/MPa	Temperature/°C										
	400	425	450	475	500	550	600	650	700	750	800
0.1	54.76	57.74	60.77	63.85	66.98	73.36	79.90	86.57	93.38	100.3	107.3
0.5	55.14	58.08	61.09	64.15	67.26	73.61	80.14	86.80	93.60	100.5	107.5
1	55.62	58.52	61.49	64.52	67.61	73.94	80.44	87.10	93.88	100.8	107.8
2.5	57.15	59.90	62.75	65.69	68.71	74.95	81.40	88.02	94.76	101.6	108.5
5	60.06	62.49	65.10	67.86	70.74	76.79	83.13	89.67	96.35	103.1	109.9
7.5	63.56	65.54	67.82	70.33	73.03	78.84	85.04	91.49	98.09	104.8	111.5
10	67.88	69.18	70.99	73.16	75.61	81.11	87.14	93.48	99.98	106.6	113.2
12.5	73.39	73.62	74.72	76.41	78.52	83.61	89.43	95.63	102.0	108.5	115.0
15	80.68	79.12	79.17	80.18	81.83	86.38	91.92	97.96	104.2	110.6	116.9
17.5	90.77	86.10	84.52	84.55	85.58	89.43	94.62	100.5	106.6	112.8	119.0
20	105.5	95.14	91.02	89.67	89.85	92.78	97.55	103.2	109.1	115.2	121.2
22.5	128.5	107.1	99.01	95.66	94.70	96.47	100.7	106.0	111.8	117.7	123.6
25	168.2	123.3	108.9	102.7	100.2	100.5	104.1	109.1	114.6	120.3	126.0
27.5	245.5	145.4	121.1	111.0	106.5	104.9	107.8	112.3	117.6	123.1	128.6
30	332.0	175.8	136.2	120.7	113.6	109.8	111.7	115.8	120.8	126.0	131.3
35	384.7	257.9	176.5	145.0	130.7	120.7	120.3	123.2	127.5	132.2	137.0
40	414.2	323.8	227.2	176.0	151.7	133.4	129.9	131.4	134.8	138.9	143.2
45	434.9	363.6	275.8	211.5	176.2	147.8	140.5	140.3	142.6	146.0	149.7
50	451.3	391.3	315.5	247.0	202.9	163.7	152.0	149.7	150.9	153.4	156.5
55	465.2	412.5	346.3	279.4	230.0	180.6	164.2	159.7	159.6	161.2	163.5
60	477.4	429.7	370.8	307.9	255.8	198.1	176.9	169.9	168.5	169.1	170.7
65	488.4	444.1	391.0	332.2	279.7	215.6	189.8	180.4	177.5	177.2	177.9
70	498.5	456.7	408.0	353.2	301.5	232.8	202.7	190.9	186.5	185.2	185.2
75	507.9	468.0	422.7	371.5	321.2	249.2	215.3	201.2	195.5	193.2	192.4
80	516.8	478.2	435.6	387.6	338.9	264.9	227.6	211.4	204.2	201.0	199.5
85	525.2	487.7	447.2	401.8	354.9	279.7	239.5	221.1	212.7	208.6	206.4
90	533.2	496.5	457.6	414.6	369.4	293.7	250.8	230.5	220.9	215.9	213.0
95	540.8	504.9	467.2	426.1	382.7	306.9	261.7	239.5	228.7	222.9	219.4
100	548.2	512.8	476.1	436.6	394.8	319.3	272.0	248.0	236.0	229.5	225.4

Table E.II. Values of the Thermal Conductivity of Ordinary Water Substance Obtained with the Aid of the Recommended Interpolating Equation for General and Scientific Use, Calculated along the Saturation Line

t °C	p MPa	λ' mW K^{-1} m^{-1}	λ'' mW K^{-1} m^{-1}
0.01	0.000 611 7	561.0	17.07
10	0.001 228	580.0	17.62
20	0.002 339	598.4	18.23
30	0.004 247	615.5	18.89
40	0.007 385	630.6	19.60
50	0.012 35	643.6	20.36
60	0.019 95	654.3	21.19
70	0.031 20	663.1	22.07
80	0.047 41	670.0	23.01
90	0.070 18	675.3	24.02
100	0.1014	679.1	25.10
110	0.1434	681.7	26.24
120	0.1987	683.2	27.47
130	0.2703	683.7	28.76
140	0.3615	683.3	30.14
150	0.4762	682.0	31.60
160	0.6182	680.0	33.13
170	0.7922	677.0	34.75
180	1.0028	673.3	36.45
190	1.255	668.8	38.24
200	1.555	663.3	40.11
210	1.908	657.0	42.09
220	2.320	649.7	44.17
230	2.797	641.3	46.38
240	3.347	631.8	48.73
250	3.976	621.2	51.26
260	4.692	609.2	54.03
270	5.503	595.9	57.11
280	6.417	581.1	60.61
290	7.442	565.0	64.71
300	8.588	547.4	69.65
310	9.865	528.7	75.84
320	11.284	509.2	83.91
330	12.858	489.1	94.94
340	14.601	468.5	110.9
350	16.529	447.4	135.9
360	18.666	425.7	181.5
370	21.044	425.0	323.8
371	21.297	438.4	367.3
372	21.554	467.4	438.1
373	21.814	547.9	590.7