

# Appendice A

## Tabelle delle proprietà e diagrammi

**TABELLA A.1** Massa molare, costante dei gas e proprietà di punto critico

Sostanza	Formula	M Massa molecolare kg/kmol	R Costante dei gas kJ/kg · K*	Proprietà di punto critico		
				Temperatura K	Pressione MPa	Volume m <sup>3</sup> /kmol
Acqua	H <sub>2</sub> O	18.015	0.4615	647.3	22.09	0.0568
Alcool etilico	C <sub>2</sub> H <sub>5</sub> OH	46.070	0.1805	516	6.38	0.1673
Alcool metilico	CH <sub>3</sub> OH	32.042	0.2595	513.2	7.95	0.1180
Ammoniaca	NH <sub>3</sub>	17.030	0.4882	405.5	11.28	0.0724
Argon	Ar	39.948	0.2081	151	4.86	0.0749
Aria	—	28.970	0.2870	132.5	3.77	0.0883
Azoto	N <sub>2</sub>	28.013	0.2968	126.2	3.39	0.0899
Benzene	C <sub>6</sub> H <sub>6</sub>	78.115	0.1064	562	4.92	0.2603
Bromo	Br <sub>2</sub>	159.808	0.0520	584	10.34	0.1355
n-Butano	C <sub>4</sub> H <sub>10</sub>	58.124	0.1430	425.2	3.80	0.2547
Carbonio, biossido di	CO <sub>2</sub>	44.010	0.1889	304.2	7.39	0.0943
Carbonio, monossido di	CO	28.011	0.2968	133	3.50	0.0930
Carbonio, tetracloruro	CCl <sub>4</sub>	153.820	0.05405	556.4	4.56	0.2759
Cloro	Cl <sub>2</sub>	70.906	0.1173	417	7.71	0.1242
Cloroformio	CHCl <sub>3</sub>	119.380	0.06964	536.6	5.47	0.2403
Cloruro di metile	CH <sub>3</sub> Cl	50.488	0.1647	416.3	6.68	0.1430
Cripto	Kr	83.800	0.09921	209.4	5.50	0.0924
Diclorodifluorometano (R-12)	CCl <sub>2</sub> F <sub>2</sub>	120.910	0.06876	384.7	4.01	0.2179
Diclorofluorometano (R-21)	CHCl <sub>2</sub> F	102.920	0.08078	451.7	5.17	0.1973
Elio	He	4.003	2.0769	5.3	0.23	0.0578
n-Esano	C <sub>6</sub> H <sub>14</sub>	86.179	0.09647	507.9	3.03	0.3677
Etano	C <sub>2</sub> H <sub>6</sub>	30.070	0.2765	305.5	4.48	0.1480
Etilene	C <sub>2</sub> H <sub>4</sub>	28.054	0.2964	282.4	5.12	0.1242
Idrogeno (normale)	H <sub>2</sub>	2.016	4.1240	33.3	1.30	0.0649
Metano	CH <sub>4</sub>	16.043	0.5182	191.1	4.64	0.0993
Neon	Ne	20.183	0.4119	44.5	2.73	0.0417
Ossido nitroso	N <sub>2</sub> O	44.013	0.1889	309.7	7.27	0.0961
Ossigeno	O <sub>2</sub>	31.999	0.2598	154.8	5.08	0.0780
Propano	C <sub>3</sub> H <sub>8</sub>	44.097	0.1885	370	4.26	0.1998
Propilene	C <sub>3</sub> H <sub>6</sub>	42.081	0.1976	365	4.62	0.1810
Tetrafluoretano (R-134a)	CF <sub>3</sub> CH <sub>2</sub> F	102.03	0.08149	374.3	4.067	0.1847
Triclorofluoretano (R-11)	CCl <sub>3</sub> F	137.37	0.06052	471.2	4.38	0.2478
Xeon	Xe	131.30	0.06332	289.8	5.88	0.1186
Zolfo, biossido di	So <sub>2</sub>	64.063	0.1298	430.7	7.88	0.1217

\* L'unità kJ/(kg · K) è equivalente a kPa · m<sup>3</sup>/(kg · K). La costante dei gas è calcolata con  $R = R_u/M$ , dove  $R_u = 8.314$  kJ/(kmol · K) e  $M$  è la massa molare.

Fonte: K.A. Kobe, R.E. Lynn Jr., «Chemical Review», 1953, vol. 52, pp. 117-236, e ASHRAE Handbook of Fundamentals, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta (GA) 1993, pp. 16.4 e 36.1.

**TABELLA A.2** Calori specifici dei gas ideali di diversi gas comuni (300 K)

A 300 K					
Gas	Formula	Costante dei gas $R$ kJ/kg · K	$c_{p0}$ kJ/kg · K	$c_{v0}$ kJ/kg · K	$k$
Aria	—	0.2870	1.005	0.718	1.400
Argon	Ar	0.2081	0.5203	0.3122	1.667
Butano	C <sub>4</sub> H <sub>10</sub>	0.1433	1.7164	1.5734	1.091
Carbonio, biossido di	CO <sub>2</sub>	0.1889	0.846	0.657	1.289
Carbonio, monossido di	CO	0.2968	1.040	0.744	1.400
Etano	C <sub>2</sub> H <sub>6</sub>	0.2765	1.7662	1.4897	1.186
Etilene	C <sub>2</sub> H <sub>4</sub>	0.2964	1.5482	1.2518	1.237
Elio	He	2.0769	5.1926	3.1156	1.667
Idrogeno	H <sub>2</sub>	4.1240	14.307	10.183	1.405
Metano	CH <sub>4</sub>	0.5182	2.2537	1.7354	1.299
Neon	Ne	0.4119	1.0299	0.6179	1.667
Azoto	N <sub>2</sub>	0.2968	1.039	0.743	1.400
Ottano	C <sub>8</sub> H <sub>18</sub>	0.0729	1.7113	1.6385	1.044
Ossigeno	O <sub>2</sub>	0.2598	0.918	0.658	1.395
Propano	C <sub>3</sub> H <sub>8</sub>	0.1885	1.6794	1.4909	1.126
Vapore	H <sub>2</sub> O	0.4615	1.8723	1.4108	1.327

Fonte: *Chemical and Process Thermodynamics 3/E* by Kyle, B.G., © 2000. Riproduzione autorizzata da Pearson Education, Inc., Upper Saddle River, NJ, con modifiche.

**TABELLA A.3** Calori specifici dei gas ideali di diversi gas comuni (varie temperature)

A diverse temperature									
Temperatura K	$c_{p0}$	$c_{v0}$	$\lambda$	$c_{p0}$	$c_{v0}$	$\lambda$	$c_{p0}$	$c_{v0}$	$\lambda$
	kJ/kg · K	kJ/kg · K		kJ/kg · K	kJ/kg · K		kJ/kg · K	kJ/kg · K	
	Aria			Biossido di carbonio, CO <sub>2</sub>			Monossido di carbonio, CO		
250	1.003	0.716	1.401	0.791	0.602	1.314	1.039	0.743	1.400
300	1.005	0.718	1.400	0.846	0.657	1.288	1.040	0.744	1.399
350	1.008	0.721	1.398	0.895	0.706	1.268	1.043	0.746	1.398
400	1.013	0.726	1.395	0.939	0.750	1.252	1.047	0.751	1.395
450	1.020	0.733	1.391	0.978	0.790	1.239	1.054	0.757	1.392
500	1.029	0.742	1.387	1.014	0.825	1.229	1.063	0.767	1.387
550	1.040	0.753	1.381	1.046	0.857	1.220	1.075	0.778	1.382
600	1.051	0.764	1.376	1.075	0.886	1.213	1.087	0.790	1.376
650	1.063	0.776	1.370	1.102	0.913	1.207	1.100	0.803	1.370
700	1.075	0.788	1.364	1.126	0.937	1.202	1.113	0.816	1.364
750	1.087	0.800	1.359	1.148	0.959	1.197	1.126	0.829	1.358
800	1.099	0.812	1.354	1.169	0.980	1.193	1.139	0.842	1.353
900	1.121	0.834	1.344	1.204	1.015	1.186	1.163	0.866	1.343
1000	1.142	0.855	1.336	1.234	1.045	1.181	1.185	0.888	1.335
	Idrogeno, H <sub>2</sub>			Azoto, N <sub>2</sub>			Ossigeno, O <sub>2</sub>		
250	14.051	9.927	1.416	1.039	0.742	1.400	0.913	0.653	1.398
300	14.307	10.183	1.405	1.039	0.743	1.400	0.918	0.658	1.395
350	14.427	10.302	1.400	1.041	0.744	1.399	0.928	0.668	1.389
400	14.476	10.352	1.398	1.044	0.747	1.397	0.941	0.681	1.382
450	14.501	10.377	1.398	1.049	0.752	1.395	0.956	0.696	1.373
500	14.513	10.389	1.397	1.056	0.759	1.391	0.972	0.712	1.365
550	14.530	10.405	1.396	1.065	0.768	1.387	0.988	0.728	1.358
600	14.546	10.422	1.396	1.075	0.778	1.382	1.003	0.743	1.350
650	14.571	10.447	1.395	1.086	0.789	1.376	1.017	0.758	1.343
700	14.604	10.480	1.394	1.098	0.801	1.371	1.031	0.771	1.337
750	14.645	10.521	1.392	1.110	0.813	1.365	1.043	0.783	1.332
800	14.695	10.570	1.390	1.121	0.825	1.360	1.054	0.794	1.327
900	14.822	10.698	1.385	1.145	0.849	1.349	1.074	0.814	1.319
1000	14.983	10.859	1.380	1.167	0.870	1.341	1.090	0.830	1.313

Fonte: K. Wark, *Thermodynamics*, 4<sup>a</sup> ed., McGraw-Hill, New York 1983, p. 783, Tab. A-4M. Originariamente pubblicato in *Tables of Thermal Properties of Gases*, NBS Circ. 564, 1955.

TABELLA A.4 Calori specifici dei gas ideali di diversi gas comuni (in funzione della temperatura)

Come funzione della temperatura								
$c_{p0} = a + bT + cT^2 + dT^3$								
(T in K, $c_{p0}$ in kJ/kmol·K)								
Sostanza	Formula	a	b	c	d	Intervallo di temperatura K	% errore	
							Max.	Med.
Azoto	N <sub>2</sub>	28.90	-0.1571 × 10 <sup>-2</sup>	0.8081 × 10 <sup>-5</sup>	-2.873 × 10 <sup>-9</sup>	273-1800	0.59	0.34
Ossigeno	O <sub>2</sub>	25.48	1.520 × 10 <sup>-2</sup>	-0.7155 × 10 <sup>-5</sup>	1.312 × 10 <sup>-9</sup>	273-1800	1.19	0.28
Aria		28.11	0.1967 × 10 <sup>-2</sup>	0.4802 × 10 <sup>-5</sup>	-1.966 × 10 <sup>-9</sup>	273-1800	0.72	0.33
Idrogeno	H <sub>2</sub>	29.11	-0.1916 × 10 <sup>-2</sup>	0.4003 × 10 <sup>-5</sup>	-0.8704 × 10 <sup>-9</sup>	273-1800	1.01	0.26
Carbonio, monoss.	CO	28.16	0.1675 × 10 <sup>-2</sup>	0.5372 × 10 <sup>-5</sup>	-2.222 × 10 <sup>-9</sup>	273-1800	0.89	0.37
Carbonio, biossido	CO <sub>2</sub>	22.26	5.981 × 10 <sup>-2</sup>	-3.501 × 10 <sup>-5</sup>	7.469 × 10 <sup>-9</sup>	273-1800	0.67	0.22
Vapor d'acqua	H <sub>2</sub> O	32.24	0.1923 × 10 <sup>-2</sup>	1.055 × 10 <sup>-5</sup>	-3.595 × 10 <sup>-9</sup>	273-1800	0.53	0.24
Ossido nitrico	NO	29.34	-0.09395 × 10 <sup>-2</sup>	0.9747 × 10 <sup>-5</sup>	-4.187 × 10 <sup>-9</sup>	273-1500	0.97	0.36
Ossido nitroso	N <sub>2</sub> O	24.11	5.8632 × 10 <sup>-2</sup>	-3.562 × 10 <sup>-5</sup>	10.58 × 10 <sup>-9</sup>	273-1500	0.59	0.26
Azoto, biossido di	NO <sub>2</sub>	22.9	5.715 × 10 <sup>-2</sup>	-3.52 × 10 <sup>-5</sup>	7.87 × 10 <sup>-9</sup>	273-1500	0.46	0.18
Ammoniaca	NH <sub>3</sub>	27.568	2.5630 × 10 <sup>-2</sup>	0.99072 × 10 <sup>-5</sup>	-6.6909 × 10 <sup>-9</sup>	273-1500	0.91	0.36
Zolfo	S <sub>2</sub>	27.21	2.218 × 10 <sup>-2</sup>	-1.628 × 10 <sup>-5</sup>	3.986 × 10 <sup>-9</sup>	273-1800	0.99	0.38
Zolfo, biossido di	SO <sub>2</sub>	25.78	5.795 × 10 <sup>-2</sup>	-3.812 × 10 <sup>-5</sup>	8.612 × 10 <sup>-9</sup>	273-1800	0.45	0.24
Zolfo, triossido di	SO <sub>3</sub>	16.40	14.58 × 10 <sup>-2</sup>	-11.20 × 10 <sup>-5</sup>	32.42 × 10 <sup>-9</sup>	273-1300	0.29	0.13
Acetilene	C <sub>2</sub> H <sub>2</sub>	21.8	9.2143 × 10 <sup>-2</sup>	-6.527 × 10 <sup>-5</sup>	18.21 × 10 <sup>-9</sup>	273-1500	1.46	0.59
Benzene	C <sub>6</sub> H <sub>6</sub>	-36.22	48.475 × 10 <sup>-2</sup>	-31.57 × 10 <sup>-5</sup>	77.62 × 10 <sup>-9</sup>	273-1500	0.34	0.20
Metanolo	CH <sub>3</sub> O	19.0	9.152 × 10 <sup>-2</sup>	-1.22 × 10 <sup>-5</sup>	-8.039 × 10 <sup>-9</sup>	273-1000	0.18	0.08
Etanolo	C <sub>2</sub> H <sub>6</sub> O	19.9	20.96 × 10 <sup>-2</sup>	-10.38 × 10 <sup>-5</sup>	20.05 × 10 <sup>-9</sup>	273-1500	0.40	0.22
Idrogeno, cloruro di	HCl	30.33	-0.7620 × 10 <sup>-2</sup>	1.327 × 10 <sup>-5</sup>	-4.338 × 10 <sup>-9</sup>	273-1500	0.22	0.08
Metano	CH <sub>4</sub>	19.89	5.024 × 10 <sup>-2</sup>	1.269 × 10 <sup>-5</sup>	-11.01 × 10 <sup>-9</sup>	273-1500	1.33	0.57
Etano	C <sub>2</sub> H <sub>6</sub>	6.900	17.27 × 10 <sup>-2</sup>	-6.406 × 10 <sup>-5</sup>	7.285 × 10 <sup>-9</sup>	273-1500	0.83	0.28
Propano	C <sub>3</sub> H <sub>8</sub>	-4.04	30.48 × 10 <sup>-2</sup>	-15.72 × 10 <sup>-5</sup>	31.74 × 10 <sup>-9</sup>	273-1500	0.40	0.12
n-Butano	C <sub>4</sub> H <sub>10</sub>	3.96	37.15 × 10 <sup>-2</sup>	-18.34 × 10 <sup>-5</sup>	35.00 × 10 <sup>-9</sup>	273-1500	0.54	0.24
i-Butano	C <sub>4</sub> H <sub>10</sub>	-7.913	41.60 × 10 <sup>-2</sup>	-23.01 × 10 <sup>-5</sup>	49.91 × 10 <sup>-9</sup>	273-1500	0.25	0.13
n-Pentano	C <sub>5</sub> H <sub>12</sub>	6.774	45.43 × 10 <sup>-2</sup>	-22.46 × 10 <sup>-5</sup>	42.29 × 10 <sup>-9</sup>	273-1500	0.56	0.21
n-Esano	C <sub>6</sub> H <sub>14</sub>	6.938	55.22 × 10 <sup>-2</sup>	-28.65 × 10 <sup>-5</sup>	57.69 × 10 <sup>-9</sup>	273-1500	0.72	0.20
Etilene	C <sub>2</sub> H <sub>4</sub>	3.95	15.64 × 10 <sup>-2</sup>	-8.344 × 10 <sup>-5</sup>	17.67 × 10 <sup>-9</sup>	273-1500	0.54	0.13
Propilene	C <sub>3</sub> H <sub>6</sub>	3.15	23.83 × 10 <sup>-2</sup>	-12.18 × 10 <sup>-5</sup>	24.62 × 10 <sup>-9</sup>	273-1500	0.73	0.17

Fonte: *Chemical and Process Thermodynamics 3/E* by Kyle B.G., © 2000. Riproduzione autorizzata da Pearson Education, Inc., Upper Saddle River, NJ, con modifiche.

**TABELLA A.5** Proprietà di liquidi, solidi e cibi comuni

Sostanza	Dati di ebollizione a 1 atm		Dati di congelamento		Proprietà del liquido		
	Punto normale di ebollizione °C	Calore latente di vaporizzazione $h_{1\text{sat}} - v_{\text{sat}}$ kJ/kg	Punto di congelamento °C	Calore latente di fusione $h_{\text{fl}}$ kJ/kg	Temp. °C	Densità $\rho$ kg/m <sup>3</sup>	Calore specifico $c_p$ kJ/kg · K
Ammoniaca	- 33.3	1357	- 77.7	322.4	- 33.3	682	4.43
					- 20	665	4.52
					0	639	4.60
					25	602	4.80
					- 185.6	1394	1.14
Argon	- 185.9	161.6	- 189.3	28	- 185.6	1394	1.14
Benzene	80.2	394	5.5	126	20	879	1.72
Salamoia (20% in massa di cloruro di sodio)	103.9	—	- 17.4	—	20	1150	3.11
<i>n</i> -Butano	- 0.5	385.2	- 138.5	80.3	- 0.5	601	2.31
Carbonio, biossido di	- 78.4*	230.5 (a 0°C)	- 56.6	—	0	298	0.59
Etanolo	78.2	838.3	- 114.2	109	25	783	2.46
Glicole etilenico	198.1	800.1	- 10.8	181.1	20	1109	2.84
Alcool etilico	78.6	855	- 156	108	20	789	2.84
Glicerina	179.9	974	18.9	200.6	20	1261	2.32
Elio	- 268.9	22.8	—	—	- 268.9	146.2	22.8
Idrogeno	- 252.8	445.7	- 259.2	59.5	- 252.8	70.7	10.0
Isobutano	- 11.7	367.1	- 160	105.7	- 11.7	593.8	2.28
Petrolio	204-293	251	- 24.9	—	20	820	2.00
Mercurio	356.7	294.7	- 38.9	11.4	25	13560	0.139
Metano	- 161.5	510.4	- 182.2	58.4	- 161.5	423	3.49
					- 100	301	5.79
					25	787	2.55
Metanolo	64.5	1100	- 97.7	99.2	25	787	2.55
Azoto	- 195.8	198.6	- 210	25.3	- 195.8	809	2.06
					- 160	596	2.97
					20	703	2.10
Ottano	124.8	306.3	- 57.5	180.7	25	910	1.80
Olio (leggero)	—	—	—	—	25	910	1.80
Ossigeno	- 183	212.7	- 218.8	13.7	- 183	1141	1.71
Petrolio grezzo	—	230-384	—	—	20	640	2.0
Propano	- 42.1	427.8	- 187.7	80.0	- 42.1	581	2.25
					0	529	2.53
					50	449	3.13
					- 50	1443	1.23
Refrigerante-134a	- 26.1	216.8	- 96.6	—	- 26.1	1374	1.27
					0	1294	1.34
					25	1206	1.42
Acqua	100	2257	0.0	333.7	0	1000	4.23
					25	997	4.18
					50	988	4.18
					75	975	4.19
					100	958	4.22

\* Temperatura di sublimazione (a pressioni al di sotto della pressione di punto triplo di 518 kPa, il biossido di carbonio esiste sotto forma di solido o gas. Inoltre, la temperatura di punto di refrigerazione del biossido di carbonio è la temperatura di punto triplo di - 56.5°C).

(Segue)

**TABELLA A.5** Proprietà di liquidi, solidi e cibi comuni (*Continua*)

Sostanza			Densità, $\rho$ kg/m <sup>3</sup>		Calore specifico, $c_p$ kJ/kg · K		Sostanza			Densità, $\rho$ kg/m <sup>3</sup>		Calore specifico, $c_p$ kJ/kg · K	
<b>Metalli</b>						<b>Non metalli</b>							
Alluminio							Asfalto			2110			0.920
200 K					0.797		Mattone, comune			1922			0.79
250 K					0.859		Mattone, argilla refrattaria (500°C)			2300			0.960
300 K				2,700	0.902		Calcestruzzo			2300			0.653
350 K					0.929		Argilla			1000			0.920
400 K					0.949		Diamante			2420			0.616
450 K					0.973		Vetro, finestra			2700			0.800
500 K					0.997		Vetro, pyrex			2230			0.840
Bronzo (76% Cu, 2% Zn, 2% Al)				8,280	0.400		Grafite			2500			0.711
Ottone, giallo (65% Cu, 35% Zn)				8,310	0.400		Granito			2700			1.017
Rame							Gesso o intonaco in pannelli			800			1.09
-173°C					0.254		Ghiaccio						
-100°C					0.342		200 K						1.56
-50°C					0.367		220 K						1.71
0°C					0.381		240 K						1.86
27°C				8,900	0.386		260 K						2.01
100°C					0.393		273 K			921			2.11
200°C					0.403		Calcicare			1650			0.909
Ferro				7,840	0.45		Marmo			2600			0.880
Piombo				11,310	0.128		Legno compensato (Abete Douglas)			545			1.21
Magnesio				1,730	1.000		Gomma (morbida)			1100			1.840
Nichel				8,890	0.440		Gomma (dura)			1150			2.009
Argento				10,470	0.235		Sabbia			1520			0.800
Acciaio, dolce				7,830	0.500		Pietra			1500			0.800
Tungsteno				19,400	0.130		Legno, duro (acero, quercia, ecc.)			721			1.26
							Legno, dolce (abete, pino, ecc.)			513			1.38

Cibo	Cont. d'acqua % (massa)	Punto di conge- lamento °C	Calore specifico kJ/kg · K		Calore latente di fusione kJ/kg	Cibo	Cont. d'acqua % (massa)	Punto di conge- lamento °C	Calore specifico kJ/kg · K		Calore latente di fusione kJ/kg
			Sopra il conge- lamento	Sotto il conge- lamento					Sopra il conge- lamento	Sotto il conge- lamento	
Mele	84	-1.1	3.65	1.90	281	Lattuga	95	-0.2	4.02	2.04	317
Banane	75	-0.8	3.35	1.78	251	Latte, intero	88	-0.6	3.79	1.95	294
Manzo, girello	67	—	3.08	1.68	224	Arance	87	-0.8	3.75	1.94	291
Broccoli	90	-0.6	3.86	1.97	301	Patate	78	-0.6	3.45	1.82	261
Burro	16	—	—	1.04	53	Salmone	64	-2.2	2.98	1.65	214
Formaggio, svizzero	39	-10.0	2.15	1.33	130	Gamberetti	83	-2.2	3.62	1.89	277
Ciliegie	80	-1.8	3.52	1.85	267	Spinaci	93	-0.3	3.96	2.01	311
Pollo	74	-2.8	3.32	1.77	247	Fragole	90	-0.8	3.86	1.97	301
Grano, dolce	74	-0.6	3.32	1.77	247	Pomodori, maturi	94	-0.5	3.99	2.02	314
Uova, intere	74	-0.6	3.32	1.77	247	Tacchino	64	—	2.98	1.65	214
Gelato	63	-5.6	2.95	1.63	210	Anguria	93	-0.4	3.96	2.01	311

Fonte: I valori sono ottenuti da diversi manuali e altre fonti o sono calcolati. I dati di contenuto d'acqua e punto di congelamento dei cibi sono tratti da *ASHRAE Handbook of Fundamentals*, SI version, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta (GA) 1993, Cap. 30, Tab. 1. Il punto di congelamento è la temperatura a cui inizia il congelamento per frutta e verdura e la temperatura media di congelamento per gli altri cibi.

**TABELLA A.6** Acqua saturo – Tabella della temperatura

Temp., T °C	Pressione saturo, $p_{sat}$ kPa	Volume specifico, m <sup>3</sup> /kg		Energia interna, kJ/kg			Entalpia, kJ/kg			Entropia, kJ/kg · K		
		Liquido saturo, $v_{l sat}$	Vapore saturo, $v_{v sat}$	Liquido saturo, $u_{l sat}$	Evap., $u_{l sat v sat}$	Vapore saturo, $u_{v sat}$	Liquido saturo, $h_{l sat}$	Evap., $h_{l sat v sat}$	Vapore saturo, $h_{v sat}$	Liquido saturo, $s_{l sat}$	Evap., $s_{l sat v sat}$	Vapore saturo, $s_{v sat}$
0.01	0.6117	0.001000	206.00	0.000	2374.9	2374.9	0.001	2500.9	2500.9	0.0000	9.1556	9.1556
5	0.8725	0.001000	147.03	21.019	2360.8	2381.8	21.020	2489.1	2510.1	0.0763	8.9487	9.0249
10	1.2281	0.001000	106.32	42.020	2346.6	2388.7	42.022	2477.2	2519.2	0.1511	8.7488	8.8999
15	1.7057	0.001001	77.885	62.980	2332.5	2395.5	62.982	2465.4	2528.3	0.2245	8.5559	8.7803
20	2.3392	0.001002	57.762	83.913	2318.4	2402.3	83.915	2453.5	2537.4	0.2965	8.3696	8.6661
25	3.1698	0.001003	43.340	104.83	2304.3	2409.1	104.83	2441.7	2546.5	0.3672	8.1895	8.5567
30	4.2469	0.001004	32.879	125.73	2290.2	2415.9	125.74	2429.8	2555.6	0.4368	8.0152	8.4520
35	5.6291	0.001006	25.205	146.63	2276.0	2422.7	146.64	2417.9	2564.6	0.5051	7.8466	8.3517
40	7.3851	0.001008	19.515	167.53	2261.9	2429.4	167.53	2406.0	2573.5	0.5724	7.6832	8.2556
45	9.5953	0.001010	15.251	188.43	2247.7	2436.1	188.44	2394.0	2582.4	0.6386	7.5247	8.1633
50	12.352	0.001012	12.026	209.33	2233.4	2442.7	209.34	2382.0	2591.3	0.7038	7.3710	8.0748
55	15.763	0.001015	9.5639	230.24	2219.1	2449.3	230.26	2369.8	2600.1	0.7680	7.2218	7.9898
60	19.947	0.001017	7.6670	251.16	2204.7	2455.9	251.18	2357.7	2608.8	0.8313	7.0769	7.9082
65	25.043	0.001020	6.1935	272.09	2190.3	2462.4	272.12	2345.4	2617.5	0.8937	6.9360	7.8296
70	31.202	0.001023	5.0396	293.04	2175.8	2468.9	293.07	2333.0	2626.1	0.9551	6.7989	7.7540
75	38.597	0.001026	4.1291	313.99	2161.3	2475.3	314.03	2320.6	2634.6	1.0158	6.6655	7.6812
80	47.416	0.001029	3.4053	334.97	2146.6	2481.6	335.02	2308.0	2643.0	1.0756	6.5355	7.6111
85	57.868	0.001032	2.8261	355.96	2131.9	2487.8	356.02	2295.3	2651.4	1.1346	6.4089	7.5435
90	70.183	0.001036	2.3593	376.97	2117.0	2494.0	377.04	2282.5	2659.6	1.1929	6.2853	7.4782
95	84.609	0.001040	1.9808	398.00	2102.0	2500.1	398.09	2269.6	2667.6	1.2504	6.1647	7.4151
100	101.42	0.001043	1.6720	419.06	2087.0	2506.0	419.17	2256.4	2675.6	1.3072	6.0470	7.3542
105	120.90	0.001047	1.4186	440.15	2071.8	2511.9	440.28	2243.1	2683.4	1.3634	5.9319	7.2952
110	143.38	0.001052	1.2094	461.27	2056.4	2517.7	461.42	2229.7	2691.1	1.4188	5.8193	7.2382
115	169.18	0.001056	1.0360	482.42	2040.9	2523.3	482.59	2216.0	2698.6	1.4737	5.7092	7.1829
120	198.67	0.001060	0.89133	503.60	2025.3	2528.9	503.81	2202.1	2706.0	1.5279	5.6013	7.1292
125	232.23	0.001065	0.77012	524.83	2009.5	2534.3	525.07	2188.1	2713.1	1.5816	5.4956	7.0771
130	270.28	0.001070	0.66808	546.10	1993.4	2539.5	546.38	2173.7	2720.1	1.6346	5.3919	7.0265
135	313.22	0.001075	0.58179	567.41	1977.3	2544.7	567.75	2159.1	2726.9	1.6872	5.2901	6.9773
140	361.53	0.001080	0.50850	588.77	1960.9	2549.6	589.16	2144.3	2733.5	1.7392	5.1901	6.9294
145	415.68	0.001085	0.44600	610.19	1944.2	2554.4	610.64	2129.2	2739.8	1.7908	5.0919	6.8827
150	476.16	0.001091	0.39248	631.66	1927.4	2559.1	632.18	2113.8	2745.9	1.8418	4.9953	6.8371
155	543.49	0.001096	0.34648	653.19	1910.3	2563.5	653.79	2098.0	2751.8	1.8924	4.9002	6.7927
160	618.23	0.001102	0.30680	674.79	1893.0	2567.8	675.47	2082.0	2757.5	1.9426	4.8066	6.7492
165	700.93	0.001108	0.27244	696.46	1875.4	2571.9	697.24	2065.6	2762.8	1.9923	4.7143	6.7067
170	792.18	0.001114	0.24260	718.20	1857.5	2575.7	719.08	2048.8	2767.9	2.0417	4.6233	6.6650
175	892.60	0.001121	0.21659	740.02	1839.4	2579.4	741.02	2031.7	2772.7	2.0906	4.5335	6.6242
180	1002.8	0.001127	0.19384	761.92	1820.9	2582.8	763.05	2014.2	2777.2	2.1392	4.4448	6.5841
185	1123.5	0.001134	0.17390	783.91	1802.1	2586.0	785.19	1996.2	2781.4	2.1875	4.3572	6.5447
190	1255.2	0.001141	0.15636	806.00	1783.0	2589.0	807.43	1977.9	2785.3	2.2355	4.2705	6.5059
195	1398.8	0.001149	0.14089	828.18	1763.6	2591.7	829.78	1959.0	2788.8	2.2831	4.1847	6.4678
200	1554.9	0.001157	0.12721	850.46	1743.7	2594.2	852.26	1939.8	2792.0	2.3305	4.0997	6.4302
205	1724.3	0.001164	0.11508	872.86	1723.5	2596.4	874.87	1920.0	2794.8	2.3776	4.0154	6.3930

(Segue)

TABELLA A.6 Acqua saturo – Tabella della temperatura (Continua)

Temp., T °C	Pressione saturo, $p_{\text{sat}}$ kPa	Volume specifico, m <sup>3</sup> /kg		Energia interna, kJ/kg			Entalpia, kJ/kg			Entropia, kJ/kg · K		
		Liquido saturo, $v_{\text{li sat}}$	Vapore saturo, $v_{\text{v sat}}$	Liquido saturo, $u_{\text{li sat}}$	Evap., $u_{\text{li sat v sat}}$	Vapore saturo, $u_{\text{v sat}}$	Liquido saturo, $h_{\text{li sat}}$	Evap., $h_{\text{li sat v sat}}$	Vapore saturo, $h_{\text{v sat}}$	Liquido saturo, $s_{\text{li sat}}$	Evap., $s_{\text{li sat v sat}}$	Vapore saturo, $s_{\text{v sat}}$
210	1907.7	0.001173	0.10429	895.38	1702.9	2598.3	897.61	1899.7	2797.3	2.4245	3.9318	6.3563
215	2105.9	0.001181	0.094680	918.02	1681.9	2599.9	920.50	1878.8	2799.3	2.4712	3.8489	6.3200
220	2319.6	0.001190	0.086094	940.79	1660.5	2601.3	943.55	1857.4	2801.0	2.5176	3.7664	6.2840
225	2549.7	0.001199	0.078405	963.70	1638.6	2602.3	966.76	1835.4	2802.2	2.5639	3.6844	6.2483
230	2797.1	0.001209	0.071505	986.76	1616.1	2602.9	990.14	1812.8	2802.9	2.6100	3.6028	6.2128
235	3062.6	0.001219	0.065300	1010.0	1593.2	2603.2	1013.7	1789.5	2803.2	2.6560	3.5216	6.1775
240	3347.0	0.001229	0.059707	1033.4	1569.8	2603.1	1037.5	1765.5	2803.0	2.7018	3.4405	6.1424
245	3651.2	0.001240	0.054656	1056.9	1545.7	2602.7	1061.5	1740.8	2802.2	2.7476	3.3596	6.1072
250	3976.2	0.001252	0.050085	1080.7	1521.1	2601.8	1085.7	1715.3	2801.0	2.7933	3.2788	6.0721
255	4322.9	0.001263	0.045941	1104.7	1495.8	2600.5	1110.1	1689.0	2799.1	2.8390	3.1979	6.0369
260	4692.3	0.001276	0.042175	1128.8	1469.9	2598.7	1134.8	1661.8	2796.6	2.8847	3.1169	6.0017
265	5085.3	0.001289	0.038748	1153.3	1443.2	2596.5	1159.8	1633.7	2793.5	2.9304	3.0358	5.9662
270	5503.0	0.001303	0.035622	1177.9	1415.7	2593.7	1185.1	1604.6	2789.7	2.9762	2.9542	5.9305
275	5946.4	0.001317	0.032767	1202.9	1387.4	2590.3	1210.7	1574.5	2785.2	3.0221	2.8723	5.8944
280	6416.6	0.001333	0.030153	1228.2	1358.2	2586.4	1236.7	1543.2	2779.9	3.0681	2.7898	5.8579
285	6914.6	0.001349	0.027756	1253.7	1328.1	2581.8	1263.1	1510.7	2773.7	3.1144	2.7066	5.8210
290	7441.8	0.001366	0.025554	1279.7	1296.9	2576.5	1289.8	1476.9	2766.7	3.1608	2.6225	5.7834
295	7999.0	0.001384	0.023528	1306.0	1264.5	2570.5	1317.1	1441.6	2758.7	3.2076	2.5374	5.7450
300	8587.9	0.001404	0.021659	1332.7	1230.9	2563.6	1344.8	1404.8	2749.6	3.2548	2.4511	5.7059
305	9209.4	0.001425	0.019932	1360.0	1195.9	2555.8	1373.1	1366.3	2739.4	3.3024	2.3633	5.6657
310	9865.0	0.001447	0.018333	1387.7	1159.3	2547.1	1402.0	1325.9	2727.9	3.3506	2.2737	5.6243
315	10556	0.001472	0.016849	1416.1	1121.1	2537.2	1431.6	1283.4	2715.0	3.3994	2.1821	5.5816
320	11284	0.001499	0.015470	1445.1	1080.9	2526.0	1462.0	1238.5	2700.6	3.4491	2.0881	5.5372
325	12051	0.001528	0.014183	1475.0	1038.5	2513.4	1493.4	1191.0	2684.3	3.4998	1.9911	5.4908
330	12858	0.001560	0.012979	1505.7	993.5	2499.2	1525.8	1140.3	2666.0	3.5516	1.8906	5.4422
335	13707	0.001597	0.011848	1537.5	945.5	2483.0	1559.4	1086.0	2645.4	3.6050	1.7857	5.3907
340	14601	0.001638	0.010783	1570.7	893.8	2464.5	1594.6	1027.4	2622.0	3.6602	1.6756	5.3358
345	15541	0.001685	0.009772	1605.5	837.7	2443.2	1631.7	963.4	2595.1	3.7179	1.5585	5.2765
350	16529	0.001741	0.008806	1642.4	775.9	2418.3	1671.2	892.7	2563.9	3.7788	1.4326	5.2114
355	17570	0.001808	0.007872	1682.2	706.4	2388.6	1714.0	812.9	2526.9	3.8442	1.2942	5.1384
360	18666	0.001895	0.006950	1726.2	625.7	2351.9	1761.5	720.1	2481.6	3.9165	1.1373	5.0537
365	19822	0.002015	0.006009	1777.2	526.4	2303.6	1817.2	605.5	2422.7	4.0004	0.9489	4.9493
370	21044	0.002217	0.004953	1844.5	385.6	2230.1	1891.2	443.1	2334.3	4.1119	0.6890	4.8009
373.95	22064	0.003106	0.003106	2015.7	0	2015.7	2084.3	0	2084.3	4.4070	0	4.4070

Fonte: Le tabelle sono generate usando l'Engineering Equation Solver (EES), software sviluppato da S.A. Klein e F.L. Alvarado. La routine usata durante i calcoli è il preciso Steam\_IAPWS, che include il 1995 Formulation for the Thermodynamic Properties of Ordinary Water Substance for General and Scientific Use, rilasciato da The International Association for the Properties of Water and Steam (IAPWS). Questa formulazione replica quella del 1984 di Haar, Gallagher e Kell (NBS/NRC Steam Tables, Hemisphere Publishing Co., 1984), che è disponibile in EES come la routine STEAM. La nuova formulazione è basata sulla correlazione di Saul e Wagner (J. Phys. Chem. Ref. Data, 16, 893, 1987) con modifiche apportate da The International Temperature Scale del 1990. Le modifiche sono descritte da Wagner e Pruss (J. Phys. Chem. Ref. Data, 22, 783, 1993). Le proprietà del ghiaccio sono basate su Hyland e Wexler, "Formulations for the Thermodynamic Properties of the Saturated Phases of H2O from 173.15 K to 473.15 K," ASHRAE Trans., parte 2A, pagina 2793, 1983.



**TABELLA A.7** Acqua saturo – Tabella della pressione

Pressione, <i>p</i> kPa	Temp. saturo, <i>T</i> <sub>sat</sub> °C	Volume specifico, m <sup>3</sup> /kg		Energia interna, kJ/kg			Entalpia, kJ/kg			Entropia, kJ/kg · K		
		Liquido saturo, <i>v</i> <sub>l sat</sub>	Vapore saturo, <i>v</i> <sub>v sat</sub>	Liquido saturo, <i>u</i> <sub>l sat</sub>	Evap., <i>u</i> <sub>l sat v sat</sub>	Vapore saturo, <i>u</i> <sub>v sat</sub>	Liquido saturo, <i>h</i> <sub>l sat</sub>	Evap., <i>h</i> <sub>l sat v sat</sub>	Vapore saturo, <i>h</i> <sub>v sat</sub>	Liquido saturo, <i>s</i> <sub>l sat</sub>	Evap., <i>s</i> <sub>l sat v sat</sub>	Vapore saturo, <i>s</i> <sub>v sat</sub>
1.0	6.97	0.001000	129.19	29.302	2355.2	2384.5	29.303	2484.4	2513.7	0.1059	8.8690	8.9749
1.5	13.02	0.001001	87.964	54.686	2338.1	2392.8	54.688	2470.1	2524.7	0.1956	8.6314	8.8270
2.0	17.50	0.001001	66.990	73.431	2325.5	2398.9	73.433	2459.5	2532.9	0.2606	8.4621	8.7227
2.5	21.08	0.001002	54.242	88.422	2315.4	2403.8	88.424	2451.0	2539.4	0.3118	8.3302	8.6421
3.0	24.08	0.001003	45.654	100.98	2306.9	2407.9	100.98	2443.9	2544.8	0.3543	8.2222	8.5765
4.0	28.96	0.001004	34.791	121.39	2293.1	2414.5	121.39	2432.3	2553.7	0.4224	8.0510	8.4734
5.0	32.87	0.001005	28.185	137.75	2282.1	2419.8	137.75	2423.0	2560.7	0.4762	7.9176	8.3938
7.5	40.29	0.001008	19.233	168.74	2261.1	2429.8	168.75	2405.3	2574.0	0.5763	7.6738	8.2501
10	45.81	0.001010	14.670	191.79	2245.4	2437.2	191.81	2392.1	2583.9	0.6492	7.4996	8.1488
15	53.97	0.001014	10.020	225.93	2222.1	2448.0	225.94	2372.3	2598.3	0.7549	7.2522	8.0071
20	60.06	0.001017	7.6481	251.40	2204.6	2456.0	251.42	2357.5	2608.9	0.8320	7.0752	7.9073
25	64.96	0.001020	6.2034	271.93	2190.4	2462.4	271.96	2345.5	2617.5	0.8932	6.9370	7.8302
30	69.09	0.001022	5.2287	289.24	2178.5	2467.7	289.27	2335.3	2624.6	0.9441	6.8234	7.7675
40	75.86	0.001026	3.9933	317.58	2158.8	2476.3	317.62	2318.4	2636.1	1.0261	6.6430	7.6691
50	81.32	0.001030	3.2403	340.49	2142.7	2483.2	340.54	2304.7	2645.2	1.0912	6.5019	7.5931
75	91.76	0.001037	2.2172	384.36	2111.8	2496.1	384.44	2278.0	2662.4	1.2132	6.2426	7.4558
100	99.61	0.001043	1.6941	417.40	2088.2	2505.6	417.51	2257.5	2675.0	1.3028	6.0562	7.3589
101.325	99.97	0.001043	1.6734	418.95	2087.0	2506.0	419.06	2256.5	2675.6	1.3069	6.0476	7.3545
125	105.97	0.001048	1.3750	444.23	2068.8	2513.0	444.36	2240.6	2684.9	1.3741	5.9100	7.2841
150	111.35	0.001053	1.1594	466.97	2052.3	2519.2	467.13	2226.0	2693.1	1.4337	5.7894	7.2231
175	116.04	0.001057	1.0037	486.82	2037.7	2524.5	487.01	2213.1	2700.2	1.4850	5.6865	7.1716
200	120.21	0.001061	0.88578	504.50	2024.6	2529.1	504.71	2201.6	2706.3	1.5302	5.5968	7.1270
225	123.97	0.001064	0.79329	520.47	2012.7	2533.2	520.71	2191.0	2711.7	1.5706	5.5171	7.0877
250	127.41	0.001067	0.71873	535.08	2001.8	2536.8	535.35	2181.2	2716.5	1.6072	5.4453	7.0525
275	130.58	0.001070	0.65732	548.57	1991.6	2540.1	548.86	2172.0	2720.9	1.6408	5.3800	7.0207
300	133.52	0.001073	0.60582	561.11	1982.1	2543.2	561.43	2163.5	2724.9	1.6717	5.3200	6.9917
325	136.27	0.001076	0.56199	572.84	1973.1	2545.9	573.19	2155.4	2728.6	1.7005	5.2645	6.9650
350	138.86	0.001079	0.52422	583.89	1964.6	2548.5	584.26	2147.7	2732.0	1.7274	5.2128	6.9402
375	141.30	0.001081	0.49133	594.32	1956.6	2550.9	594.73	2140.4	2735.1	1.7526	5.1645	6.9171
400	143.61	0.001084	0.46242	604.22	1948.9	2553.1	604.66	2133.4	2738.1	1.7765	5.1191	6.8955
450	147.90	0.001088	0.41392	622.65	1934.5	2557.1	623.14	2120.3	2743.4	1.8205	5.0356	6.8561
500	151.83	0.001093	0.37483	639.54	1921.2	2560.7	640.09	2108.0	2748.1	1.8604	4.9603	6.8207
550	155.46	0.001097	0.34261	655.16	1908.8	2563.9	655.77	2096.6	2752.4	1.8970	4.8916	6.7886
600	158.83	0.001101	0.31560	669.72	1897.1	2566.8	670.38	2085.8	2756.2	1.9308	4.8285	6.7593
650	161.98	0.001104	0.29260	683.37	1886.1	2569.4	684.08	2075.5	2759.6	1.9623	4.7699	6.7322
700	164.95	0.001108	0.27278	696.23	1875.6	2571.8	697.00	2065.8	2762.8	1.9918	4.7153	6.7071
750	167.75	0.001111	0.25552	708.40	1865.6	2574.0	709.24	2056.4	2765.7	2.0195	4.6642	6.6837
800	170.41	0.001115	0.24035	719.97	1856.1	2576.0	720.87	2047.5	2768.3	2.0457	4.6160	6.6616
850	172.94	0.001118	0.22690	731.00	1846.9	2577.9	731.95	2038.8	2770.8	2.0705	4.5705	6.6409
900	175.35	0.001121	0.21489	741.55	1838.1	2579.6	742.56	2030.5	2773.0	2.0941	4.5273	6.6213
950	177.66	0.001124	0.20411	751.67	1829.6	2581.3	752.74	2022.4	2775.2	2.1166	4.4862	6.6027
1000	179.88	0.001127	0.19436	761.39	1821.4	2582.8	762.51	2014.6	2777.1	2.1381	4.4470	6.5850

(Segue)

TABELLA A.7 Acqua satura – Tabella della pressione (Continua)

Pressione, $p$ kPa	Temp. satura, $T_{\text{sat}}$ °C	Volume specifico, $\text{m}^3/\text{kg}$		Energia interna, kJ/kg			Entalpia, kJ/kg			Entropia, kJ/kg · K		
		Liquido saturato, $v_{\text{l sat}}$	Vapore saturato, $v_{\text{v sat}}$	Liquido saturato, $u_{\text{l sat}}$	Evap., $u_{\text{l sat v sat}}$	Vapore saturato, $u_{\text{v sat}}$	Liquido saturato, $h_{\text{l sat}}$	Evap., $h_{\text{l sat v sat}}$	Vapore saturato, $h_{\text{v sat}}$	Liquido saturato, $s_{\text{l sat}}$	Evap., $s_{\text{l sat v sat}}$	Vapore saturato, $s_{\text{v sat}}$
1100	184.06	0.001133	0.17745	779.78	1805.7	2585.5	781.03	1999.6	2780.7	2.1785	4.3735	6.5520
1200	187.96	0.001138	0.16326	796.96	1790.9	2587.8	798.33	1985.4	2783.8	2.2159	4.3058	6.5217
1300	191.60	0.001144	0.15119	813.10	1776.8	2589.9	814.59	1971.9	2786.5	2.2508	4.2428	6.4936
1400	195.04	0.001149	0.14078	828.35	1763.4	2591.8	829.96	1958.9	2788.9	2.2835	4.1840	6.4675
1500	198.29	0.001154	0.13171	842.82	1750.6	2593.4	844.55	1946.4	2791.0	2.3143	4.1287	6.4430
1750	205.72	0.001166	0.11344	876.12	1720.6	2596.7	878.16	1917.1	2795.2	2.3844	4.0033	6.3877
2000	212.38	0.001177	0.099587	906.12	1693.0	2599.1	908.47	1889.8	2798.3	2.4467	3.8923	6.3390
2250	218.41	0.001187	0.088717	933.54	1667.3	2600.9	936.21	1864.3	2800.5	2.5029	3.7926	6.2954
2500	223.95	0.001197	0.079952	958.87	1643.2	2602.1	961.87	1840.1	2801.9	2.5542	3.7016	6.2558
3000	233.85	0.001217	0.066667	1004.6	1598.5	2603.2	1008.3	1794.9	2803.2	2.6454	3.5402	6.1856
3500	242.56	0.001235	0.057061	1045.4	1557.6	2603.0	1049.7	1753.0	2802.7	2.7253	3.3991	6.1244
4000	250.35	0.001252	0.049779	1082.4	1519.3	2601.7	1087.4	1713.5	2800.8	2.7966	3.2731	6.0696
5000	263.94	0.001286	0.039448	1148.1	1448.9	2597.0	1154.5	1639.7	2794.2	2.9207	3.0530	5.9737
6000	275.59	0.001319	0.032449	1205.8	1384.1	2589.9	1213.8	1570.9	2784.6	3.0275	2.8627	5.8902
7000	285.83	0.001352	0.027378	1258.0	1323.0	2581.0	1267.5	1505.2	2772.6	3.1220	2.6927	5.8148
8000	295.01	0.001384	0.023525	1306.0	1264.5	2570.5	1317.1	1441.6	2758.7	3.2077	2.5373	5.7450
9000	303.35	0.001418	0.020489	1350.9	1207.6	2558.5	1363.7	1379.3	2742.9	3.2866	2.3925	5.6791
10000	311.00	0.001452	0.018028	1393.3	1151.8	2545.2	1407.8	1317.6	2725.5	3.3603	2.2556	5.6159
11000	318.08	0.001488	0.015988	1433.9	1096.6	2530.4	1450.2	1256.1	2706.3	3.4299	2.1245	5.5544
12000	324.68	0.001526	0.014264	1473.0	1041.3	2514.3	1491.3	1194.1	2685.4	3.4964	1.9975	5.4939
13000	330.85	0.001566	0.012781	1511.0	985.5	2496.6	1531.4	1131.3	2662.7	3.5606	1.8730	5.4336
14000	336.67	0.001610	0.011487	1548.4	928.7	2477.1	1571.0	1067.0	2637.9	3.6232	1.7497	5.3728
15000	342.16	0.001657	0.010341	1585.5	870.3	2455.7	1610.3	1000.5	2610.8	3.6848	1.6261	5.3108
16000	347.36	0.001710	0.009312	1622.6	809.4	2432.0	1649.9	931.1	2581.0	3.7461	1.5005	5.2466
17000	352.29	0.001770	0.008374	1660.2	745.1	2405.4	1690.3	857.4	2547.7	3.8082	1.3709	5.1791
18000	356.99	0.001840	0.007504	1699.1	675.9	2375.0	1732.2	777.8	2510.0	3.8720	1.2343	5.1064
19000	361.47	0.001926	0.006677	1740.3	598.9	2339.2	1776.8	689.2	2466.0	3.9396	1.0860	5.0256
20000	365.75	0.002038	0.005862	1785.8	509.0	2294.8	1826.6	585.5	2412.1	4.0146	0.9164	4.9310
21000	369.83	0.002207	0.004994	1841.6	391.9	2233.5	1888.0	450.4	2338.4	4.1071	0.7005	4.8076
22000	373.71	0.002703	0.003644	1951.7	140.8	2092.4	2011.1	161.5	2172.6	4.2942	0.2496	4.5439
22064	373.95	0.003106	0.003106	2015.7	0	2015.7	2084.3	0	2084.3	4.4070	0	4.4070

TABELLA A.8 Acqua surriscaldata

<i>T</i> °C	<i>v</i> m <sup>3</sup> /kg	<i>u</i> kJ/kg	<i>h</i> kJ/kg	<i>s</i> kJ/kg·K	<i>v</i> m <sup>3</sup> /kg	<i>u</i> kJ/kg	<i>h</i> kJ/kg	<i>s</i> kJ/kg·K	<i>v</i> m <sup>3</sup> /kg	<i>u</i> kJ/kg	<i>h</i> kJ/kg	<i>s</i> kJ/kg·K
<b><i>p</i> = 0.01 MPa (45.81 °C)*</b>				<b><i>p</i> = 0.05 MPa (81.32 °C)</b>				<b><i>p</i> = 0.10 MPa (99.61 °C)</b>				
Sat.†	14.670	2437.2	2583.9	8.1488	3.2403	2483.2	2645.2	7.5931	1.6941	2505.6	2675.0	7.3589
50	14.867	2443.3	2592.0	8.1741								
100	17.196	2515.5	2687.5	8.4489	3.4187	2511.5	2682.4	7.6953	1.6959	2506.2	2675.8	7.3611
150	19.513	2587.9	2783.0	8.6893	3.8897	2585.7	2780.2	7.9413	1.9367	2582.9	2776.6	7.6148
200	21.826	2661.4	2879.6	8.9049	4.3562	2660.0	2877.8	8.1592	2.1724	2658.2	2875.5	7.8356
250	24.136	2736.1	2977.5	9.1015	4.8206	2735.1	2976.2	8.3568	2.4062	2733.9	2974.5	8.0346
300	26.446	2812.3	3076.7	9.2827	5.2841	2811.6	3075.8	8.5387	2.6389	2810.7	3074.5	8.2172
400	31.063	2969.3	3280.0	9.6094	6.2094	2968.9	3279.3	8.8659	3.1027	2968.3	3278.6	8.5452
500	35.680	3132.9	3489.7	9.8998	7.1338	3132.6	3489.3	9.1566	3.5655	3132.2	3488.7	8.8362
600	40.296	3303.3	3706.3	10.1631	8.0577	3303.1	3706.0	9.4201	4.0279	3302.8	3705.6	9.0999
700	44.911	3480.8	3929.9	10.4056	8.9813	3480.6	3929.7	9.6626	4.4900	3480.4	3929.4	9.3424
800	49.527	3665.4	4160.6	10.6312	9.9047	3665.2	4160.4	9.8883	4.9519	3665.0	4160.2	9.5682
900	54.143	3856.9	4398.3	10.8429	10.8280	3856.8	4398.2	10.1000	5.4137	3856.7	4398.0	9.7800
1000	58.758	4055.3	4642.8	11.0429	11.7513	4055.2	4642.7	10.3000	5.8755	4055.0	4642.6	9.9800
1100	63.373	4260.0	4893.8	11.2326	12.6745	4259.9	4893.7	10.4897	6.3372	4259.8	4893.6	10.1698
1200	67.989	4470.9	5150.8	11.4132	13.5977	4470.8	5150.7	10.6704	6.7988	4470.7	5150.6	10.3504
1300	72.604	4687.4	5413.4	11.5857	14.5209	4687.3	5413.3	10.8429	7.2605	4687.2	5413.3	10.5229
<b><i>p</i> = 0.20 MPa (120.21 °C)</b>				<b><i>p</i> = 0.30 MPa (133.52 °C)</b>				<b><i>p</i> = 0.40 MPa (143.61 °C)</b>				
Sat.	0.88578	2529.1	2706.3	7.1270	0.60582	2543.2	2724.9	6.9917	0.46242	2553.1	2738.1	6.8955
150	0.95986	2577.1	2769.1	7.2810	0.63402	2571.0	2761.2	7.0792	0.47088	2564.4	2752.8	6.9306
200	1.08049	2654.6	2870.7	7.5081	0.71643	2651.0	2865.9	7.3132	0.53434	2647.2	2860.9	7.1723
250	1.19890	2731.4	2971.2	7.7100	0.79645	2728.9	2967.9	7.5180	0.59520	2726.4	2964.5	7.3804
300	1.31623	2808.8	3072.1	7.8941	0.87535	2807.0	3069.6	7.7037	0.65489	2805.1	3067.1	7.5677
400	1.54934	2967.2	3277.0	8.2236	1.03155	2966.0	3275.5	8.0347	0.77265	2964.9	3273.9	7.9003
500	1.78142	3131.4	3487.7	8.5153	1.18672	3130.6	3486.6	8.3271	0.88936	3129.8	3485.5	8.1933
600	2.01302	3302.2	3704.8	8.7793	1.34139	3301.6	3704.0	8.5915	1.00558	3301.0	3703.3	8.4580
700	2.24434	3479.9	3928.8	9.0221	1.49580	3479.5	3928.2	8.8345	1.12152	3479.0	3927.6	8.7012
800	2.47550	3664.7	4159.8	9.2479	1.65004	3664.3	4159.3	9.0605	1.23730	3663.9	4158.9	8.9274
900	2.70656	3856.3	4397.7	9.4598	1.80417	3856.0	4397.3	9.2725	1.35298	3855.7	4396.9	9.1394
1000	2.93755	4054.8	4642.3	9.6599	1.95824	4054.5	4642.0	9.4726	1.46859	4054.3	4641.7	9.3396
1100	3.16848	4259.6	4893.3	9.8497	2.11226	4259.4	4893.1	9.6624	1.58414	4259.2	4892.9	9.5295
1200	3.39938	4470.5	5150.4	10.0304	2.26624	4470.3	5150.2	9.8431	1.69966	4470.2	5150.0	9.7102
1300	3.63026	4687.1	5413.1	10.2029	2.42019	4686.9	5413.0	10.0157	1.81516	4686.7	5412.8	9.8828
<b><i>p</i> = 0.50 MPa (151.83 °C)</b>				<b><i>p</i> = 0.60 MPa (158.83 °C)</b>				<b><i>p</i> = 0.80 MPa (170.41 °C)</b>				
Sat.	0.37483	2560.7	2748.1	6.8207	0.31560	2566.8	2756.2	6.7593	0.24035	2576.0	2768.3	6.6616
200	0.42503	2643.3	2855.8	7.0610	0.35212	2639.4	2850.6	6.9683	0.26088	2631.1	2839.8	6.8177
250	0.47443	2723.8	2961.0	7.2725	0.39390	2721.2	2957.6	7.1833	0.29321	2715.9	2950.4	7.0402
300	0.52261	2803.3	3064.6	7.4614	0.43442	2801.4	3062.0	7.3740	0.32416	2797.5	3056.9	7.2345
350	0.57015	2883.0	3168.1	7.6346	0.47428	2881.6	3166.1	7.5481	0.35442	2878.6	3162.2	7.4107
400	0.61731	2963.7	3272.4	7.7956	0.51374	2962.5	3270.8	7.7097	0.38429	2960.2	3267.7	7.5735
500	0.71095	3129.0	3484.5	8.0893	0.59200	3128.2	3483.4	8.0041	0.44332	3126.6	3481.3	7.8692
600	0.80409	3300.4	3702.5	8.3544	0.66976	3299.8	3701.7	8.2695	0.50186	3298.7	3700.1	8.1354
700	0.89696	3478.6	3927.0	8.5978	0.74725	3478.1	3926.4	8.5132	0.56011	3477.2	3925.3	8.3794

(Segue)

**TABELLA A.8** Acqua surriscaldata (*Continua*)

<i>T</i> °C	<i>v</i> m <sup>3</sup> /kg	<i>u</i> kJ/kg	<i>h</i> kJ/kg	<i>s</i> kJ/kg·K	<i>v</i> m <sup>3</sup> /kg	<i>u</i> kJ/kg	<i>h</i> kJ/kg	<i>s</i> kJ/kg·K	<i>v</i> m <sup>3</sup> /kg	<i>u</i> kJ/kg	<i>h</i> kJ/kg	<i>s</i> kJ/kg·K
800	0.98966	3663.6	4158.4	8.8240	0.82457	3663.2	4157.9	8.7395	0.61820	3662.5	4157.0	8.6061
900	1.08227	3855.4	4396.6	9.0362	0.90179	3855.1	4396.2	8.9518	0.67619	3854.5	4395.5	8.8185
1000	1.17480	4054.0	4641.4	9.2364	0.97893	4053.8	4641.1	9.1521	0.73411	4053.3	4640.5	9.0189
1100	1.26728	4259.0	4892.6	9.4263	1.05603	4258.8	4892.4	9.3420	0.79197	4258.3	4891.9	9.2090
1200	1.35972	4470.0	5149.8	9.6071	1.13309	4469.8	5149.6	9.5229	0.84980	4469.4	5149.3	9.3898
1300	1.45214	4686.6	5412.6	9.7797	1.21012	4686.4	5412.5	9.6955	0.90761	4686.1	5412.2	9.5625
<b><i>p</i> = 1.00 MPa (179.88 °C)</b>				<b><i>p</i> = 1.20 MPa (187.96 °C)</b>				<b><i>p</i> = 1.40 MPa (195.04 °C)</b>				
Sat.	0.19437	2582.8	2777.1	6.5850	0.16326	2587.8	2783.8	6.5217	0.14078	2591.8	2788.9	6.4675
200	0.20602	2622.3	2828.3	6.6956	0.16934	2612.9	2816.1	6.5909	0.14303	2602.7	2803.0	6.4975
250	0.23275	2710.4	2943.1	6.9265	0.19241	2704.7	2935.6	6.8313	0.16356	2698.9	2927.9	6.7488
300	0.25799	2793.7	3051.6	7.1246	0.21386	2789.7	3046.3	7.0335	0.18233	2785.7	3040.9	6.9553
350	0.28250	2875.7	3158.2	7.3029	0.23455	2872.7	3154.2	7.2139	0.20029	2869.7	3150.1	7.1379
400	0.30661	2957.9	3264.5	7.4670	0.25482	2955.5	3261.3	7.3793	0.21782	2953.1	3258.1	7.3046
500	0.35411	3125.0	3479.1	7.7642	0.29464	3123.4	3477.0	7.6779	0.25216	3121.8	3474.8	7.6047
600	0.40111	3297.5	3698.6	8.0311	0.33395	3296.3	3697.0	7.9456	0.28597	3295.1	3695.5	7.8730
700	0.44783	3476.3	3924.1	8.2755	0.37297	3475.3	3922.9	8.1904	0.31951	3474.4	3921.7	8.1183
800	0.49438	3661.7	4156.1	8.5024	0.41184	3661.0	4155.2	8.4176	0.35288	3660.3	4154.3	8.3458
900	0.54083	3853.9	4394.8	8.7150	0.45059	3853.3	4394.0	8.6303	0.38614	3852.7	4393.3	8.5587
1000	0.58721	4052.7	4640.0	8.9155	0.48928	4052.2	4639.4	8.8310	0.41933	4051.7	4638.8	8.7595
1100	0.63354	4257.9	4891.4	9.1057	0.52792	4257.5	4891.0	9.0212	0.45247	4257.0	4890.5	8.9497
1200	0.67983	4469.0	5148.9	9.2866	0.56652	4468.7	5148.5	9.2022	0.48558	4468.3	5148.1	9.1308
1300	0.72610	4685.8	5411.9	9.4593	0.60509	4685.5	5411.6	9.3750	0.51866	4685.1	5411.3	9.3036
<b><i>p</i> = 1.60 MPa (201.37 °C)</b>				<b><i>p</i> = 1.80 MPa (207.11 °C)</b>				<b><i>p</i> = 2.00 MPa (212.38 °C)</b>				
Sat.	0.12374	2594.8	2792.8	6.4200	0.11037	2597.3	2795.9	6.3775	0.09959	2599.1	2798.3	6.3390
225	0.13293	2645.1	2857.8	6.5537	0.11678	2637.0	2847.2	6.4825	0.10381	2628.5	2836.1	6.4160
250	0.14190	2692.9	2919.9	6.6753	0.12502	2686.7	2911.7	6.6088	0.11150	2680.3	2903.3	6.5475
300	0.15866	2781.6	3035.4	6.8864	0.14025	2777.4	3029.9	6.8246	0.12551	2773.2	3024.2	6.7684
350	0.17459	2866.6	3146.0	7.0713	0.15460	2863.6	3141.9	7.0120	0.13860	2860.5	3137.7	6.9583
400	0.19007	2950.8	3254.9	7.2394	0.16849	2948.3	3251.6	7.1814	0.15122	2945.9	3248.4	7.1292
500	0.22029	3120.1	3472.6	7.5410	0.19551	3118.5	3470.4	7.4845	0.17568	3116.9	3468.3	7.4337
600	0.24999	3293.9	3693.9	7.8101	0.22200	3292.7	3692.3	7.7543	0.19962	3291.5	3690.7	7.7043
700	0.27941	3473.5	3920.5	8.0558	0.24822	3472.6	3919.4	8.0005	0.22326	3471.7	3918.2	7.9509
800	0.30865	3659.5	4153.4	8.2834	0.27426	3658.8	4152.4	8.2284	0.24674	3658.0	4151.5	8.1791
900	0.33780	3852.1	4392.6	8.4965	0.30020	3851.5	4391.9	8.4417	0.27012	3850.9	4391.1	8.3925
1000	0.36687	4051.2	4638.2	8.6974	0.32606	4050.7	4637.6	8.6427	0.29342	4050.2	4637.1	8.5936
1100	0.39589	4256.6	4890.0	8.8878	0.35188	4256.2	4889.6	8.8331	0.31667	4255.7	4889.1	8.7842
1200	0.42488	4467.9	5147.7	9.0689	0.37766	4467.6	5147.3	9.0143	0.33989	4467.2	5147.0	8.9654
1300	0.45383	4684.8	5410.9	9.2418	0.40341	4684.5	5410.6	9.1872	0.36308	4684.2	5410.3	9.1384
<b><i>p</i> = 2.50 MPa (223.95 °C)</b>				<b><i>p</i> = 3.00 MPa (233.85 °C)</b>				<b><i>p</i> = 3.50 MPa (242.56 °C)</b>				
Sat.	0.07995	2602.1	2801.9	6.2558	0.06667	2603.2	2803.2	6.1856	0.05706	2603.0	2802.7	6.1244
225	0.08026	2604.8	2805.5	6.2629								
250	0.08705	2663.3	2880.9	6.4107	0.07063	2644.7	2856.5	6.2893	0.05876	2624.0	2829.7	6.1764
300	0.09894	2762.2	3009.6	6.6459	0.08118	2750.8	2994.3	6.5412	0.06845	2738.8	2978.4	6.4484
350	0.10979	2852.5	3127.0	6.8424	0.09056	2844.4	3116.1	6.7450	0.07680	2836.0	3104.9	6.6601

(Segue)

**TABELLA A.8** Acqua surriscaldata (*Continua*)

<i>T</i> °C	<i>v</i> m <sup>3</sup> /kg	<i>u</i> kJ/kg	<i>h</i> kJ/kg	<i>s</i> kJ/kg·K	<i>v</i> m <sup>3</sup> /kg	<i>u</i> kJ/kg	<i>h</i> kJ/kg	<i>s</i> kJ/kg·K	<i>v</i> m <sup>3</sup> /kg	<i>u</i> kJ/kg	<i>h</i> kJ/kg	<i>s</i> kJ/kg·K
400	0.12012	2939.8	3240.1	7.0170	0.09938	2933.6	3231.7	6.9235	0.08456	2927.2	3223.2	6.8428
450	0.13015	3026.2	3351.6	7.1768	0.10789	3021.2	3344.9	7.0856	0.09198	3016.1	3338.1	7.0074
500	0.13999	3112.8	3462.8	7.3254	0.11620	3108.6	3457.2	7.2359	0.09919	3104.5	3451.7	7.1593
600	0.15931	3288.5	3686.8	7.5979	0.13245	3285.5	3682.8	7.5103	0.11325	3282.5	3678.9	7.4357
700	0.17835	3469.3	3915.2	7.8455	0.14841	3467.0	3912.2	7.7590	0.12702	3464.7	3909.3	7.6855
800	0.19722	3656.2	4149.2	8.0744	0.16420	3654.3	4146.9	7.9885	0.14061	3652.5	4144.6	7.9156
900	0.21597	3849.4	4389.3	8.2882	0.17988	3847.9	4387.5	8.2028	0.15410	3846.4	4385.7	8.1304
1000	0.23466	4049.0	4635.6	8.4897	0.19549	4047.7	4634.2	8.4045	0.16751	4046.4	4632.7	8.3324
1100	0.25330	4254.7	4887.9	8.6804	0.21105	4253.6	4886.7	8.5955	0.18087	4252.5	4885.6	8.5236
1200	0.27190	4466.3	5146.0	8.8618	0.22658	4465.3	5145.1	8.7771	0.19420	4464.4	5144.1	8.7053
1300	0.29048	4683.4	5409.5	9.0349	0.24207	4682.6	5408.8	8.9502	0.20750	4681.8	5408.0	8.8786
<b><i>p</i> = 4.0 MPa (250.35 °C)</b>				<b><i>p</i> = 4.5 MPa (257.44 °C)</b>				<b><i>p</i> = 5.0 MPa (263.94 °C)</b>				
Sat.	0.04978	2601.7	2800.8	6.0696	0.04406	2599.7	2798.0	6.0198	0.03945	2597.0	2794.2	5.9737
275	0.05461	2668.9	2887.3	6.2312	0.04733	2651.4	2864.4	6.1429	0.04144	2632.3	2839.5	6.0571
300	0.05887	2726.2	2961.7	6.3639	0.05138	2713.0	2944.2	6.2854	0.04535	2699.0	2925.7	6.2111
350	0.06647	2827.4	3093.3	6.5843	0.05842	2818.6	3081.5	6.5153	0.05197	2809.5	3069.3	6.4516
400	0.07343	2920.8	3214.5	6.7714	0.06477	2914.2	3205.7	6.7071	0.05784	2907.5	3196.7	6.6483
450	0.08004	3011.0	3331.2	6.9386	0.07076	3005.8	3324.2	6.8770	0.06332	3000.6	3317.2	6.8210
500	0.08644	3100.3	3446.0	7.0922	0.07652	3096.0	3440.4	7.0323	0.06858	3091.8	3434.7	6.9781
600	0.09886	3279.4	3674.9	7.3706	0.08766	3276.4	3670.9	7.3127	0.07870	3273.3	3666.9	7.2605
700	0.11098	3462.4	3906.3	7.6214	0.09850	3460.0	3903.3	7.5647	0.08852	3457.7	3900.3	7.5136
800	0.12292	3650.6	4142.3	7.8523	0.10916	3648.8	4140.0	7.7962	0.09816	3646.9	4137.7	7.7458
900	0.13476	3844.8	4383.9	8.0675	0.11972	3843.3	4382.1	8.0118	0.10769	3841.8	4380.2	7.9619
1000	0.14653	4045.1	4631.2	8.2698	0.13020	4043.9	4629.8	8.2144	0.11715	4042.6	4628.3	8.1648
1100	0.15824	4251.4	4884.4	8.4612	0.14064	4250.4	4883.2	8.4060	0.12655	4249.3	4882.1	8.3566
1200	0.16992	4463.5	5143.2	8.6430	0.15103	4462.6	5142.2	8.5880	0.13592	4461.6	5141.3	8.5388
1300	0.18157	4680.9	5407.2	8.8164	0.16140	4680.1	5406.5	8.7616	0.14527	4679.3	5405.7	8.7124
<b><i>p</i> = 6.0 MPa (275.59 °C)</b>				<b><i>p</i> = 7.0 MPa (285.83 °C)</b>				<b><i>p</i> = 8.0 MPa (295.01 °C)</b>				
Sat.	0.03245	2589.9	2784.6	5.8902	0.027378	2581.0	2772.6	5.8148	0.023525	2570.5	2758.7	5.7450
300	0.03619	2668.4	2885.6	6.0703	0.029492	2633.5	2839.9	5.9337	0.024279	2592.3	2786.5	5.7937
350	0.04225	2790.4	3043.9	6.3357	0.035262	2770.1	3016.9	6.2305	0.029975	2748.3	2988.1	6.1321
400	0.04742	2893.7	3178.3	6.5432	0.039958	2879.5	3159.2	6.4502	0.034344	2864.6	3139.4	6.3658
450	0.05217	2989.9	3302.9	6.7219	0.044187	2979.0	3288.3	6.6353	0.038194	2967.8	3273.3	6.5579
500	0.05667	3083.1	3423.1	6.8826	0.048157	3074.3	3411.4	6.8000	0.041767	3065.4	3399.5	6.7266
550	0.06102	3175.2	3541.3	7.0308	0.051966	3167.9	3531.6	6.9507	0.045172	3160.5	3521.8	6.8800
600	0.06527	3267.2	3658.8	7.1693	0.055665	3261.0	3650.6	7.0910	0.048463	3254.7	3642.4	7.0221
700	0.07355	3453.0	3894.3	7.4247	0.062850	3448.3	3888.3	7.3487	0.054829	3443.6	3882.2	7.2822
800	0.08165	3643.2	4133.1	7.6582	0.069856	3639.5	4128.5	7.5836	0.061011	3635.7	4123.8	7.5185
900	0.08964	3838.8	4376.6	7.8751	0.076750	3835.7	4373.0	7.8014	0.067082	3832.7	4369.3	7.7372
1000	0.09756	4040.1	4625.4	8.0786	0.083571	4037.5	4622.5	8.0055	0.073079	4035.0	4619.6	7.9419
1100	0.10543	4247.1	4879.7	8.2709	0.090341	4245.0	4877.4	8.1982	0.079025	4242.8	4875.0	8.1350
1200	0.11326	4459.8	5139.4	8.4534	0.097075	4457.9	5137.4	8.3810	0.084934	4456.1	5135.5	8.3181
1300	0.12107	4677.7	5404.1	8.6273	0.103781	4676.1	5402.6	8.5551	0.090817	4674.5	5401.0	8.4925

(Segue)

**TABELLA A.8** Acqua surriscaldata (*Continua*)

<i>T</i> °C	<i>v</i> m <sup>3</sup> /kg	<i>u</i> kJ/kg	<i>h</i> kJ/kg	<i>s</i> kJ/kg·K	<i>v</i> m <sup>3</sup> /kg	<i>u</i> kJ/kg	<i>h</i> kJ/kg	<i>s</i> kJ/kg·K	<i>v</i> m <sup>3</sup> /kg	<i>u</i> kJ/kg	<i>h</i> kJ/kg	<i>s</i> kJ/kg·K
<b><i>p</i> = 9.0 MPa (303.35 °C)</b>					<b><i>p</i> = 10.0 MPa (311.00 °C)</b>				<b><i>p</i> = 12.5 MPa (327.81 °C)</b>			
Sat.	0.020489	2558.5	2742.9	5.6791	0.018028	2545.2	2725.5	5.6159	0.013496	2505.6	2674.3	5.4638
325	0.023284	2647.6	2857.1	5.8738	0.019877	2611.6	2810.3	5.7596				
350	0.025816	2725.0	2957.3	6.0380	0.022440	2699.6	2924.0	5.9460	0.016138	2624.9	2826.6	5.7130
400	0.029960	2849.2	3118.8	6.2876	0.026436	2833.1	3097.5	6.2141	0.020030	2789.6	3040.0	6.0433
450	0.033524	2956.3	3258.0	6.4872	0.029782	2944.5	3242.4	6.4219	0.023019	2913.7	3201.5	6.2749
500	0.036793	3056.3	3387.4	6.6603	0.032811	3047.0	3375.1	6.5995	0.025630	3023.2	3343.6	6.4651
550	0.039885	3153.0	3512.0	6.8164	0.035655	3145.4	3502.0	6.7585	0.028033	3126.1	3476.5	6.6317
600	0.042861	3248.4	3634.1	6.9605	0.038378	3242.0	3625.8	6.9045	0.030306	3225.8	3604.6	6.7828
650	0.045755	3343.4	3755.2	7.0954	0.041018	3338.0	3748.1	7.0408	0.032491	3324.1	3730.2	6.9227
700	0.048589	3438.8	3876.1	7.2229	0.043597	3434.0	3870.0	7.1693	0.034612	3422.0	3854.6	7.0540
800	0.054132	3632.0	4119.2	7.4606	0.048629	3628.2	4114.5	7.4085	0.038724	3618.8	4102.8	7.2967
900	0.059562	3829.6	4365.7	7.6802	0.053547	3826.5	4362.0	7.6290	0.042720	3818.9	4352.9	7.5195
1000	0.064919	4032.4	4616.7	7.8855	0.058391	4029.9	4613.8	7.8349	0.046641	4023.5	4606.5	7.7269
1100	0.070224	4240.7	4872.7	8.0791	0.063183	4238.5	4870.3	8.0289	0.050510	4233.1	4864.5	7.9220
1200	0.075492	4454.2	5133.6	8.2625	0.067938	4452.4	5131.7	8.2126	0.054342	4447.7	5127.0	8.1065
1300	0.080733	4672.9	5399.5	8.4371	0.072667	4671.3	5398.0	8.3874	0.058147	4667.3	5394.1	8.2819
<b><i>p</i> = 15.0 MPa (342.16 °C)</b>					<b><i>p</i> = 17.5 MPa (354.67 °C)</b>				<b><i>p</i> = 20.0 MPa (365.75 °C)</b>			
Sat.	0.010341	2455.7	2610.8	5.3108	0.007932	2390.7	2529.5	5.1435	0.005862	2294.8	2412.1	4.9310
350	0.011481	2520.9	2693.1	5.4438								
400	0.015671	2740.6	2975.7	5.8819	0.012463	2684.3	2902.4	5.7211	0.009950	2617.9	2816.9	5.5526
450	0.018477	2880.8	3157.9	6.1434	0.015204	2845.4	3111.4	6.0212	0.012721	2807.3	3061.7	5.9043
500	0.020828	2998.4	3310.8	6.3480	0.017385	2972.4	3276.7	6.2424	0.014793	2945.3	3241.2	6.1446
550	0.022945	3106.2	3450.4	6.5230	0.019305	3085.8	3423.6	6.4266	0.016571	3064.7	3396.2	6.3390
600	0.024921	3209.3	3583.1	6.6796	0.021073	3192.5	3561.3	6.5890	0.018185	3175.3	3539.0	6.5075
650	0.026804	3310.1	3712.1	6.8233	0.022742	3295.8	3693.8	6.7366	0.019695	3281.4	3675.3	6.6593
700	0.028621	3409.8	3839.1	6.9573	0.024342	3397.5	3823.5	6.8735	0.021134	3385.1	3807.8	6.7991
800	0.032121	3609.3	4091.1	7.2037	0.027405	3599.7	4079.3	7.1237	0.023870	3590.1	4067.5	7.0531
900	0.035503	3811.2	4343.7	7.4288	0.030348	3803.5	4334.6	7.3511	0.026484	3795.7	4325.4	7.2829
1000	0.038808	4017.1	4599.2	7.6378	0.033215	4010.7	4592.0	7.5616	0.029020	4004.3	4584.7	7.4950
1100	0.042062	4227.7	4858.6	7.8339	0.036029	4222.3	4852.8	7.7588	0.031504	4216.9	4847.0	7.6933
1200	0.045279	4443.1	5122.3	8.0192	0.038806	4438.5	5117.6	7.9449	0.033952	4433.8	5112.9	7.8802
1300	0.048469	4663.3	5390.3	8.1952	0.041556	4659.2	5386.5	8.1215	0.036371	4655.2	5382.7	8.0574
<b><i>p</i> = 25.0 MPa</b>					<b><i>p</i> = 30.0 MPa</b>				<b><i>p</i> = 35.0 MPa</b>			
375	0.001978	1799.9	1849.4	4.0345	0.001792	1738.1	1791.9	3.9313	0.001701	1702.8	1762.4	3.8724
400	0.006005	2428.5	2578.7	5.1400	0.002798	2068.9	2152.8	4.4758	0.002105	1914.9	1988.6	4.2144
425	0.007886	2607.8	2805.0	5.4708	0.005299	2452.9	2611.8	5.1473	0.003434	2253.3	2373.5	4.7751
450	0.009176	2721.2	2950.6	5.6759	0.006737	2618.9	2821.0	5.4422	0.004957	2497.5	2671.0	5.1946
500	0.011143	2887.3	3165.9	5.9643	0.008691	2824.0	3084.8	5.7956	0.006933	2755.3	2997.9	5.6331
550	0.012736	3020.8	3339.2	6.1816	0.010175	2974.5	3279.7	6.0403	0.008348	2925.8	3218.0	5.9093
600	0.014140	3140.0	3493.5	6.3637	0.011445	3103.4	3446.8	6.2373	0.009523	3065.6	3399.0	6.1229
650	0.015430	3251.9	3637.7	6.5243	0.012590	3221.7	3599.4	6.4074	0.010565	3190.9	3560.7	6.3030
700	0.016643	3359.9	3776.0	6.6702	0.013654	3334.3	3743.9	6.5599	0.011523	3308.3	3711.6	6.4623
800	0.018922	3570.7	4043.8	6.9322	0.015628	3551.2	4020.0	6.8301	0.013278	3531.6	3996.3	6.7409

(Segue)

**TABELLA A.8** Acqua surriscaldata (*Continua*)

<i>T</i> °C	<i>v</i> m <sup>3</sup> /kg	<i>u</i> kJ/kg	<i>h</i> kJ/kg	<i>s</i> kJ/kg·K	<i>v</i> m <sup>3</sup> /kg	<i>u</i> kJ/kg	<i>h</i> kJ/kg	<i>s</i> kJ/kg·K	<i>v</i> m <sup>3</sup> /kg	<i>u</i> kJ/kg	<i>h</i> kJ/kg	<i>s</i> kJ/kg·K
900	0.021075	3780.2	4307.1	7.1668	0.017473	3764.6	4288.8	7.0695	0.014904	3749.0	4270.6	6.9853
1000	0.023150	3991.5	4570.2	7.3821	0.019240	3978.6	4555.8	7.2880	0.016450	3965.8	4541.5	7.2069
1100	0.025172	4206.1	4835.4	7.5825	0.020954	4195.2	4823.9	7.4906	0.017942	4184.4	4812.4	7.4118
1200	0.027157	4424.6	5103.5	7.7710	0.022630	4415.3	5094.2	7.6807	0.019398	4406.1	5085.0	7.6034
1300	0.029115	4647.2	5375.1	7.9494	0.024279	4639.2	5367.6	7.8602	0.020827	4631.2	5360.2	7.7841
<b><i>p</i> = 40.0 MPa</b>					<b><i>p</i> = 50.0 MPa</b>				<b><i>p</i> = 60.0 MPa</b>			
375	0.001641	1677.0	1742.6	3.8290	0.001560	1638.6	1716.6	3.7642	0.001503	1609.7	1699.9	3.7149
400	0.001911	1855.0	1931.4	4.1145	0.001731	1787.8	1874.4	4.0029	0.001633	1745.2	1843.2	3.9317
425	0.002538	2097.5	2199.0	4.5044	0.002009	1960.3	2060.7	4.2746	0.001816	1892.9	2001.8	4.1630
450	0.003692	2364.2	2511.8	4.9449	0.002487	2160.3	2284.7	4.5896	0.002086	2055.1	2180.2	4.4140
500	0.005623	2681.6	2906.5	5.4744	0.003890	2528.1	2722.6	5.1762	0.002952	2393.2	2570.3	4.9356
550	0.006985	2875.1	3154.4	5.7857	0.005118	2769.5	3025.4	5.5563	0.003955	2664.6	2901.9	5.3517
600	0.008089	3026.8	3350.4	6.0170	0.006108	2947.1	3252.6	5.8245	0.004833	2866.8	3156.8	5.6527
650	0.009053	3159.5	3521.6	6.2078	0.006957	3095.6	3443.5	6.0373	0.005591	3031.3	3366.8	5.8867
700	0.009930	3282.0	3679.2	6.3740	0.007717	3228.7	3614.6	6.2179	0.006265	3175.4	3551.3	6.0814
800	0.011521	3511.8	3972.6	6.6613	0.009073	3472.2	3925.8	6.5225	0.007456	3432.6	3880.0	6.4033
900	0.012980	3733.3	4252.5	6.9107	0.010296	3702.0	4216.8	6.7819	0.008519	3670.9	4182.1	6.6725
1000	0.014360	3952.9	4527.3	7.1355	0.011441	3927.4	4499.4	7.0131	0.009504	3902.0	4472.2	6.9099
1100	0.015686	4173.7	4801.1	7.3425	0.012534	4152.2	4778.9	7.2244	0.010439	4130.9	4757.3	7.1255
1200	0.016976	4396.9	5075.9	7.5357	0.013590	4378.6	5058.1	7.4207	0.011339	4360.5	5040.8	7.3248
1300	0.018239	4623.3	5352.8	7.7175	0.014620	4607.5	5338.5	7.6048	0.012213	4591.8	5324.5	7.5111

\* La temperatura in parentesi è la temperatura di saturazione alla pressione specifica.

† Proprietà del vapore saturo alla pressione specifica.

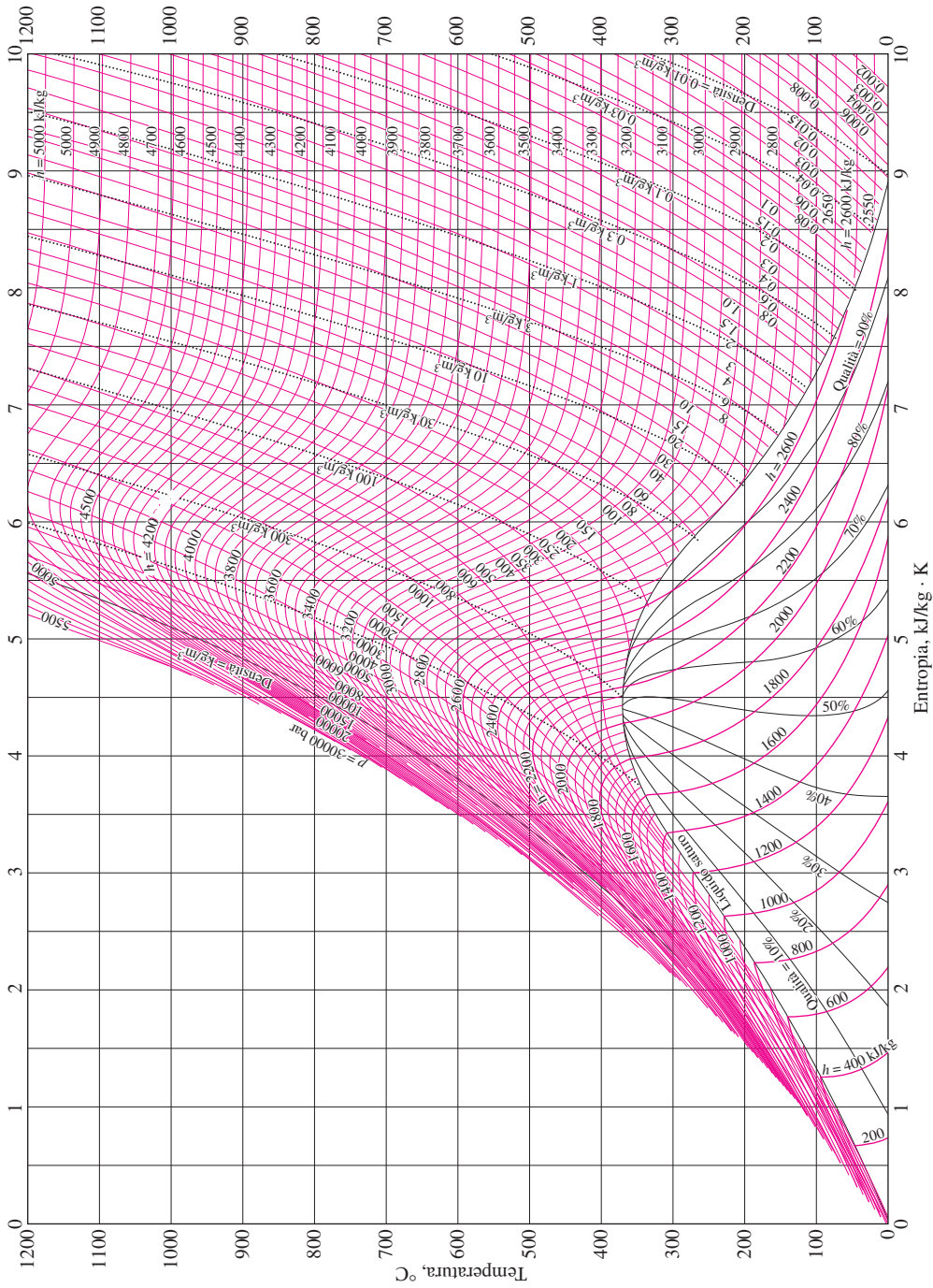
TABELLA A.9 Acqua liquida compressa

$T$ °C	$v$ m <sup>3</sup> /kg	$u$ kJ/kg	$h$ kJ/kg	$s$ kJ/kg·K	$v$ m <sup>3</sup> /kg	$u$ kJ/kg	$h$ kJ/kg	$s$ kJ/kg·K	$v$ m <sup>3</sup> /kg	$u$ kJ/kg	$h$ kJ/kg	$s$ kJ/kg·K
<b><math>p = 5 \text{ MPa (263.94 °C)}</math></b>					<b><math>p = 10 \text{ MPa (311.00 °C)}</math></b>				<b><math>p = 15 \text{ MPa (342.16 °C)}</math></b>			
Sat.	0.0012862	1148.1	1154.5	2.9207	0.0014522	1393.3	1407.9	3.3603	0.0016572	1585.5	1610.3	3.6848
0	0.0009977	0.04	5.03	0.0001	0.0009952	0.12	10.07	0.0003	0.0009928	0.18	15.07	0.0004
20	0.0009996	83.61	88.61	0.2954	0.0009973	83.31	93.28	0.2943	0.0009951	83.01	97.93	0.2932
40	0.0010057	166.92	171.95	0.5705	0.0010035	166.33	176.37	0.5685	0.0010013	165.75	180.77	0.5666
60	0.0010149	250.29	255.36	0.8287	0.0010127	249.43	259.55	0.8260	0.0010105	248.58	263.74	0.8234
80	0.0010267	333.82	338.96	1.0723	0.0010244	332.69	342.94	1.0691	0.0010221	331.59	346.92	1.0659
100	0.0010410	417.65	422.85	1.3034	0.0010385	416.23	426.62	1.2996	0.0010361	414.85	430.39	1.2958
120	0.0010576	501.91	507.19	1.5236	0.0010549	500.18	510.73	1.5191	0.0010522	498.50	514.28	1.5148
140	0.0010769	586.80	592.18	1.7344	0.0010738	584.72	595.45	1.7293	0.0010708	582.69	598.75	1.7243
160	0.0010988	672.55	678.04	1.9374	0.0010954	670.06	681.01	1.9316	0.0010920	667.63	684.01	1.9259
180	0.0011240	759.47	765.09	2.1338	0.0011200	756.48	767.68	2.1271	0.0011160	753.58	770.32	2.1206
200	0.0011531	847.92	853.68	2.3251	0.0011482	844.32	855.80	2.3174	0.0011435	840.84	858.00	2.3100
220	0.0011868	938.39	944.32	2.5127	0.0011809	934.01	945.82	2.5037	0.0011752	929.81	947.43	2.4951
240	0.0012268	1031.6	1037.7	2.6983	0.0012192	1026.2	1038.3	2.6876	0.0012121	1021.0	1039.2	2.6774
260	0.0012755	1128.5	1134.9	2.8841	0.0012653	1121.6	1134.3	2.8710	0.0012560	1115.1	1134.0	2.8586
280					0.0013226	1221.8	1235.0	3.0565	0.0013096	1213.4	1233.0	3.0410
300					0.0013980	1329.4	1343.3	3.2488	0.0013783	1317.6	1338.3	3.2279
320									0.0014733	1431.9	1454.0	3.4263
340									0.0016311	1567.9	1592.4	3.6555
<b><math>p = 20 \text{ MPa (365.75 °C)}</math></b>					<b><math>p = 30 \text{ MPa}</math></b>				<b><math>p = 50 \text{ MPa}</math></b>			
Sat.	0.0020378	1785.8	1826.6	4.0146								
0	0.0009904	0.23	20.03	0.0005	0.0009857	0.29	29.86	0.0003	0.0009767	0.29	49.13	-0.0010
20	0.0009929	82.71	102.57	0.2921	0.0009886	82.11	111.77	0.2897	0.0009805	80.93	129.95	0.2845
40	0.0009992	165.17	185.16	0.5646	0.0009951	164.05	193.90	0.5607	0.0009872	161.90	211.25	0.5528
60	0.0010084	247.75	267.92	0.8208	0.0010042	246.14	276.26	0.8156	0.0009962	243.08	292.88	0.8055
80	0.0010199	330.50	350.90	1.0627	0.0010155	328.40	358.86	1.0564	0.0010072	324.42	374.78	1.0442
100	0.0010337	413.50	434.17	1.2920	0.0010290	410.87	441.74	1.2847	0.0010201	405.94	456.94	1.2705
120	0.0010496	496.85	517.84	1.5105	0.0010445	493.66	525.00	1.5020	0.0010349	487.69	539.43	1.4859
140	0.0010679	580.71	602.07	1.7194	0.0010623	576.90	608.76	1.7098	0.0010517	569.77	622.36	1.6916
160	0.0010886	665.28	687.05	1.9203	0.0010823	660.74	693.21	1.9094	0.0010704	652.33	705.85	1.8889
180	0.0011122	750.78	773.02	2.1143	0.0011049	745.40	778.55	2.1020	0.0010914	735.49	790.06	2.0790
200	0.0011390	837.49	860.27	2.3027	0.0011304	831.11	865.02	2.2888	0.0011149	819.45	875.19	2.2628
220	0.0011697	925.77	949.16	2.4867	0.0011595	918.15	952.93	2.4707	0.0011412	904.39	961.45	2.4414
240	0.0012053	1016.1	1040.2	2.6676	0.0011927	1006.9	1042.7	2.6491	0.0011708	990.55	1049.1	2.6156
260	0.0012472	1109.0	1134.0	2.8469	0.0012314	1097.8	1134.7	2.8250	0.0012044	1078.2	1138.4	2.7864
280	0.0012978	1205.6	1231.5	3.0265	0.0012770	1191.5	1229.8	3.0001	0.0012430	1167.7	1229.9	2.9547
300	0.0013611	1307.2	1334.4	3.2091	0.0013322	1288.9	1328.9	3.1761	0.0012879	1259.6	1324.0	3.1218
320	0.0014450	1416.6	1445.5	3.3996	0.0014014	1391.7	1433.7	3.3558	0.0013409	1354.3	1421.4	3.2888
340	0.0015693	1540.2	1571.6	3.6086	0.0014932	1502.4	1547.1	3.5438	0.0014049	1452.9	1523.1	3.4575
360	0.0018248	1703.6	1740.1	3.8787	0.0016276	1626.8	1675.6	3.7499	0.0014848	1556.5	1630.7	3.6301
380					0.0018729	1782.0	1838.2	4.0026	0.0015884	1667.1	1746.5	3.8102



TABELLA A.10 Vapore acqueo saturo

Temp., $T$ °C	Pressione satura, $p_{\text{sat}}$ kPa	Volume specifico, $\text{m}^3/\text{kg}$		Energia interna, kJ/kg			Entalpia, kJ/kg			Entropia, kJ/kg · K		
		Ghiaccio saturato, $v_{\text{g sat}}$	Vapore saturato, $v_{\text{v sat}}$	Ghiaccio saturato, $u_{\text{g sat}}$	Subl., $u_{\text{g sat v sat}}$	Vapore saturato, $u_{\text{v sat}}$	Ghiaccio saturato, $h_{\text{g sat}}$	Subl., $h_{\text{g sat v sat}}$	Vapore saturato, $h_{\text{v sat}}$	Ghiaccio saturato, $s_{\text{g sat}}$	Subl., $s_{\text{g sat v sat}}$	Vapore saturato, $s_{\text{v sat}}$
0.01	0.61169	0.001091	205.99	-333.40	2707.9	2374.5	-333.40	2833.9	2500.5	-1.2202	10.374	9.154
0	0.61115	0.001091	206.17	-333.43	2707.9	2374.5	-333.43	2833.9	2500.5	-1.2204	10.375	9.154
-2	0.51772	0.001091	241.62	-337.63	2709.4	2371.8	-337.63	2834.5	2496.8	-1.2358	10.453	9.218
-4	0.43748	0.001090	283.84	-341.80	2710.8	2369.0	-341.80	2835.0	2493.2	-1.2513	10.533	9.282
-6	0.36873	0.001090	334.27	-345.94	2712.2	2366.2	-345.93	2835.4	2489.5	-1.2667	10.613	9.347
-8	0.30998	0.001090	394.66	-350.04	2713.5	2363.5	-350.04	2835.8	2485.8	-1.2821	10.695	9.413
-10	0.25990	0.001089	467.17	-354.12	2714.8	2360.7	-354.12	2836.2	2482.1	-1.2976	10.778	9.480
-12	0.21732	0.001089	554.47	-358.17	2716.1	2357.9	-358.17	2836.6	2478.4	-1.3130	10.862	9.549
-14	0.18121	0.001088	659.88	-362.18	2717.3	2355.2	-362.18	2836.9	2474.7	-1.3284	10.947	9.618
-16	0.15068	0.001088	787.51	-366.17	2718.6	2352.4	-366.17	2837.2	2471.0	-1.3439	11.033	9.689
-18	0.12492	0.001088	942.51	-370.13	2719.7	2349.6	-370.13	2837.5	2467.3	-1.3593	11.121	9.761
-20	0.10326	0.001087	1131.3	-374.06	2720.9	2346.8	-374.06	2837.7	2463.6	-1.3748	11.209	9.835
-22	0.08510	0.001087	1362.0	-377.95	2722.0	2344.1	-377.95	2837.9	2459.9	-1.3903	11.300	9.909
-24	0.06991	0.001087	1644.7	-381.82	2723.1	2341.3	-381.82	2838.1	2456.2	-1.4057	11.391	9.985
-26	0.05725	0.001087	1992.2	-385.66	2724.2	2338.5	-385.66	2838.2	2452.5	-1.4212	11.484	10.063
-28	0.04673	0.001086	2421.0	-389.47	2725.2	2335.7	-389.47	2838.3	2448.8	-1.4367	11.578	10.141
-30	0.03802	0.001086	2951.7	-393.25	2726.2	2332.9	-393.25	2838.4	2445.1	-1.4521	11.673	10.221
-32	0.03082	0.001086	3610.9	-397.00	2727.2	2330.2	-397.00	2838.4	2441.4	-1.4676	11.770	10.303
-34	0.02490	0.001085	4432.4	-400.72	2728.1	2327.4	-400.72	2838.5	2437.7	-1.4831	11.869	10.386
-36	0.02004	0.001085	5460.1	-404.40	2729.0	2324.6	-404.40	2838.4	2434.0	-1.4986	11.969	10.470
-38	0.01608	0.001085	6750.5	-408.07	2729.9	2321.8	-408.07	2838.4	2430.3	-1.5141	12.071	10.557
-40	0.01285	0.001084	8376.7	-411.70	2730.7	2319.0	-411.70	2838.3	2426.6	-1.5296	12.174	10.644

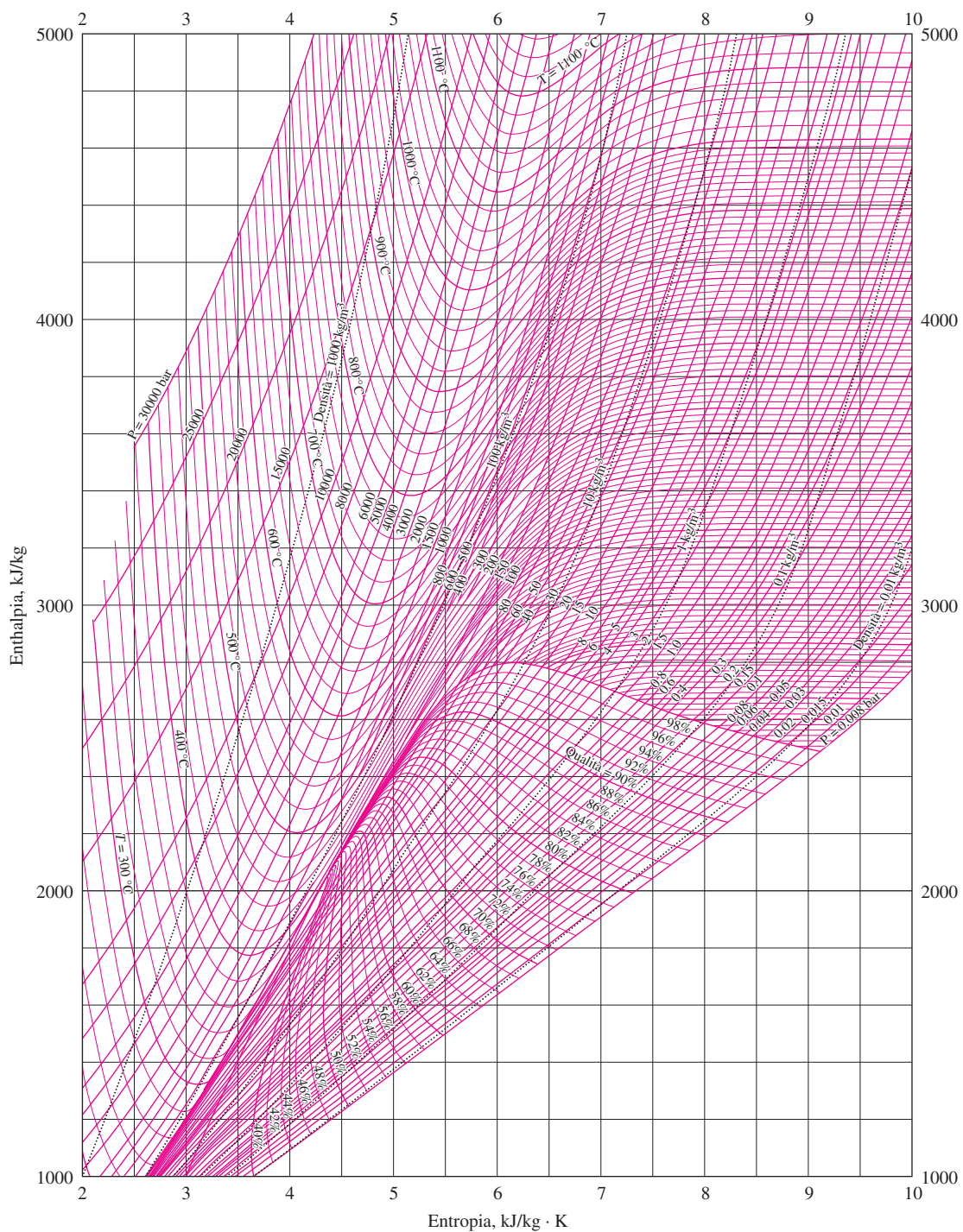


**FIGURA A.11**

Diagramma T-s per l'acqua

(Fonte: L. Haar, J.S. Gallagher e G.S. Kell, NBS/NCR Steam Tables, Hemisphere Publishing Corporation, New York 1984, pp. 256-57, Fig. 9.

Riproduzione autorizzata).



**FIGURA A.12**

Diagramma di Mollier del vapore d'acqua.

(Fonte: L. Haar, J.S. Gallagher e G.S. Kell, NBS/NCR Steam Tables, Hemisphere Publishing Corporation, New York 1984, Riproduzione autorizzata).

TABELLA A.13 Refrigerante R-134a saturo – Tabella della temperatura

Temp., $T$ °C	Pressione satura, $p_{\text{sat}}$ kPa	Volume specifico, $\text{m}^3/\text{kg}$		Energia interna, kJ/kg			Entalpia, kJ/kg			Entropia, kJ/kg · K		
		Liquido saturato, $v_{\text{l sat}}$	Vapore saturato, $v_{\text{v sat}}$	Liquido saturato, $u_{\text{l sat}}$	Evap., $u_{\text{l sat v sat}}$	Vapore saturato, $u_{\text{v sat}}$	Liquido saturato, $h_{\text{l sat}}$	Evap., $h_{\text{l sat v sat}}$	Vapore saturato, $h_{\text{v sat}}$	Liquido saturato, $s_{\text{l sat}}$	Evap., $s_{\text{l sat v sat}}$	Vapore saturato, $s_{\text{v sat}}$
-40	51.25	0.0007054	0.36081	-0.036	207.40	207.37	0.000	225.86	225.86	0.00000	0.96866	0.96866
-38	56.86	0.0007083	0.32732	2.475	206.04	208.51	2.515	224.61	227.12	0.01072	0.95511	0.96584
-36	62.95	0.0007112	0.29751	4.992	204.67	209.66	5.037	223.35	228.39	0.02138	0.94176	0.96315
-34	69.56	0.0007142	0.27090	7.517	203.29	210.81	7.566	222.09	229.65	0.03199	0.92859	0.96058
-32	76.71	0.0007172	0.24711	10.05	201.91	211.96	10.10	220.81	230.91	0.04253	0.91560	0.95813
-30	84.43	0.0007203	0.22580	12.59	200.52	213.11	12.65	219.52	232.17	0.05301	0.90278	0.95579
-28	92.76	0.0007234	0.20666	15.13	199.12	214.25	15.20	218.22	233.43	0.06344	0.89012	0.95356
-26	101.73	0.0007265	0.18946	17.69	197.72	215.40	17.76	216.92	234.68	0.07382	0.87762	0.95144
-24	111.37	0.0007297	0.17395	20.25	196.30	216.55	20.33	215.59	235.92	0.08414	0.86527	0.94941
-22	121.72	0.0007329	0.15995	22.82	194.88	217.70	22.91	214.26	237.17	0.09441	0.85307	0.94748
-20	132.82	0.0007362	0.14729	25.39	193.45	218.84	25.49	212.91	238.41	0.10463	0.84101	0.94564
-18	144.69	0.0007396	0.13583	27.98	192.01	219.98	28.09	211.55	239.64	0.11481	0.82908	0.94389
-16	157.38	0.0007430	0.12542	30.57	190.56	221.13	30.69	210.18	240.87	0.12493	0.81729	0.94222
-14	170.93	0.0007464	0.11597	33.17	189.09	222.27	33.30	208.79	242.09	0.13501	0.80561	0.94063
-12	185.37	0.0007499	0.10736	35.78	187.62	223.40	35.92	207.38	243.30	0.14504	0.79406	0.93911
-10	200.74	0.0007535	0.099516	38.40	186.14	224.54	38.55	205.96	244.51	0.15504	0.78263	0.93766
-8	217.08	0.0007571	0.092352	41.03	184.64	225.67	41.19	204.52	245.72	0.16498	0.77130	0.93629
-6	234.44	0.0007608	0.085802	43.66	183.13	226.80	43.84	203.07	246.91	0.17489	0.76008	0.93497
-4	252.85	0.0007646	0.079804	46.31	181.61	227.92	46.50	201.60	248.10	0.18476	0.74896	0.93372
-2	272.36	0.0007684	0.074304	48.96	180.08	229.04	49.17	200.11	249.28	0.19459	0.73794	0.93253
0	293.01	0.0007723	0.069255	51.63	178.53	230.16	51.86	198.60	250.45	0.20439	0.72701	0.93139
2	314.84	0.0007763	0.064612	54.30	176.97	231.27	54.55	197.07	251.61	0.21415	0.71616	0.93031
4	337.90	0.0007804	0.060338	56.99	175.39	232.38	57.25	195.51	252.77	0.22387	0.70540	0.92927
6	362.23	0.0007845	0.056398	59.68	173.80	233.48	59.97	193.94	253.91	0.23356	0.69471	0.92828
8	387.88	0.0007887	0.052762	62.39	172.19	234.58	62.69	192.35	255.04	0.24323	0.68410	0.92733
10	414.89	0.0007930	0.049403	65.10	170.56	235.67	65.43	190.73	256.16	0.25286	0.67356	0.92641
12	443.31	0.0007975	0.046295	67.83	168.92	236.75	68.18	189.09	257.27	0.26246	0.66308	0.92554
14	473.19	0.0008020	0.043417	70.57	167.26	237.83	70.95	187.42	258.37	0.27204	0.65266	0.92470
16	504.58	0.0008066	0.040748	73.32	165.58	238.90	73.73	185.73	259.46	0.28159	0.64230	0.92389
18	537.52	0.0008113	0.038271	76.08	163.88	239.96	76.52	184.01	260.53	0.29112	0.63198	0.92310
20	572.07	0.0008161	0.035969	78.86	162.16	241.02	79.32	182.27	261.59	0.30063	0.62172	0.92234
22	608.27	0.0008210	0.033828	81.64	160.42	242.06	82.14	180.49	262.64	0.31011	0.61149	0.92160
24	646.18	0.0008261	0.031834	84.44	158.65	243.10	84.98	178.69	263.67	0.31958	0.60130	0.92088
26	685.84	0.0008313	0.029976	87.26	156.87	244.12	87.83	176.85	264.68	0.32903	0.59115	0.92018
28	727.31	0.0008366	0.028242	90.09	155.05	245.14	90.69	174.99	265.68	0.33846	0.58102	0.91948
30	770.64	0.0008421	0.026622	92.93	153.22	246.14	93.58	173.08	266.66	0.34789	0.57091	0.91879
32	815.89	0.0008478	0.025108	95.79	151.35	247.14	96.48	171.14	267.62	0.35730	0.56082	0.91811
34	863.11	0.0008536	0.023691	98.66	149.46	248.12	99.40	169.17	268.57	0.36670	0.55074	0.91743
36	912.35	0.0008595	0.022364	101.55	147.54	249.08	102.33	167.16	269.49	0.37609	0.54066	0.91675
38	963.68	0.0008657	0.021119	104.45	145.58	250.04	105.29	165.10	270.39	0.38548	0.53058	0.91606
40	1017.1	0.0008720	0.019952	107.38	143.60	250.97	108.26	163.00	271.27	0.39486	0.52049	0.91536
42	1072.8	0.0008786	0.018855	110.32	141.58	251.89	111.26	160.86	272.12	0.40425	0.51039	0.91464

(Segue)

**TABELLA A.13** Refrigerante 134A saturo – Tabella della temperatura (*Continua*)

Temp., $T$ °C	Pressione satura, $p_{\text{sat}}$ kPa	Volume specifico, $\text{m}^3/\text{kg}$		Energia interna, kJ/kg			Entalpia, kJ/kg			Entropia, kJ/kg · K		
		Liquido saturato, $v_{\text{l sat}}$	Vapore saturato, $v_{\text{v sat}}$	Liquido saturato, $u_{\text{l sat}}$	Evap., $u_{\text{l sat v sat}}$	Vapore saturato, $u_{\text{v sat}}$	Liquido saturato, $h_{\text{l sat}}$	Evap., $h_{\text{l sat v sat}}$	Vapore saturato, $h_{\text{v sat}}$	Liquido saturato, $s_{\text{l sat}}$	Evap., $s_{\text{l sat v sat}}$	Vapore saturato, $s_{\text{v sat}}$
44	1130.7	0.0008854	0.017824	113.28	139.52	252.80	114.28	158.67	272.95	0.41363	0.50027	0.91391
46	1191.0	0.0008924	0.016853	116.26	137.42	253.68	117.32	156.43	273.75	0.42302	0.49012	0.91315
48	1253.6	0.0008996	0.015939	119.26	135.29	254.55	120.39	154.14	274.53	0.43242	0.47993	0.91236
52	1386.2	0.0009150	0.014265	125.33	130.88	256.21	126.59	149.39	275.98	0.45126	0.45941	0.91067
56	1529.1	0.0009317	0.012771	131.49	126.28	257.77	132.91	144.38	277.30	0.47018	0.43863	0.90880
60	1682.8	0.0009498	0.011434	137.76	121.46	259.22	139.36	139.10	278.46	0.48920	0.41749	0.90669
65	1891.0	0.0009750	0.009950	145.77	115.05	260.82	147.62	132.02	279.64	0.51320	0.39039	0.90359
70	2118.2	0.0010037	0.008642	154.01	108.14	262.15	156.13	124.32	280.46	0.53755	0.36227	0.89982
75	2365.8	0.0010372	0.007480	162.53	100.60	263.13	164.98	115.85	280.82	0.56241	0.33272	0.89512
80	2635.3	0.0010772	0.006436	171.40	92.23	263.63	174.24	106.35	280.59	0.58800	0.30111	0.88912
85	2928.2	0.0011270	0.005486	180.77	82.67	263.44	184.07	95.44	279.51	0.61473	0.26644	0.88117
90	3246.9	0.0011932	0.004599	190.89	71.29	262.18	194.76	82.35	277.11	0.64336	0.22674	0.87010
95	3594.1	0.0012933	0.003726	202.40	56.47	258.87	207.05	65.21	272.26	0.67578	0.17711	0.85289
100	3975.1	0.0015269	0.002630	218.72	29.19	247.91	224.79	33.58	258.37	0.72217	0.08999	0.81215

Fonte: Le tabelle sono generate usando l'Engineering Equation Solver (EES), software sviluppato da S.A. Klein e F.L. Alvarado. La routine usata durante i calcoli è il refrigerante R-134a, che si basa sulla fondamentale equazione di stato sviluppata da R. Tillner-Roth e H.D. Baehr, "An International Standard Formulation for the Thermodynamic Properties of 1,1,1,2-Tetrafluoroethane (HFC-134a) for temperatures from 170 K to 455 K and Pressures up to 70 MPa," *J. Phys. Chem. Ref. Data*, Vol. 23, No. 5, 1994. I valori di entalpia e di entropia del liquido saturato sono settati da zero a  $-40$  °C.

TABELLA A.14 Refrigerante R-134a saturo – Tabella della pressione

Press., $p$ kPa	Temp. saturo, $T_{\text{sat}}$ °C	Volume specifico, $\text{m}^3/\text{kg}$		Energia interna, kJ/kg			Entalpia, kJ/kg			Entropia, kJ/kg · K		
		Liquido saturo, $v_{\text{l sat}}$	Vapore saturo, $v_{\text{v sat}}$	Liquido saturo, $u_{\text{l sat}}$	Evap., $u_{\text{l sat v sat}}$	Vapore saturo, $u_{\text{v sat}}$	Liquido saturo, $h_{\text{l sat}}$	Evap., $h_{\text{l sat v sat}}$	Vapore saturo, $h_{\text{v sat}}$	Liquido saturo, $s_{\text{l sat}}$	Evap., $s_{\text{l sat v sat}}$	Vapore saturo, $s_{\text{v sat}}$
60	-36.95	0.0007098	0.31121	3.798	205.32	209.12	3.841	223.95	227.79	0.01634	0.94807	0.96441
70	-33.87	0.0007144	0.26929	7.680	203.20	210.88	7.730	222.00	229.73	0.03267	0.92775	0.96042
80	-31.13	0.0007185	0.23753	11.15	201.30	212.46	11.21	220.25	231.46	0.04711	0.90999	0.95710
90	-28.65	0.0007223	0.21263	14.31	199.57	213.88	14.37	218.65	233.02	0.06008	0.89419	0.95427
100	-26.37	0.0007259	0.19254	17.21	197.98	215.19	17.28	217.16	234.44	0.07188	0.87995	0.95183
120	-22.32	0.0007324	0.16212	22.40	195.11	217.51	22.49	214.48	236.97	0.09275	0.85503	0.94779
140	-18.77	0.0007383	0.14014	26.98	192.57	219.54	27.08	212.08	239.16	0.11087	0.83368	0.94456
160	-15.60	0.0007437	0.12348	31.09	190.27	221.35	31.21	209.90	241.11	0.12693	0.81496	0.94190
180	-12.73	0.0007487	0.11041	34.83	188.16	222.99	34.97	207.90	242.86	0.14139	0.79826	0.93965
200	-10.09	0.0007533	0.099867	38.28	186.21	224.48	38.43	206.03	244.46	0.15457	0.78316	0.93773
240	-5.38	0.0007620	0.083897	44.48	182.67	227.14	44.66	202.62	247.28	0.17794	0.75664	0.93458
280	-1.25	0.0007699	0.072352	49.97	179.50	229.46	50.18	199.54	249.72	0.19829	0.73381	0.93210
320	2.46	0.0007772	0.063604	54.92	176.61	231.52	55.16	196.71	251.88	0.21637	0.71369	0.93006
360	5.82	0.0007841	0.056738	59.44	173.94	233.38	59.72	194.08	253.81	0.23270	0.69566	0.92836
400	8.91	0.0007907	0.051201	63.62	171.45	235.07	63.94	191.62	255.55	0.24761	0.67929	0.92691
450	12.46	0.0007985	0.045619	68.45	168.54	237.00	68.81	188.71	257.53	0.26465	0.66069	0.92535
500	15.71	0.0008059	0.041118	72.93	165.82	238.75	73.33	185.98	259.30	0.28023	0.64377	0.92400
550	18.73	0.0008130	0.037408	77.10	163.25	240.35	77.54	183.38	260.92	0.29461	0.62821	0.92282
600	21.55	0.0008199	0.034295	81.02	160.81	241.83	81.51	180.90	262.40	0.30799	0.61378	0.92177
650	24.20	0.0008266	0.031646	84.72	158.48	243.20	85.26	178.51	263.77	0.32051	0.60030	0.92081
700	26.69	0.0008331	0.029361	88.24	156.24	244.48	88.82	176.21	265.03	0.33230	0.58763	0.91994
750	29.06	0.0008395	0.027371	91.59	154.08	245.67	92.22	173.98	266.20	0.34345	0.57567	0.91912
800	31.31	0.0008458	0.025621	94.79	152.00	246.79	95.47	171.82	267.29	0.35404	0.56431	0.91835
850	33.45	0.0008520	0.024069	97.87	149.98	247.85	98.60	169.71	268.31	0.36413	0.55349	0.91762
900	35.51	0.0008580	0.022683	100.83	148.01	248.85	101.61	167.66	269.26	0.37377	0.54315	0.91692
950	37.48	0.0008641	0.021438	103.69	146.10	249.79	104.51	165.64	270.15	0.38301	0.53323	0.91624
1000	39.37	0.0008700	0.020313	106.45	144.23	250.68	107.32	163.67	270.99	0.39189	0.52368	0.91558
1200	46.29	0.0008934	0.016715	116.70	137.11	253.81	117.77	156.10	273.87	0.42441	0.48863	0.91303
1400	52.40	0.0009166	0.014107	125.94	130.43	256.37	127.22	148.90	276.12	0.45315	0.45734	0.91050
1600	57.88	0.0009400	0.012123	134.43	124.04	258.47	135.93	141.93	277.86	0.47911	0.42873	0.90784
1800	62.87	0.0009639	0.010559	142.33	117.83	260.17	144.07	135.11	279.17	0.50294	0.40204	0.90498
2000	67.45	0.0009886	0.009288	149.78	111.73	261.51	151.76	128.33	280.09	0.52509	0.37675	0.90184
2500	77.54	0.0010566	0.006936	166.99	96.47	263.45	169.63	111.16	280.79	0.57531	0.31695	0.89226
3000	86.16	0.0011406	0.005275	183.04	80.22	263.26	186.46	92.63	279.09	0.62118	0.25776	0.87894

**TABELLA A.15** Refrigerante R-134a surriscaldato

$T$ °C	$v$ m <sup>3</sup> /kg	$u$ kJ/kg	$h$ kJ/kg	$s$ kJ/kg · K	$v$ m <sup>3</sup> /kg	$u$ kJ/kg	$h$ kJ/kg	$s$ kJ/kg · K	$v$ m <sup>3</sup> /kg	$u$ kJ/kg	$h$ kJ/kg	$s$ kJ/kg · K	
<b><math>p = 0.06</math> MPa (<math>T_{\text{sat}} = -36.95</math> °C)</b>					<b><math>p = 0.10</math> MPa (<math>T_{\text{sat}} = -26.37</math> °C)</b>					<b><math>p = 0.14</math> MPa (<math>T_{\text{sat}} = -18.77</math> °C)</b>			
Sat.	0.31121	209.12	227.79	0.9644	0.19254	215.19	234.44	0.9518	0.14014	219.54	239.16	0.9446	
-20	0.33608	220.60	240.76	1.0174	0.19841	219.66	239.50	0.9721					
-10	0.35048	227.55	248.58	1.0477	0.20743	226.75	247.49	1.0030	0.14605	225.91	246.36	0.9724	
0	0.36476	234.66	256.54	1.0774	0.21630	233.95	255.58	1.0332	0.15263	233.23	254.60	1.0031	
10	0.37893	241.92	264.66	1.1066	0.22506	241.30	263.81	1.0628	0.15908	240.66	262.93	1.0331	
20	0.39302	249.35	272.94	1.1353	0.23373	248.79	272.17	1.0918	0.16544	248.22	271.38	1.0624	
30	0.40705	256.95	281.37	1.1636	0.24233	256.44	280.68	1.1203	0.17172	255.93	279.97	1.0912	
40	0.42102	264.71	289.97	1.1915	0.25088	264.25	289.34	1.1484	0.17794	263.79	288.70	1.1195	
50	0.43495	272.64	298.74	1.2191	0.25937	272.22	298.16	1.1762	0.18412	271.79	297.57	1.1474	
60	0.44883	280.73	307.66	1.2463	0.26783	280.35	307.13	1.2035	0.19025	279.96	306.59	1.1749	
70	0.46269	288.99	316.75	1.2732	0.27626	288.64	316.26	1.2305	0.19635	288.28	315.77	1.2020	
80	0.47651	297.41	326.00	1.2997	0.28465	297.08	325.55	1.2572	0.20242	296.75	325.09	1.2288	
90	0.49032	306.00	335.42	1.3260	0.29303	305.69	334.99	1.2836	0.20847	305.38	334.57	1.2553	
100	0.50410	314.74	344.99	1.3520	0.30138	314.46	344.60	1.3096	0.21449	314.17	344.20	1.2814	
<b><math>p = 0.18</math> MPa (<math>T_{\text{sat}} = -12.73</math> °C)</b>					<b><math>p = 0.20</math> MPa (<math>T_{\text{sat}} = -10.09</math> °C)</b>					<b><math>p = 0.24</math> MPa (<math>T_{\text{sat}} = -5.38</math> °C)</b>			
Sat.	0.11041	222.99	242.86	0.9397	0.09987	224.48	244.46	0.9377	0.08390	227.14	247.28	0.9346	
-10	0.11189	225.02	245.16	0.9484	0.09991	224.55	244.54	0.9380					
0	0.11722	232.48	253.58	0.9798	0.10481	232.09	253.05	0.9698	0.08617	231.29	251.97	0.9519	
10	0.12240	240.00	262.04	1.0102	0.10955	239.67	261.58	1.0004	0.09026	238.98	260.65	0.9831	
20	0.12748	247.64	270.59	1.0399	0.11418	247.35	270.18	1.0303	0.09423	246.74	269.36	1.0134	
30	0.13248	255.41	279.25	1.0690	0.11874	255.14	278.89	1.0595	0.09812	254.61	278.16	1.0429	
40	0.13741	263.31	288.05	1.0975	0.12322	263.08	287.72	1.0882	0.10193	262.59	287.06	1.0718	
50	0.14230	271.36	296.98	1.1256	0.12766	271.15	296.68	1.1163	0.10570	270.71	296.08	1.1001	
60	0.14715	279.56	306.05	1.1532	0.13206	279.37	305.78	1.1441	0.10942	278.97	305.23	1.1280	
70	0.15196	287.91	315.27	1.1805	0.13641	287.73	315.01	1.1714	0.11310	287.36	314.51	1.1554	
80	0.15673	296.42	324.63	1.2074	0.14074	296.25	324.40	1.1983	0.11675	295.91	323.93	1.1825	
90	0.16149	305.07	334.14	1.2339	0.14504	304.92	333.93	1.2249	0.12038	304.60	333.49	1.2092	
100	0.16622	313.88	343.80	1.2602	0.14933	313.74	343.60	1.2512	0.12398	313.44	343.20	1.2356	
<b><math>p = 0.28</math> MPa (<math>T_{\text{sat}} = -1.25</math> °C)</b>					<b><math>p = 0.32</math> MPa (<math>T_{\text{sat}} = 2.46</math> °C)</b>					<b><math>p = 0.40</math> MPa (<math>T_{\text{sat}} = 8.91</math> °C)</b>			
Sat.	0.07235	229.46	249.72	0.9321	0.06360	231.52	251.88	0.9301	0.051201	235.07	255.55	0.9269	
0	0.07282	230.44	250.83	0.9362									
10	0.07646	238.27	259.68	0.9680	0.06609	237.54	258.69	0.9544	0.051506	235.97	256.58	0.9305	
20	0.07997	246.13	268.52	0.9987	0.06925	245.50	267.66	0.9856	0.054213	244.18	265.86	0.9628	
30	0.08338	254.06	277.41	1.0285	0.07231	253.50	276.65	1.0157	0.056796	252.36	275.07	0.9937	
40	0.08672	262.10	286.38	1.0576	0.07530	261.60	285.70	1.0451	0.059292	260.58	284.30	1.0236	
50	0.09000	270.27	295.47	1.0862	0.07823	269.82	294.85	1.0739	0.061724	268.90	293.59	1.0528	
60	0.09324	278.56	304.67	1.1142	0.08111	278.15	304.11	1.1021	0.064104	277.32	302.96	1.0814	
70	0.09644	286.99	314.00	1.1418	0.08395	286.62	313.48	1.1298	0.066443	285.86	312.44	1.1094	
80	0.09961	295.57	323.46	1.1690	0.08675	295.22	322.98	1.1571	0.068747	294.53	322.02	1.1369	
90	0.10275	304.29	333.06	1.1958	0.08953	303.97	332.62	1.1840	0.071023	303.32	331.73	1.1640	
100	0.10587	313.15	342.80	1.2222	0.09229	312.86	342.39	1.2105	0.073274	312.26	341.57	1.1907	
110	0.10897	322.16	352.68	1.2483	0.09503	321.89	352.30	1.2367	0.075504	321.33	351.53	1.2171	
120	0.11205	331.32	362.70	1.2742	0.09775	331.07	362.35	1.2626	0.077717	330.55	361.63	1.2431	

(Segue)

**TABELLA A.15** Refrigerante R-134a surriscaldato (*Continua*)

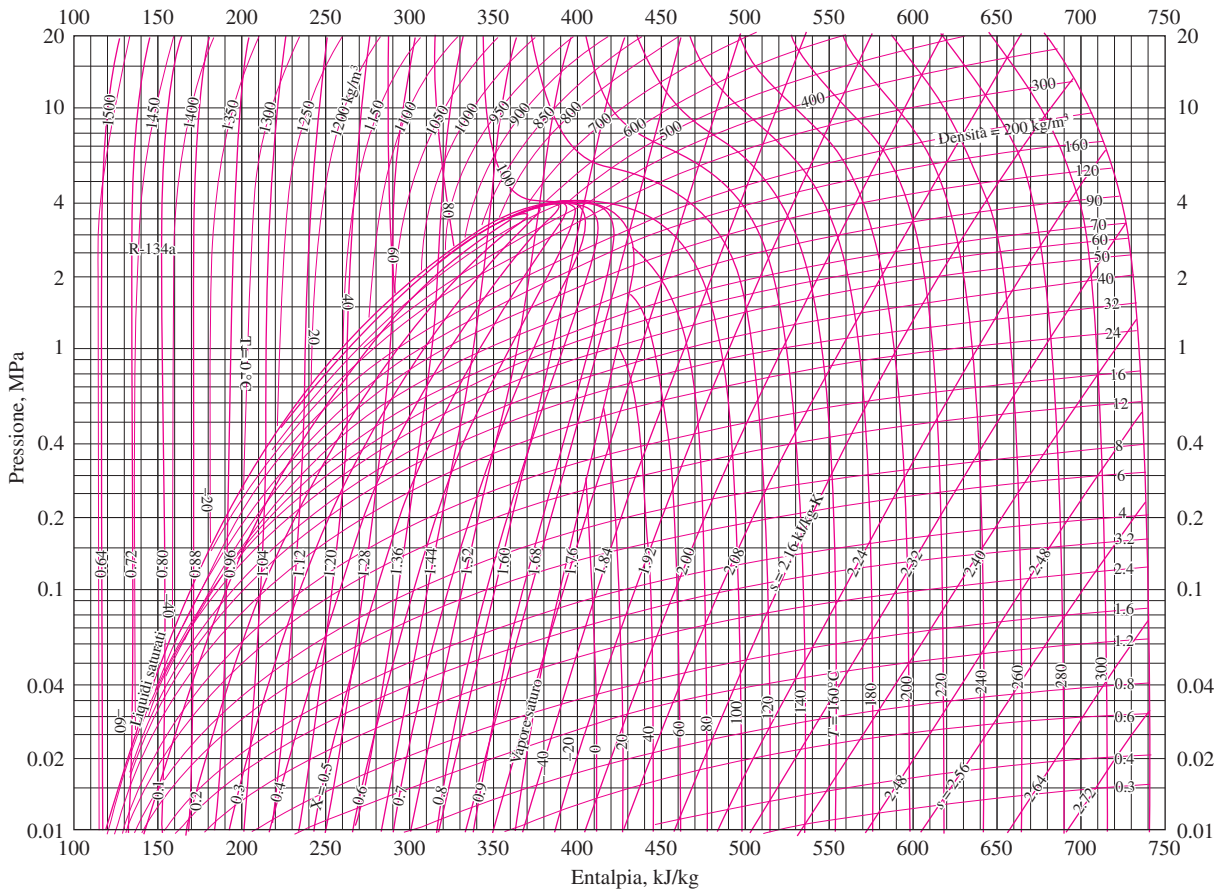
<i>T</i> °C	<i>v</i> m <sup>3</sup> /kg	<i>u</i> kJ/kg	<i>h</i> kJ/kg	<i>s</i> kJ/kg · K	<i>v</i> m <sup>3</sup> /kg	<i>u</i> kJ/kg	<i>h</i> kJ/kg	<i>s</i> kJ/kg · K	<i>v</i> m <sup>3</sup> /kg	<i>u</i> kJ/kg	<i>h</i> kJ/kg	<i>s</i> kJ/kg · K
130	0.11512	340.63	372.87	1.2997	0.10045	340.39	372.54	1.2882	0.079913	339.90	371.87	1.2688
140	0.11818	350.09	383.18	1.3250	0.10314	349.86	382.87	1.3135	0.082096	349.41	382.24	1.2942
<b><i>p</i> = 0.50 MPa (<i>T</i><sub>sat</sub> = 15.71 °C)</b>					<b><i>p</i> = 0.60 MPa (<i>T</i><sub>sat</sub> = 21.55 °C)</b>				<b><i>p</i> = 0.70 MPa (<i>T</i><sub>sat</sub> = 26.69 °C)</b>			
Sat.	0.041118	238.75	259.30	0.9240	0.034295	241.83	262.40	0.9218	0.029361	244.48	265.03	0.9199
20	0.042115	242.40	263.46	0.9383								
30	0.044338	250.84	273.01	0.9703	0.035984	249.22	270.81	0.9499	0.029966	247.48	268.45	0.9313
40	0.046456	259.26	282.48	1.0011	0.037865	257.86	280.58	0.9816	0.031696	256.39	278.57	0.9641
50	0.048499	267.72	291.96	1.0309	0.039659	266.48	290.28	1.0121	0.033322	265.20	288.53	0.9954
60	0.050485	276.25	301.50	1.0599	0.041389	275.15	299.98	1.0417	0.034875	274.01	298.42	1.0256
70	0.052427	284.89	311.10	1.0883	0.043069	283.89	309.73	1.0705	0.036373	282.87	308.33	1.0549
80	0.054331	293.64	320.80	1.1162	0.044710	292.73	319.55	1.0987	0.037829	291.80	318.28	1.0835
90	0.056205	302.51	330.61	1.1436	0.046318	301.67	329.46	1.1264	0.039250	300.82	328.29	1.1114
100	0.058053	311.50	340.53	1.1705	0.047900	310.73	339.47	1.1536	0.040642	309.95	338.40	1.1389
110	0.059880	320.63	350.57	1.1971	0.049458	319.91	349.59	1.1803	0.042010	319.19	348.60	1.1658
120	0.061687	329.89	360.73	1.2233	0.050997	329.23	359.82	1.2067	0.043358	328.55	358.90	1.1924
130	0.063479	339.29	371.03	1.2491	0.052519	338.67	370.18	1.2327	0.044688	338.04	369.32	1.2186
140	0.065256	348.83	381.46	1.2747	0.054027	348.25	380.66	1.2584	0.046004	347.66	379.86	1.2444
150	0.067021	358.51	392.02	1.2999	0.055522	357.96	391.27	1.2838	0.047306	357.41	390.52	1.2699
160	0.068775	368.33	402.72	1.3249	0.057006	367.81	402.01	1.3088	0.048597	367.29	401.31	1.2951
<b><i>p</i> = 0.80 MPa (<i>T</i><sub>sat</sub> = 31.31 °C)</b>					<b><i>p</i> = 0.90 MPa (<i>T</i><sub>sat</sub> = 35.51 °C)</b>				<b><i>p</i> = 1.00 MPa (<i>T</i><sub>sat</sub> = 39.37 °C)</b>			
Sat.	0.025621	246.79	267.29	0.9183	0.022683	248.85	269.26	0.9169	0.020313	250.68	270.99	0.9156
40	0.027035	254.82	276.45	0.9480	0.023375	253.13	274.17	0.9327	0.020406	251.30	271.71	0.9179
50	0.028547	263.86	286.69	0.9802	0.024809	262.44	284.77	0.9660	0.021796	260.94	282.74	0.9525
60	0.029973	272.83	296.81	1.0110	0.026146	271.60	295.13	0.9976	0.023068	270.32	293.38	0.9850
70	0.031340	281.81	306.88	1.0408	0.027413	280.72	305.39	1.0280	0.024261	279.59	303.85	1.0160
80	0.032659	290.84	316.97	1.0698	0.028630	289.86	315.63	1.0574	0.025398	288.86	314.25	1.0458
90	0.033941	299.95	327.10	1.0981	0.029806	299.06	325.89	1.0860	0.026492	298.15	324.64	1.0748
100	0.035193	309.15	337.30	1.1258	0.030951	308.34	336.19	1.1140	0.027552	307.51	335.06	1.1031
110	0.036420	318.45	347.59	1.1530	0.032068	317.70	346.56	1.1414	0.028584	316.94	345.53	1.1308
120	0.037625	327.87	357.97	1.1798	0.033164	327.18	357.02	1.1684	0.029592	326.47	356.06	1.1580
130	0.038813	337.40	368.45	1.2061	0.034241	336.76	367.58	1.1949	0.030581	336.11	366.69	1.1846
140	0.039985	347.06	379.05	1.2321	0.035302	346.46	378.23	1.2210	0.031554	345.85	377.40	1.2109
150	0.041143	356.85	389.76	1.2577	0.036349	356.28	389.00	1.2467	0.032512	355.71	388.22	1.2368
160	0.042290	366.76	400.59	1.2830	0.037384	366.23	399.88	1.2721	0.033457	365.70	399.15	1.2623
170	0.043427	376.81	411.55	1.3080	0.038408	376.31	410.88	1.2972	0.034392	375.81	410.20	1.2875
180	0.044554	386.99	422.64	1.3327	0.039423	386.52	422.00	1.3221	0.035317	386.04	421.36	1.3124
<b><i>p</i> = 1.20 MPa (<i>T</i><sub>sat</sub> = 46.29 °C)</b>					<b><i>p</i> = 1.40 MPa (<i>T</i><sub>sat</sub> = 52.40 °C)</b>				<b><i>p</i> = 1.60 MPa (<i>T</i><sub>sat</sub> = 57.88 °C)</b>			
Sat.	0.016715	253.81	273.87	0.9130	0.014107	256.37	276.12	0.9105	0.012123	258.47	277.86	0.9078
50	0.017201	257.63	278.27	0.9267								
60	0.018404	267.56	289.64	0.9614	0.015005	264.46	285.47	0.9389	0.012372	260.89	280.69	0.9163
70	0.019502	277.21	300.61	0.9938	0.016060	274.62	297.10	0.9733	0.013430	271.76	293.25	0.9535
80	0.020529	286.75	311.39	1.0248	0.017023	284.51	308.34	1.0056	0.014362	282.09	305.07	0.9875
90	0.021506	296.26	322.07	1.0546	0.017923	294.28	319.37	1.0364	0.015215	292.17	316.52	1.0194
100	0.022442	305.80	332.73	1.0836	0.018778	304.01	330.30	1.0661	0.016014	302.14	327.76	1.0500

(Segue)



**TABELLA A.15** Refrigerante R-134a surriscaldato (*Continua*)

$T$ °C	$v$ m <sup>3</sup> /kg	$u$ kJ/kg	$h$ kJ/kg	$s$ kJ/kg · K	$v$ m <sup>3</sup> /kg	$u$ kJ/kg	$h$ kJ/kg	$s$ kJ/kg · K	$v$ m <sup>3</sup> /kg	$u$ kJ/kg	$h$ kJ/kg	$s$ kJ/kg · K
110	0.023348	315.38	343.40	1.1118	0.019597	313.76	341.19	1.0949	0.016773	312.07	338.91	1.0795
120	0.024228	325.03	354.11	1.1394	0.020388	323.55	352.09	1.1230	0.017500	322.02	350.02	1.1081
130	0.025086	334.77	364.88	1.1664	0.021155	333.41	363.02	1.1504	0.018201	332.00	361.12	1.1360
140	0.025927	344.61	375.72	1.1930	0.021904	343.34	374.01	1.1773	0.018882	342.05	372.26	1.1632
150	0.026753	354.56	386.66	1.2192	0.022636	353.37	385.07	1.2038	0.019545	352.17	383.44	1.1900
160	0.027566	364.61	397.69	1.2449	0.023355	363.51	396.20	1.2298	0.020194	362.38	394.69	1.2163
170	0.028367	374.78	408.82	1.2703	0.024061	373.75	407.43	1.2554	0.020830	372.69	406.02	1.2421
180	0.029158	385.08	420.07	1.2954	0.024757	384.10	418.76	1.2807	0.021456	383.11	417.44	1.2676



**FIGURA A.16**

Diagramma  $p$ - $h$  per il refrigerante R-134a.

*Nota:* Il punto di riferimento usato per il grafico è diverso rispetto a quello usato per le tabelle del refrigerante R-134a. Pertanto i problemi dovrebbero essere risolti usando tutti i dati di proprietà entrambi provenienti dalle tabelle o dal grafico, ma non da entrambe. (Riprodotta su licenza di American Society of Heating, Refrigerating, and Air Conditioning Engineers, Inc., Atlanta, GA.).

**TABELLA A.17** Costanti che accompagnano le equazioni di stato di Beattie-Bridgeman e Benedict-Webb-Rubin

(a) L'equazione di stato di Beattie-Bridgeman è

$$p = \frac{R_u T}{\bar{v}^2} \left( 1 - \frac{c}{\bar{v} T^3} \right) (\bar{v} + B) - \frac{A}{\bar{v}}, \quad \text{dove } A = A_0 \left( 1 - \frac{a}{\bar{v}} \right) \quad \text{e} \quad B = B_0 \left( 1 - \frac{b}{\bar{v}} \right)$$

Dove  $p$  è in kPa,  $\bar{v}$  è in m<sup>3</sup>/kmol,  $T$  è in K, e  $R_u = 8.314 \text{ kPa} \cdot \text{m}^3/(\text{kmol} \cdot \text{K})$ , le cinque costanti nella equazione di Beattie-Bridgeman sono le seguenti:

Gas	$A_0$	$a$	$B_0$	$b$	$c$
Aria	131.8441	0.01931	0.04611	-0.001101	$4.34 \times 10^4$
Argon, Ar	130.7802	0.02328	0.03931	0.0	$5.99 \times 10^4$
Biossido di carbonio, CO <sub>2</sub>	507.2836	0.07132	0.10476	0.07235	$6.60 \times 10^5$
Elio, He	2.1886	0.05984	0.01400	0.0	40
Idrogeno, H <sub>2</sub>	20.0117	-0.00506	0.02096	-0.04359	504
Azoto, N <sub>2</sub>	136.2315	0.02617	0.05046	-0.00691	$4.20 \times 10^4$
Ossigeno, O <sub>2</sub>	151.0857	0.02562	0.04624	0.004208	$4.80 \times 10^4$

Fonte: G.J. Van Wylen e R.E. Sonntag, *Fundamentals of Classical Thermodynamics*, English/SI Version, 3<sup>a</sup> ed., Wiley, New York 1986, p. 46, Tab. 3.3.

(b) L'equazione di stato di Benedict-Webb-Rubin è

$$p = \frac{R_u T}{\bar{v}} + \left( B_0 R_u T - A_0 - \frac{C_0}{T^2} \right) \frac{1}{\bar{v}^2} + \frac{b R_u T - a}{\bar{v}^3} + \frac{a \alpha}{\bar{v}^6} + \frac{c}{\bar{v}^3 T^2} \left( 1 + \frac{\gamma}{\bar{v}^3} \right) e^{-\gamma/\bar{v}^2}$$

Dove  $p$  è in kPa,  $\bar{v}$  è in m<sup>3</sup>/kmol,  $T$  è in K, e  $R_u = 8.314 \text{ kPa} \cdot \text{m}^3/(\text{kmol} \cdot \text{K})$ , le otto costanti nella equazione di Benedict-Webb-Rubin sono le seguenti:

Gas	$a$	$A_0$	$b$	$B_0$	$c$	$C_0$	$\alpha$	$\gamma$
<i>n</i> -Butano, C <sub>4</sub> H <sub>10</sub>	190.68	1021.6	0.039998	0.12436	$3.205 \times 10^7$	$1.006 \times 10^8$	$1.101 \times 10^{-3}$	0.0340
Biossido di carbonio, CO <sub>2</sub>	13.86	277.30	0.007210	0.04991	$1.511 \times 10^6$	$1.404 \times 10^7$	$8.470 \times 10^{-5}$	0.00539
Monossido di carbonio, CO	3.71	135.87	0.002632	0.05454	$1.054 \times 10^5$	$8.673 \times 10^5$	$1.350 \times 10^{-4}$	0.0060
Metano, CH <sub>4</sub>	5.00	187.91	0.003380	0.04260	$2.578 \times 10^5$	$2.286 \times 10^6$	$1.244 \times 10^{-4}$	0.0060
Azoto, N <sub>2</sub>	2.54	106.73	0.002328	0.04074	$7.379 \times 10^4$	$8.164 \times 10^5$	$1.272 \times 10^{-4}$	0.0053

Fonte: K. Wark, *Thermodynamics*, 4<sup>a</sup> ed., McGraw-Hill, New York 1983, p. 815, Tav. A-21M. Originariamente pubblicata in H.W. Cooper e J.C. Goldfrank, in «Hydrocarbon Processing», 1967, vol. 46, n. 12, p. 141.

**TABELLA A.18** Proprietà dell'acqua satura

Temp. $T, ^\circ\text{C}$	Pressione satura $p_{\text{sat}}, \text{kPa}$	Densità $\rho, \text{kg/m}^3$		Entalpia di vaporiz- zazione $h_{\text{f sat v sat}},$ $\text{kJ/kg}$	Calore specifico $c_p, \text{J/kg}\cdot\text{K}$		Conduttività termica $\lambda, \text{W/m}\cdot\text{k}$		Viscosità dinamica $\mu, \text{kg/m}\cdot\text{s}$		Numero di Prandtl Pr		Coefficiente di espansione del volume $\beta, 1/\text{K}$ Liquido
		Liquido	Vapore		Liquido	Vapore	Liquido	Vapore	Liquido	Vapore	Liquido	Vapore	
0.01	0.6113	999.8	0.0048	2501	4217	1854	0.561	0.0171	$1.792 \times 10^{-3}$	$0.922 \times 10^{-5}$	13.5	1.00	$-0.068 \times 10^{-3}$
5	0.8721	999.9	0.0068	2490	4205	1857	0.571	0.0173	$1.519 \times 10^{-3}$	$0.934 \times 10^{-5}$	11.2	1.00	$0.015 \times 10^{-3}$
10	1.2276	999.7	0.0094	2478	4194	1862	0.580	0.0176	$1.307 \times 10^{-3}$	$0.946 \times 10^{-5}$	9.45	1.00	$0.733 \times 10^{-3}$
15	1.7051	999.1	0.0128	2466	4185	1863	0.589	0.0179	$1.138 \times 10^{-3}$	$0.959 \times 10^{-5}$	8.09	1.00	$0.138 \times 10^{-3}$
20	2.339	998.0	0.0173	2454	4182	1867	0.598	0.0182	$1.002 \times 10^{-3}$	$0.973 \times 10^{-5}$	7.01	1.00	$0.195 \times 10^{-3}$
25	3.169	997.0	0.0231	2442	4180	1870	0.607	0.0186	$0.891 \times 10^{-3}$	$0.987 \times 10^{-5}$	6.14	1.00	$0.247 \times 10^{-3}$
30	4.246	996.0	0.0304	2431	4178	1875	0.615	0.0189	$0.798 \times 10^{-3}$	$1.001 \times 10^{-5}$	5.42	1.00	$0.294 \times 10^{-3}$
35	5.628	994.0	0.0397	2419	4178	1880	0.623	0.0192	$0.720 \times 10^{-3}$	$1.016 \times 10^{-5}$	4.83	1.00	$0.337 \times 10^{-3}$
40	7.384	992.1	0.0512	2407	4179	1885	0.631	0.0196	$0.653 \times 10^{-3}$	$1.031 \times 10^{-5}$	4.32	1.00	$0.377 \times 10^{-3}$
45	9.593	990.1	0.0655	2395	4180	1892	0.637	0.0200	$0.596 \times 10^{-3}$	$1.046 \times 10^{-5}$	3.91	1.00	$0.415 \times 10^{-3}$
50	12.35	988.1	0.0831	2383	4181	1900	0.644	0.0204	$0.547 \times 10^{-3}$	$1.062 \times 10^{-5}$	3.55	1.00	$0.451 \times 10^{-3}$
55	15.76	985.2	0.1045	2371	4183	1908	0.649	0.0208	$0.504 \times 10^{-3}$	$1.077 \times 10^{-5}$	3.25	1.00	$0.484 \times 10^{-3}$
60	19.94	983.3	0.1304	2359	4185	1916	0.654	0.0212	$0.467 \times 10^{-3}$	$1.093 \times 10^{-5}$	2.99	1.00	$0.517 \times 10^{-3}$
65	25.03	980.4	0.1614	2346	4187	1926	0.659	0.0216	$0.433 \times 10^{-3}$	$1.110 \times 10^{-5}$	2.75	1.00	$0.548 \times 10^{-3}$
70	31.19	977.5	0.1983	2334	4190	1936	0.663	0.0221	$0.404 \times 10^{-3}$	$1.126 \times 10^{-5}$	2.55	1.00	$0.578 \times 10^{-3}$
75	38.58	974.7	0.2421	2321	4193	1948	0.667	0.0225	$0.378 \times 10^{-3}$	$1.142 \times 10^{-5}$	2.38	1.00	$0.607 \times 10^{-3}$
80	47.39	971.8	0.2935	2309	4197	1962	0.670	0.0230	$0.355 \times 10^{-3}$	$1.159 \times 10^{-5}$	2.22	1.00	$0.653 \times 10^{-3}$
85	57.83	968.1	0.3536	2296	4201	1977	0.673	0.0235	$0.333 \times 10^{-3}$	$1.176 \times 10^{-5}$	2.08	1.00	$0.670 \times 10^{-3}$
90	70.14	965.3	0.4235	2283	4206	1993	0.675	0.0240	$0.315 \times 10^{-3}$	$1.193 \times 10^{-5}$	1.96	1.00	$0.702 \times 10^{-3}$
95	84.55	961.5	0.5045	2270	4212	2010	0.677	0.0246	$0.297 \times 10^{-3}$	$1.210 \times 10^{-5}$	1.85	1.00	$0.716 \times 10^{-3}$
100	101.33	957.9	0.5978	2257	4217	2029	0.679	0.0251	$0.282 \times 10^{-3}$	$1.227 \times 10^{-5}$	1.75	1.00	$0.750 \times 10^{-3}$
110	143.27	950.6	0.8263	2230	4229	2071	0.682	0.0262	$0.255 \times 10^{-3}$	$1.261 \times 10^{-5}$	1.58	1.00	$0.798 \times 10^{-3}$
120	198.53	943.4	1.121	2203	4244	2120	0.683	0.0275	$0.232 \times 10^{-3}$	$1.296 \times 10^{-5}$	1.44	1.00	$0.858 \times 10^{-3}$
130	270.1	934.6	1.496	2174	4263	2177	0.684	0.0288	$0.213 \times 10^{-3}$	$1.330 \times 10^{-5}$	1.33	1.01	$0.913 \times 10^{-3}$
140	361.3	921.7	1.965	2145	4286	2244	0.683	0.0301	$0.197 \times 10^{-3}$	$1.365 \times 10^{-5}$	1.24	1.02	$0.970 \times 10^{-3}$
150	475.8	916.6	2.546	2114	4311	2314	0.682	0.0316	$0.183 \times 10^{-3}$	$1.399 \times 10^{-5}$	1.16	1.02	$1.025 \times 10^{-3}$
160	617.8	907.4	3.256	2083	4340	2420	0.680	0.0331	$0.170 \times 10^{-3}$	$1.434 \times 10^{-5}$	1.09	1.05	$1.145 \times 10^{-3}$
170	791.7	897.7	4.119	2050	4370	2490	0.677	0.0347	$0.160 \times 10^{-3}$	$1.468 \times 10^{-5}$	1.03	1.05	$1.178 \times 10^{-3}$
180	1002.1	887.3	5.153	2015	4410	2590	0.673	0.0364	$0.150 \times 10^{-3}$	$1.502 \times 10^{-5}$	0.983	1.07	$1.210 \times 10^{-3}$
190	1254.4	876.4	6.388	1979	4460	2710	0.669	0.0382	$0.142 \times 10^{-3}$	$1.537 \times 10^{-5}$	0.947	1.09	$1.280 \times 10^{-3}$
200	1553.8	864.3	7.852	1941	4500	2840	0.663	0.0401	$0.134 \times 10^{-3}$	$1.571 \times 10^{-5}$	0.910	1.11	$1.350 \times 10^{-3}$
220	2318	840.3	11.60	1859	4610	3110	0.650	0.0442	$0.122 \times 10^{-3}$	$1.641 \times 10^{-5}$	0.865	1.15	$1.520 \times 10^{-3}$
240	3344	813.7	16.73	1767	4760	3520	0.632	0.0487	$0.111 \times 10^{-3}$	$1.712 \times 10^{-5}$	0.836	1.24	$1.720 \times 10^{-3}$
260	4688	783.7	23.69	1663	4970	4070	0.609	0.0540	$0.102 \times 10^{-3}$	$1.788 \times 10^{-5}$	0.832	1.35	$2.000 \times 10^{-3}$
280	6412	750.8	33.15	1544	5280	4835	0.581	0.0605	$0.094 \times 10^{-3}$	$1.870 \times 10^{-5}$	0.854	1.49	$2.380 \times 10^{-3}$
300	8581	713.8	46.15	1405	5750	5980	0.548	0.0695	$0.086 \times 10^{-3}$	$1.965 \times 10^{-5}$	0.902	1.69	$2.950 \times 10^{-3}$
320	11274	667.1	64.57	1239	6540	7900	0.509	0.0836	$0.078 \times 10^{-3}$	$2.084 \times 10^{-5}$	1.00	1.97	
340	14586	610.5	92.62	1028	8240	11870	0.469	0.110	$0.070 \times 10^{-3}$	$2.255 \times 10^{-5}$	1.23	2.43	
360	18651	528.3	144.0	720	14690	25800	0.427	0.178	$0.060 \times 10^{-3}$	$2.571 \times 10^{-5}$	2.06	3.73	
374.14	22090	317.0	317.0	0	-	-	-	-	$0.043 \times 10^{-3}$	$4.313 \times 10^{-5}$			

Nota 1: La viscosità cinematica  $\nu$  e la diffusività termica  $\alpha$  possono essere calcolate dalle loro definizioni,  $\nu = \mu/\rho$  e  $\alpha = k/\rho c_p = \nu/\text{Pr}$ . Le temperature 0.01 °C, 100 °C, e 374.14 °C sono il triplo-, ebollizione-, e punto critico temperatura dell'acqua, rispettivamente. Le proprietà elencate sopra (ad eccezione della densità del vapore) possono essere usate per ogni pressione con trascurabile errore ad eccezione delle temperature vicino al valore del punto critico.

Nota 2: L'unità  $\text{kJ/kg}\cdot^\circ\text{C}$  per il calore specifico è equivalente a  $\text{kJ/kg}\cdot\text{K}$ , e le unità  $\text{W/m}\cdot^\circ\text{C}$  per la conduttività termica è equivalente a  $\text{W/m}\cdot\text{K}$ .

Fonte: La viscosità e il dato della conduttività termica sono ripresi da J.V. Sengers and J.T.R. Watson, *Journal of Physical and Chemical Reference Data* 15 (1986), pp. 1291–1322. Gli altri dati sono derivano da diverse fonti o calcoli.

**TABELLA A.19** Proprietà del refrigerante saturo R-134a

Temp. $T, ^\circ\text{C}$	Satura- zione della pres- sione $p, \text{kPa}$	Densità $\rho, \text{kg/m}^3$		Entalpia di vaporiz- zazione $h_{\text{sat } v \text{ sat}},$ $\text{kJ/kg}$	Calore specifico $c_p, \text{J/kg} \cdot \text{K}$		Conduktività termica $\lambda, \text{W/m} \cdot \text{K}$		Viscosità dinamica $\mu, \text{kg/m} \cdot \text{s}$		Numero di Prandtl Pr		Coefficiente di espans- ione del volume $\beta, 1/\text{K}$	Tensione della super- ficie, $\text{N/m}$
		Liquido	Vapore		Liquido	Vapore	Liquido	Vapore	Liquido	Vapore	Liquido	Vapore		
		-40	51.2	1418	2.773	225.9	1254	748.6	0.1101	0.00811	$4.878 \times 10^{-4}$	$2.550 \times 10^{-6}$	5.558	0.235
-35	66.2	1403	3.524	222.7	1264	764.1	0.1084	0.00862	$4.509 \times 10^{-4}$	$3.003 \times 10^{-6}$	5.257	0.266	0.00209	0.01682
-30	84.4	1389	4.429	219.5	1273	780.2	0.1066	0.00913	$4.178 \times 10^{-4}$	$3.504 \times 10^{-6}$	4.992	0.299	0.00215	0.01604
-25	106.5	1374	5.509	216.3	1283	797.2	0.1047	0.00963	$3.882 \times 10^{-4}$	$4.054 \times 10^{-6}$	4.757	0.335	0.00220	0.01527
-20	132.8	1359	6.787	213.0	1294	814.9	0.1028	0.01013	$3.614 \times 10^{-4}$	$4.651 \times 10^{-6}$	4.548	0.374	0.00227	0.01451
-15	164.0	1343	8.288	209.5	1306	833.5	0.1009	0.01063	$3.371 \times 10^{-4}$	$5.295 \times 10^{-6}$	4.363	0.415	0.00233	0.01376
-10	200.7	1327	10.04	206.0	1318	853.1	0.0989	0.01112	$3.150 \times 10^{-4}$	$5.982 \times 10^{-6}$	4.198	0.459	0.00241	0.01302
-5	243.5	1311	12.07	202.4	1330	873.8	0.0968	0.01161	$2.947 \times 10^{-4}$	$6.709 \times 10^{-6}$	4.051	0.505	0.00249	0.01229
0	293.0	1295	14.42	198.7	1344	895.6	0.0947	0.01210	$2.761 \times 10^{-4}$	$7.471 \times 10^{-6}$	3.919	0.553	0.00258	0.01156
5	349.9	1278	17.12	194.8	1358	918.7	0.0925	0.01259	$2.589 \times 10^{-4}$	$8.264 \times 10^{-6}$	3.802	0.603	0.00269	0.01084
10	414.9	1261	20.22	190.8	1374	943.2	0.0903	0.01308	$2.430 \times 10^{-4}$	$9.081 \times 10^{-6}$	3.697	0.655	0.00280	0.01014
15	488.7	1244	23.75	186.6	1390	969.4	0.0880	0.01357	$2.281 \times 10^{-4}$	$9.915 \times 10^{-6}$	3.604	0.708	0.00293	0.00944
20	572.1	1226	27.77	182.3	1408	997.6	0.0856	0.01406	$2.142 \times 10^{-4}$	$1.075 \times 10^{-5}$	3.521	0.763	0.00307	0.00876
25	665.8	1207	32.34	177.8	1427	1028	0.0833	0.01456	$2.012 \times 10^{-4}$	$1.160 \times 10^{-5}$	3.448	0.819	0.00324	0.00808
30	770.6	1188	37.53	173.1	1448	1061	0.0808	0.01507	$1.888 \times 10^{-4}$	$1.244 \times 10^{-5}$	3.383	0.877	0.00342	0.00742
35	887.5	1168	43.41	168.2	1471	1098	0.0783	0.01558	$1.772 \times 10^{-4}$	$1.327 \times 10^{-5}$	3.328	0.935	0.00364	0.00677
40	1017.1	1147	50.08	163.0	1498	1138	0.0757	0.01610	$1.660 \times 10^{-4}$	$1.408 \times 10^{-5}$	3.285	0.995	0.00390	0.00613
45	1160.5	1125	57.66	157.6	1529	1184	0.0731	0.01664	$1.554 \times 10^{-4}$	$1.486 \times 10^{-5}$	3.253	1.058	0.00420	0.00550
50	1318.6	1102	66.27	151.8	1566	1237	0.0704	0.01720	$1.453 \times 10^{-4}$	$1.562 \times 10^{-5}$	3.231	1.123	0.00455	0.00489
55	1492.3	1078	76.11	145.7	1608	1298	0.0676	0.01777	$1.355 \times 10^{-4}$	$1.634 \times 10^{-5}$	3.223	1.193	0.00500	0.00429
60	1682.8	1053	87.38	139.1	1659	1372	0.0647	0.01838	$1.260 \times 10^{-4}$	$1.704 \times 10^{-5}$	3.229	1.272	0.00554	0.00372
65	1891.0	1026	100.4	132.1	1722	1462	0.0618	0.01902	$1.167 \times 10^{-4}$	$1.771 \times 10^{-5}$	3.255	1.362	0.00624	0.00315
70	2118.2	996.2	115.6	124.4	1801	1577	0.0587	0.01972	$1.077 \times 10^{-4}$	$1.839 \times 10^{-5}$	3.307	1.471	0.00716	0.00261
75	2365.8	964	133.6	115.9	1907	1731	0.0555	0.02048	$9.891 \times 10^{-5}$	$1.908 \times 10^{-5}$	3.400	1.612	0.00843	0.00209
80	2635.2	928.2	155.3	106.4	2056	1948	0.0521	0.02133	$9.011 \times 10^{-5}$	$1.982 \times 10^{-5}$	3.558	1.810	0.01031	0.00160
85	2928.2	887.1	182.3	95.4	2287	2281	0.0484	0.02233	$8.124 \times 10^{-5}$	$2.071 \times 10^{-5}$	3.837	2.116	0.01336	0.00114
90	3246.9	837.7	217.8	82.2	2701	2865	0.0444	0.02357	$7.203 \times 10^{-5}$	$2.187 \times 10^{-5}$	4.385	2.658	0.01911	0.00071
95	3594.1	772.5	269.3	64.9	3675	4144	0.0396	0.02544	$6.190 \times 10^{-5}$	$2.370 \times 10^{-5}$	5.746	3.862	0.03343	0.00033
100	3975.1	651.7	376.3	33.9	7959	8785	0.0322	0.02989	$4.765 \times 10^{-5}$	$2.833 \times 10^{-5}$	11.77	8.326	0.10047	0.00004

Nota 1: La viscosità cinematica  $\nu$  e la diffusività termica  $\alpha$  possono essere calcolate dalle loro definizioni,  $\nu = \mu/\rho$  e  $\alpha = k/\rho c_p = \nu/\text{Pr}$ . Le proprietà elencate qui (ad eccezione della densità del vapore) possono essere usate per tutte le pressioni con trascurabile errore ad eccezione della temperatura vicina al valore del punto critico.

Nota 2: L'unità  $\text{kJ/kg} \cdot ^\circ\text{C}$  per il calore specifico è equivalente a  $\text{kJ/kg} \cdot \text{K}$  e all'unità  $\text{W/m} \cdot ^\circ\text{C}$  per la conduttività termica è equivalente a  $\text{W/m} \cdot \text{K}$ .

Fonte: Dati generati dal software EES sviluppato da S.A. Klein e F.L. Alvarado. Fonte originale: R. Tillner-Roth e H.D. Baehr, "An International Standard Formulation for the Thermodynamic Properties of 1,1,1,2-Tetrafluoroethane (HFC-134a) for temperatures from 170 K to 455 K and Pressures up to 70 MPa," *J. Phys. Chem. Ref. Data*, Vol. 23, No. 5, 1994; M. J. Assael, N.K. Dalaouti, A.A. Griva, and J.H. Dymond, "Viscosity and Thermal Conductivity of Halogenated Methane and Ethane Refrigerants," *IJR*, Vol. 22, pp. 525-535, 1999; NIST REFPROP 6 program (M.O. McLinden, S.A. Klein, E.W. Lemmon, and A.P. Peskin, Physical and Chemical Properties Division National Institute of Standards and Technology, Boulder, CO 80303, 1995).

TABELLA A.20 Proprietà dell'ammoniaca satura

Temp. $T, ^\circ\text{C}$	Satura- zione della pres- sione $p, \text{kPa}$	Densità $\rho, \text{kg/m}^3$		Entalpia di vaporiz- zazione $h_{1 \text{ sat } v \text{ sat}},$ kJ/kg	Calore specifico $c_p, \text{J/kg} \cdot \text{K}$		Conduktività termica $\lambda, \text{W/m} \cdot \text{K}$		Viscosità dinamica $\mu, \text{kg/m} \cdot \text{s}$		Numero di Prandtl Pr		Coefficient e di espan- sione del volume $\beta, 1/\text{K}$	Tensione della super- ficie, N/m
		Liquido	Vapore		Liquido	Vapore	Liquido	Vapore	Liquido	Vapore	Liquido	Vapore		
-40	71.66	690.2	0.6435	1389	4414	2242	-	0.01792	$2.926 \times 10^{-4}$	$7.957 \times 10^{-6}$	-	0.9955	0.00176	0.03565
-30	119.4	677.8	1.037	1360	4465	2322	-	0.01898	$2.630 \times 10^{-4}$	$8.311 \times 10^{-6}$	-	1.017	0.00185	0.03341
-25	151.5	671.5	1.296	1345	4489	2369	0.5968	0.01957	$2.492 \times 10^{-4}$	$8.490 \times 10^{-6}$	1.875	1.028	0.00190	0.03229
-20	190.1	665.1	1.603	1329	4514	2420	0.5853	0.02015	$2.361 \times 10^{-4}$	$8.669 \times 10^{-6}$	1.821	1.041	0.00194	0.03118
-15	236.2	658.6	1.966	1313	4538	2476	0.5737	0.02075	$2.236 \times 10^{-4}$	$8.851 \times 10^{-6}$	1.769	1.056	0.00199	0.03007
-10	290.8	652.1	2.391	1297	4564	2536	0.5621	0.02138	$2.117 \times 10^{-4}$	$9.034 \times 10^{-6}$	1.718	1.072	0.00205	0.02896
-5	354.9	645.4	2.886	1280	4589	2601	0.5505	0.02203	$2.003 \times 10^{-4}$	$9.218 \times 10^{-6}$	1.670	1.089	0.00210	0.02786
0	429.6	638.6	3.458	1262	4617	2672	0.5390	0.02270	$1.896 \times 10^{-4}$	$9.405 \times 10^{-6}$	1.624	1.107	0.00216	0.02676
5	516	631.7	4.116	1244	4645	2749	0.5274	0.02341	$1.794 \times 10^{-4}$	$9.593 \times 10^{-6}$	1.580	1.126	0.00223	0.02566
10	615.3	624.6	4.870	1226	4676	2831	0.5158	0.02415	$1.697 \times 10^{-4}$	$9.784 \times 10^{-6}$	1.539	1.147	0.00230	0.02457
15	728.8	617.5	5.729	1206	4709	2920	0.5042	0.02492	$1.606 \times 10^{-4}$	$9.978 \times 10^{-6}$	1.500	1.169	0.00237	0.02348
20	857.8	610.2	6.705	1186	4745	3016	0.4927	0.02573	$1.519 \times 10^{-4}$	$1.017 \times 10^{-5}$	1.463	1.193	0.00245	0.02240
25	1003	602.8	7.809	1166	4784	3120	0.4811	0.02658	$1.438 \times 10^{-4}$	$1.037 \times 10^{-5}$	1.430	1.218	0.00254	0.02132
30	1167	595.2	9.055	1144	4828	3232	0.4695	0.02748	$1.361 \times 10^{-4}$	$1.057 \times 10^{-5}$	1.399	1.244	0.00264	0.02024
35	1351	587.4	10.46	1122	4877	3354	0.4579	0.02843	$1.288 \times 10^{-4}$	$1.078 \times 10^{-5}$	1.372	1.272	0.00275	0.01917
40	1555	579.4	12.03	1099	4932	3486	0.4464	0.02943	$1.219 \times 10^{-4}$	$1.099 \times 10^{-5}$	1.347	1.303	0.00287	0.01810
45	1782	571.3	13.8	1075	4993	3631	0.4348	0.03049	$1.155 \times 10^{-4}$	$1.121 \times 10^{-5}$	1.327	1.335	0.00301	0.01704
50	2033	562.9	15.78	1051	5063	3790	0.4232	0.03162	$1.094 \times 10^{-4}$	$1.143 \times 10^{-5}$	1.310	1.371	0.00316	0.01598
55	2310	554.2	18.00	1025	5143	3967	0.4116	0.03283	$1.037 \times 10^{-4}$	$1.166 \times 10^{-5}$	1.297	1.409	0.00334	0.01493
60	2614	545.2	20.48	997.4	5234	4163	0.4001	0.03412	$9.846 \times 10^{-5}$	$1.189 \times 10^{-5}$	1.288	1.452	0.00354	0.01389
65	2948	536.0	23.26	968.9	5340	4384	0.3885	0.03550	$9.347 \times 10^{-5}$	$1.213 \times 10^{-5}$	1.285	1.499	0.00377	0.01285
70	3312	526.3	26.39	939.0	5463	4634	0.3769	0.03700	$8.879 \times 10^{-5}$	$1.238 \times 10^{-5}$	1.287	1.551	0.00404	0.01181
75	3709	516.2	29.90	907.5	5608	4923	0.3653	0.03862	$8.440 \times 10^{-5}$	$1.264 \times 10^{-5}$	1.296	1.612	0.00436	0.01079
80	4141	505.7	33.87	874.1	5780	5260	0.3538	0.04038	$8.030 \times 10^{-5}$	$1.292 \times 10^{-5}$	1.312	1.683	0.00474	0.00977
85	4609	494.5	38.36	838.6	5988	5659	0.3422	0.04232	$7.646 \times 10^{-5}$	$1.322 \times 10^{-5}$	1.338	1.768	0.00521	0.00876
90	5116	482.8	43.48	800.6	6242	6142	0.3306	0.04447	$7.284 \times 10^{-5}$	$1.354 \times 10^{-5}$	1.375	1.871	0.00579	0.00776
95	5665	470.2	49.35	759.8	6561	6740	0.3190	0.04687	$6.946 \times 10^{-5}$	$1.389 \times 10^{-5}$	1.429	1.999	0.00652	0.00677
100	6257	456.6	56.15	715.5	6972	7503	0.3075	0.04958	$6.628 \times 10^{-5}$	$1.429 \times 10^{-5}$	1.503	2.163	0.00749	0.00579

Nota 1: La viscosità cinematica  $\nu$  e la diffusività termica  $\alpha$  possono essere calcolate dalle loro definizioni,  $\nu = \mu/\rho$  e  $\alpha = k/\rho c_p = \nu/\text{Pr}$ . Le proprietà elencate qui (ad eccezione della densità del vapore) possono essere usate per tutte le pressioni con trascurabile errore ad eccezione della temperatura vicina al valore del punto critico.

Nota 2: L'unità kJ/kg·°C per il calore specifico è equivalente a kJ/kg·K e all'unità W/m·°C per la conduttività termica è equivalente a W/m·K.

Fonte: Dati generati dal software EES sviluppato da S.A. Klein e F.L. Alvarado. Fonte originale: Tillner-Roth, Harms-Watzenberg, and Baehr, "Eine neue Fundamentalgleichung für Ammoniak," DKV-Tagungsbericht 20:167-181, 1993; Liley and Desai, "Thermophysical Properties of Refrigerants," ASHRAE, 1993, ISBN 1-1883413-10-9.

**TABELLA A.21** Proprietà del propano saturo

Temp. $T, ^\circ\text{C}$	Satura- zione della pres- sione $p, \text{kPa}$	Densità $\rho, \text{kg/m}^3$		Entalpia di vaporiz- zazione $h_{\text{sat v sat}},$ kJ/kg	Calore specifico $c_p, \text{J/kg} \cdot \text{K}$		Conduttività termica $\lambda, \text{W/m} \cdot \text{K}$		Viscosità dinamica $\mu, \text{kg/m} \cdot \text{s}$		Numero di Prandtl Pr		Coefficiente di espan- sione del volume $\beta, 1/\text{K}$	Tensione della super- ficie, N/m
		Liquido	Vapore		Liquido	Vapore	Liquido	Vapore	Liquido	Vapore	Liquido	Vapore		
-120	0.4053	664.7	0.01408	498.3	2003	1115	0.1802	0.00589	$6.136 \times 10^{-4}$	$4.372 \times 10^{-6}$	6.820	0.827	0.00153	0.02630
-110	1.157	654.5	0.03776	489.3	2021	1148	0.1738	0.00645	$5.054 \times 10^{-4}$	$4.625 \times 10^{-6}$	5.878	0.822	0.00157	0.02486
-100	2.881	644.2	0.08872	480.4	2044	1183	0.1672	0.00705	$4.252 \times 10^{-4}$	$4.881 \times 10^{-6}$	5.195	0.819	0.00161	0.02344
-90	6.406	633.8	0.1870	471.5	2070	1221	0.1606	0.00769	$3.635 \times 10^{-4}$	$5.143 \times 10^{-6}$	4.686	0.817	0.00166	0.02202
-80	12.97	623.2	0.3602	462.4	2100	1263	0.1539	0.00836	$3.149 \times 10^{-4}$	$5.409 \times 10^{-6}$	4.297	0.817	0.00171	0.02062
-70	24.26	612.5	0.6439	453.1	2134	1308	0.1472	0.00908	$2.755 \times 10^{-4}$	$5.680 \times 10^{-6}$	3.994	0.818	0.00177	0.01923
-60	42.46	601.5	1.081	443.5	2173	1358	0.1407	0.00985	$2.430 \times 10^{-4}$	$5.956 \times 10^{-6}$	3.755	0.821	0.00184	0.01785
-50	70.24	590.3	1.724	433.6	2217	1412	0.1343	0.01067	$2.158 \times 10^{-4}$	$6.239 \times 10^{-6}$	3.563	0.825	0.00192	0.01649
-40	110.7	578.8	2.629	423.1	2258	1471	0.1281	0.01155	$1.926 \times 10^{-4}$	$6.529 \times 10^{-6}$	3.395	0.831	0.00201	0.01515
-30	167.3	567.0	3.864	412.1	2310	1535	0.1221	0.01250	$1.726 \times 10^{-4}$	$6.827 \times 10^{-6}$	3.266	0.839	0.00213	0.01382
-20	243.8	554.7	5.503	400.3	2368	1605	0.1163	0.01351	$1.551 \times 10^{-4}$	$7.136 \times 10^{-6}$	3.158	0.848	0.00226	0.01251
-10	344.4	542.0	7.635	387.8	2433	1682	0.1107	0.01459	$1.397 \times 10^{-4}$	$7.457 \times 10^{-6}$	3.069	0.860	0.00242	0.01122
0	473.3	528.7	10.36	374.2	2507	1768	0.1054	0.01576	$1.259 \times 10^{-4}$	$7.794 \times 10^{-6}$	2.996	0.875	0.00262	0.00996
5	549.8	521.8	11.99	367.0	2547	1814	0.1028	0.01637	$1.195 \times 10^{-4}$	$7.970 \times 10^{-6}$	2.964	0.883	0.00273	0.00934
10	635.1	514.7	13.81	359.5	2590	1864	0.1002	0.01701	$1.135 \times 10^{-4}$	$8.151 \times 10^{-6}$	2.935	0.893	0.00286	0.00872
15	729.8	507.5	15.85	351.7	2637	1917	0.0977	0.01767	$1.077 \times 10^{-4}$	$8.339 \times 10^{-6}$	2.909	0.905	0.00301	0.00811
20	834.4	500.0	18.13	343.4	2688	1974	0.0952	0.01836	$1.022 \times 10^{-4}$	$8.534 \times 10^{-6}$	2.886	0.918	0.00318	0.00751
25	949.7	492.2	20.68	334.8	2742	2036	0.0928	0.01908	$9.702 \times 10^{-5}$	$8.738 \times 10^{-6}$	2.866	0.933	0.00337	0.00691
30	1076	484.2	23.53	325.8	2802	2104	0.0904	0.01982	$9.197 \times 10^{-5}$	$8.952 \times 10^{-6}$	2.850	0.950	0.00358	0.00633
35	1215	475.8	26.72	316.2	2869	2179	0.0881	0.02061	$8.710 \times 10^{-5}$	$9.178 \times 10^{-6}$	2.837	0.971	0.00384	0.00575
40	1366	467.1	30.29	306.1	2943	2264	0.0857	0.02142	$8.240 \times 10^{-5}$	$9.417 \times 10^{-6}$	2.828	0.995	0.00413	0.00518
45	1530	458.0	34.29	295.3	3026	2361	0.0834	0.02228	$7.785 \times 10^{-5}$	$9.674 \times 10^{-6}$	2.824	1.025	0.00448	0.00463
50	1708	448.5	38.79	283.9	3122	2473	0.0811	0.02319	$7.343 \times 10^{-5}$	$9.950 \times 10^{-6}$	2.826	1.061	0.00491	0.00408
60	2110	427.5	49.66	258.4	3283	2769	0.0765	0.02517	$6.487 \times 10^{-5}$	$1.058 \times 10^{-5}$	2.784	1.164	0.00609	0.00303
70	2580	403.2	64.02	228.0	3595	3241	0.0717	0.02746	$5.649 \times 10^{-5}$	$1.138 \times 10^{-5}$	2.834	1.343	0.00811	0.00204
80	3127	373.0	84.28	189.7	4501	4173	0.0663	0.03029	$4.790 \times 10^{-5}$	$1.249 \times 10^{-5}$	3.251	1.722	0.01248	0.00114
90	3769	329.1	118.6	133.2	6977	7239	0.0595	0.03441	$3.807 \times 10^{-5}$	$1.448 \times 10^{-5}$	4.465	3.047	0.02847	0.00037

Nota 1: La viscosità cinematica  $\nu$  e la diffusività termica  $\alpha$  possono essere calcolate dalle loro definizioni,  $\nu = \mu/\rho$  e  $\alpha = k/\mu c_p = \nu/\text{Pr}$ . Le proprietà elencate qui (ad eccezione della densità del vapore) possono essere usate per tutte le pressioni con trascurabile errore ad eccezione della temperatura vicina al valore del punto critico.

Nota 2: L'unità kJ/kg·°C per il calore specifico è equivalente a kJ/kg·K e all'unità W/m·°C per la conduttività termica è equivalente a W/m·K.

Fonte: Dati generati dal software EES sviluppato da S.A. Klein e F.L. Alvarado. Fonte originale: Reiner Tillner-Roth, "Fundamental Equations of State," Shaker, Verlag, Aachen, 1998; B.A. Younglove and J.F. Ely, "Thermophysical Properties of Fluids. II Methane, Ethane, Propane, Isobutane, and Normal Butane," *J. Phys. Chem. Ref. Data*, Vol. 16, No. 4, 1987; G.R. Somayajulu, "A Generalized Equation for Surface Tension from the Triple-Point to the Critical-Point," *International Journal of Thermophysics*, Vol. 9, No. 4, 1988.

TABELLA A.22 Proprietà di alcuni liquidi

Temperatura $T$ °C	Densità $\rho$ kg/m <sup>3</sup>	Calore specifico $c_p$ J/kg · °C	Conduttività termica $\lambda$ W/m · °C	Diffusività termica $\alpha$ m <sup>2</sup> /s	Viscosità dinamica $\mu$ kg/m · s	Viscosità cinematica $\nu$ m <sup>2</sup> /s	Numero di Prandtl Pr
<b>Ammoniaca</b>							
-40	692	4467	0.546	$1.78 \times 10^{-7}$	$2.81 \times 10^{-4}$	$4.06 \times 10^{-7}$	2.28
-20	667	4509	0.546	$1.82 \times 10^{-7}$	$2.54 \times 10^{-4}$	$3.81 \times 10^{-7}$	2.09
0	640	4635	0.540	$1.82 \times 10^{-7}$	$2.39 \times 10^{-4}$	$3.73 \times 10^{-7}$	2.05
20	612	4798	0.521	$1.78 \times 10^{-7}$	$2.20 \times 10^{-4}$	$3.59 \times 10^{-7}$	2.02
40	581	4999	0.493	$1.70 \times 10^{-7}$	$1.98 \times 10^{-4}$	$3.40 \times 10^{-7}$	2.00
<b>Alcol etilico (C<sub>2</sub>H<sub>6</sub>O)</b>							
-40	823	2037	0.186	$1.11 \times 10^{-7}$	$4.81 \times 10^{-3}$	$5.84 \times 10^{-6}$	52.7
-20	815	2124	0.179	$1.03 \times 10^{-7}$	$2.83 \times 10^{-3}$	$3.47 \times 10^{-6}$	33.6
0	806	2249	0.174	$0.960 \times 10^{-7}$	$1.77 \times 10^{-3}$	$2.20 \times 10^{-6}$	22.9
20	789	2395	0.168	$0.889 \times 10^{-7}$	$1.20 \times 10^{-3}$	$1.52 \times 10^{-6}$	17.0
40	772	2572	0.162	$0.816 \times 10^{-7}$	$0.834 \times 10^{-3}$	$1.08 \times 10^{-6}$	13.2
60	755	2731	0.156	$0.743 \times 10^{-7}$	$0.592 \times 10^{-3}$	$0.784 \times 10^{-6}$	10.6
80	738	3026	0.150	$0.672 \times 10^{-7}$	$0.430 \times 10^{-3}$	$0.583 \times 10^{-6}$	8.7
<b>Glicole etilenico (C<sub>2</sub>H<sub>6</sub>O<sub>2</sub>)</b>							
0	1131	2295	0.254	$9.79 \times 10^{-8}$	$65.1 \times 10^{-3}$	$57.5 \times 10^{-6}$	588
20	1117	2386	0.257	$9.64 \times 10^{-8}$	$21.4 \times 10^{-3}$	$19.2 \times 10^{-6}$	199
40	1101	2476	0.259	$9.50 \times 10^{-8}$	$9.57 \times 10^{-3}$	$8.69 \times 10^{-6}$	91
60	1088	2565	0.262	$9.39 \times 10^{-8}$	$5.17 \times 10^{-3}$	$4.75 \times 10^{-6}$	51
80	1078	2656	0.265	$9.26 \times 10^{-8}$	$3.21 \times 10^{-3}$	$2.98 \times 10^{-6}$	32
100	1059	2750	0.267	$9.17 \times 10^{-8}$	$2.15 \times 10^{-3}$	$2.03 \times 10^{-6}$	22
<b>Refrigerante Freon-12 (CCl<sub>2</sub>F<sub>2</sub>)</b>							
-40	1515	885	0.069	$5.14 \times 10^{-8}$	$4.24 \times 10^{-4}$	$2.80 \times 10^{-7}$	5.4
-20	1457	907	0.071	$5.38 \times 10^{-8}$	$3.43 \times 10^{-4}$	$2.35 \times 10^{-7}$	4.4
0	1393	935	0.073	$5.59 \times 10^{-8}$	$2.98 \times 10^{-4}$	$2.14 \times 10^{-7}$	3.8
20	1327	966	0.073	$5.66 \times 10^{-8}$	$2.62 \times 10^{-4}$	$1.97 \times 10^{-7}$	3.5
40	1254	1002	0.069	$5.46 \times 10^{-8}$	$2.40 \times 10^{-4}$	$1.91 \times 10^{-7}$	3.5
<b>Glicerina</b>							
-20	1288	2143	0.282	$1.02 \times 10^{-7}$	134	$104 \times 10^{-3}$	1.020
0	1276	2261	0.284	$0.98 \times 10^{-7}$	12.1	$9.5 \times 10^{-3}$	0.096
20	1264	2386	0.287	$0.95 \times 10^{-7}$	1.49	$1.2 \times 10^{-3}$	0.0124
40	1252	2513	0.290	$0.92 \times 10^{-7}$	0.27	$0.2 \times 10^{-3}$	0.0023
<b>Olio lubrificante non usato</b>							
0	899	1796	0.147	$9.11 \times 10^{-8}$	$3850 \times 10^{-3}$	$4280 \times 10^{-6}$	47100
20	888	1880	0.145	$8.72 \times 10^{-8}$	$800 \times 10^{-3}$	$901 \times 10^{-6}$	10400
40	876	1964	0.144	$8.34 \times 10^{-8}$	$212 \times 10^{-3}$	$242 \times 10^{-6}$	2870
60	864	2047	0.140	$8.00 \times 10^{-8}$	$72.5 \times 10^{-3}$	$83.9 \times 10^{-6}$	1050
80	852	2131	0.138	$7.69 \times 10^{-8}$	$32.0 \times 10^{-3}$	$37.5 \times 10^{-6}$	490
100	840	2219	0.137	$7.38 \times 10^{-8}$	$17.1 \times 10^{-3}$	$20.3 \times 10^{-6}$	276
120	829	2307	0.135	$7.10 \times 10^{-8}$	$10.2 \times 10^{-3}$	$12.4 \times 10^{-6}$	175
140	817	2395	0.133	$6.86 \times 10^{-8}$	$6.53 \times 10^{-3}$	$8.0 \times 10^{-6}$	116
160	806	2483	0.132	$6.63 \times 10^{-8}$	$4.49 \times 10^{-3}$	$5.6 \times 10^{-6}$	84
<b>Acqua (T in K)</b>							
273.2	000	4205	0.564	$1.34 \times 10^{-7}$	$1.79 \times 10^{-3}$	$1.79 \times 10^{-6}$	13.4
280	000	4197	0.582	$1.39 \times 10^{-7}$	$1.44 \times 10^{-3}$	$1.44 \times 10^{-6}$	10.4
300	997	4177	0.608	$1.46 \times 10^{-7}$	$0.857 \times 10^{-3}$	$0.86 \times 10^{-6}$	5.88
320	989	4176	0.637	$1.54 \times 10^{-7}$	$0.579 \times 10^{-3}$	$0.59 \times 10^{-6}$	3.79
340	980	4187	0.659	$1.61 \times 10^{-7}$	$0.423 \times 10^{-3}$	$0.43 \times 10^{-6}$	2.69
360	967	4204	0.674	$1.66 \times 10^{-7}$	$0.320 \times 10^{-3}$	$0.33 \times 10^{-6}$	2.00
373.2	958	4220	0.681	$1.68 \times 10^{-7}$	$0.282 \times 10^{-3}$	$0.29 \times 10^{-6}$	1.75
400	937	4241	0.686	$1.73 \times 10^{-7}$	$0.219 \times 10^{-3}$	$0.23 \times 10^{-6}$	1.35
450	890	4419	0.673	$1.71 \times 10^{-7}$	$0.153 \times 10^{-3}$	$0.17 \times 10^{-6}$	1.01
500	832	4647	0.635	$1.64 \times 10^{-7}$	$0.118 \times 10^{-3}$	$0.14 \times 10^{-6}$	0.86
550	756	5272	0.571	$1.43 \times 10^{-7}$	$0.095 \times 10^{-3}$	$0.13 \times 10^{-6}$	0.88
600	650	6691	0.481	$1.11 \times 10^{-7}$	$0.076 \times 10^{-3}$	$0.12 \times 10^{-6}$	1.05
647.3*	315	—	—	—	—	—	—



**TABELLA A.23** Proprietà di alcuni metalli liquidi

Temp. $T$ , °C	Densità $\rho$ , kg/m <sup>3</sup>	Calore specifico $c_p$ , J/kg·K	Conduttività termica $\lambda$ , W/m·K	Diffusività termica $\alpha$ , m <sup>2</sup> /s	Viscosità dinamica $\mu$ , kg/m·s	Viscosità cinematica $\nu$ , m <sup>2</sup> /s	Numero di Prandtl Pr	Coefficiente di espansione del volume $\beta$ , 1/K
<b>Mercurio (Hg) Punto di fusione: -39 °C</b>								
0	13595	140.4	8.18200	$4.287 \times 10^{-6}$	$1.687 \times 10^{-3}$	$1.241 \times 10^{-7}$	0.0289	$1.810 \times 10^{-4}$
25	13534	139.4	8.51533	$4.514 \times 10^{-6}$	$1.534 \times 10^{-3}$	$1.133 \times 10^{-7}$	0.0251	$1.810 \times 10^{-4}$
50	13473	138.6	8.83632	$4.734 \times 10^{-6}$	$1.423 \times 10^{-3}$	$1.056 \times 10^{-7}$	0.0223	$1.810 \times 10^{-4}$
75	13412	137.8	9.15632	$4.956 \times 10^{-6}$	$1.316 \times 10^{-3}$	$9.819 \times 10^{-8}$	0.0198	$1.810 \times 10^{-4}$
100	13351	137.1	9.46706	$5.170 \times 10^{-6}$	$1.245 \times 10^{-3}$	$9.326 \times 10^{-8}$	0.0180	$1.810 \times 10^{-4}$
150	13231	136.1	10.07780	$5.595 \times 10^{-6}$	$1.126 \times 10^{-3}$	$8.514 \times 10^{-8}$	0.0152	$1.810 \times 10^{-4}$
200	13112	135.5	10.65465	$5.996 \times 10^{-6}$	$1.043 \times 10^{-3}$	$7.959 \times 10^{-8}$	0.0133	$1.815 \times 10^{-4}$
250	12993	135.3	11.18150	$6.363 \times 10^{-6}$	$9.820 \times 10^{-4}$	$7.558 \times 10^{-8}$	0.0119	$1.829 \times 10^{-4}$
300	12873	135.3	11.68150	$6.705 \times 10^{-6}$	$9.336 \times 10^{-4}$	$7.252 \times 10^{-8}$	0.0108	$1.854 \times 10^{-4}$
<b>Bismuto (Bi) Punto di fusione: 271 °C</b>								
350	9969	146.0	16.28	$1.118 \times 10^{-5}$	$1.540 \times 10^{-3}$	$1.545 \times 10^{-7}$	0.01381	
400	9908	148.2	16.10	$1.096 \times 10^{-5}$	$1.422 \times 10^{-3}$	$1.436 \times 10^{-7}$	0.01310	
500	9785	152.8	15.74	$1.052 \times 10^{-5}$	$1.188 \times 10^{-3}$	$1.215 \times 10^{-7}$	0.01154	
600	9663	157.3	15.60	$1.026 \times 10^{-5}$	$1.013 \times 10^{-3}$	$1.048 \times 10^{-7}$	0.01022	
700	9540	161.8	15.60	$1.010 \times 10^{-5}$	$8.736 \times 10^{-4}$	$9.157 \times 10^{-8}$	0.00906	
<b>Piombo (Pb) Punto di fusione: 327 °C</b>								
400	10506	158	15.97	$9.623 \times 10^{-6}$	$2.277 \times 10^{-3}$	$2.167 \times 10^{-7}$	0.02252	
450	10449	156	15.74	$9.649 \times 10^{-6}$	$2.065 \times 10^{-3}$	$1.976 \times 10^{-7}$	0.02048	
500	10390	155	15.54	$9.651 \times 10^{-6}$	$1.884 \times 10^{-3}$	$1.814 \times 10^{-7}$	0.01879	
550	10329	155	15.39	$9.610 \times 10^{-6}$	$1.758 \times 10^{-3}$	$1.702 \times 10^{-7}$	0.01771	
600	10267	155	15.23	$9.568 \times 10^{-6}$	$1.632 \times 10^{-3}$	$1.589 \times 10^{-7}$	0.01661	
650	10206	155	15.07	$9.526 \times 10^{-6}$	$1.505 \times 10^{-3}$	$1.475 \times 10^{-7}$	0.01549	
700	10145	155	14.91	$9.483 \times 10^{-6}$	$1.379 \times 10^{-3}$	$1.360 \times 10^{-7}$	0.01434	
<b>Sodio (Na) Punto di fusione: 98 °C</b>								
100	927.3	1378	85.84	$6.718 \times 10^{-5}$	$6.892 \times 10^{-4}$	$7.432 \times 10^{-7}$	0.01106	
200	902.5	1349	80.84	$6.639 \times 10^{-5}$	$5.385 \times 10^{-4}$	$5.967 \times 10^{-7}$	0.008987	
300	877.8	1320	75.84	$6.544 \times 10^{-5}$	$3.878 \times 10^{-4}$	$4.418 \times 10^{-7}$	0.006751	
400	853.0	1296	71.20	$6.437 \times 10^{-5}$	$2.720 \times 10^{-4}$	$3.188 \times 10^{-7}$	0.004953	
500	828.5	1284	67.41	$6.335 \times 10^{-5}$	$2.411 \times 10^{-4}$	$2.909 \times 10^{-7}$	0.004593	
600	804.0	1272	63.63	$6.220 \times 10^{-5}$	$2.101 \times 10^{-4}$	$2.614 \times 10^{-7}$	0.004202	
<b>Potassio (K) Punto di fusione: 64 °C</b>								
200	795.2	790.8	43.99	$6.995 \times 10^{-5}$	$3.350 \times 10^{-4}$	$4.213 \times 10^{-7}$	0.006023	
300	771.6	772.8	42.01	$7.045 \times 10^{-5}$	$2.667 \times 10^{-4}$	$3.456 \times 10^{-7}$	0.004906	
400	748.0	754.8	40.03	$7.090 \times 10^{-5}$	$1.984 \times 10^{-4}$	$2.652 \times 10^{-7}$	0.00374	
500	723.9	750.0	37.81	$6.964 \times 10^{-5}$	$1.668 \times 10^{-4}$	$2.304 \times 10^{-7}$	0.003309	
600	699.6	750.0	35.50	$6.765 \times 10^{-5}$	$1.487 \times 10^{-4}$	$2.126 \times 10^{-7}$	0.003143	

(Segue)

**TABELLA A.23** Proprietà di alcuni materiali liquidi (*Continua*)

Temp. $T, ^\circ\text{C}$	Densità $\rho, \text{kg/m}^3$	Calore specifico $c_p, \text{J/kg}\cdot\text{K}$	Conduttività termica $\lambda, \text{W/m}\cdot\text{K}$	Diffusività termica $\alpha, \text{m}^2/\text{s}$	Viscosità dinamica $\mu, \text{kg/m}\cdot\text{s}$	Viscosità cinematica $\nu, \text{m}^2/\text{s}$	Numero di Prandtl Pr	Coefficiente di espansione del volume $\beta, 1/\text{K}$
<b>Sodio-Potassio (%22Na-%78K) Punto di fusione: <math>-11^\circ\text{C}</math></b>								
100	847.3	944.4	25.64	$3.205 \times 10^{-5}$	$5.707 \times 10^{-4}$	$6.736 \times 10^{-7}$	0.02102	
200	823.2	922.5	26.27	$3.459 \times 10^{-5}$	$4.587 \times 10^{-4}$	$5.572 \times 10^{-7}$	0.01611	
300	799.1	900.6	26.89	$3.736 \times 10^{-5}$	$3.467 \times 10^{-4}$	$4.339 \times 10^{-7}$	0.01161	
400	775.0	879.0	27.50	$4.037 \times 10^{-5}$	$2.357 \times 10^{-4}$	$3.041 \times 10^{-7}$	0.00753	
500	751.5	880.1	27.89	$4.217 \times 10^{-5}$	$2.108 \times 10^{-4}$	$2.805 \times 10^{-7}$	0.00665	
600	728.0	881.2	28.28	$4.408 \times 10^{-5}$	$1.859 \times 10^{-4}$	$2.553 \times 10^{-7}$	0.00579	

Fonte: Dati generati dal software EES sviluppato da S.A. Klein e F.L. Alvarado.

**TABELLA A.24** Proprietà dell'aria come gas ideale

$T$ K	$h$ kJ/kg	$p_r$	$u$ kJ/kg	$v_r$	$s^\circ$ kJ/kg · K	$T$ K	$h$ kJ/kg	$p_r$	$u$ kJ/kg	$v_r$	$s^\circ$ kJ/kg · K
200	199.97	0.3363	142.56	1707.0	1.29559	580	586.04	14.38	419.55	115.7	2.37348
210	209.97	0.3987	149.69	1512.0	1.34444	590	596.52	15.31	427.15	110.6	2.39140
220	219.97	0.4690	156.82	1346.0	1.39105	600	607.02	16.28	434.78	105.8	2.40902
230	230.02	0.5477	164.00	1205.0	1.43557	610	617.53	17.30	442.42	101.2	2.42644
240	240.02	0.6355	171.13	1084.0	1.47824	620	628.07	18.36	450.09	96.92	2.44356
250	250.05	0.7329	178.28	979.0	1.51917	630	638.63	19.84	457.78	92.84	2.46048
260	260.09	0.8405	185.45	887.8	1.55848	640	649.22	20.64	465.50	88.99	2.47716
270	270.11	0.9590	192.60	808.0	1.59634	650	659.84	21.86	473.25	85.34	2.49364
280	280.13	1.0889	199.75	738.0	1.63279	660	670.47	23.13	481.01	81.89	2.50985
285	285.14	1.1584	203.33	706.1	1.65055	670	681.14	24.46	488.81	78.61	2.52589
290	290.16	1.2311	206.91	676.1	1.66802	680	691.82	25.85	496.62	75.50	2.54175
295	295.17	1.3068	210.49	647.9	1.68515	690	702.52	27.29	504.45	72.56	2.55731
298	298.18	1.3543	212.64	631.9	1.69528	700	713.27	28.80	512.33	69.76	2.57277
300	300.19	1.3860	214.07	621.2	1.70203	710	724.04	30.38	520.23	67.07	2.58810
305	305.22	1.4686	217.67	596.0	1.71865	720	734.82	32.02	528.14	64.53	2.60319
310	310.24	1.5546	221.25	572.3	1.73498	730	745.62	33.72	536.07	62.13	2.61803
315	315.27	1.6442	224.85	549.8	1.75106	740	756.44	35.50	544.02	59.82	2.63280
320	320.29	1.7375	228.42	528.6	1.76690	750	767.29	37.35	551.99	57.63	2.64737
325	325.31	1.8345	232.02	508.4	1.78249	760	778.18	39.27	560.01	55.54	2.66176
330	330.34	1.9352	235.61	489.4	1.79783	780	800.03	43.35	576.12	51.64	2.69013
340	340.42	2.149	242.82	454.1	1.82790	800	821.95	47.75	592.30	48.08	2.71787
350	350.49	2.379	250.02	422.2	1.85708	820	843.98	52.59	608.59	44.84	2.74504
360	360.58	2.626	257.24	393.4	1.88543	840	866.08	57.60	624.95	41.85	2.77170
370	370.67	2.892	264.46	367.2	1.91313	860	888.27	63.09	641.40	39.12	2.79783
380	380.77	3.176	271.69	343.4	1.94001	880	910.56	68.98	657.95	36.61	2.82344
390	390.88	3.481	278.93	321.5	1.96633	900	932.93	75.29	674.58	34.31	2.84856
400	400.98	3.806	286.16	301.6	1.99194	920	955.38	82.05	691.28	32.18	2.87324
410	411.12	4.153	293.43	283.3	2.01699	940	977.92	89.28	708.08	30.22	2.89748
420	421.26	4.522	300.69	266.6	2.04142	960	1000.55	97.00	725.02	28.40	2.92128
430	431.43	4.915	307.99	251.1	2.06533	980	1023.25	105.2	741.98	26.73	2.94468
440	441.61	5.332	315.30	236.8	2.08870	1000	1046.04	114.0	758.94	25.17	2.96770
450	451.80	5.775	322.62	223.6	2.11161	1020	1068.89	123.4	776.10	23.72	2.99034
460	462.02	6.245	329.97	211.4	2.13407	1040	1091.85	133.3	793.36	23.29	3.01260
470	472.24	6.742	337.32	200.1	2.15604	1060	1114.86	143.9	810.62	21.14	3.03449
480	482.49	7.268	344.70	189.5	2.17760	1080	1137.89	155.2	827.88	19.98	3.05608
490	492.74	7.824	352.08	179.7	2.19876	1100	1161.07	167.1	845.33	18.896	3.07732
500	503.02	8.411	359.49	170.6	2.21952	1120	1184.28	179.7	862.79	17.886	3.09825
510	513.32	9.031	366.92	162.1	2.23993	1140	1207.57	193.1	880.35	16.946	3.11883
520	523.63	9.684	374.36	154.1	2.25997	1160	1230.92	207.2	897.91	16.064	3.13916
530	533.98	10.37	381.84	146.7	2.27967	1180	1254.34	222.2	915.57	15.241	3.15916
540	544.35	11.10	389.34	139.7	2.29906	1200	1277.79	238.0	933.33	14.470	3.17888
550	555.74	11.86	396.86	133.1	2.31809	1220	1301.31	254.7	951.09	13.747	3.19834
560	565.17	12.66	404.42	127.0	2.33685	1240	1324.93	272.3	968.95	13.069	3.21751
570	575.59	13.50	411.97	121.2	2.35531						
1260	1348.55	290.8	986.90	12.435	3.23638	1600	1757.57	791.2	1298.30	5.804	3.52364
1280	1372.24	310.4	1004.76	11.835	3.25510	1620	1782.00	834.1	1316.96	5.574	3.53879

(Segue)

**TABELLA A.24** Proprietà dell'aria come gas ideale (*Continua*)

$T$ K	$h$ kJ/kg	$p_r$	$u$ kJ/kg	$v_r$	$s^\circ$ kJ/kg · K	$T$ K	$h$ kJ/kg	$p_r$	$u$ kJ/kg	$v_r$	$s^\circ$ kJ/kg · K
1300	1395.97	330.9	1022.82	11.275	3.27345	1640	1806.46	878.9	1335.72	5.355	3.55381
1320	1419.76	352.5	1040.88	10.747	3.29160	1660	1830.96	925.6	1354.48	5.147	3.56867
1340	1443.60	375.3	1058.94	10.247	3.30959	1680	1855.50	974.2	1373.24	4.949	3.58335
1360	1467.49	399.1	1077.10	9.780	3.32724	1700	1880.1	1025	1392.7	4.761	3.5979
1380	1491.44	424.2	1095.26	9.337	3.34474	1750	1941.6	1161	1439.8	4.328	3.6336
1400	1515.42	450.5	1113.52	8.919	3.36200	1800	2003.3	1310	1487.2	3.994	3.6684
1420	1539.44	478.0	1131.77	8.526	3.37901	1850	2065.3	1475	1534.9	3.601	3.7023
1440	1563.51	506.9	1150.13	8.153	3.39586	1900	2127.4	1655	1582.6	3.295	3.7354
1460	1587.63	537.1	1168.49	7.801	3.41247	1950	2189.7	1852	1630.6	3.022	3.7677
1480	1611.79	568.8	1186.95	7.468	3.42892	2000	2252.1	2068	1678.7	2.776	3.7994
1500	1635.97	601.9	1205.41	7.152	3.44516	2050	2314.6	2303	1726.8	2.555	3.8303
1520	1660.23	636.5	1223.87	6.854	3.46120	2100	2377.7	2559	1775.3	2.356	3.8605
1540	1684.51	672.8	1242.43	6.569	3.47712	2150	2440.3	2837	1823.8	2.175	3.8901
1560	1708.82	710.5	1260.99	6.301	3.49276	2200	2503.2	3138	1872.4	2.012	3.9191
1580	1733.17	750.0	1279.65	6.046	3.50829	2250	2566.4	3464	1921.3	1.864	3.9474

*Nota:* Le proprietà  $p_r$  (pressione relativa) e  $v_r$  (volume specifico relativo) sono variabili adimensionali usate nelle analisi dei processi e non dovrebbe essere confuso con le proprietà della pressione e del volume specifico.

*Fonte:* Kenneth Wark, *Thermodynamics*, 4th ed. (New York: McGraw-Hill, 1983), pp. 785–86, tabella A.5. Pubblicato originalmente in J.H. Keenan and J. Kaye, *Gas Tables* (New York: John Wiley & Sons, 1948).

**TABELLA A.25** Proprietà dell'aria alla pressione di 101 325 Pa

Temp. $T, ^\circ\text{C}$	Densità $\rho, \text{kg/m}^3$	Calore specifico $c_p, \text{J/kg} \cdot \text{K}$	Conduttività termica $\lambda, \text{W/m} \cdot \text{K}$	Diffusività termica $\alpha, \text{m}^2/\text{s}$	Viscosità dinamica $\mu, \text{kg/m} \cdot \text{s}$	Viscosità cinematica $\nu, \text{m}^2/\text{s}$	Numero di Prandtl Pr
-150	2.866	983	0.01171	$4.158 \times 10^{-6}$	$8.636 \times 10^{-6}$	$3.013 \times 10^{-6}$	0.7246
-100	2.038	966	0.01582	$8.036 \times 10^{-6}$	$1.189 \times 10^{-6}$	$5.837 \times 10^{-6}$	0.7263
-50	1.582	999	0.01979	$1.252 \times 10^{-5}$	$1.474 \times 10^{-5}$	$9.319 \times 10^{-6}$	0.7440
-40	1.514	1002	0.02057	$1.356 \times 10^{-5}$	$1.527 \times 10^{-5}$	$1.008 \times 10^{-5}$	0.7436
-30	1.451	1004	0.02134	$1.465 \times 10^{-5}$	$1.579 \times 10^{-5}$	$1.087 \times 10^{-5}$	0.7425
-20	1.394	1005	0.02211	$1.578 \times 10^{-5}$	$1.630 \times 10^{-5}$	$1.169 \times 10^{-5}$	0.7408
-10	1.341	1006	0.02288	$1.696 \times 10^{-5}$	$1.680 \times 10^{-5}$	$1.252 \times 10^{-5}$	0.7387
0	1.292	1006	0.02364	$1.818 \times 10^{-5}$	$1.729 \times 10^{-5}$	$1.338 \times 10^{-5}$	0.7362
5	1.269	1006	0.02401	$1.880 \times 10^{-5}$	$1.754 \times 10^{-5}$	$1.382 \times 10^{-5}$	0.7350
10	1.246	1006	0.02439	$1.944 \times 10^{-5}$	$1.778 \times 10^{-5}$	$1.426 \times 10^{-5}$	0.7336
15	1.225	1007	0.02476	$2.009 \times 10^{-5}$	$1.802 \times 10^{-5}$	$1.470 \times 10^{-5}$	0.7323
20	1.204	1007	0.02514	$2.074 \times 10^{-5}$	$1.825 \times 10^{-5}$	$1.516 \times 10^{-5}$	0.7309
25	1.184	1007	0.02551	$2.141 \times 10^{-5}$	$1.849 \times 10^{-5}$	$1.562 \times 10^{-5}$	0.7296
30	1.164	1007	0.02588	$2.208 \times 10^{-5}$	$1.872 \times 10^{-5}$	$1.608 \times 10^{-5}$	0.7282
35	1.145	1007	0.02625	$2.277 \times 10^{-5}$	$1.895 \times 10^{-5}$	$1.655 \times 10^{-5}$	0.7268
40	1.127	1007	0.02662	$2.346 \times 10^{-5}$	$1.918 \times 10^{-5}$	$1.702 \times 10^{-5}$	0.7255
45	1.109	1007	0.02699	$2.416 \times 10^{-5}$	$1.941 \times 10^{-5}$	$1.750 \times 10^{-5}$	0.7241
50	1.092	1007	0.02735	$2.487 \times 10^{-5}$	$1.963 \times 10^{-5}$	$1.798 \times 10^{-5}$	0.7228
60	1.059	1007	0.02808	$2.632 \times 10^{-5}$	$2.008 \times 10^{-5}$	$1.896 \times 10^{-5}$	0.7202
70	1.028	1007	0.02881	$2.780 \times 10^{-5}$	$2.052 \times 10^{-5}$	$1.995 \times 10^{-5}$	0.7177
80	0.9994	1008	0.02953	$2.931 \times 10^{-5}$	$2.096 \times 10^{-5}$	$2.097 \times 10^{-5}$	0.7154
90	0.9718	1008	0.03024	$3.086 \times 10^{-5}$	$2.139 \times 10^{-5}$	$2.201 \times 10^{-5}$	0.7132
100	0.9458	1009	0.03095	$3.243 \times 10^{-5}$	$2.181 \times 10^{-5}$	$2.306 \times 10^{-5}$	0.7111
120	0.8977	1011	0.03235	$3.565 \times 10^{-5}$	$2.264 \times 10^{-5}$	$2.522 \times 10^{-5}$	0.7073
140	0.8542	1013	0.03374	$3.898 \times 10^{-5}$	$2.345 \times 10^{-5}$	$2.745 \times 10^{-5}$	0.7041
160	0.8148	1016	0.03511	$4.241 \times 10^{-5}$	$2.420 \times 10^{-5}$	$2.975 \times 10^{-5}$	0.7014
180	0.7788	1019	0.03646	$4.593 \times 10^{-5}$	$2.504 \times 10^{-5}$	$3.212 \times 10^{-5}$	0.6992
200	0.7459	1023	0.03779	$4.954 \times 10^{-5}$	$2.577 \times 10^{-5}$	$3.455 \times 10^{-5}$	0.6974
250	0.6746	1033	0.04104	$5.890 \times 10^{-5}$	$2.760 \times 10^{-5}$	$4.091 \times 10^{-5}$	0.6946
300	0.6158	1044	0.04418	$6.871 \times 10^{-5}$	$2.934 \times 10^{-5}$	$4.765 \times 10^{-5}$	0.6935
350	0.5664	1056	0.04721	$7.892 \times 10^{-5}$	$3.101 \times 10^{-5}$	$5.475 \times 10^{-5}$	0.6937
400	0.5243	1069	0.05015	$8.951 \times 10^{-5}$	$3.261 \times 10^{-5}$	$6.219 \times 10^{-5}$	0.6948
450	0.4880	1081	0.05298	$1.004 \times 10^{-4}$	$3.415 \times 10^{-5}$	$6.997 \times 10^{-5}$	0.6965
500	0.4565	1093	0.05572	$1.117 \times 10^{-4}$	$3.563 \times 10^{-5}$	$7.806 \times 10^{-5}$	0.6986
600	0.4042	1115	0.06093	$1.352 \times 10^{-4}$	$3.846 \times 10^{-5}$	$9.515 \times 10^{-5}$	0.7037
700	0.3627	1135	0.06581	$1.598 \times 10^{-4}$	$4.111 \times 10^{-5}$	$1.133 \times 10^{-4}$	0.7092
800	0.3289	1153	0.07037	$1.855 \times 10^{-4}$	$4.362 \times 10^{-5}$	$1.326 \times 10^{-4}$	0.7149
900	0.3008	1169	0.07465	$2.122 \times 10^{-4}$	$4.600 \times 10^{-5}$	$1.529 \times 10^{-4}$	0.7206
1000	0.2772	1184	0.07868	$2.398 \times 10^{-4}$	$4.826 \times 10^{-5}$	$1.741 \times 10^{-4}$	0.7260
1500	0.1990	1234	0.09599	$3.908 \times 10^{-4}$	$5.817 \times 10^{-5}$	$2.922 \times 10^{-4}$	0.7478
2000	0.1553	1264	0.11113	$5.664 \times 10^{-4}$	$6.630 \times 10^{-5}$	$4.270 \times 10^{-4}$	0.7539

Nota: Per i gas ideali le proprietà  $c_p$ ,  $k$ ,  $\mu$ , e Pr sono indipendenti rispetto alla pressione. Le proprietà  $\rho$ ,  $\nu$ , e  $\alpha$  alla pressione  $p$  (in atm) oltre che 1 atm sono determinati dalla moltiplicazione dei valori di  $\rho$  alla temperatura data da  $p$  e dalla divisione di  $\nu$  e  $\alpha$  da  $p$ .

Fonte: Dati generati dal software EES sviluppato da S.A. Klein e F.L. Alvarado. Fonte originale: Keenan, Chao, Keyes, Gas Tables, Wiley, 1984; and Thermophysical Properties of Matter. Vol. 3: Thermal Conductivity, Y.S. Touloukian, P.E. Liley, S.C. Saxena, Vol. 11: Viscosity, Y.S. Touloukian, S.C. Saxena, and P. Hestermans, IFI/Plenum, NY, 1970, ISBN 0-306067020-8.

**TABELLA A.26** Proprietà di alcuni gas alla pressione di 101 325 Pa

Temp. $T, ^\circ\text{C}$	Densità $\rho, \text{kg/m}^3$	Calore specifico $c_p, \text{J/kg} \cdot \text{K}$	Conduttività termica $\lambda, \text{W/m} \cdot \text{K}$	Diffusività termica $\alpha, \text{m}^2/\text{s}$	Viscosità dinamica $\mu, \text{kg/m} \cdot \text{s}$	Viscosità cinematica $\nu, \text{m}^2/\text{s}$	Numero di Prandtl Pr
<b>Diossido di carbonio, CO<sub>2</sub></b>							
-50	2.4035	746	0.01051	$5.860 \times 10^{-6}$	$1.129 \times 10^{-5}$	$4.699 \times 10^{-6}$	0.8019
0	1.9635	811	0.01456	$9.141 \times 10^{-6}$	$1.375 \times 10^{-5}$	$7.003 \times 10^{-6}$	0.7661
50	1.6597	866.6	0.01858	$1.291 \times 10^{-5}$	$1.612 \times 10^{-5}$	$9.714 \times 10^{-6}$	0.7520
100	1.4373	914.8	0.02257	$1.716 \times 10^{-5}$	$1.841 \times 10^{-5}$	$1.281 \times 10^{-5}$	0.7464
150	1.2675	957.4	0.02652	$2.186 \times 10^{-5}$	$2.063 \times 10^{-5}$	$1.627 \times 10^{-5}$	0.7445
200	1.1336	995.2	0.03044	$2.698 \times 10^{-5}$	$2.276 \times 10^{-5}$	$2.008 \times 10^{-5}$	0.7442
300	0.9358	1060	0.03814	$3.847 \times 10^{-5}$	$2.682 \times 10^{-5}$	$2.866 \times 10^{-5}$	0.7450
400	0.7968	1112	0.04565	$5.151 \times 10^{-5}$	$3.061 \times 10^{-5}$	$3.842 \times 10^{-5}$	0.7458
500	0.6937	1156	0.05293	$6.600 \times 10^{-5}$	$3.416 \times 10^{-5}$	$4.924 \times 10^{-5}$	0.7460
1000	0.4213	1292	0.08491	$1.560 \times 10^{-4}$	$4.898 \times 10^{-5}$	$1.162 \times 10^{-4}$	0.7455
1500	0.3025	1356	0.10688	$2.606 \times 10^{-4}$	$6.106 \times 10^{-5}$	$2.019 \times 10^{-4}$	0.7745
2000	0.2359	1387	0.11522	$3.521 \times 10^{-4}$	$7.322 \times 10^{-5}$	$3.103 \times 10^{-4}$	0.8815
<b>Monossido di carbonio, CO</b>							
-50	1.5297	1081	0.01901	$1.149 \times 10^{-5}$	$1.378 \times 10^{-5}$	$9.012 \times 10^{-6}$	0.7840
0	1.2497	1048	0.02278	$1.739 \times 10^{-5}$	$1.629 \times 10^{-5}$	$1.303 \times 10^{-5}$	0.7499
50	1.0563	1039	0.02641	$2.407 \times 10^{-5}$	$1.863 \times 10^{-5}$	$1.764 \times 10^{-5}$	0.7328
100	0.9148	1041	0.02992	$3.142 \times 10^{-5}$	$2.080 \times 10^{-5}$	$2.274 \times 10^{-5}$	0.7239
150	0.8067	1049	0.03330	$3.936 \times 10^{-5}$	$2.283 \times 10^{-5}$	$2.830 \times 10^{-5}$	0.7191
200	0.7214	1060	0.03656	$4.782 \times 10^{-5}$	$2.472 \times 10^{-5}$	$3.426 \times 10^{-5}$	0.7164
300	0.5956	1085	0.04277	$6.619 \times 10^{-5}$	$2.812 \times 10^{-5}$	$4.722 \times 10^{-5}$	0.7134
400	0.5071	1111	0.04860	$8.628 \times 10^{-5}$	$3.111 \times 10^{-5}$	$6.136 \times 10^{-5}$	0.7111
500	0.4415	1135	0.05412	$1.079 \times 10^{-4}$	$3.379 \times 10^{-5}$	$7.653 \times 10^{-5}$	0.7087
1000	0.2681	1226	0.07894	$2.401 \times 10^{-4}$	$4.557 \times 10^{-5}$	$1.700 \times 10^{-4}$	0.7080
1500	0.1925	1279	0.10458	$4.246 \times 10^{-4}$	$6.321 \times 10^{-5}$	$3.284 \times 10^{-4}$	0.7733
2000	0.1502	1309	0.13833	$7.034 \times 10^{-4}$	$9.826 \times 10^{-5}$	$6.543 \times 10^{-4}$	0.9302
<b>Metano, CH<sub>4</sub></b>							
-50	0.8761	2243	0.02367	$1.204 \times 10^{-5}$	$8.564 \times 10^{-6}$	$9.774 \times 10^{-6}$	0.8116
0	0.7158	2217	0.03042	$1.917 \times 10^{-5}$	$1.028 \times 10^{-5}$	$1.436 \times 10^{-5}$	0.7494
50	0.6050	2302	0.03766	$2.704 \times 10^{-5}$	$1.191 \times 10^{-5}$	$1.969 \times 10^{-5}$	0.7282
100	0.5240	2443	0.04534	$3.543 \times 10^{-5}$	$1.345 \times 10^{-5}$	$2.567 \times 10^{-5}$	0.7247
150	0.4620	2611	0.05344	$4.431 \times 10^{-5}$	$1.491 \times 10^{-5}$	$3.227 \times 10^{-5}$	0.7284
200	0.4132	2791	0.06194	$5.370 \times 10^{-5}$	$1.630 \times 10^{-5}$	$3.944 \times 10^{-5}$	0.7344
300	0.3411	3158	0.07996	$7.422 \times 10^{-5}$	$1.886 \times 10^{-5}$	$5.529 \times 10^{-5}$	0.7450
400	0.2904	3510	0.09918	$9.727 \times 10^{-5}$	$2.119 \times 10^{-5}$	$7.297 \times 10^{-5}$	0.7501
500	0.2529	3836	0.11933	$1.230 \times 10^{-4}$	$2.334 \times 10^{-5}$	$9.228 \times 10^{-5}$	0.7502
1000	0.1536	5042	0.22562	$2.914 \times 10^{-4}$	$3.281 \times 10^{-5}$	$2.136 \times 10^{-4}$	0.7331
1500	0.1103	5701	0.31857	$5.068 \times 10^{-4}$	$4.434 \times 10^{-5}$	$4.022 \times 10^{-4}$	0.7936
2000	0.0860	6001	0.36750	$7.120 \times 10^{-4}$	$6.360 \times 10^{-5}$	$7.395 \times 10^{-4}$	1.0386

(Segue)

**TABELLA A.26** Proprietà di alcuni gas alla pressione di 101 325 Pa (*Continua*)

Temp. $T, ^\circ\text{C}$	Densità $\rho, \text{kg/m}^3$	Calore specifico $c_p, \text{J/kg} \cdot \text{K}$	Conduttività termica $\lambda, \text{W/m} \cdot \text{K}$	Diffusività termica $\alpha, \text{m}^2/\text{s}$	Viscosità dinamica $\mu, \text{kg/m} \cdot \text{s}$	Viscosità cinematica $\nu, \text{m}^2/\text{s}$	Numero di Prandtl Pr
<b>Idrogeno, H<sub>2</sub></b>							
-50	0.11010	12635	0.1404	$1.009 \times 10^{-4}$	$7.293 \times 10^{-6}$	$6.624 \times 10^{-5}$	0.6562
0	0.08995	13920	0.1652	$1.319 \times 10^{-4}$	$8.391 \times 10^{-6}$	$9.329 \times 10^{-5}$	0.7071
50	0.07603	14349	0.1881	$1.724 \times 10^{-4}$	$9.427 \times 10^{-6}$	$1.240 \times 10^{-4}$	0.7191
100	0.06584	14473	0.2095	$2.199 \times 10^{-4}$	$1.041 \times 10^{-5}$	$1.582 \times 10^{-4}$	0.7196
150	0.05806	14492	0.2296	$2.729 \times 10^{-4}$	$1.136 \times 10^{-5}$	$1.957 \times 10^{-4}$	0.7174
200	0.05193	14482	0.2486	$3.306 \times 10^{-4}$	$1.228 \times 10^{-5}$	$2.365 \times 10^{-4}$	0.7155
300	0.04287	14481	0.2843	$4.580 \times 10^{-4}$	$1.403 \times 10^{-5}$	$3.274 \times 10^{-4}$	0.7149
400	0.03650	14540	0.3180	$5.992 \times 10^{-4}$	$1.570 \times 10^{-5}$	$4.302 \times 10^{-4}$	0.7179
500	0.03178	14653	0.3509	$7.535 \times 10^{-4}$	$1.730 \times 10^{-5}$	$5.443 \times 10^{-4}$	0.7224
1000	0.01930	15577	0.5206	$1.732 \times 10^{-3}$	$2.455 \times 10^{-5}$	$1.272 \times 10^{-3}$	0.7345
1500	0.01386	16553	0.6581	$2.869 \times 10^{-3}$	$3.099 \times 10^{-5}$	$2.237 \times 10^{-3}$	0.7795
2000	0.01081	17400	0.5480	$2.914 \times 10^{-3}$	$3.690 \times 10^{-5}$	$3.414 \times 10^{-3}$	1.1717
<b>Nitrogeno, N<sub>2</sub></b>							
-50	1.5299	957.3	0.02001	$1.366 \times 10^{-5}$	$1.390 \times 10^{-5}$	$9.091 \times 10^{-6}$	0.6655
0	1.2498	1035	0.02384	$1.843 \times 10^{-5}$	$1.640 \times 10^{-5}$	$1.312 \times 10^{-5}$	0.7121
50	1.0564	1042	0.02746	$2.494 \times 10^{-5}$	$1.874 \times 10^{-5}$	$1.774 \times 10^{-5}$	0.7114
100	0.9149	1041	0.03090	$3.244 \times 10^{-5}$	$2.094 \times 10^{-5}$	$2.289 \times 10^{-5}$	0.7056
150	0.8068	1043	0.03416	$4.058 \times 10^{-5}$	$2.300 \times 10^{-5}$	$2.851 \times 10^{-5}$	0.7025
200	0.7215	1050	0.03727	$4.921 \times 10^{-5}$	$2.494 \times 10^{-5}$	$3.457 \times 10^{-5}$	0.7025
300	0.5956	1070	0.04309	$6.758 \times 10^{-5}$	$2.849 \times 10^{-5}$	$4.783 \times 10^{-5}$	0.7078
400	0.5072	1095	0.04848	$8.727 \times 10^{-5}$	$3.166 \times 10^{-5}$	$6.242 \times 10^{-5}$	0.7153
500	0.4416	1120	0.05358	$1.083 \times 10^{-4}$	$3.451 \times 10^{-5}$	$7.816 \times 10^{-5}$	0.7215
1000	0.2681	1213	0.07938	$2.440 \times 10^{-4}$	$4.594 \times 10^{-5}$	$1.713 \times 10^{-4}$	0.7022
1500	0.1925	1266	0.11793	$4.839 \times 10^{-4}$	$5.562 \times 10^{-5}$	$2.889 \times 10^{-4}$	0.5969
2000	0.1502	1297	0.18590	$9.543 \times 10^{-4}$	$6.426 \times 10^{-5}$	$4.278 \times 10^{-4}$	0.4483
<b>Ossigeno, O<sub>2</sub></b>							
-50	1.7475	984.4	0.02067	$1.201 \times 10^{-5}$	$1.616 \times 10^{-5}$	$9.246 \times 10^{-6}$	0.7694
0	1.4277	928.7	0.02472	$1.865 \times 10^{-5}$	$1.916 \times 10^{-5}$	$1.342 \times 10^{-5}$	0.7198
50	1.2068	921.7	0.02867	$2.577 \times 10^{-5}$	$2.194 \times 10^{-5}$	$1.818 \times 10^{-5}$	0.7053
100	1.0451	931.8	0.03254	$3.342 \times 10^{-5}$	$2.451 \times 10^{-5}$	$2.346 \times 10^{-5}$	0.7019
150	0.9216	947.6	0.03637	$4.164 \times 10^{-5}$	$2.694 \times 10^{-5}$	$2.923 \times 10^{-5}$	0.7019
200	0.8242	964.7	0.04014	$5.048 \times 10^{-5}$	$2.923 \times 10^{-5}$	$3.546 \times 10^{-5}$	0.7025
300	0.6804	997.1	0.04751	$7.003 \times 10^{-5}$	$3.350 \times 10^{-5}$	$4.923 \times 10^{-5}$	0.7030
400	0.5793	1025	0.05463	$9.204 \times 10^{-5}$	$3.744 \times 10^{-5}$	$6.463 \times 10^{-5}$	0.7023
500	0.5044	1048	0.06148	$1.163 \times 10^{-4}$	$4.114 \times 10^{-5}$	$8.156 \times 10^{-5}$	0.7010
1000	0.3063	1121	0.09198	$2.678 \times 10^{-4}$	$5.732 \times 10^{-5}$	$1.871 \times 10^{-4}$	0.6986
1500	0.2199	1165	0.11901	$4.643 \times 10^{-4}$	$7.133 \times 10^{-5}$	$3.243 \times 10^{-4}$	0.6985
2000	0.1716	1201	0.14705	$7.139 \times 10^{-4}$	$8.417 \times 10^{-5}$	$4.907 \times 10^{-4}$	0.6873

(Segue)

**TABELLA A.26** Proprietà di alcuni gas alla pressione di 101 325 Pa (*Continua*)

Temp. $T$ , °C	Densità $\rho$ , kg/m <sup>3</sup>	Calore specifico $c_p$ , J/kg · K	Conduttività termica $\lambda$ , W/m · K	Diffusività termica $\alpha$ , m <sup>2</sup> /s	Viscosità dinamica $\mu$ , kg/m · s	Viscosità cinematica $\nu$ , m <sup>2</sup> /s	Numero di Prandtl Pr
<b>Vapore acqueo, H<sub>2</sub>O</b>							
-50	0.9839	1892	0.01353	$7.271 \times 10^{-6}$	$7.187 \times 10^{-6}$	$7.305 \times 10^{-6}$	1.0047
0	0.8038	1874	0.01673	$1.110 \times 10^{-5}$	$8.956 \times 10^{-6}$	$1.114 \times 10^{-5}$	1.0033
50	0.6794	1874	0.02032	$1.596 \times 10^{-5}$	$1.078 \times 10^{-5}$	$1.587 \times 10^{-5}$	0.9944
100	0.5884	1887	0.02429	$2.187 \times 10^{-5}$	$1.265 \times 10^{-5}$	$2.150 \times 10^{-5}$	0.9830
150	0.5189	1908	0.02861	$2.890 \times 10^{-5}$	$1.456 \times 10^{-5}$	$2.806 \times 10^{-5}$	0.9712
200	0.4640	1935	0.03326	$3.705 \times 10^{-5}$	$1.650 \times 10^{-5}$	$3.556 \times 10^{-5}$	0.9599
300	0.3831	1997	0.04345	$5.680 \times 10^{-5}$	$2.045 \times 10^{-5}$	$5.340 \times 10^{-5}$	0.9401
400	0.3262	2066	0.05467	$8.114 \times 10^{-5}$	$2.446 \times 10^{-5}$	$7.498 \times 10^{-5}$	0.9240
500	0.2840	2137	0.06677	$1.100 \times 10^{-4}$	$2.847 \times 10^{-5}$	$1.002 \times 10^{-4}$	0.9108
1000	0.1725	2471	0.13623	$3.196 \times 10^{-4}$	$4.762 \times 10^{-5}$	$2.761 \times 10^{-4}$	0.8639
1500	0.1238	2736	0.21301	$6.288 \times 10^{-4}$	$6.411 \times 10^{-5}$	$5.177 \times 10^{-4}$	0.8233
2000	0.0966	2928	0.29183	$1.032 \times 10^{-3}$	$7.808 \times 10^{-5}$	$8.084 \times 10^{-4}$	0.7833

*Nota:* Per i gas ideali le proprietà  $c_p$ ,  $k$ ,  $\mu$ , e Pr sono indipendenti rispetto alla pressione. Le proprietà  $\rho$ ,  $\nu$  e  $\alpha$  alla pressione  $p$  (in atm) oltre che 1 atm sono determinati dalla moltiplicazione dei valori di  $p$  alla temperatura data da  $p$  e dalla divisione di  $\nu$  e  $\alpha$  da  $p$ .

*Fonte:* Dati generati dal software EES sviluppato da S.A. Klein e F.L. Alvarado. Basato originariamente su diverse fonti.



**TABELLA A.27** Proprietà dei metalli solidi

Composizione	Punto di fusione K	Proprietà a 300 K				Proprietà a varie temperature									
		$\rho$ kg/m <sup>3</sup>	$c_p$ J/kg · K	$\lambda$ W/m · K	$\alpha \times 10^6$ m <sup>2</sup> /s	$\lambda$ (W/m · K)/ $c_p$ (J/kg · K)									
						100	200	400	600	800	1000	1200			
Alluminio puro	933	2,702	903	237	97.1	302	237	240	231	218					
						482	798	949	1033	1146					
Lega 2024-T6 (4.5% Cu, 1.5% Mg, 0.6% Mn)	775	2,770	875	177	73.0	65	163	186	186						
						473	787	925	1042						
Lega 195, Fusione (4.5% Cu)		2,790	883	168	68.2			174	185						
Berillio	1550	1,850	1825	200	59.2	990	301	161	126	106	90.8	78.7			
						203	1114	2191	2604	2823	3018	3227			
Biscrento	545	9,780	122	7.86	6.59	16.5	9.69	7.04							
						112	120	127							
Boro	2573	2,500	1107	27.0	9.76	190	55.5	16.8	10.6	9.60	9.85				
						128	600	1463	1892	2160	2338				
Cadmio	594	8,650	231	96.8	48.4	203	99.3	94.7							
						198	222	242							
Cromo	2118	7,160	449	93.7	29.1	159	111	90.9	80.7	71.3	65.4	61.9			
						192	384	484	542	581	616	682			
Cobalto	1769	8,862	421	99.2	26.6	167	122	85.4	67.4	58.2	52.1	49.3			
						236	379	450	503	550	628	733			
Rame puro	1358	8,933	385	401	117	482	413	393	379	366	352	339			
						252	356	397	417	433	451	480			
Bronzo commerciale (90% Cu, 10% Al)	1293	8,800	420	52	14		42	52	59						
							785	160	545						
Bronzo fosforoso (89% Cu, 11% Sn)	1104	8,780	355	54	17		41	65	74						
Ottone giallo (70% Cu, 30% Zn)	1188	8,530	380	110	33.9	75	95	137	149						
							360	395	425						
Costantana (55% Cu, 45% Ni)	1493	8,920	384	23	6.71	17	19								
						237	362								
Germanio	1211	5,360	322	59.9	34.7	232	96.8	43.2	27.3	19.8	17.4	17.4			
						190	290	337	348	357	375	395			
Oro	1336	19,300	129	317	127	327	323	311	298	284	270	255			
						109	124	131	135	140	145	155			
Iridio	2720	22,500	130	147	50.3	172	153	144	138	132	126	120			
						90	122	133	138	144	153	161			
Ferro puro	1810	7,870	447	80.2	23.1	134	94.0	69.5	54.7	43.3	32.8	28.3			
						216	384	490	574	680	975	609			
Armco (puro al 99.75%)		7,870	447	72.7	20.7	95.6	80.6	65.7	53.1	42.2	32.3	28.7			
						215	384	490	574	680	975	609			
Acciaio al carbonio Carbonio semplice (Mn ≤ 1%, Si ≤ 0.1%)		7,854	434	60.5	17.7			56.7	48.0	39.2	30.0				
								487	559	685	1169				
AISI 1010		7,832	434	63.9	18.8			58.7	48.8	39.2	31.3				
								487	559	685	1168				
Carbonio-silicio (Mn ≤ 1%, 0.1% < Si ≤ 0.6%)		7,817	446	51.9	14.9			49.8	44.0	37.4	29.3				
								501	582	699	971				
Carbonio-manganese- silicio (1% < Mn ≤ 1.65%, 0.1% < Si ≤ 0.6%)		8,131	434	41.0	11.6			42.2	39.7	35.0	27.6				
								487	559	685	1090				

(Segue)

TABELLA A.27 Proprietà dei metalli solidi (Continua)

Composizione	Punto di fusione K	Proprietà a 300 K				Proprietà a varie temperature														
		$\rho$ kg/m <sup>3</sup>	$c_p$ J/kg · K	$\lambda$ W/m · K	$\alpha \times 10^6$ m <sup>2</sup> /s	$\lambda$ (W/m · K)/ $c_p$ (J/kg · K)														
						100	200	400	600	800	1000	1200								
<i>Acciaio al cromo</i>																				
½Cr - ½Mo - Si (0.18% C, 0.65% Cr, 0.23% Mo, 0.6% Si)		7,822	444	37.7	10.9			38.2	36.7	33.3	26.9									
1Cr - ½Mo (0.16% C, 1% Cr, 0.54% Mo, 0.39% Si)		7,858	442	42.3	12.2			492	575	688	969									
1 Cr - V (0.2% C, 1.02% Cr, 0.15% V)		7,836	443	48.9	14.1			492	575	688	969									
<i>Acciaio inossidabile</i>																				
AISI 302		8,055	480	15.1	3.91			17.3	20.0	22.8	25.4									
AISI 304	1670	7,900	477	14.9	3.95	9.2	12.6	512	559	585	606									
AISI 316		8,238	468	13.4	3.48	272	402	16.6	19.8	22.6	25.4	28.0								
AISI 347		7,978	480	14.2	3.71			515	557	582	611	640								
Piombo	601	11,340	129	35.3	24.1			15.2	18.3	21.3	24.2									
Magnesio	923	1,740	1024	156	87.6			504	550	576	602									
Molibdeno	2894	10,240	251	138	53.7			15.8	18.9	21.9	24.7									
Nichel puro	1728	8,900	444	90.7	23.0	39.7	36.7	513	559	585	606									
Nicromo (80% Ni, 20% Cr)	1672	8,400	420	12	3.4	118	125	34.0	31.4											
Inconel X-750 (73% Ni, 15% Cr, 6.7% Fe)	1665	8,510	439	11.7	3.1	169	159	132	142											
Niobio	2741	8,570	265	53.7	23.6	649	934	149	146											
Palladio	1827	12,020	244	71.8	24.5	179	143	1074	1170	1267										
Platino puro	2045	21,450	133	71.6	25.1	141	224	134	126	118	112	105								
Lega 60 Pt - 40% Rh (60% Pt, 40% Rh)	1800	16,630	162	47	17.4	164	107	261	275	285	295	308								
Renio	3453	21,100	136	47.9	16.7	232	383	80.2	65.6	67.6	71.8	76.2								
Rodio	2236	12,450	243	150	49.6	485	592	14	16	21										
Silicio	1685	2,330	712	148	89.2	480	525	13.5	17.0	20.5	24.0	27.6								
Argento	1235	10,500	235	429	174	—	372	55.2	52.6	55.2	58.2	61.3	64.4	67.5						
Tantalo	3269	16,600	140	57.5	24.7	188	249	473	510	546	626	—								
Torio	2023	11,700	118	54.0	39.1	188	249	73.6	79.7	86.9	94.2	102								
						168	227	251	261	271	281	291								
						77.5	72.6	71.8	73.2	75.6	78.7	82.6								
						100	125	136	141	146	152	157								
						52	59	65	69	73										
						58.9	51.0	46.1	44.2	44.1	44.6	45.7								
						97	127	139	145	151	156	162								
						186	154	146	136	127	121	116								
						147	220	253	274	293	311	327								
						884	264	98.9	61.9	42.4	31.2	25.7								
						259	556	790	867	913	946	967								
						444	430	425	412	396	379	361								
						187	225	239	250	262	277	292								
						59.2	57.5	57.8	58.6	59.4	60.2	61.0								
						110	133	144	146	149	152	155								
						59.8	54.6	54.5	55.8	56.9	56.9	58.7								
						99	112	124	134	145	156	167								

(Segue)

**TABELLA A.27** Proprietà dei metalli solidi (*Continua*)

Composizione	Punto di fusione K	Proprietà a 300 K				Proprietà a varie temperature								
		$\rho$ kg/m <sup>3</sup>	$c_p$ J/kg · K	$\lambda$ W/m · K	$\alpha \times 10^6$ m <sup>2</sup> /s	$\lambda$ (W/m · K)/ $c_p$ (J/kg · K)								
						100	200	400	600	800	1000	1200		
Stagno	505	7,310	227	66.6	40.1	85.2	73.3	62.2						
Titanio	1953	4,500	522	21.9	9.32	188	215	243						
						30.5	24.5	20.4	19.4	19.7	20.7	22.0		
Tungsteno	3660	19,300	132	174	68.3	300	465	551	591	633	675	620		
						208	186	159	137	125	118	113		
Uranio	1406	19,070	116	27.6	12.5	87	122	137	142	145	148	152		
						21.7	25.1	29.6	34.0	38.8	43.9	49.0		
Vanadio	2192	6,100	489	30.7	10.3	94	108	125	146	176	180	161		
						35.8	31.3	31.3	33.3	35.7	38.2	40.8		
Zinco	693	7,140	389	116	41.8	258	430	515	540	563	597	645		
						117	118	111	103					
Zirconio	2125	6,570	278	22.7	12.4	297	367	402	436					
						33.2	25.2	21.6	20.7	21.6	23.7	26.0		
						205	264	300	332	342	362	344		

Fonte per le tabelle da A.14 fino ad A.16: F.P. Incropera e D.P. DeWitt, *Fundamentals of Heat and Mass Transfer*, 3<sup>a</sup> ed., Wiley, New York 1990, pp. A3-A14. Originariamente compilate da varie fonti. Riprodotte su licenza di John Wiley & Sons, Inc.

**TABELLA A.28** Proprietà dei solidi non metallici

Composizione	Punto di fusione K	Proprietà a 300 K				Proprietà a varie temperature									
		$\rho$ kg/m <sup>3</sup>	$c_p$ J/kg · K	$\lambda$ W/m · K	$\alpha \times 10^6$ m <sup>2</sup> /s	$\lambda(W/m \cdot K)/c_p(J/kg \cdot K)$									
						100	200	400	600	800	1000	1200			
Ossido di alluminio, zaffiro	2323	3970	765	46	15.1	450	82	32.4	18.9	13.0	10.5				
Ossido di alluminio, policristallino	2323	3970	765	36.0	11.9	133	55	26.4	15.8	10.4	7.85	6.55			
Ossido di berillio	2725	3000	1030	272	88.0			940	1110	1180	1225				
Boro	2573	2500	1105	27.6	9.99			196	111	70	47	33			
Composto epossidico di fibre di boro (30% vol.)	590	2080						1350	1690	1865	1975	2055			
$\lambda$ ,    alle fibre				2.29				2.10	2.23	2.28					
$\lambda$ , $\perp$ alle fibre				0.59				0.37	0.49	0.60					
$c_p$			1122					364	757	1431					
Carbonio amorfo	1500	1950	—	1.60	—			0.67	1.18	1.89	21.9	2.37	2.53	2.84	
Diamante, isolante tipo IIa	—	3500	509	2300		10 000	4000	1540							
Grafite, pirolitica	2273	2210				21	194	853							
$\lambda$ ,    agli strati				1950		4970	3230	1390	892	667	534	448			
$\lambda$ , $\perp$ agli strati				5.70		16.8	9.23	4.09	2.68	2.01	1.60	1.34			
$c_p$			709			136	411	992	1406	1650	1793	1890			
Composto (25% vol.) epossidico di fibre di grafite	450	1400													
$\lambda$ , flusso termico    alle fibre				11.1		5.7	8.7	13.0							
$\lambda$ , flusso termico $\perp$ alle fibre				0.87		0.46	0.68	1.1							
$c_p$			935			337	642	1216							
Piroceramica, Corning 9606	1623	2600	808	3.98	1.89	5.25	4.78	3.64	3.28	3.08	2.96	2.87			
Carburo di silicio	3100	3160	675	490	230			908	1038	1122	1197	1264			
Biossido di silicio, cristallino (quarzo)	1883	2650						880	1050	1135	1195	1243			
$\lambda$ ,    all'asse c				10.4		39	16.4	7.6	5.0	4.2					
$\lambda$ , $\perp$ all'asse c				6.21		20.8	9.5	4.70	3.4	3.1					
$c_p$			745					885	1075	1250					
Biossido di silicio, policristallino (silice fusa)	1883	2220	745	1.38	0.834	0.69	1.14	1.51	1.75	2.17	2.87	4.00			
Nitruro di silicio	2173	2400	691	16.0	9.65			905	1040	1105	1155	1195			
Zolfo	392	2070	708	0.206	0.141			13.9	11.3	9.88	8.76	8.00			
Biossido di torio	3573	9110	235	13	6.1			778	937	1063	1155	1226			
Biossido di titanio, policristallino	2133	4157	710	8.4	2.8	0.165	0.185								
						403	606								
								10.2	6.6	4.7	3.68	3.12			
								255	274	285	295	303			
								7.01	5.02	3.94	3.46	3.28			
								805	880	910	930	945			

**TABELLA A.29** Proprietà dei materiali comuni (a) Materiali da costruzione

Descrizione/composizione	Proprietà tipiche a 300 K		
	Densità $\rho$ kg/m <sup>3</sup>	Conduttività termica $\lambda$ W/m · K	Calore specifico $c_p$ J/kg · K
<b>Pannelli da costruzione</b>			
Pannello di asbesto-cemento	1920	0.58	—
Pannello di gesso o intonaco	800	0.17	—
Legno compensato	545	0.12	1215
Tavole per tetto, densità normale	290	0.055	1300
Pannello acustico	290	0.058	1340
Pannello rigido, di raccordo	640	0.094	1170
Pannello rigido, alta densità	1010	0.15	1380
Pannello di particelle, bassa densità	590	0.078	1300
Pannello di particelle, alta densità	1000	0.170	1300
<b>Legni</b>			
Legni duri (quercia, acero)	720	0.16	1255
Legni teneri (abete, pino)	510	0.12	1380
<b>Materiali per mattoni</b>			
Mattone di cemento	1860	0.72	780
Laterizio, ordinario	1920	0.72	835
Laterizio, faccia-vista	2083	1.3	—
<b>Blocco di laterizio, cavo</b>			
1 fila di fori, spessore 10 cm	—	0.52	—
3 file di fori, spessore 30 cm	—	0.69	—
<b>Blocco di calcestruzzo, 3 fori ovali</b>			
Sabbia/ghiaia, spessore 20 cm	—	1.0	—
Aggregati di scorie, spessore 20 cm	—	0.67	—
<b>Blocco di calcestruzzo, fori rettangolari</b>			
2 fori, spessore 20 cm, 16 kg	—	1.1	—
Idem con fori pieni	—	0.60	—
<b>Materiali per intonaco</b>			
Intonaco di cemento, aggregato di sabbia	1860	0.72	—
Intonaco di gesso, aggregato di sabbia	1680	0.22	1085
Intonaco di gesso, aggregato di	720	0.25	—
Vermiculite			

(Segue)

**TABELLA A.29** Proprietà dei materiali comuni (b) Materiali isolanti (*Continua*)

Descrizione/composizione	Proprietà tipiche a 300 K		
	Densità $\rho$ kg/m <sup>3</sup>	Conduttività termica $\lambda$ W/m · K	Calore specifico $c_p$ J/kg · K
<b>Copertura e rivestimento</b>			
Fibra di vetro, rivestita di carta	16	0.046	---
	28	0.038	—
	40	0.035	—
Fibra di vetro, verniciata; rivest. condotti	32	0.038	835
<b>Pannello e lastra</b>			
Vetro cellulare	145	0.058	1000
Fibra di vetro, con legante organico	105	0.036	795
<b>Polistirene, espanso</b>			
estruso (R-12)	55	0.027	1210
Perle stampate	16	0.040	1210
Pannello in fibra minerale; materiale per tetti	265	0.049	—
Lana di legno con leganti inorganici	350	0.087	1590
Sughero	120	0.039	1800
<b>Materiali di riempimento</b>			
Sughero, in granuli	160	0.045	—
Silice di diatomee, grezza	350	0.069	—
in polvere	400	0.091	—
Silice di diatomee, polvere fine	200	0.052	—
	275	0.061	—
Fibra di vetro, colata o soffiata	16	0.043	835
Vermiculite, scaglie	80	0.068	835
	160	0.063	1000
<b>Formato/schiumato in situ</b>			
Lana minerale in granuli con asbesto / leganti inorganici, a spruzzo	190	0.046	—
Mastice di sughero acetato polivinilico; a spruzzo o liscio	—	0.100	—
Uretano, miscela bicomponente; forma rigida	70	0.026	1045
<b>Riflettivo</b>			
Foglio di alluminio che separa materiali vetrosi leggeri; 10-12 strati; sotto vuoto; per applicazioni criogeniche (150 K)	40	0.00016	---
Foglio di alluminio e carta vetrata laminata; 75-150 strati; sotto vuoto; per applicazioni criogeniche (150 K)	120	0.000017	—
Polvere di silice tipica, sotto vuoto	160	0.0017	---

(Segue)

**TABELLA A.29** Proprietà dei materiali comuni (c) Altri materiali (*Continua*)

Descrizione/composizione	Temp. K	Proprietà tipiche a 300 K		
		Densità $\rho$ kg/m <sup>3</sup>	Conduttività termica $\lambda$ W/m · K	Calore specifico $c_p$ J/kg · K
Asfalto	300	2115	0.062	920
Bakelite	300	1300	1.4	1465
Mattoni, refrattario				
al carborundum	872	—	18.5	—
	1672	—	11.0	—
al cromo	473	3010	2.3	835
	823		2.5	
	1173		2.0	
Silice di diatomee, cotta	478	—	0.25	—
	1145	—	0.30	
Argilla refrattaria, cotta a 1600 K	773	2050	1.0	960
	1073	—	1.1	
	1373	—	1.1	
Argilla refrattaria, cotta a 1725 K	773	2325	1.3	960
	1073		1.4	
	1373		1.4	
Mattoni di argilla refrattaria	478	2645	1.0	960
	922		1.5	
	1478		1.8	
Magnesite	478	—	3.8	1130
	922	—	2.8	
	1478		1.9	
Argilla	300	1460	1.3	880
Carbone, antracite	300	1350	0.26	1260
Calcestruzzo (con pietrisco)	300	2300	1.4	880
Cotone	300	80	0.06	1300
Prodotti alimentari				
Banana (contenuto d'acqua 75.7%)	300	980	0.481	3350
Mela, rossa (contenuto d'acqua 75%)	300	840	0.513	3600
Torta, pasta	300	720	0.223	—
Torta, completamente cotta	300	280	0.121	—
Carne di pollo, bianca, (contenuto d'acqua 74.4%)	198	—	1.60	—
	233	—	1.49	
	253		1.35	
	263		1.20	
	273		0.476	
	283		0.480	
	293		0.489	

(Segue)

**TABELLA A.29** Proprietà dei materiali comuni (c) Altri materiali (*Continua*)

Descrizione/composizione	Temp. K	Proprietà tipiche a 300 K		
		Densità $\rho$ kg/m <sup>3</sup>	Conduttività termica $\lambda$ W/m · K	Calore specifico $c_p$ J/kg · K
Vetro				
Lastra (calce sodata)	300	2500	1.4	750
Pyrex	300	2225	1.4	835
Ghiaccio	273	920	1.88	2040
	253	—	2.03	1945
Cuoio (suola)	300	998	0.159	—
Carta	300	930	0.180	1340
Paraffina	300	900	0.240	2890
Roccia				
Granito	300	2630	2.79	775
Calcare	300	2320	2.15	810
Marmo	300	2680	2.80	830
Quarzite	300	2640	5.38	1105
Arenaria	300	2150	2.90	745
Gomma, vulcanizzata				
Tenera	300	1100	0.13	2010
Dura	300	1190	0.16	—
Sabbia	300	1515	0.27	800
Terreno	300	2050	0.52	1840
Neve	273	110	0.049	—
		500	0.190	—
Teflon	300	2200	0.35	—
	400		0.45	—
Tessuto, umano				
Pelle	300	—	0.37	—
Strato grasso (adiposo)	300	—	0.2	—
Muscolo	300	—	0.41	—
Legno, in direzione normale alle fibre				
Balsa	300	140	0.055	—
Cipresso	300	465	0.097	—
Abete	300	415	0.11	2720
Quercia	300	545	0.17	2385
Pino giallo	300	640	0.15	2805
Pino bianco	300	435	0.11	—
Legno, nella direzione delle fibre				
Quercia	300	545	0.19	2385
Abete	300	420	0.14	2720



**TABELLA A.30** Proprietà dell'atmosfera in alta quota

Altitudine m	Temperatura °C	Pressione kPa	Gravità, <i>g</i> m/s <sup>2</sup>	Velocità del suono m/s	Densità kg/m <sup>3</sup>	Viscosità $\mu$ kg/m · s	Conduttività termica $\lambda$ W/m · °C
0	15.00	101.33	9.807	340.3	1.225	$1.789 \times 10^{-5}$	0.0253
200	13.70	98.95	9.806	339.5	1.202	$1.783 \times 10^{-5}$	0.0252
400	12.40	96.61	9.805	338.8	1.179	$1.777 \times 10^{-5}$	0.0252
600	11.10	94.32	9.805	338.0	1.156	$1.771 \times 10^{-5}$	0.0251
800	9.80	92.08	9.804	337.2	1.134	$1.764 \times 10^{-5}$	0.0250
1,000	8.50	89.88	9.804	336.4	1.112	$1.758 \times 10^{-5}$	0.0249
1,200	7.20	87.72	9.803	335.7	1.090	$1.752 \times 10^{-5}$	0.0248
1,400	5.90	85.60	9.802	334.9	1.069	$1.745 \times 10^{-5}$	0.0247
1,600	4.60	83.53	9.802	334.1	1.048	$1.739 \times 10^{-5}$	0.0245
1,800	3.30	81.49	9.801	333.3	1.027	$1.732 \times 10^{-5}$	0.0244
2,000	2.00	79.50	9.800	332.5	1.007	$1.726 \times 10^{-5}$	0.0243
2,200	0.70	77.55	9.800	331.7	0.987	$1.720 \times 10^{-5}$	0.0242
2,400	-0.59	75.63	9.799	331.0	0.967	$1.713 \times 10^{-5}$	0.0241
2,600	-1.89	73.76	9.799	330.2	0.947	$1.707 \times 10^{-5}$	0.0240
2,800	-3.19	71.92	9.798	329.4	0.928	$1.700 \times 10^{-5}$	0.0239
3,000	-4.49	70.12	9.797	328.6	0.909	$1.694 \times 10^{-5}$	0.0238
3,200	-5.79	68.36	9.797	327.8	0.891	$1.687 \times 10^{-5}$	0.0237
3,400	-7.09	66.63	9.796	327.0	0.872	$1.681 \times 10^{-5}$	0.0236
3,600	-8.39	64.94	9.796	326.2	0.854	$1.674 \times 10^{-5}$	0.0235
3,800	-9.69	63.28	9.795	325.4	0.837	$1.668 \times 10^{-5}$	0.0234
4,000	-10.98	61.66	9.794	324.6	0.819	$1.661 \times 10^{-5}$	0.0233
4,200	-12.3	60.07	9.794	323.8	0.802	$1.655 \times 10^{-5}$	0.0232
4,400	-13.6	58.52	9.793	323.0	0.785	$1.648 \times 10^{-5}$	0.0231
4,600	-14.9	57.00	9.793	322.2	0.769	$1.642 \times 10^{-5}$	0.0230
4,800	-16.2	55.51	9.792	321.4	0.752	$1.635 \times 10^{-5}$	0.0229
5,000	-17.5	54.05	9.791	320.5	0.736	$1.628 \times 10^{-5}$	0.0228
5,200	-18.8	52.62	9.791	319.7	0.721	$1.622 \times 10^{-5}$	0.0227
5,400	-20.1	51.23	9.790	318.9	0.705	$1.615 \times 10^{-5}$	0.0226
5,600	-21.4	49.86	9.789	318.1	0.690	$1.608 \times 10^{-5}$	0.0224
5,800	-22.7	48.52	9.785	317.3	0.675	$1.602 \times 10^{-5}$	0.0223
6,000	-24.0	47.22	9.788	316.5	0.660	$1.595 \times 10^{-5}$	0.0222
6,200	-25.3	45.94	9.788	315.6	0.646	$1.588 \times 10^{-5}$	0.0221
6,400	-26.6	44.69	9.787	314.8	0.631	$1.582 \times 10^{-5}$	0.0220
6,600	-27.9	43.47	9.786	314.0	0.617	$1.575 \times 10^{-5}$	0.0219
6,800	-29.2	42.27	9.785	313.1	0.604	$1.568 \times 10^{-5}$	0.0218
7,000	-30.5	41.11	9.785	312.3	0.590	$1.561 \times 10^{-5}$	0.0217
8,000	-36.9	35.65	9.782	308.1	0.526	$1.527 \times 10^{-5}$	0.0212
9,000	-43.4	30.80	9.779	303.8	0.467	$1.493 \times 10^{-5}$	0.0206
10,000	-49.9	26.50	9.776	299.5	0.414	$1.458 \times 10^{-5}$	0.0201
12,000	-56.5	19.40	9.770	295.1	0.312	$1.422 \times 10^{-5}$	0.0195
14,000	-56.5	14.17	9.764	295.1	0.228	$1.422 \times 10^{-5}$	0.0195
16,000	-56.5	10.53	9.758	295.1	0.166	$1.422 \times 10^{-5}$	0.0195
18,000	-56.5	7.57	9.751	295.1	0.122	$1.422 \times 10^{-5}$	0.0195

Fonte: U.S. Standard Atmosphere Supplements, U.S. Government Printing Office, 1966. Valori basati su condizioni mediate su tutto l'anno a 45° di latitudine, essi variano con il tempo dell'anno e le condizioni climatiche. Le condizioni al livello del mare sono:  $p = 101\,325$  Pa,  $T = 15^\circ\text{C}$ ,  $\rho = 1.2250$  Kg/m<sup>3</sup>,  $g = 9.80665$  m<sup>2</sup>/s.

**TABELLA A.31** Emissività di alcune superfici

Materiale	Temperatura K	Emissività $\epsilon$	Materiale	Temperatura K	Emissività $\epsilon$
<b>(a) Metalli</b>					
Alluminio			Magnesio, lucido	300-500	0.07-0.13
Lucido	300-900	0.04-0.06	Mercurio	300-400	0.09-0.12
Foglio commerciale	400	0.09	Molibdeno		
Molto ossidato	400-800	0.20-0.33	Lucido	300-2000	0.05-0.21
Anodizzato	300	0.8	Ossidato	600-800	0.80-0.82
Bismuto, brillante	350	0.34	Nichel		
Ottone			Lucido	500-1200	0.07-0.17
Molto lucido	500-650	0.03-0.04	Ossidato	450-100	0.37-0.57
Lucido	350	0.09	Platino, lucido	500-1500	0.06-0.18
Piastra appannata	300-600	0.22	Argento, lucido	300-1000	0.02-0.07
Ossidato	450-800	0.6	Acciaio inossidabile		
Cromo, lucido	300-1400	0.08-0.40	Lucido	300-1000	0.17-0.30
Rame			Leggermente ossidato	600-1000	0.30-0.40
Molto lucido	300	0.02	Molto ossidato	600-1000	0.70-0.80
Lucido	300-500	0.04-0.05	Acciaio		
Foglio commerciale	300	0.15	Lamierino lucido	300-500	0.08-0.14
Ossidato	600-1000	0.5-0.8	Lamierino commerciale	500-1200	0.20-0.32
Ossidato nero	300	0.78	Molto ossidato	300	0.81
Oro			Stagno, lucido	300	0.05
Molto lucido	300-1000	0.03-0.06	Tungsteno		
Foglio brillante	300	0.07	Lucido	300-2500	0.03-0.29
Ferro			Filamento	3500	0.39
Molto lucido	300-500	0.05-0.07	Zinco		
Ghisa	300	0.44	Lucido	300-800	0.02-0.05
Ferro battuto	300-500	0.28	Ossidato	300	0.25
Arrugginito	300	0.61			
Ossidato	500-900	0.64-0.78			
Piombo					
Lucido	300-500	0.06-0.08			
Nonossidato ruvido	300	0.43			
Ossidato	300	0.63			

(Segue)

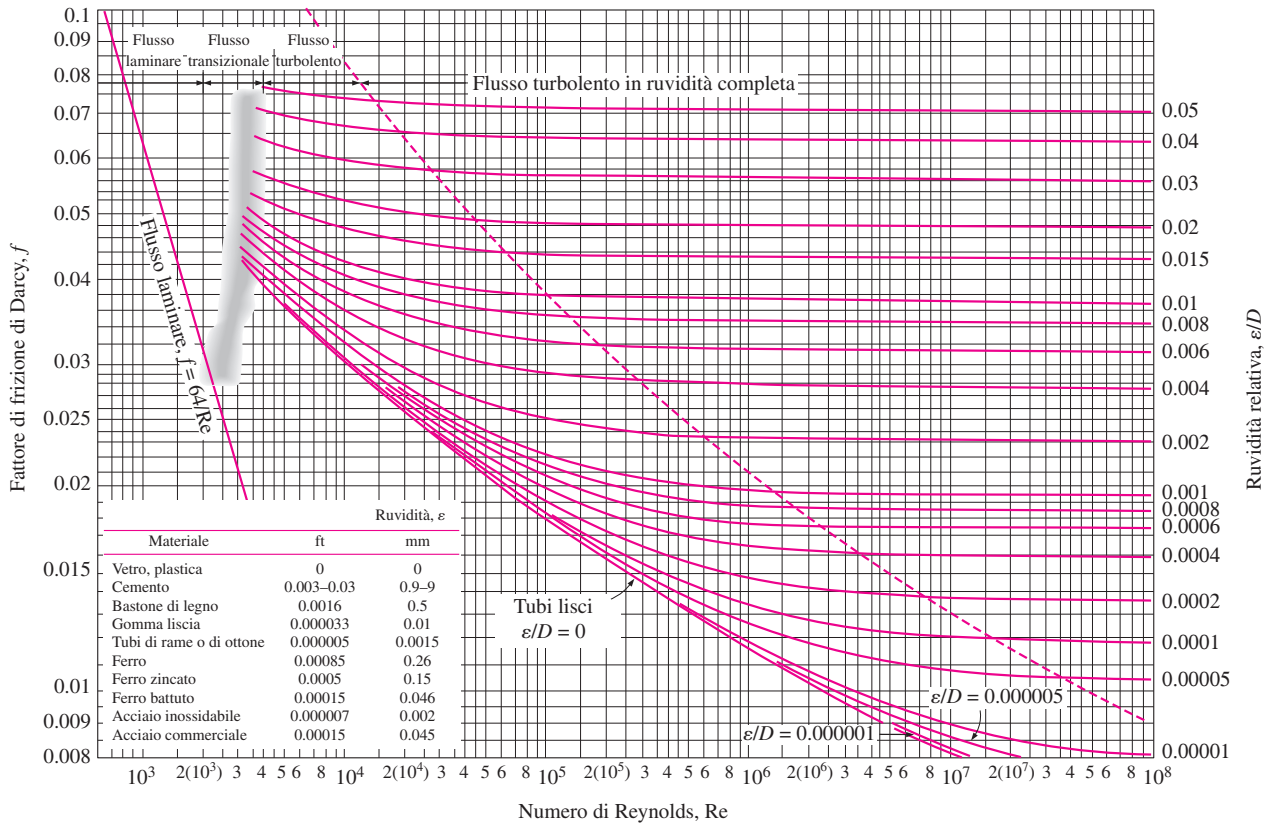
**TABELLA A.31** Emissività di alcune superfici (*Continua*)

Materiale	Temperatura K	Emissività $\epsilon$	Materiale	Temperatura K	Emissività $\epsilon$
<b>(b) Non metalli</b>					
Allumina	800-1400	0.65-0.45	Carta, bianca	300	0.90
Ossido di alluminio	600-1500	0.69-0.41	Intonaco, bianco	300	0.93
Asbesto	300	0.96	Porcellana, vetrata	300	0.92
Pavimento di asfalto	300	0.85-0.93	Quarzo, grezzo, fuso	300	0.93
Laterizio			Gomma		
Comune	300	0.93-0.96	Soffice	300	0.86
Argilla refrattaria	1200	0.75	Dura	300	0.93
Filamento al carbonio	2000	0.53	Sabbia	300	0.90
Stoffa	300	0.75-0.90	Carburo di silicio	600-1500	0.87-0.85
Calcestruzzo	300	0.88-0.94	Pelle umana	300	0.95
Vetro			Neve	273	0.80-0.90
Da finestra	300	0.90-0.95	Terreno, terrestre	300	0.93-0.96
Pyrex	300-1200	0.82-0.62	Nero fumo	300-500	0.95
Pyroceramico	300-1500	0.85-0.57	Teflon	300-500	0.85-0.92
Ghiaccio	273	0.95-0.99	Acqua, profonda	273-373	0.95-0.96
Ossido di magnesio	400-800	0.69-0.55	Legno		
Muratura	300	0.80	Faggio	300	0.94
Vernici			Quercia	300	0.90
Alluminio	300	0.40-0.50			
Nera, laccatura, lucida	300	0.88			
Olii, tutti i colori	300	0.92-0.96			
Acrilico bianco	300	0.90			
Smalto bianco	300	0.90			
Fondo rosso	300	0.93			

**TABELLA A.32** Proprietà di alcuni materiali alla radiazione solare

Descrizione/composizione	Coefficiente di assorbimento solare $\alpha_s$	Emissività $\varepsilon$ a 300 K	Rapporto $\alpha_s/\varepsilon$	Coefficiente di trasmissione solare $\tau_s$
Alluminio				
Lucido	0.09	0.03	3.0	
Anodizzato	0.14	0.84	0.17	
Rivestito al quarzo	0.11	0.37	0.30	
In foglio	0.15	0.05	3.0	
Mattone, rosso	0.63	0.93	0.68	
Calcestruzzo	0.60	0.88	0.68	
Foglio di metallo galvanizzato				
Pulito, nuovo	0.65	0.13	5.0	
Ossidato, atmosferico	0.80	0.28	2.9	
Vetro, spessore 3.2 mm				
In polvere o temprato				0.79
A basso tenore di ferro				0.88
Marmo, leggermente non bianco (non riflettivo)	0.40	0.88	0.45	
Metallo, piastra				
Solfuro nero	0.92	0.10	9.2	
Ossido di cobalto nero	0.93	0.30	3.1	
Ossido di nichel nero	0.92	0.08	11	
Cromo nero	0.87	0.09	9.7	
Mylar, spessore 0.13 mm				0.87
Vernici				
Nera	0.98	0.98	1.0	
Bianca, acrilica	0.26	0.90	0.29	
Bianca, ossido di zinco	0.16	0.93	0.17	
Carta bianca	0.27	0.83	0.32	
Plexiglas, spessore 3.2 mm				0.90
Tegole di porcellana, bianche (superficie vetrata riflettiva)	0.26	0.85	0.30	
Tegole per tetto, rosso vivo				
Superficie secca	0.65	0.85	0.76	
Superficie umida	0.88	0.91	0.96	
Sabbia, secca				
Bianco brillante	0.52	0.82	0.63	
Rosso opaco	0.73	0.86	0.82	
Neve				
In particelle fini, fresca	0.13	0.82	0.16	
Granuli di ghiaccio	0.33	0.89	0.37	
Acciaio				
Finito a specchio	0.41	0.05	8.2	
Molto arrugginito	0.89	0.92	0.96	
Pietra (leggermente rosa)	0.65	0.87	0.74	
Tedlar, spessore 0.10 mm				0.92
Teflon, spessore 0.13 mm				0.92
Legno	0.59	0.90	0.66	

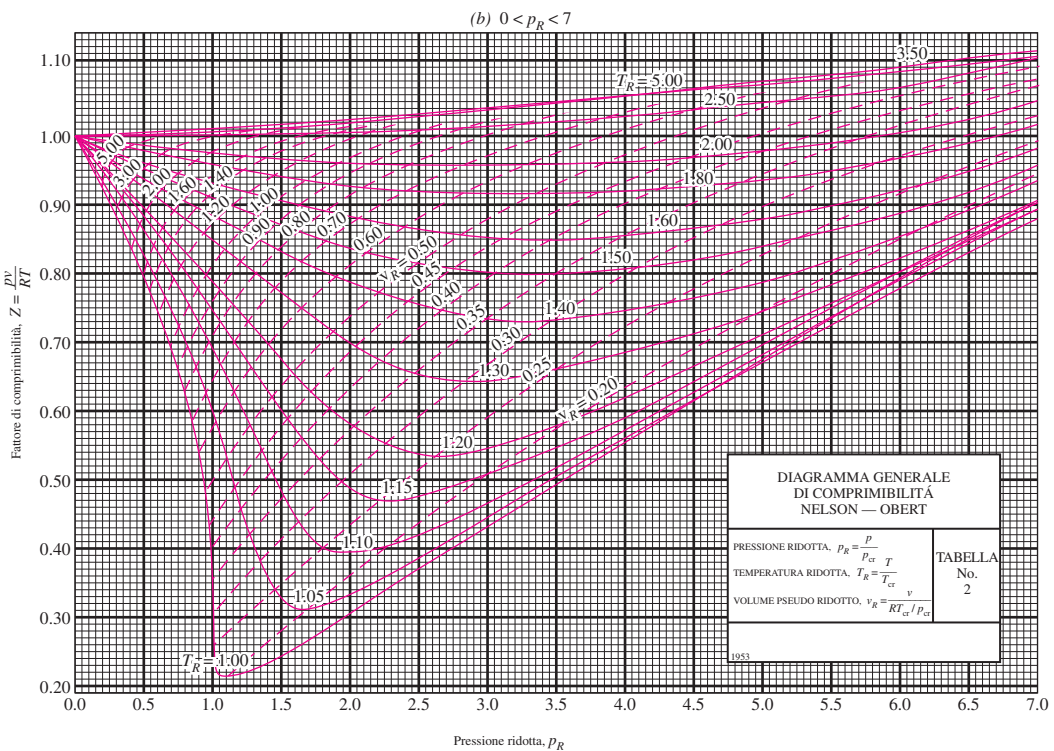
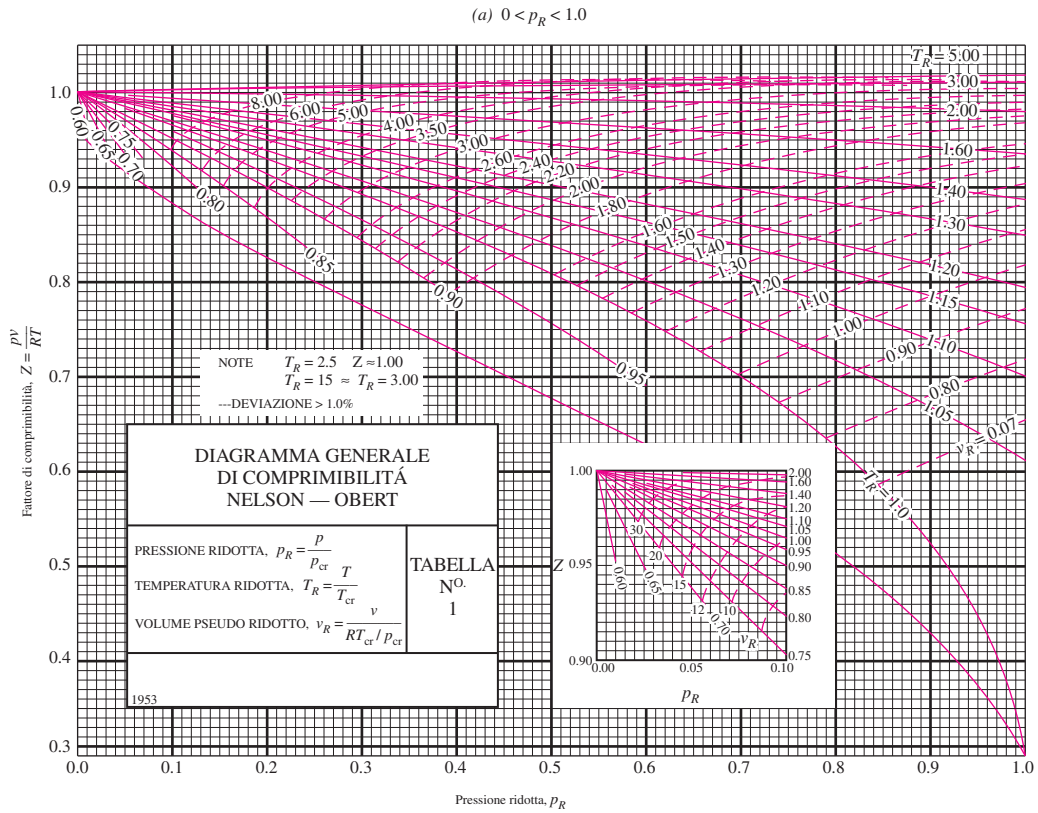
Fonte: V.C. Sharma e A. Sharma, *Solar Properties of Some Building Element*, in «Energy», 1989, vol. 14, pp. 805-10, e altri riferimenti.



**FIGURA A.33**

La tabella di Moody per il fattore di attrito completamente sviluppato dal flusso di tubi circolari per l'uso della perdita di calore in relazione  $h_L = f \frac{L}{D} \frac{w^2}{2g}$ .

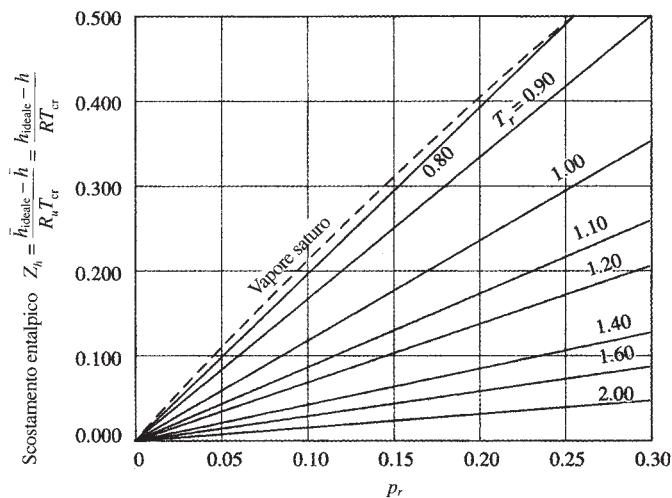
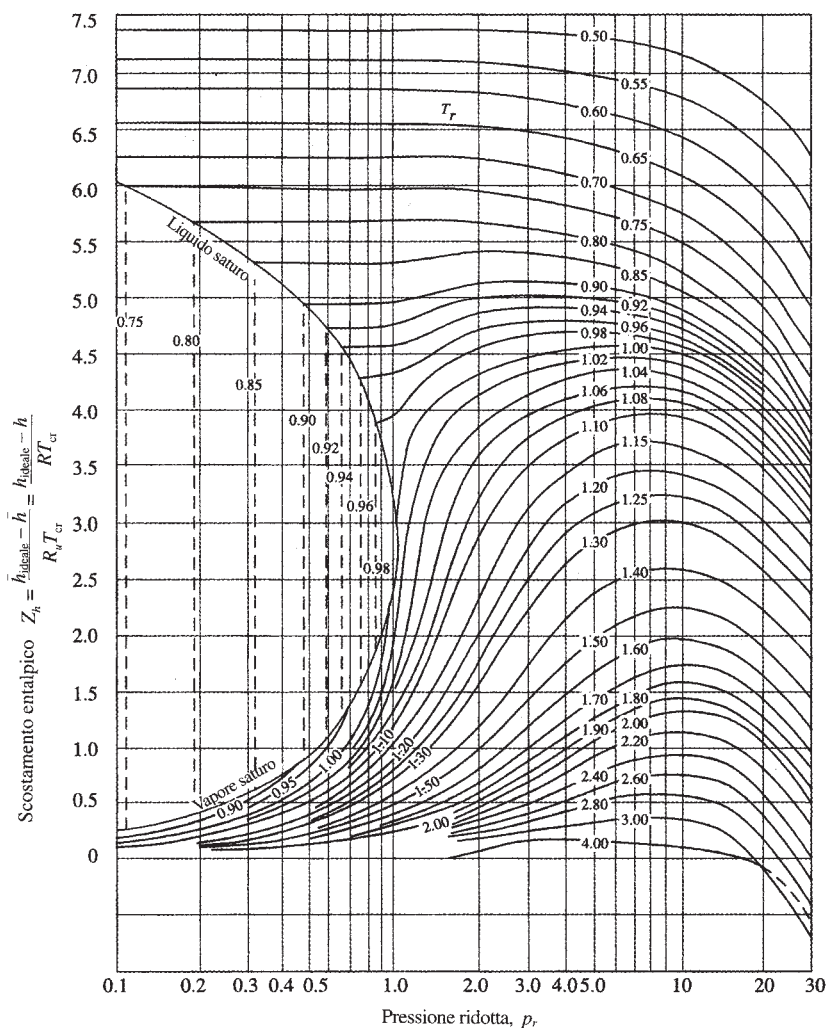
I fattori di attrito nei flussi di turbolenze sono misurati tramite l'equazione di Colebrook  $\frac{1}{\sqrt{f}} = -2 \log_{10} \left( \frac{\epsilon/D}{3.7} + \frac{2.51}{Re \sqrt{f}} \right)$ .



**FIGURA A.34**

Diagramma generale di comprimibilità di Nelson Obert.  
 Riprodotta con il permesso del Dr Edward E. Obert, Università del Winsconsin.

**TABELLA A.35** Tabella generalizzata dello scostamento entalpico



(Fonte: John R. Howell, Richard O. Buckius, Fundamentals of Engineering Thermodynamics, SI Version, McGraw-Hill, New York 1987).

**TABELLA A.36** Proprietà dell'azoto,  $N_2$ , come gas ideale

$T$ K	$\bar{h}$ kJ/kmol	$\bar{u}$ kJ/kmol	$\bar{s}^\circ$ kJ/kmol · K	$T$ K	$\bar{h}$ kJ/kmol	$\bar{u}$ kJ/kmol	$\bar{s}^\circ$ kJ/kmol · K
0	0	0	0	600	17 563	12 574	212.066
220	6 391	4 562	182.639	610	17 864	12 792	212.564
230	6 683	4 770	183.938	620	18 166	13 011	213.055
240	6 975	4 979	185.180	630	18 468	13 230	213.541
250	7 266	5 188	186.370	640	18 772	13 450	214.018
260	7 558	5 396	187.514	650	19 075	13 671	214.489
270	7 849	5 604	188.614	660	19 380	13 892	214.954
280	8 141	5 813	189.673	670	19 685	14 114	215.413
290	8 432	6 021	190.695	680	19 991	14 337	215.866
298	8 669	6 190	191.502	690	20 297	14 560	216.314
300	8 723	6 229	191.682	700	20 604	14 784	216.756
310	9 014	6 437	192.638	710	20 912	15 008	217.192
320	9 306	6 645	193.562	720	21 220	15 234	217.624
330	9 597	6 853	194.459	730	21 529	15 460	218.059
340	9 888	7 061	195.328	740	21 839	15 686	218.472
350	10 180	7 270	196.173	750	22 149	15 913	218.889
360	10 471	7 478	196.995	760	22 460	16 141	219.301
370	10 763	7 687	197.794	770	22 772	16 370	219.709
380	11 055	7 895	198.572	780	23 085	16 599	220.113
390	11 347	8 104	199.331	790	23 398	16 830	220.512
400	11 640	8 314	200.071	800	23 714	17 061	220.907
410	11 932	8 523	200.794	810	24 027	17 292	221.298
420	12 225	8 733	201.499	820	24 342	17 524	221.684
430	12 518	8 943	202.189	830	24 658	17 757	222.067
440	12 811	9 153	202.863	840	24 974	17 990	222.447
450	13 105	9 363	203.523	850	25 292	18 224	222.822
460	13 399	9 574	204.170	860	25 610	18 459	223.194
470	13 693	9 786	204.803	870	25 928	18 695	223.562
480	13 988	9 997	205.424	880	26 248	18 931	223.927
490	14 285	10 210	206.033	890	26 568	19 168	224.288
500	14 581	10 423	206.630	900	26 890	19 407	224.647
510	14 876	10 635	207.216	910	27 210	19 644	225.002
520	15 172	10 848	207.792	920	27 532	19 883	225.353
530	15 469	11 062	208.358	930	27 854	20 122	225.701
540	15 766	11 277	208.914	940	28 178	20 362	226.047
550	16 064	11 492	209.461	950	28 501	20 603	226.389
560	16 363	11 707	209.999	960	28 826	20 844	226.728
570	16 662	11 923	210.528	970	29 151	21 086	227.064
580	16 962	12 139	211.049	980	29 476	21 328	227.398
590	17 262	12 356	211.562	990	29 803	21 571	227.728

(Segue)



TABELLA A.36 Proprietà dell'azoto, N<sub>2</sub>, come gas ideale (Continua)

$T$ K	$\bar{h}$ kJ/kmol	$\bar{u}$ kJ/kmol	$\bar{s}^\circ$ kJ/kmol · K	$T$ K	$\bar{h}$ kJ/kmol	$\bar{u}$ kJ/kmol	$\bar{s}^\circ$ kJ/kmol · K
1000	30 129	21 815	228.057	1760	56 227	41 594	247.396
1020	30 784	22 304	228.706	1780	56 938	42 139	247.798
1040	31 442	22 795	229.344	1800	57 651	42 685	248.195
1060	32 101	23 288	229.973	1820	58 363	43 231	248.589
1080	32 762	23 782	230.591	1840	59 075	43 777	248.979
1100	33 426	24 280	231.199	1860	59 790	44 324	249.365
1120	34 092	24 780	231.799	1880	60 504	44 873	249.748
1140	34 760	25 282	232.391	1900	61 220	45 423	250.128
1160	35 430	25 786	232.973	1920	61 936	45 973	250.502
1180	36 104	26 291	233.549	1940	62 654	46 524	250.874
1200	36 777	26 799	234.115	1960	63 381	47 075	251.242
1220	37 452	27 308	234.673	1980	64 090	47 627	251.607
1240	38 129	27 819	235.223	2000	64 810	48 181	251.969
1260	38 807	28 331	235.766	2050	66 612	49 567	252.858
1280	39 488	28 845	236.302	2100	68 417	50 957	253.726
1300	40 170	29 361	236.831	2150	70 226	52 351	254.578
1320	40 853	29 378	237.353	2200	72 040	53 749	255.412
1340	41 539	30 398	237.867	2250	73 856	55 149	256.227
1360	42 227	30 919	238.376	2300	75 676	56 553	257.027
1380	42 915	31 441	238.878	2350	77 496	57 958	257.810
1400	43 605	31 964	239.375	2400	79 320	59 366	258.580
1420	44 295	32 489	239.865	2450	81 149	60 779	259.332
1440	44 988	33 014	240.350	2500	82 981	62 195	260.073
1460	45 682	33 543	240.827	2550	84 814	63 613	260.799
1480	46 377	34 071	241.301	2600	86 650	65 033	261.512
1500	47 073	34 601	241.768	2650	88 488	66 455	262.213
1520	47 771	35 133	242.228	2700	90 328	67 880	262.902
1540	48 470	35 665	242.685	2750	92 171	69 306	263.577
1560	49 168	36 197	243.137	2800	94 014	70 734	264.241
1580	49 869	36 732	243.585	2850	95 859	72 163	264.895
1600	50 571	37 268	244.028	2900	97 705	73 593	265.538
1620	51 275	37 806	244.464	2950	99 556	75 028	266.170
1640	51 980	38 344	244.896	3000	101 407	76 464	266.793
1660	52 686	38 884	245.324	3050	103 260	77 902	267.404
1680	53 393	39 424	245.747	3100	105 115	79 341	268.007
1700	54 099	39 965	246.166	3150	106 972	80 782	268.601
1720	54 807	40 507	246.580	3200	108 830	82 224	269.186
1740	55 516	41 049	246.990	3250	110 690	83 668	269.763

Fonte: Le Tabelle A.25 e A.26 sono adattate da K. Wark, *Thermodynamics*, 4<sup>a</sup> ed., McGraw Hill, New York 1983, pubblicate originariamente in JANAF, *Thermochemical Tables*, NSRDS-NBS-37, 1971.

**TABELLA A.37** Proprietà dell'ossigeno, O<sub>2</sub>, come gas ideale

<i>T</i> K	<i>h</i> kJ/kmol	<i>u</i> kJ/kmol	<i>s</i> <sup>o</sup> kJ/kmol · K	<i>T</i> K	<i>h</i> kJ/kmol	<i>u</i> kJ/kmol	<i>s</i> <sup>o</sup> kJ/kmol · K
0	0	0	0	600	17 929	12 940	226.346
220	6 404	4 575	196.171	610	18 250	13 178	226.877
230	6 694	4 782	197.461	620	18 572	13 417	227.400
240	6 984	4 989	198.696	630	18 895	13 657	227.918
250	7 275	5 197	199.885	640	19 219	13 898	228.429
260	7 566	5 405	201.027	650	19 544	14 140	228.932
270	7 858	5 613	202.128	660	19 870	14 383	229.430
280	8 150	5 822	203.191	670	20 197	14 626	229.920
290	8 443	6 032	204.218	680	20 524	14 871	230.405
298	8 682	6 203	205.033	690	20 854	15 116	230.885
300	8 736	6 242	205.213	700	21 184	15 364	231.358
310	9 030	6 453	206.177	710	21 514	15 611	231.827
320	9 325	6 664	207.112	720	21 845	15 859	232.291
330	9 620	6 877	208.020	730	22 177	16 107	232.748
340	9 916	7 090	208.904	740	22 510	16 357	233.201
350	10 213	7 303	209.765	750	22 844	16 607	233.649
360	10 511	7 518	210.604	760	23 178	16 859	234.091
370	10 809	7 733	211.423	770	23 513	17 111	234.528
380	11 109	7 949	212.222	780	23 850	17 364	234.960
390	11 409	8 166	213.002	790	24 186	17 618	235.387
400	11 711	8 384	213.765	800	24 523	17 872	235.810
410	12 012	8 603	214.510	810	24 861	18 126	236.230
420	12 314	8 822	215.241	820	25 199	18 382	236.644
430	12 618	9 043	215.955	830	25 537	18 637	237.055
440	12 923	9 264	216.656	840	25 877	18 893	237.462
450	13 228	9 487	217.342	850	26 218	19 150	237.864
460	13 525	9 710	218.016	860	26 559	19 408	238.264
470	13 842	9 935	218.676	870	26 899	19 666	238.660
480	14 151	10 160	219.326	880	27 242	19 925	239.051
490	14 460	10 386	219.963	890	27 584	20 185	239.439
500	14 770	10 614	220.589	900	27 928	20 445	239.823
510	15 082	10 842	221.206	910	28 272	20 706	240.203
520	15 395	11 071	221.812	920	28 616	20 967	240.580
530	15 708	11 301	222.409	930	28 960	21 228	240.953
540	16 022	11 533	222.997	940	29 306	21 491	241.323
550	16 338	11 765	223.576	950	29 652	21 754	241.689
560	16 654	11 998	224.146	960	29 999	22 017	242.052
570	16 971	12 232	224.708	970	30 345	22 280	242.411
580	17 290	12 467	225.262	980	30 692	22 544	242.768
590	17 609	12 703	225.808	990	31 041	22 809	242.120

(Segue)

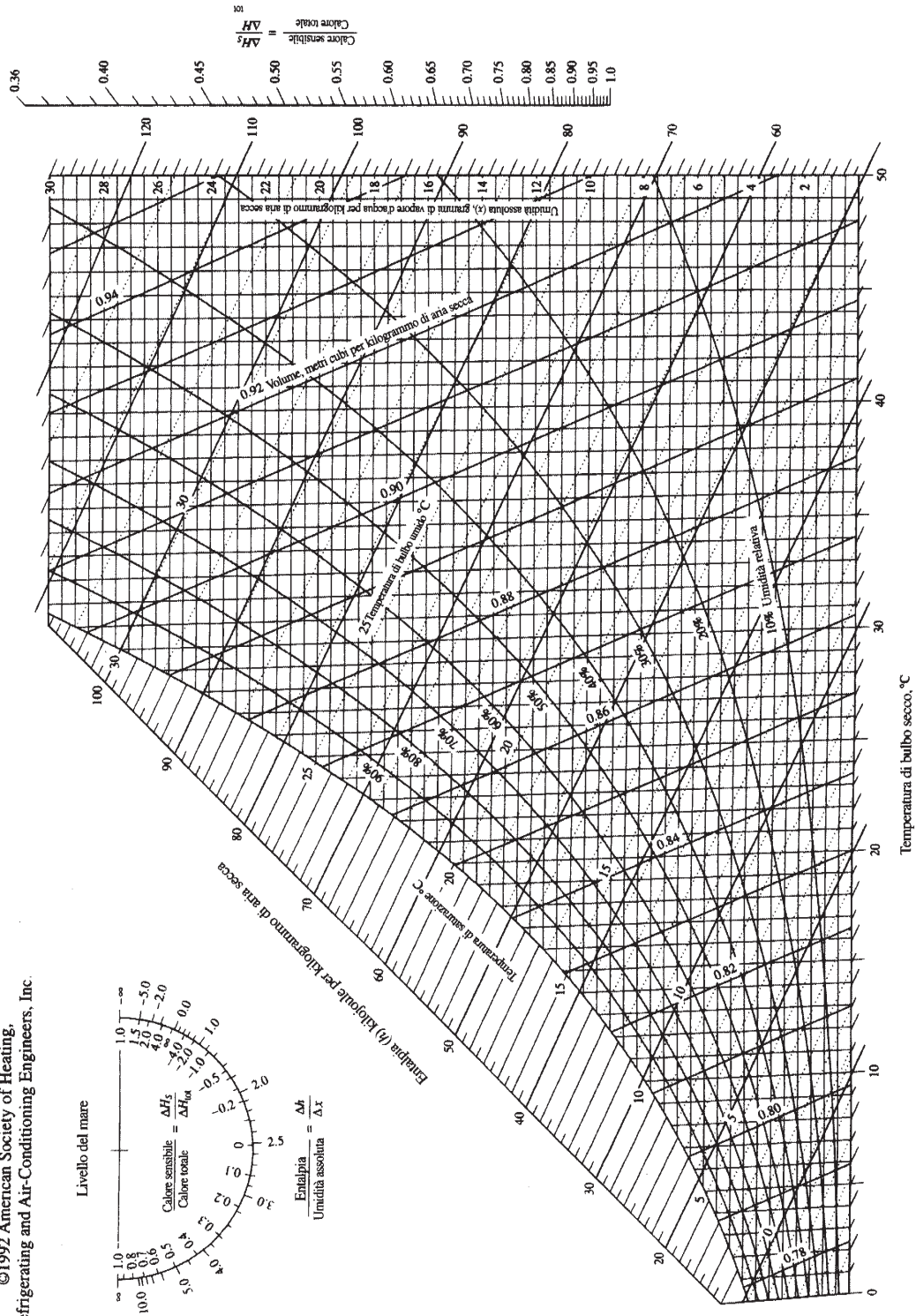
**TABELLA A.37** Proprietà dell'ossigeno, O<sub>2</sub>, come gas ideale (*Continua*)

$T$ K	$h$ kJ/kmol	$u$ kJ/kmol	$s^\circ$ kJ/kmol · K	$T$ K	$h$ kJ/kmol	$u$ kJ/kmol	$s^\circ$ kJ/kmol · K
1000	31 389	23 075	243.471	1760	58 880	44 247	263 861
1020	32 088	23 607	244.164	1780	59 624	44 825	264.283
1040	32 789	24 142	244.844	1800	60 371	45 405	264.701
1060	33 490	24 677	245.513	1820	61 118	45 986	265.113
1080	34 194	25 214	246.171	1840	61 866	46 568	265.521
1100	34 899	25 753	246.818	1860	62 616	47 151	265.925
1120	35 606	26 294	247.454	1880	63 365	47 734	266.326
1140	36 314	26 836	248.081	1900	64 116	48 319	266.722
1160	37 023	27 379	248.698	1920	64 868	48 904	267.115
1180	37 734	27 923	249.307	1940	65 620	49 490	267.505
1200	38 447	28 469	249.906	1960	66 374	50 078	267.891
1220	39 162	29 018	250.497	1980	67 127	50 665	268.275
1240	39 877	29 568	251.079	2000	67 881	51 253	268.655
1260	40 594	30 118	251.653	2050	69 772	52 727	269.588
1280	41 312	30 670	252.219	2100	71 668	54 208	270.504
1300	42 033	31 224	252.776	2150	73 573	55 697	271.399
1320	42 753	31 778	253.325	2200	75 484	57 192	272.278
1340	43 475	32 334	253.868	2250	77 397	58 690	273.136
1360	44 198	32 891	254.404	2300	79 316	60 193	273.891
1380	44 923	33 449	254.932	2350	81 243	61 704	274.809
1400	45 648	34 008	255.454	2400	83 174	63 219	275.625
1420	46 374	34 567	255.968	2450	85 112	64 742	276.424
1440	47 102	35 129	256.475	2500	87 057	66 271	277.207
1460	47 831	35 692	256.978	2550	89 004	67 802	277.979
1480	48 561	36 256	257.474	2600	90 956	69 339	278.738
1500	49 292	36 821	257.965	2650	92 916	70 883	279.485
1520	50 024	37 387	258.450	2700	94 881	72 433	280.219
1540	50 756	37 952	258.928	2750	96 852	73 987	280.942
1560	51 490	38 520	259.402	2800	98 826	75 546	281.654
1580	52 224	39 088	259.870	2850	100 808	77 112	282.357
1600	52 961	39 658	260.333	2900	102 793	78 682	283.048
1620	53 696	40 227	260.791	2950	104 785	80 258	283.728
1640	54 434	40 799	261.242	3000	106 780	81 837	284.399
1660	55 172	41 370	261.690	3050	108 778	83 419	285.060
1680	55 912	41 944	262.132	3100	110 784	85 009	285.713
1700	56 652	42 517	262.571	3150	112 795	86 601	286.355
1720	57 394	43 093	263.005	3200	114 809	88 203	286.989
1740	58 136	43 669	263.435	3250	116 827	89 804	287.614



ASHRAE Diagramma psicrometrico N. 1  
 Temperatura normale  
 Pressione barometrica: 101.325 Pa

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**FIGURA A.38**  
 Diagramma psicrometrico alla pressione di 101.325 Pa.

**TABELLA A.39** Pressioni di saturazione del vapore d'acqua per temperature da -34.9 a +34.9 °C

°C	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
-34	0.0347	0.0344	0.0340	0.0337	0.0334	0.0331	0.0327	0.0324	0.0321	0.0318
-33	0.0383	0.0379	0.0375	0.0372	0.0368	0.0365	0.0361	0.0358	0.0354	0.0351
-32	0.0422	0.0417	0.0413	0.0410	0.0406	0.0402	0.0398	0.0394	0.0390	0.0386
-31	0.0464	0.0459	0.0455	0.0451	0.0446	0.0442	0.0438	0.0434	0.0430	0.0426
-30	0.0510	0.0505	0.0500	0.0496	0.0491	0.0486	0.0482	0.0477	0.0473	0.0468
-29	0.0560	0.0555	0.0550	0.0545	0.0539	0.0534	0.0529	0.0524	0.0520	0.0515
-28	0.0615	0.0609	0.0603	0.0598	0.0592	0.0587	0.0581	0.0576	0.0571	0.0565
-27	0.0674	0.0668	0.0662	0.0656	0.0650	0.0644	0.0638	0.0632	0.0626	0.0620
-26	0.0738	0.0732	0.0725	0.0719	0.0712	0.0706	0.0699	0.0693	0.0686	0.0680
-25	0.0808	0.0801	0.0794	0.0787	0.0780	0.0773	0.0766	0.0759	0.0752	0.0745
-24	0.0884	0.0876	0.0869	0.0861	0.0853	0.0846	0.0838	0.0831	0.0823	0.0816
-23	0.0966	0.0958	0.0949	0.0941	0.0933	0.0925	0.0916	0.0908	0.0900	0.0892
-22	0.1055	0.1046	0.1037	0.1028	0.1019	0.1010	0.1001	0.0992	0.0984	0.0975
-21	0.1152	0.1142	0.1132	0.1122	0.1112	0.1103	0.1093	0.1084	0.1074	0.1065
-20	0.1256	0.1245	0.1234	0.1224	0.1213	0.1203	0.1192	0.1182	0.1172	0.1162
-19	0.1368	0.1357	0.1345	0.1334	0.1322	0.1311	0.1300	0.1289	0.1278	0.1267
-18	0.1490	0.1477	0.1465	0.1452	0.1440	0.1428	0.1416	0.1404	0.1392	0.1380
-17	0.1621	0.1607	0.1594	0.1580	0.1567	0.1554	0.1541	0.1528	0.1515	0.1502
-16	0.1762	0.1747	0.1733	0.1718	0.1704	0.1690	0.1676	0.1662	0.1648	0.1634
-15	0.1914	0.1898	0.1883	0.1867	0.1852	0.1837	0.1821	0.1806	0.1791	0.1777
-14	0.2078	0.2061	0.2044	0.2027	0.2011	0.1994	0.1978	0.1962	0.1946	0.1930
-13	0.2254	0.2236	0.2218	0.2200	0.2182	0.2164	0.2147	0.2129	0.2112	0.2095
-12	0.2444	0.2424	0.2405	0.2385	0.2366	0.2347	0.2328	0.2310	0.2291	0.2272
-11	0.2647	0.2626	0.2605	0.2584	0.2564	0.2543	0.2523	0.2503	0.2483	0.2463
-10	0.2866	0.2843	0.2821	0.2798	0.2776	0.2754	0.2733	0.2711	0.2690	0.2668
-9	0.3100	0.3076	0.3052	0.3028	0.3004	0.2981	0.2957	0.2934	0.2911	0.2888
-8	0.3352	0.3326	0.3300	0.3274	0.3249	0.3224	0.3199	0.3174	0.3149	0.3124
-7	0.3621	0.3593	0.3566	0.3538	0.3511	0.3484	0.3457	0.3430	0.3404	0.3378
-6	0.3910	0.3880	0.3850	0.3821	0.3792	0.3763	0.3734	0.3705	0.3677	0.3649
-5	0.4218	0.4187	0.4155	0.4124	0.4092	0.4061	0.4031	0.4000	0.3970	0.3940
-4	0.4549	0.4515	0.4481	0.4447	0.4414	0.4381	0.4348	0.4315	0.4283	0.4250
-3	0.4902	0.4866	0.4829	0.4794	0.4758	0.4722	0.4687	0.4652	0.4618	0.4583
-2	0.5279	0.5240	0.5202	0.5163	0.5125	0.5088	0.5050	0.5013	0.4975	0.4939
-1	0.5682	0.5641	0.5599	0.5559	0.5518	0.5477	0.5437	0.5397	0.5358	0.5318

(Segue)

**TABELLA A.39** Pressioni di saturazione del vapore d'acqua per temperature da  $-34.9$  a  $+34.9$  °C (*Continua*)

°C	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
0	0.6112	0.6157	0.6201	0.6247	0.6292	0.6338	0.6384	0.6430	0.6477	0.6523
1	0.6571	0.6618	0.6666	0.6714	0.6762	0.6811	0.6860	0.6909	0.6959	0.7009
2	0.7059	0.7110	0.7161	0.7212	0.7264	0.7316	0.7368	0.7420	0.7473	0.7527
3	0.7580	0.7634	0.7688	0.7743	0.7798	0.7853	0.7909	0.7964	0.8021	0.8077
4	0.8134	0.8192	0.8250	0.8308	0.8366	0.8425	0.8484	0.8544	0.8603	0.8664
5	0.8724	0.8785	0.8847	0.8909	0.8971	0.9033	0.9096	0.9160	0.9223	0.9287
6	0.9352	0.9417	0.9482	0.9548	0.9614	0.9680	0.9747	0.9814	0.9882	0.9950
7	1.002	1.009	1.016	1.023	1.030	1.037	1.044	1.051	1.058	1.065
8	1.073	1.080	1.087	1.095	1.102	1.110	1.117	1.125	1.133	1.140
9	1.148	1.156	1.164	1.171	1.179	1.187	1.195	1.203	1.212	1.220
10	1.228	1.236	1.244	1.253	1.261	1.270	1.278	1.287	1.295	1.304
11	1.313	1.321	1.330	1.339	1.348	1.357	1.366	1.375	1.384	1.393
12	1.402	1.412	1.421	1.430	1.440	1.449	1.459	1.468	1.478	1.488
13	1.498	1.507	1.517	1.527	1.537	1.547	1.557	1.568	1.578	1.588
14	1.598	1.609	1.619	1.630	1.640	1.651	1.662	1.673	1.683	1.694
15	1.705	1.716	1.727	1.738	1.750	1.761	1.772	1.784	1.795	1.807
16	1.818	1.830	1.841	1.853	1.865	1.877	1.889	1.901	1.913	1.925
17	1.938	1.950	1.962	1.975	1.987	2.000	2.013	2.025	2.038	2.051
18	2.064	2.077	2.090	2.103	2.116	2.130	2.143	2.157	2.170	2.184
19	2.197	2.211	2.225	2.239	2.253	2.267	2.281	2.295	2.310	2.324
20	2.338	2.353	2.367	2.382	2.397	2.412	2.427	2.442	2.457	2.472
21	2.487	2.502	2.518	2.533	2.549	2.565	2.580	2.596	2.612	2.628
22	2.644	2.660	2.677	2.693	2.709	2.726	2.743	2.759	2.776	2.793
23	2.810	2.827	2.844	2.861	2.879	2.896	2.914	2.931	2.949	2.967
24	2.984	3.002	3.021	3.039	3.057	3.075	3.094	3.112	3.131	3.150
25	3.169	3.187	3.207	3.226	3.245	3.264	3.284	3.303	3.323	3.343
26	3.362	3.382	3.402	3.423	3.443	3.463	3.484	3.504	3.525	3.546
27	3.567	3.588	3.609	3.630	3.651	3.673	3.694	3.716	3.738	3.759
28	3.781	3.803	3.826	3.848	3.870	3.893	3.916	3.938	3.961	3.984
29	4.007	4.031	4.054	4.077	4.101	4.125	4.149	4.173	4.197	4.221
30	4.245	4.270	4.294	4.319	4.344	4.369	4.394	4.419	4.444	4.469
31	4.495	4.521	4.546	4.572	4.598	4.625	4.651	4.677	4.704	4.731
32	4.758	4.785	4.812	4.839	4.866	4.894	4.921	4.949	4.977	5.005
33	5.033	5.062	5.090	5.119	5.147	5.176	5.205	5.235	5.264	5.293
34	5.323	5.353	5.382	5.413	5.443	5.473	5.503	5.534	5.565	5.596