

**UNIVERSITI SAINS MALAYSIA**

**Peperiksaan Semester Kedua  
Sidang Akademik 1997/98**

**Februari 1998**

**IOK 223 - Termodinamik**

**Masa : [3 jam]**

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Sila pastikan bahawa kertas soalan ini mengandungi SEMBILAN BELAS (19) mukasurat termasuk lampiran yang bercetak sebelum anda memulakan peperiksaan ini.

Jawab DUA (2) dari TIGA (3) soalan dari bahagian A dan semua soalan di Bahagian B. Semua soalan mesti dijawab di dalam Bahasa Malaysia.

**BAHAGIAN A**

1. (a) Terangkan perbezaan antara sebutan-sebutan berikut:

- (i) fungsi keadaan dengan fungsi laluan
- (ii) sistem terbuka dengan sistem tertutup.

(8 markah)

(b) Suatu gas di dalam bekas anjal mengembang dengan hasil darab tekanan dan isipadu adalah malar dalam proses tersebut, iaitu:

$$PV = C$$

'C' adalah pemalar.

(i) Dapatkan persamaan kerja yang dijalankan oleh gas ke keliling semasa pengembangan  $P_1, V_1$  ke  $P_2, V_2$ .

(ii) Bandingkan kerja yang dilakukan menggunakan laluan di (i) dengan laluan yang mempunyai keadaan mula dan akhir yang sama tetapi terdiri dari proses isipadu malar hingga tekanan jatuh ke  $P_2$  diikuti dengan proses tekanan malar yang berhenti pada keadaan 2.

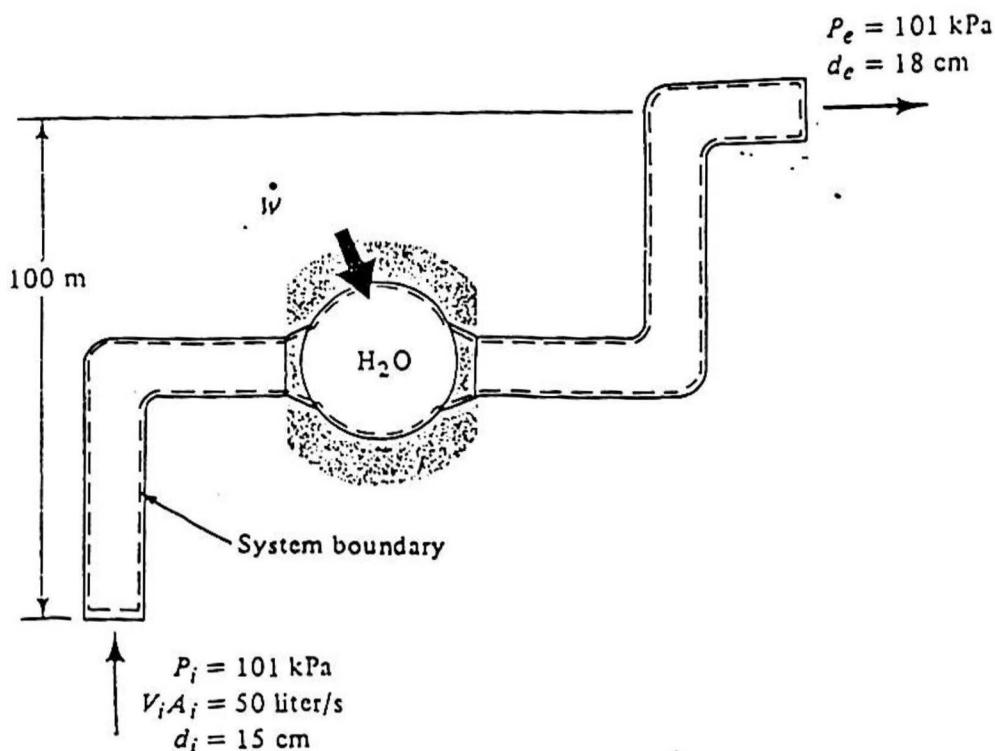
Lakarkan gambarajah P - V bagi kedua-dua proses 1 dan 2.

(8 markah)

...3/-

- (c) Satu pam digunakan untuk menaikkan air pada kadar aliran 50 liter/s seperti yang ditunjukkan di Rajah 1. Garispusat paip masukan ialah 15 cm dan garispusat paip keluaran ialah 18 cm. Kuasa input kepada pam ialah 60 kW. Air diambil dari satu tasik pada tekanan atmosfera dan 20°C dan dikeluarkan 100 m atas paras tasik pada tekanan atmosfera. Pam tersebut adalah tertebat dan pemanasan air akibat kesan-kesan geseran adalah kecil dan boleh diabaikan. Kirakan suhu air pada paip keluaran.

(9 markah)



Rajah 1

...4/-

2. (a) Secara ringkas, terangkan sebutan-sebutan berikut:

- (i) sifat khas
- (ii) sistem thermodinamik
- (iii) adiabatik
- (iv) politropik

(8 markah)

(b) Satu gas unggul mengalir melalui tiub melintang pada keadaan mantap. Tiada haba yang ditambah dan tiada kerja shaf yang dilakukan. Luas keratan tiub berubah bersama panjang, dan menyebabkan halaju berubah. Terbitkan persamaan yang mengaitkan suhu dengan halaju gas. Jika nitrogen pada  $150^{\circ}\text{C}$  mengalir pada satu keratan tiub pada halaju  $2.5 \text{ m/s}$ , apakah suhu pada keratan lain di mana halajunya ialah  $50 \text{ m/s}$ .  $C_p = (7/2)\text{R}$ .

(7 markah)

(c) Satu mol gas unggul dengan  $C_p = (7/2)\text{R}$  dan  $C_v = (5/2)\text{R}$  mengembang dari  $P_1 = 8 \text{ bar}$  dan  $T_1 = 600 \text{ K}$  ke  $P_2 = 1 \text{ bar}$  menggunakan setiap laluan-laluan berikut:

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- (i) isipadu malar
- (ii) suhu malar
- (iii) secara adiabatik

Dengan menganggap proses di atas adalah bolehbalik mekanikal, hitung W, Q, U dan H bagi setiap proses. Lakarkan setiap laluan menggunakan satu gambarajah P-V.

(10 markah)

3. (a) (i) Apakah yang dimaksudkan dengan kualiti stim lembab?
- (ii) Adakah kenyataan bahawa ‘air mendidih pada suhu yang lebih tinggi pada tekanan yang lebih tinggi’ benar? Terangkan.
- (iii) Lakar dan labelkan satu gambarajah P-T (gambarajah fasa) bagi bahan tulin yang mengecut bila beku.

(8 markah)

...6/-

- (b) 3 mol nitrogen pada  $30^{\circ}\text{C}$ , terkandung dalam bekas tegar dipanaskan ke  $250^{\circ}\text{C}$ . Berapa banyakkah haba yang diperlukan jika bekas tersebut mempunyai kemudahan haba yang boleh diabaikan? Jika bekas tersebut adalah 100 kg dan mempunyai kemudahan haba  $0.5 \text{ kJ/kg } ^{\circ}\text{C}$ , berapa banyakkah haba yang diperlukan? Ambil nilai  $C_v = 20.8$  dan  $C_p = 29.1 \text{ J/mol bagi gas nitrogen.}$

(8 markah)

- (c) Satu periuk tekanan menggunakan pengatur tekanan untuk menghadkan tekanan tolak dalaman kepada 99 kPa. Jumlah air yang cukup telah ditambah sebelum dimasak untuk memastikan keadaan tepu wujud semasa proses pemasakan. Keadaan ini membenarkan proses masakan pada suhu terkawal, biasanya tinggi dari  $100^{\circ}\text{C}$ , dan dengan itu masa memasak dikurangkan. Pada mulanya suhu yang sederhana digunakan sehingga periuk tekanan tersebut mencapai tekanan pengendalian. Kadar aliran haba kemudiannya dikurangkan untuk mengurangkan kehilangan lembapan melalui pengatur tekanan semasa proses masakan.

Katakan, semasa tekanan pengendalian (operating pressure) dicapai pada mulanya, periuk tekanan mengandungi 0.25 kg campuran cecair air dan wap, dan isipadu periuk ialah  $0.004 \text{ m}^3$ . Tentukan

- (i) suhu di mana proses pemasakan terjadi
- (ii) jisim cecair dan jisim wap semasa tekanan pengendalian dicapai.

(9 markah)

## BAHAGIAN B

(4) Hukum Termodinamik Kedua (15 Markah)

Suatu pam haba Carnot mengambil haba daripada atmosfera pada  $30^{\circ}\text{C}$  dan membekal haba kepada takungan suhu malar ("constant-temperature reservoir") pada 420 K. Pam haba itu menerima kuasanya daripada suatu enjin haba yang mengambil 400 kJ/s haba daripada takungan suhu malar pada 1050 K. Enjin haba itu juga mengeluarkan haba kepada takungan 420 K yang tersebut di atas. Kecekapan termal enjin haba itu hanya 50% kecekapan enjin haba Carnot yang beroperasi di antara suhu-suhu yang sama.

Kirakan kuantiti-kuantiti yang berikut:

- kuasa yang dibekalkan kepada pam haba oleh enjin haba
- angkali prestasi ("coefficient of performance") pam haba
- pecahan haba kepada takungan suhu malar 420 K yang dibekalkan oleh pam haba (yang lain dibekalkan oleh enjin haba)

(5) Entropi (10 Markah)

Adalah suatu blok loyang ("brass") 3 kg pada suhu 800 K dan suatu blok inkonel (suatu aloi logam) 3 kg pada suhu 400 K yang disambungkan. Haba dibiarkan mengalir daripada blok loyang kepada blok inkonel sehingga kedua-dua blok mencapai keseimbangan ("equilibrium"), di mana suhu kedua-dua blok adalah sama. Dalam seluruh proses itu tiada apa-apa kesan daripada alam sekitar. Andaikan bahawa haba tentu loyang adalah malar pada 0.4 kJ/kg  $^{\circ}\text{C}$  dan haba tentu inkonel adalah malar pada 0.8 kJ/kg  $^{\circ}\text{C}$ .

- Apakah suhu keseimbangan selepas proses berlaku?
- Apakah perubahan jumlahan entropi?
- Adakah proses ini boleh balik ("reversible"), tak boleh balik ("irreversible"), atau mustahil?

(6) Enjin Pembakar Dalam (15 Markah)

Terangkan secara ringkas setiap satu kitar kuasa gas yang disenaraikan di bawah ini. Untuk setiap satu kitar, lukiskan gambarajah  $T_s$  yang sesuai dan terangkan setiap satu proses dalam kitar itu. Senaraikan juga sekurang-kurangnya satu aplikasi bagi setiap satu kitar.

- Kitar Otto Standard Udara
- Kitar Diesel Standard Udara
- Kitar Brayton Standard Udara

...9/-

(7) Kilang Kuasa Stim (10 Markah)

Kirakan kecekapan termal sesuatu kitar Rankine unggul ("ideal Rankine cycle") di mana stim keluar daripada dandang sebagai wap tepu ("saturated vapor") pada 30 bar dan kemudian dipeluwapkan ("condensed") pada 0.1 bar. Bandingkan kecekapan itu dengan kecekapan kitar Carnot di antara suhu maksimum dan suhu minimum yang sama.

**TABLE A-13M**  
**Properties of saturated water: Pressure table**  
 $v$ ,  $\text{cm}^3/\text{g}$ ;  $u$ ,  $\text{kJ/kg}$ ;  $h$ ,  $\text{kJ/kg}$ ;  $s$ ,  $\text{kJ/(kg \cdot K)}$ ; 1 bar = 0.1 MPa

| Pres.<br>bars<br><i>P</i> | Temp.<br>°C<br><i>T</i> | Specific volume                        |                                       | Internal energy                        |                                       | Enthalpy                               |                                | Entropy                               |  |
|---------------------------|-------------------------|--|---------------------------------------|--|---------------------------------------|--|--------------------------------|---------------------------------------|--|
|                           |                         | Sat.<br>liquid<br><i>r<sub>f</sub></i> | Sat.<br>vapor<br><i>r<sub>v</sub></i> | Sat.<br>liquid<br><i>u<sub>f</sub></i> | Sat.<br>vapor<br><i>u<sub>v</sub></i> | Sat.<br>liquid<br><i>h<sub>f</sub></i> | Evap.<br><i>h<sub>fg</sub></i> | Sat.<br>vapor<br><i>h<sub>v</sub></i> | Sat.<br>liquid<br><i>s<sub>f</sub></i> |
| .040                      | 28.96                   | 1.0040                                 | 34800                                 | 121.45                                 | 2415.2                                | 121.46                                 | 2432.9                         | 2554.4                                | .4226                                  |
| .060                      | 36.16                   | 1.0064                                 | 23739                                 | 151.53                                 | 2425.0                                | 151.53                                 | 2415.9                         | 2567.4                                | .5210                                  |
| .080                      | 41.51                   | 1.0084                                 | 18103                                 | 173.87                                 | 2432.2                                | 173.88                                 | 2403.1                         | 2577.0                                | .5926                                  |
| 0.10                      | 45.81                   | 1.0102                                 | 14674                                 | 191.82                                 | 2437.9                                | 191.83                                 | 2392.8                         | 2584.7                                | .6493                                  |
| 0.20                      | 60.06                   | 1.0172                                 | 7649                                  | 251.38                                 | 2456.7                                | 251.40                                 | 2358.3                         | 2609.7                                | .8320                                  |
| 0.30                      | 69.10                   | 1.0223                                 | 5229.                                 | 289.20                                 | 2468.4                                | 289.23                                 | 2336.1                         | 2625.3                                | .9439                                  |
| 0.40                      | 75.87                   | 1.0265                                 | 3993.                                 | 317.53                                 | 2477.0                                | 317.58                                 | 2319.2                         | 2636.8                                | 1.0259                                 |
| 0.50                      | 81.33                   | 1.0300                                 | 3240.                                 | 340.44                                 | 2483.9                                | 340.49                                 | 2305.4                         | 2645.9                                | 1.0910                                 |
| 0.60                      | 85.94                   | 1.0331                                 | 2732.                                 | 359.79                                 | 2489.6                                | 359.86                                 | 2293.6                         | 2653.5                                | 1.1453                                 |
| 0.70                      | 89.95                   | 1.0360                                 | 2365.                                 | 376.63                                 | 2494.5                                | 376.70                                 | 2283.3                         | 2660.0                                | 1.1919                                 |
| 0.80                      | 93.50                   | 1.0380                                 | 2087.                                 | 391.58                                 | 2498.8                                | 391.66                                 | 2274.1                         | 2665.8                                | 1.2329                                 |
| 0.90                      | 96.71                   | 1.0410                                 | 1869.                                 | 405.06                                 | 2502.6                                | 405.15                                 | 2265.7                         | 2670.9                                | 1.2695                                 |
| 1.00                      | 99.63                   | 1.0432                                 | 1694.                                 | 417.36                                 | 2506.1                                | 417.46                                 | 2258.0                         | 2675.5                                | 1.3026                                 |
| 1.50                      | 111.4                   | 1.0528                                 | 1159.                                 | 466.94                                 | 2519.7                                | 467.11                                 | 2226.5                         | 2693.6                                | 1.4336                                 |
| 2.00                      | 120.2                   | 1.0605                                 | 885.7                                 | 504.49                                 | 2529.5                                | 504.70                                 | 2201.9                         | 2706.7                                | 1.5301                                 |
| 2.50                      | 127.4                   | 1.0672                                 | 718.7                                 | 535.10                                 | 2537.2                                | 535.37                                 | 2181.5                         | 2716.9                                | 1.6072                                 |
| 3.00                      | 133.6                   | 1.0732                                 | 605.8                                 | 561.15                                 | 2543.6                                | 561.47                                 | 2163.8                         | 2725.3                                | 1.6718                                 |
| 3.50                      | 138.9                   | 1.0786                                 | 524.3                                 | 583.95                                 | 2546.9                                | 584.33                                 | 2148.1                         | 2732.4                                | 1.7275                                 |
| 4.00                      | 143.6                   | 1.0836                                 | 462.5                                 | 604.31                                 | 2553.6                                | 604.74                                 | 2133.8                         | 2738.6                                | 1.7766                                 |
| 4.50                      | 147.9                   | 1.0882                                 | 414.0                                 | 622.25                                 | 2557.6                                | 623.25                                 | 2120.7                         | 2743.9                                | 1.8207                                 |
| 5.00                      | 151.9                   | 1.0926                                 | 374.9                                 | 639.68                                 | 2561.2                                | 640.23                                 | 2108.5                         | 2748.7                                | 1.8607                                 |
| 6.00                      | 158.9                   | 1.1006                                 | 315.7                                 | 669.90                                 | 2567.4                                | 670.56                                 | 2086.3                         | 2756.8                                | 1.9312                                 |
| 7.00                      | 165.0                   | 1.1080                                 | 272.9                                 | 696.44                                 | 2572.5                                | 697.22                                 | 2066.3                         | 2763.5                                | 1.9922                                 |
| 8.00                      | 170.4                   | 1.1148                                 | 240.4                                 | 720.22                                 | 2576.8                                | 721.11                                 | 2048.0                         | 2769.1                                | 2.0462                                 |
| 9.00                      | 175.4                   | 1.1212                                 | 215.0                                 | 741.83                                 | 2580.5                                | 742.83                                 | 2031.1                         | 2773.9                                | 2.0946                                 |
| 10.0                      | 179.9                   | 1.1273                                 | 194.4                                 | 761.68                                 | 2583.6                                | 762.81                                 | 2015.3                         | 2778.1                                | 2.1387                                 |
| 15.0                      | 198.3                   | 1.1539                                 | 131.8                                 | 843.16                                 | 2594.5                                | 844.84                                 | 1947.3                         | 2792.2                                | 2.3150                                 |
| 20.0                      | 212.4                   | 1.1767                                 | 99.63                                 | 906.44                                 | 2600.3                                | 908.79                                 | 1890.7                         | 2799.5                                | 2.4474                                 |
| 25.0                      | 224.0                   | 1.1973                                 | 79.98                                 | 959.11                                 | 2603.1                                | 962.11                                 | 1841.0                         | 2803.1                                | 2.5547                                 |
| 30.0                      | 233.9                   | 1.2165                                 | 66.68                                 | 1004.8                                 | 2604.1                                | 1008.4                                 | 1795.7                         | 2804.2                                | 2.6457                                 |
| 35.0                      | 242.6                   | 1.2347                                 | 57.07                                 | 1045.4                                 | 2603.7                                | 1049.8                                 | 1753.7                         | 2803.4                                | 2.7253                                 |
| 40.0                      | 250.4                   | 1.2522                                 | 49.78                                 | 1082.3                                 | 2602.3                                | 1087.3                                 | 1714.1                         | 2801.4                                | 2.7964                                 |
| 45.0                      | 257.5                   | 1.2692                                 | 44.06                                 | 1116.2                                 | 2600.1                                | 1121.9                                 | 1676.4                         | 2798.3                                | 2.8610                                 |
| 50.0                      | 264.0                   | 1.2859                                 | 39.44                                 | 1147.8                                 | 2597.1                                | 1154.2                                 | 1640.1                         | 2794.3                                | 2.9202                                 |
| 60.0                      | 275.6                   | 1.3187                                 | 32.44                                 | 1205.4                                 | 2589.7                                | 1213.4                                 | 1571.0                         | 2784.3                                | 3.0267                                 |
| 70.0                      | 285.9                   | 1.3513                                 | 27.37                                 | 1257.6                                 | 2580.5                                | 1267.0                                 | 1505.1                         | 2772.1                                | 3.1211                                 |
| 80.0                      | 295.1                   | 1.3842                                 | 23.52                                 | 1305.6                                 | 2569.8                                | 1316.6                                 | 1441.3                         | 2758.0                                | 3.2068                                 |
| 90.0                      | 303.4                   | 1.4178                                 | 20.48                                 | 1350.5                                 | 2557.8                                | 1363.3                                 | 1378.9                         | 2742.1                                | 3.2858                                 |
| 100.                      | 311.1                   | 1.4524                                 | 18.03                                 | 1393.0                                 | 2544.4                                | 1407.6                                 | 1317.1                         | 2724.7                                | 3.3596                                 |
| 110.                      | 318.2                   | 1.4886                                 | 15.99                                 | 1433.7                                 | 2529.8                                | 1450.1                                 | 1255.5                         | 2705.6                                | 3.4295                                 |
| 120.                      | 324.8                   | 1.5267                                 | 14.26                                 | 1473.0                                 | 2513.7                                | 1491.3                                 | 1193.6                         | 2684.9                                | 3.4962                                 |
| 130.                      | 330.9                   | 1.5671                                 | 12.78                                 | 1511.1                                 | 2496.1                                | 1531.5                                 | 1130.7                         | 2662.2                                | 3.5606                                 |
| 140.                      | 336.8                   | 1.6107                                 | 11.49                                 | 1548.6                                 | 2476.8                                | 1571.1                                 | 1066.5                         | 2637.6                                | 3.6232                                 |
| 150.                      | 342.2                   | 1.6581                                 | 10.34                                 | 1585.6                                 | 2455.5                                | 1610.5                                 | 1000.0                         | 2610.5                                | 3.6848                                 |
| 160.                      | 347.4                   | 1.7107                                 | 9.306                                 | 1622.7                                 | 2431.7                                | 1650.1                                 | 930.6                          | 2580.6                                | 3.7461                                 |
| 170.                      | 352.4                   | 1.7702                                 | 8.364                                 | 1660.2                                 | 2405.0                                | 1690.3                                 | 856.9                          | 2547.2                                | 3.8079                                 |
| 180.                      | 357.1                   | 1.8397                                 | 7.489                                 | 1698.9                                 | 2374.3                                | 1732.0                                 | 777.1                          | 2509.1                                | 3.8715                                 |
| 190.                      | 361.5                   | 1.9243                                 | 6.657                                 | 1739.9                                 | 2338.1                                | 1776.5                                 | 688.0                          | 2464.5                                | 3.9388                                 |
| 200.                      | 365.8                   | 2.036                                  | 5.834                                 | 1785.6                                 | 2293.0                                | 1826.3                                 | 583.4                          | 2409.7                                | 4.0139                                 |
| 220.9                     | 374.1                   | 3.155                                  | 3.155                                 | 2029.6                                 | 2029.6                                | 2099.3                                 | 0                              | 2099.3                                | 4.4298                                 |

Source: J. H. Keenan, F. Keyes, P. Hill, and J. Moore, "Steam Tables," Wiley, New York, 1969.

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**TABLE A-4**  
Saturated water: temperature table

| Sat.<br>Temp.,<br>°C | Specific volume<br>m³/kg                     |                                  |                                 | Internal energy<br>kJ/kg         |                          |                                 | Enthalpy<br>kJ/kg                |                          |                                 | Entropy<br>kJ/(kg · K)           |                          |                                 |
|----------------------|--|----------------------------------|---------------------------------|----------------------------------|--------------------------|---------------------------------|----------------------------------|--------------------------|---------------------------------|----------------------------------|--------------------------|---------------------------------|
|                      | Sat.<br>press.,<br>P <sub>sat</sub> ,<br>kPa | Sat.<br>liquid<br>v <sub>f</sub> | Sat.<br>vapor<br>v <sub>x</sub> | Sat.<br>liquid<br>u <sub>f</sub> | Evap.<br>u <sub>fg</sub> | Sat.<br>vapor<br>u <sub>x</sub> | Sat.<br>liquid<br>h <sub>f</sub> | Evap.<br>h <sub>fg</sub> | Sat.<br>vapor<br>h <sub>x</sub> | Sat.<br>liquid<br>s <sub>f</sub> | Evap.<br>s <sub>fg</sub> | Sat.<br>vapor<br>s <sub>x</sub> |
| 0.01                 | 0.6113                                       | 0.001000                         | 206.14                          | 0.0                              | 2375.3                   | 2375.3                          | 0.01                             | 2501.3                   | 2501.4                          | 0.000                            | 9.1562                   | 9.1562                          |
| 5                    | 0.8721                                       | 0.001000                         | 147.12                          | 20.97                            | 2361.3                   | 2382.3                          | 20.98                            | 2489.6                   | 2510.6                          | 0.0761                           | 8.9496                   | 9.0257                          |
| 10                   | 1.2276                                       | 0.001000                         | 106.38                          | 42.00                            | 2347.2                   | 2389.2                          | 42.01                            | 2477.7                   | 2519.8                          | 0.1510                           | 8.7498                   | 8.9008                          |
| 15                   | 1.7051                                       | 0.001001                         | 77.93                           | 62.99                            | 2333.1                   | 2396.1                          | 62.99                            | 2465.9                   | 2528.9                          | 0.2245                           | 8.5569                   | 8.7814                          |
| 20                   | 2.339  | 0.001002                         | 57.79                           | 83.95                            | 2319.0                   | 2402.9                          | 83.96                            | 2454.1                   | 2538.1                          | 0.2966                           | 8.3706                   | 8.6672                          |
| 25                   | 3.169  | 0.001003                         | 43.36                           | 104.88                           | 2304.9                   | 2409.8                          | 104.89                           | 2442.3                   | 2547.2                          | 0.3674                           | 8.1905                   | 8.5580                          |
| 30                   | 4.246  | 0.001004                         | 32.89                           | 125.78                           | 2290.8                   | 2416.6                          | 125.79                           | 2430.5                   | 2556.3                          | 0.4369                           | 8.0164                   | 8.4533                          |
| 35                   | 5.628  | 0.001006                         | 25.22                           | 146.67                           | 2276.7                   | 2423.4                          | 146.68                           | 2418.6                   | 2565.3                          | 0.5053                           | 7.8478                   | 8.3531                          |
| 40                   | 7.384  | 0.001008                         | 19.52                           | 167.56                           | 2262.6                   | 2430.1                          | 167.57                           | 2406.7                   | 2574.3                          | 0.5725                           | 7.6845                   | 8.2570                          |
| 45                   | 9.593  | 0.001010                         | 15.26                           | 188.44                           | 2248.4                   | 2436.8                          | 188.45                           | 2394.8                   | 2583.2                          | 0.6387                           | 7.5261                   | 8.1648                          |
| 50                   | 12.349                                       | 0.001012                         | 12.03                           | 209.32                           | 2234.2                   | 2443.5                          | 209.33                           | 2382.7                   | 2592.1                          | 0.7038                           | 7.3725                   | 8.0763                          |
| 55                   | 15.758                                       | 0.001015                         | 9.568                           | 230.21                           | 2219.9                   | 2450.1                          | 230.23                           | 2370.7                   | 2600.9                          | 0.7679                           | 7.2234                   | 7.9913                          |
| 60                   | 19.940                                       | 0.001017                         | 7.671                           | 251.11                           | 2205.5                   | 2456.6                          | 251.13                           | 2358.5                   | 2609.6                          | 0.8312                           | 7.0784                   | 7.9096                          |
| 65                   | 25.03  | 0.001020                         | 6.197                           | 272.02                           | 2191.1                   | 2463.1                          | 272.06                           | 2346.2                   | 2618.3                          | 0.8935                           | 6.9375                   | 7.830                           |
| 70                   | 31.19  | 0.001023                         | 5.042                           | 292.95                           | 2176.6                   | 2469.6                          | 292.98                           | 2333.8                   | 2626.8                          | 0.9549                           | 6.8004                   | 7.7553                          |
| 75                   | 38.58  | 0.001026                         | 4.131                           | 313.90                           | 2162.0                   | 2475.9                          | 313.93                           | 2321.4                   | 2635.3                          | 1.0155                           | 6.6669                   | 7.6824                          |
| 80                   | 47.39  | 0.001029                         | 3.407                           | 334.86                           | 2147.4                   | 2482.2                          | 334.91                           | 2308.8                   | 2643.7                          | 1.0753                           | 6.5369                   | 7.6122                          |
| 85                   | 57.83  | 0.001033                         | 2.828                           | 355.84                           | 2132.6                   | 2488.4                          | 355.90                           | 2296.0                   | 2651.9                          | 1.1343                           | 6.4102                   | 7.5445                          |
| 90                   | 70.14  | 0.001036                         | 2.361                           | 376.85                           | 2117.7                   | 2494.5                          | 376.92                           | 2283.2                   | 2660.1                          | 1.1925                           | 6.2866                   | 7.4791                          |
| 95                   | 84.55  | 0.001040                         | 1.982                           | 397.88                           | 2102.7                   | 2500.6                          | 397.96                           | 2270.2                   | 2668.1                          | 1.2500                           | 6.1659                   | 7.4159                          |
|                      | Sat.<br>press.,<br>MPa                       |                                  |                                 |                                  |                          |                                 |                                  |                          |                                 |                                  |                          |                                 |
| 100                  | 0.10133                                      | 0.001044                         | 1.6729                          | 418.94                           | 2087.6                   | 2506.5                          | 419.04                           | 2257.0                   | 2676.1                          | 1.3069                           | 6.0480                   | 7.3549                          |
| 105                  | 0.12082                                      | 0.001048                         | 1.4194                          | 440.02                           | 2072.3                   | 2512.4                          | 440.15                           | 2243.7                   | 2683.8                          | 1.3630                           | 5.9328                   | 7.2958                          |
| 110                  | 0.14327                                      | 0.001052                         | 1.2102                          | 461.14                           | 2057.0                   | 2518.1                          | 461.30                           | 2230.2                   | 2691.5                          | 1.4185                           | 5.8202                   | 7.2387                          |
| 115                  | 0.16906                                      | 0.001056                         | 1.0366                          | 482.30                           | 2041.4                   | 2523.7                          | 482.48                           | 2216.5                   | 2699.0                          | 1.4734                           | 5.7100                   | 7.1833                          |
| 120                  | 0.19853                                      | 0.001060                         | 0.8919                          | 503.50                           | 2025.8                   | 2529.3                          | 503.71                           | 2202.6                   | 2706.3                          | 1.5276                           | 5.6020                   | 7.1296                          |
| 125                  | 0.2321                                       | 0.001065                         | 0.7706                          | 524.74                           | 2009.9                   | 2534.6                          | 524.99                           | 2188.5                   | 2713.5                          | 1.5813                           | 5.4962                   | 7.0775                          |
| 130                  | 0.2701                                       | 0.001070                         | 0.6685                          | 546.02                           | 1993.9                   | 2539.9                          | 546.31                           | 2174.2                   | 2720.5                          | 1.6344                           | 5.3925                   | 7.0269                          |
| 135                  | 0.3130                                       | 0.001075                         | 0.5822                          | 567.35                           | 1977.7                   | 2545.0                          | 567.69                           | 2159.6                   | 2727.3                          | 1.6870                           | 5.2907                   | 6.9177                          |
| 140                  | 0.3613                                       | 0.001080                         | 0.5089                          | 588.74                           | 1961.3                   | 2550.0                          | 589.13                           | 2144.7                   | 2733.9                          | 1.7391                           | 5.1908                   | 6.9299                          |
| 145                  | 0.4154                                       | 0.001085                         | 0.4463                          | 610.18                           | 1944.7                   | 2554.9                          | 610.63                           | 2129.6                   | 2740.3                          | 1.7907                           | 5.0926                   | 6.8833                          |
| 150                  | 0.4758                                       | 0.001091                         | 0.3928                          | 631.68                           | 1927.9                   | 2559.5                          | 632.20                           | 2114.3                   | 2746.5                          | 1.8418                           | 4.9960                   | 6.8379                          |
| 155                  | 0.5431                                       | 0.001096                         | 0.3468                          | 653.24                           | 1910.8                   | 2564.1                          | 653.84                           | 2098.6                   | 2752.4                          | 1.8925                           | 4.9010                   | 6.7935                          |
| 160                  | 0.6178                                       | 0.001102                         | 0.3071                          | 674.87                           | 1893.5                   | 2568.4                          | 675.55                           | 2082.6                   | 2758.1                          | 1.9427                           | 4.8075                   | 6.7502                          |
| 165                  | 0.7005                                       | 0.001108                         | 0.2727                          | 696.56                           | 1876.0                   | 2572.5                          | 697.34                           | 2066.2                   | 2763.5                          | 1.9925                           | 4.7153                   | 6.7078                          |
| 170                  | 0.7917                                       | 0.001114                         | 0.2428                          | 718.33                           | 1858.1                   | 2576.5                          | 719.21                           | 2049.5                   | 2768.7                          | 2.0419                           | 4.6244                   | 6.6663                          |
| 175                  | 0.8920                                       | 0.001121                         | 0.2168                          | 740.17                           | 1840.0                   | 2580.2                          | 741.17                           | 2032.4                   | 2773.6                          | 2.0909                           | 4.5347                   | 6.6256                          |
| 180                  | 1.0021                                       | 0.001127                         | 0.19405                         | 762.09                           | 1821.6                   | 2583.7                          | 763.22                           | 2015.0                   | 2778.2                          | 2.1396                           | 4.4461                   | 6.5857                          |
| 185                  | 1.1227                                       | 0.001134                         | 0.17409                         | 784.10                           | 1802.9                   | 2587.0                          | 785.37                           | 1997.1                   | 2782.4                          | 2.1879                           | 4.3586                   | 6.5465                          |
| 190                  | 1.2544                                       | 0.001141                         | 0.15654                         | 806.19                           | 1783.8                   | 2590.0                          | 807.62                           | 1978.8                   | 2786.4                          | 2.2359                           | 4.2720                   | 6.5079                          |
| 195                  | 1.3978                                       | 0.001149                         | 0.14105                         | 828.37                           | 1764.4                   | 2592.8                          | 829.98                           | 1960.0                   | 2790.0                          | 2.2835                           | 4.1863                   | 6.4698                          |

**TABLE A-4**  
Saturated water: temperature table (Continued)

| Sat.<br>Temp.<br>°C | Specific volume<br>m³/kg    |  |                                       | Internal energy<br>kJ/kg               |                                |                                       | Enthalpy<br>kJ/kg                      |                                |                                       | Entropy<br>kJ/(kg · K)                 |                                |                                       |
|---------------------|-----------------------------|--|---------------------------------------|--|--------------------------------|---------------------------------------|--|--------------------------------|---------------------------------------|--|--------------------------------|---------------------------------------|
|                     | Temp.<br>press.<br>T<br>MPa | Sat.<br>liquid<br><i>v<sub>f</sub></i> | Sat.<br>vapor<br><i>v<sub>g</sub></i> | Sat.<br>liquid<br><i>u<sub>f</sub></i> | Evap.<br><i>u<sub>fg</sub></i> | Sat.<br>vapor<br><i>u<sub>g</sub></i> | Sat.<br>liquid<br><i>h<sub>f</sub></i> | Evap.<br><i>h<sub>fg</sub></i> | Sat.<br>vapor<br><i>h<sub>g</sub></i> | Sat.<br>liquid<br><i>s<sub>f</sub></i> | Evap.<br><i>s<sub>fg</sub></i> | Sat.<br>vapor<br><i>s<sub>g</sub></i> |
| 200                 | 1.5538                      | 0.001157                               | 0.12736                               | 850.65                                 | 1744.7                         | 2595.3                                | 852.45                                 | 1940.7                         | 2793.2                                | 2.3309                                 | 4.1014                         | 6.4323                                |
| 205                 | 1.7230                      | 0.001164                               | 0.11521                               | 873.04                                 | 1724.5                         | 2597.5                                | 875.04                                 | 1921.0                         | 2796.0                                | 2.3780                                 | 4.0172                         | 6.3952                                |
| 210                 | 1.9062                      | 0.001173                               | 0.10441                               | 895.53                                 | 1703.9                         | 2599.5                                | 897.76                                 | 1900.7                         | 2798.5                                | 2.4248                                 | 3.9337                         | 6.3585                                |
| 215                 | 2.104                       | 0.001181                               | 0.09479                               | 918.14                                 | 1682.9                         | 2601.1                                | 920.62                                 | 1879.9                         | 2800.5                                | 2.4714                                 | 3.8507                         | 6.3221                                |
| 220                 | 2.318                       | 0.001190                               | 0.08619                               | 940.87                                 | 1661.5                         | 2602.4                                | 943.62                                 | 1858.5                         | 2802.1                                | 2.5178                                 | 3.7683                         | 6.2861                                |
| 225                 | 2.548                       | 0.001199                               | 0.07849                               | 963.73                                 | 1639.6                         | 2603.3                                | 966.78                                 | 1836.5                         | 2803.3                                | 2.5639                                 | 3.6863                         | 6.2503                                |
| 230                 | 2.795                       | 0.001209                               | 0.07158                               | 986.74                                 | 1617.2                         | 2603.9                                | 990.12                                 | 1813.8                         | 2804.0                                | 2.6099                                 | 3.6047                         | 6.2146                                |
| 235                 | 3.060                       | 0.001219                               | 0.06537                               | 1009.89                                | 1594.2                         | 2604.1                                | 1013.62                                | 1790.5                         | 2804.2                                | 2.6558                                 | 3.5233                         | 6.1791                                |
| 240                 | 3.344                       | 0.001229                               | 0.05976                               | 1033.21                                | 1570.8                         | 2604.0                                | 1037.32                                | 1766.5                         | 2803.8                                | 2.7015                                 | 3.4422                         | 6.1437                                |
| 245                 | 3.648                       | 0.001240                               | 0.05471                               | 1056.71                                | 1546.7                         | 2603.4                                | 1061.23                                | 1741.7                         | 2803.0                                | 2.7472                                 | 3.3612                         | 6.1083                                |
| 250                 | 3.973                       | 0.001251                               | 0.05013                               | 1080.39                                | 1522.0                         | 2602.4                                | 1085.36                                | 1716.2                         | 2801.5                                | 2.7927                                 | 3.2802                         | 6.0730                                |
| 255                 | 4.319                       | 0.001263                               | 0.04598                               | 1104.28                                | 1596.7                         | 2600.9                                | 1109.73                                | 1689.8                         | 2799.5                                | 2.8383                                 | 3.1992                         | 6.0375                                |
| 260                 | 4.688                       | 0.001276                               | 0.04221                               | 1128.39                                | 1470.6                         | 2599.0                                | 1134.37                                | 1662.5                         | 2796.9                                | 2.8838                                 | 3.1181                         | 6.0019                                |
| 265                 | 5.081                       | 0.001289                               | 0.03977                               | 1152.74                                | 1443.9                         | 2596.6                                | 1159.28                                | 1634.4                         | 2793.6                                | 2.9294                                 | 3.0368                         | 5.9662                                |
| 270                 | 5.499                       | 0.001302                               | 0.03564                               | 1177.36                                | 1416.3                         | 2593.7                                | 1184.51                                | 1605.2                         | 2789.7                                | 2.9751                                 | 2.9551                         | 5.9301                                |
| 275                 | 5.942                       | 0.001317                               | 0.03279                               | 1202.25                                | 1387.9                         | 2590.2                                | 1210.07                                | 1574.9                         | 2785.0                                | 3.0208                                 | 2.8730                         | 5.8938                                |
| 280                 | 6.412                       | 0.001332                               | 0.03017                               | 1227.46                                | 1358.7                         | 2586.1                                | 1235.99                                | 1543.6                         | 2779.6                                | 3.0668                                 | 2.7903                         | 5.8571                                |
| 285                 | 6.909                       | 0.001348                               | 0.02777                               | 1253.00                                | 1328.4                         | 2581.4                                | 1262.31                                | 1511.0                         | 2773.3                                | 3.1130                                 | 2.7070                         | 5.8199                                |
| 290                 | 7.436                       | 0.001366                               | 0.02557                               | 1278.92                                | 1297.1                         | 2576.0                                | 1289.07                                | 1477.1                         | 2766.2                                | 3.1594                                 | 2.6227                         | 5.7821                                |
| 295                 | 7.993                       | 0.001384                               | 0.02354                               | 1305.2                                 | 1264.7                         | 2569.9                                | 1316.3                                 | 1441.8                         | 2758.1                                | 3.2062                                 | 2.5375                         | 5.7437                                |
| 300                 | 8.581                       | 0.001404                               | 0.02167                               | 1332.0                                 | 1231.0                         | 2563.0                                | 1344.0                                 | 1404.9                         | 2749.0                                | 3.2534                                 | 2.4511                         | 5.7045                                |
| 305                 | 9.202                       | 0.001425                               | 0.019948                              | 1359.3                                 | 1195.9                         | 2555.2                                | 1372.4                                 | 1366.4                         | 2738.7                                | 3.3010                                 | 2.3633                         | 5.6643                                |
| 310                 | 9.856                       | 0.001447                               | 0.018350                              | 1387.1                                 | 1159.4                         | 2546.4                                | 1401.3                                 | 1326.0                         | 2727.3                                | 3.3493                                 | 2.2737                         | 5.6230                                |
| 315                 | 10.547                      | 0.001472                               | 0.016867                              | 1415.5                                 | 1121.1                         | 2536.6                                | 1431.0                                 | 1283.5                         | 2714.5                                | 3.3982                                 | 2.1821                         | 5.5804                                |
| 320                 | 11.274                      | 0.001499                               | 0.015488                              | 1444.6                                 | 1080.9                         | 2525.5                                | 1461.5                                 | 1238.6                         | 2700.1                                | 3.4480                                 | 2.0882                         | 5.5362                                |
| 330                 | 12.845                      | 0.001561                               | 0.012996                              | 1505.3                                 | 993.7                          | 2498.9                                | 1525.3                                 | 1140.6                         | 2665.9                                | 3.5507                                 | 1.8909                         | 5.4417                                |
| 340                 | 14.586                      | 0.001638                               | 0.010797                              | 1570.3                                 | 894.3                          | 2464.6                                | 1594.2                                 | 1027.9                         | 2622.0                                | 3.6594                                 | 1.6763                         | 5.3357                                |
| 350                 | 16.513                      | 0.001740                               | 0.008813                              | 1641.9                                 | 776.6                          | 2418.4                                | 1670.6                                 | 893.4                          | 2563.9                                | 3.7777                                 | 1.4335                         | 5.2112                                |
| 360                 | 18.651                      | 0.001893                               | 0.006945                              | 1725.2                                 | 626.3                          | 2351.5                                | 1760.5                                 | 720.3                          | 2481.0                                | 3.9147                                 | 1.1379                         | 5.0526                                |
| 370                 | 21.03                       | 0.002213                               | 0.004925                              | 1844.0                                 | 384.5                          | 2228.5                                | 1890.5                                 | 441.6                          | 2332.1                                | 4.1106                                 | 0.6865                         | 4.7971                                |
| 374.14              | 22.09                       | 0.003155                               | 0.003155                              | 2029.6                                 | 0                              | 2029.6                                | 2099.3                                 | 0                              | 2099.3                                | 4.4298                                 | 0                              | 4.4298                                |

Source for Tables A-4 through A-6: Joseph H. Keenan, Frederick G. Keyes, Philip G. Hill, and Joan G. Moore, *Steam Tables*, SI Units, Wiley, New York, 1978.

... 12 /-

**TABLE A-5**  
Saturated water: pressure table

| Press.<br>kPa | Sat.<br>$T_w$<br>°C | Specific volume<br>m³/kg |                        | Internal energy<br>kJ/kg |                   |                        | Enthalpy<br>kJ/kg       |                   |                        | Entropy<br>kJ/(kg · K)  |                   |                        |
|---------------|---------------------|--------------------------|------------------------|--------------------------|-------------------|------------------------|-------------------------|-------------------|------------------------|-------------------------|-------------------|------------------------|
|               |                     | Sat.<br>liquid<br>$v_f$  | Sat.<br>vapor<br>$v_g$ | Sat.<br>liquid<br>$u_f$  | Evap.<br>$u_{fg}$ | Sat.<br>vapor<br>$u_g$ | Sat.<br>liquid<br>$h_f$ | Evap.<br>$h_{fg}$ | Sat.<br>vapor<br>$h_g$ | Sat.<br>liquid<br>$s_f$ | Evap.<br>$s_{fg}$ | Sat.<br>vapor<br>$s_g$ |
| 0.6113        | 0.01                | 0.001000                 | 206.14                 | 0.00                     | 2375.3            | 2375.3                 | 0.01                    | 2501.3            | 2501.4                 | 0.0000                  | 9.1562            | 9.1562                 |
| 1.0           | 6.98                | 0.001000                 | 129.21                 | 29.30                    | 2355.7            | 2385.0                 | 29.30                   | 2484.9            | 2514.2                 | 0.1059                  | 8.8697            | 8.9756                 |
| 1.5           | 13.03               | 0.001001                 | 87.98                  | 54.71                    | 2338.6            | 2393.3                 | 54.71                   | 2470.6            | 2525.3                 | 0.1957                  | 8.6322            | 8.8279                 |
| 2.0           | 17.50               | 0.001001                 | 67.00                  | 73.48                    | 2326.0            | 2399.5                 | 73.48                   | 2460.0            | 2533.5                 | 0.2607                  | 8.4629            | 8.7237                 |
| 2.5           | 21.08               | 0.001002                 | 54.25                  | 88.48                    | 2315.9            | 2404.4                 | 88.49                   | 2451.6            | 2540.0                 | 0.3120                  | 8.3311            | 8.6432                 |
| 3.0           | 24.08               | 0.001003                 | 45.67                  | 101.04                   | 2307.5            | 2408.5                 | 101.05                  | 2444.5            | 2545.5                 | 0.3545                  | 8.2231            | 8.5776                 |
| 4.0           | 28.96               | 0.001004                 | 34.80                  | 121.45                   | 2293.7            | 2415.2                 | 121.46                  | 2432.9            | 2554.4                 | 0.4226                  | 8.0520            | 8.4746                 |
| 5.0           | 32.88               | 0.001005                 | 28.19                  | 137.81                   | 2282.7            | 2420.5                 | 137.82                  | 2423.7            | 2561.5                 | 0.4764                  | 7.9187            | 8.3951                 |
| 7.5           | 40.29               | 0.001008                 | 19.24                  | 168.78                   | 2261.7            | 2430.5                 | 168.79                  | 2406.0            | 2574.8                 | 0.5764                  | 7.6750            | 8.2515                 |
| 10            | 45.81               | 0.001010                 | 14.67                  | 191.82                   | 2246.1            | 2437.9                 | 191.83                  | 2392.8            | 2584.7                 | 0.6493                  | 7.5009            | 8.1502                 |
| 15            | 53.97               | 0.001014                 | 10.02                  | 225.92                   | 2222.8            | 2448.7                 | 225.94                  | 2373.1            | 2599.1                 | 0.7549                  | 7.2536            | 8.0085                 |
| 20            | 60.06               | 0.001017                 | 7.649                  | 251.38                   | 2205.4            | 2456.7                 | 251.40                  | 2358.3            | 2609.7                 | 0.8320                  | 7.0766            | 7.9085                 |
| 25            | 64.97               | 0.001020                 | 6.204                  | 271.90                   | 2191.2            | 2463.1                 | 271.93                  | 2346.3            | 2618.2                 | 0.8931                  | 6.9383            | 7.8314                 |
| 30            | 69.10               | 0.001022                 | 5.229                  | 289.20                   | 2179.2            | 2468.4                 | 289.23                  | 2336.1            | 2625.3                 | 0.9439                  | 6.8247            | 7.7686                 |
| 40            | 75.87               | 0.001027                 | 3.993                  | 317.53                   | 2159.5            | 2477.0                 | 317.58                  | 2319.2            | 2636.8                 | 1.0259                  | 6.6441            | 7.6700                 |
| 50            | 81.33               | 0.001030                 | 3.240                  | 340.44                   | 2143.4            | 2483.9                 | 340.49                  | 2305.4            | 2645.9                 | 1.0910                  | 6.5029            | 7.5939                 |
| 75            | 91.78               | 0.001037                 | 2.217                  | 384.31                   | 2112.4            | 2496.7                 | 384.39                  | 2278.6            | 2663.0                 | 1.2130                  | 6.2434            | 7.4564                 |
| Press.<br>MPa |                     |                          |                        |                          |                   |                        |                         |                   |                        |                         |                   |                        |
| 0.100         | 99.63               | 0.001043                 | 1.6940                 | 417.36                   | 2088.7            | 2506.1                 | 417.46                  | 2258.0            | 2675.5                 | 1.3026                  | 6.0568            | 7.3594                 |
| 0.125         | 105.99              | 0.001048                 | 1.3749                 | 444.19                   | 2069.3            | 2513.5                 | 444.32                  | 2241.0            | 2685.4                 | 1.3740                  | 5.9104            | 7.2844                 |
| 0.150         | 111.37              | 0.001053                 | 1.1593                 | 466.94                   | 2052.7            | 2519.7                 | 467.11                  | 2226.5            | 2693.6                 | 1.4336                  | 5.7897            | 7.2233                 |
| 0.175         | 116.06              | 0.001057                 | 1.0036                 | 486.80                   | 2038.1            | 2524.9                 | 486.99                  | 2213.6            | 2700.6                 | 1.4849                  | 5.6868            | 7.1717                 |
| 0.200         | 120.23              | 0.001061                 | 0.8857                 | 504.49                   | 2025.0            | 2529.5                 | 504.70                  | 2201.9            | 2706.7                 | 1.5301                  | 5.5970            | 7.1271                 |
| 0.225         | 124.00              | 0.001064                 | 0.7933                 | 520.47                   | 2013.1            | 2533.6                 | 520.72                  | 2191.3            | 2712.1                 | 1.5706                  | 5.5173            | 7.0878                 |
| 0.250         | 127.44              | 0.001067                 | 0.7187                 | 535.10                   | 2002.1            | 2537.2                 | 535.37                  | 2181.5            | 2716.9                 | 1.6072                  | 5.4455            | 7.0527                 |
| 0.275         | 130.60              | 0.001070                 | 0.6573                 | 548.59                   | 1991.9            | 2540.5                 | 548.89                  | 2172.4            | 2721.3                 | 1.6408                  | 5.3801            | 7.0209                 |
| 0.300         | 133.55              | 0.001073                 | 0.6058                 | 561.15                   | 1982.4            | 2543.6                 | 561.47                  | 2163.8            | 2725.3                 | 1.6718                  | 5.3201            | 6.9919                 |
| 0.325         | 136.30              | 0.001076                 | 0.5620                 | 572.90                   | 1973.5            | 2546.4                 | 573.25                  | 2155.8            | 2729.0                 | 1.7006                  | 5.2646            | 6.9652                 |
| 0.350         | 138.88              | 0.001079                 | 0.5243                 | 583.95                   | 1965.0            | 2548.9                 | 584.33                  | 2148.1            | 2732.4                 | 1.7275                  | 5.2130            | 6.9405                 |
| 0.375         | 141.32              | 0.001081                 | 0.4914                 | 594.40                   | 1956.9            | 2551.3                 | 594.81                  | 2140.8            | 2735.6                 | 1.7528                  | 5.1647            | 6.9175                 |
| 0.40          | 143.63              | 0.001084                 | 0.4625                 | 604.31                   | 1949.3            | 2553.6                 | 604.74                  | 2133.8            | 2738.6                 | 1.7766                  | 5.1193            | 6.8959                 |
| 0.45          | 147.93              | 0.001088                 | 0.4140                 | 622.77                   | 1934.9            | 2557.6                 | 623.25                  | 2120.7            | 2743.9                 | 1.8207                  | 5.0359            | 6.8565                 |
| 0.50          | 151.86              | 0.001093                 | 0.3749                 | 639.68                   | 1921.6            | 2561.2                 | 640.23                  | 2108.5            | 2748.7                 | 1.8607                  | 4.9606            | 6.8213                 |
| 0.55          | 155.48              | 0.001097                 | 0.3427                 | 655.32                   | 1909.2            | 2564.5                 | 665.93                  | 2097.0            | 2753.0                 | 1.8973                  | 4.8920            | 6.7893                 |
| 0.60          | 158.85              | 0.001101                 | 0.3157                 | 669.90                   | 1897.5            | 2567.4                 | 670.56                  | 2086.3            | 2756.8                 | 1.9312                  | 4.8288            | 6.7600                 |
| 0.65          | 162.01              | 0.001104                 | 0.2927                 | 683.56                   | 1886.5            | 2570.1                 | 684.28                  | 2076.0            | 2760.3                 | 1.9627                  | 4.7703            | 6.7331                 |
| 0.70          | 164.97              | 0.001108                 | 0.2729                 | 696.44                   | 1876.1            | 2572.5                 | 697.22                  | 2066.3            | 2763.5                 | 1.9922                  | 4.7158            | 6.7080                 |
| 0.75          | 167.78              | 0.001112                 | 0.2556                 | 708.64                   | 1866.1            | 2574.7                 | 709.47                  | 2057.0            | 2766.4                 | 2.0200                  | 4.6647            | 6.6847                 |
| 0.80          | 170.43              | 0.001115                 | 0.2404                 | 720.22                   | 1856.6            | 2576.8                 | 721.11                  | 2048.0            | 2769.1                 | 2.0462                  | 4.6166            | 6.6628                 |
| 0.85          | 172.96              | 0.001118                 | 0.2270                 | 731.27                   | 1847.4            | 2578.7                 | 732.22                  | 2039.4            | 2771.6                 | 2.0710                  | 4.5711            | 6.6421                 |
| 0.90          | 175.38              | 0.001121                 | 0.2150                 | 741.83                   | 1838.6            | 2580.5                 | 742.83                  | 2031.1            | 2773.9                 | 2.0946                  | 4.5280            | 6.6226                 |
| 0.95          | 177.69              | 0.001124                 | 0.2042                 | 751.95                   | 1830.2            | 2582.1                 | 753.02                  | 2023.1            | 2776.1                 | 2.1172                  | 4.4869            | 6.6041                 |
| 1.00          | 179.91              | 0.001127                 | 0.19444                | 761.68                   | 1822.0            | 2583.6                 | 762.81                  | 2015.3            | 2778.1                 | 2.1387                  | 4.4478            | 6.5865                 |
| 1.10          | 184.09              | 0.001133                 | 0.17753                | 780.09                   | 1806.3            | 2586.4                 | 781.34                  | 2000.4            | 2781.7                 | 2.1792                  | 4.3744            | 6.5536                 |
| 1.20          | 187.99              | 0.001139                 | 0.16333                | 797.29                   | 1791.5            | 2588.8                 | 798.65                  | 1986.2            | 2784.8                 | 2.2166                  | 4.3067            | 6.5233                 |
| 1.30          | 191.64              | 0.001144                 | 0.15125                | 813.44                   | 1777.5            | 2591.0                 | 814.93                  | 1972.7            | 2787.6                 | 2.2515                  | 4.2438            | 6.4953                 |

**TABLE A-5**  
**Saturated water: pressure table (Continued)**

| Sat.<br>Press.<br>MPa | Specific volume<br>m <sup>3</sup> /kg |                                 | Internal energy<br>kJ/kg         |                          |                                 |                                  | Enthalpy<br>kJ/kg        |                                 |                                  | Entropy<br>kJ/(kg · K)   |                                 |        |
|-----------------------|---------------------------------------|---------------------------------|----------------------------------|--------------------------|---------------------------------|----------------------------------|--------------------------|---------------------------------|----------------------------------|--------------------------|---------------------------------|--------|
|                       | Sat.<br>liquid<br>v <sub>f</sub>      | Sat.<br>vapor<br>v <sub>g</sub> | Sat.<br>liquid<br>h <sub>f</sub> | Evap.<br>h <sub>fg</sub> | Sat.<br>vapor<br>h <sub>g</sub> | Sat.<br>liquid<br>h <sub>f</sub> | Evap.<br>h <sub>fg</sub> | Sat.<br>vapor<br>h <sub>g</sub> | Sat.<br>liquid<br>s <sub>f</sub> | Evap.<br>s <sub>fg</sub> | Sat.<br>vapor<br>s <sub>g</sub> |        |
| 1.40                  | 195.07                                | 0.001149                        | 0.14084                          | 828.70                   | 1764.1                          | 2592.8                           | 830.30                   | 1959.7                          | 2790.0                           | 2.2842                   | 4.1850                          | 6.4693 |
| 1.50                  | 198.32                                | 0.001154                        | 0.13177                          | 843.16                   | 1751.3                          | 2594.5                           | 844.89                   | 1947.3                          | 2792.2                           | 2.3150                   | 4.1298                          | 6.4448 |
| 1.75                  | 205.76                                | 0.001166                        | 0.11349                          | 876.46                   | 1721.4                          | 2597.8                           | 878.50                   | 1917.9                          | 2796.4                           | 2.3851                   | 4.0044                          | 6.3896 |
| 2.00                  | 212.42                                | 0.001177                        | 0.09963                          | 906.44                   | 1693.8                          | 2600.3                           | 908.79                   | 1890.7                          | 2799.5                           | 2.4474                   | 3.8935                          | 6.3409 |
| 2.25                  | 218.45                                | 0.001187                        | 0.08875                          | 933.83                   | 1668.2                          | 2602.0                           | 936.49                   | 1865.2                          | 2801.7                           | 2.5035                   | 3.7937                          | 6.2972 |
| 2.5                   | 223.99                                | 0.001197                        | 0.07998                          | 959.11                   | 1644.0                          | 2603.1                           | 962.11                   | 1841.0                          | 2803.1                           | 2.5547                   | 3.7028                          | 6.2575 |
| 3.0                   | 233.90                                | 0.001217                        | 0.06668                          | 1004.78                  | 1599.3                          | 2604.1                           | 1008.42                  | 1795.7                          | 2804.2                           | 2.6457                   | 3.5412                          | 6.1869 |
| 3.5                   | 242.60                                | 0.001235                        | 0.05707                          | 1045.43                  | 1558.3                          | 2603.7                           | 1049.75                  | 1753.7                          | 2803.4                           | 2.7253                   | 3.4000                          | 6.1253 |
| 4                     | 250.40                                | 0.001252                        | 0.04978                          | 1082.31                  | 1520.0                          | 2602.3                           | 1087.31                  | 1714.1                          | 2801.4                           | 2.7964                   | 3.2737                          | 6.0701 |
| 5                     | 263.99                                | 0.001286                        | 0.03944                          | 1147.81                  | 1449.3                          | 2597.1                           | 1154.23                  | 1640.1                          | 2794.3                           | 2.9202                   | 3.0532                          | 5.9734 |
| 6                     | 275.64                                | 0.001319                        | 0.03244                          | 1205.44                  | 1384.3                          | 2589.7                           | 1213.35                  | 1571.0                          | 2784.3                           | 3.0267                   | 2.8625                          | 5.8892 |
| 7                     | 285.88                                | 0.001351                        | 0.027437                         | 1257.55                  | 1323.0                          | 2580.5                           | 1267.00                  | 1505.1                          | 2772.1                           | 3.1211                   | 2.6922                          | 5.8133 |
| 8                     | 295.06                                | 0.001384                        | 0.02352                          | 1305.57                  | 1264.2                          | 2569.8                           | 1316.64                  | 1441.3                          | 2758.0                           | 3.2068                   | 2.5364                          | 5.7432 |
| 9                     | 303.40                                | 0.001418                        | 0.02048                          | 1350.51                  | 1207.3                          | 2557.8                           | 1363.26                  | 1378.9                          | 2742.1                           | 3.2858                   | 2.3915                          | 5.6722 |
| 10                    | 311.06                                | 0.001452                        | 0.018026                         | 1393.04                  | 1151.4                          | 2544.4                           | 1407.56                  | 1317.1                          | 2724.7                           | 3.3596                   | 2.2544                          | 5.6141 |
| 11                    | 318.15                                | 0.001489                        | 0.015987                         | 1433.7                   | 1096.0                          | 2529.8                           | 1450.1                   | 1255.5                          | 2705.6                           | 3.4295                   | 2.1233                          | 5.5527 |
| 12                    | 324.75                                | 0.001527                        | 0.014263                         | 1473.0                   | 1040.7                          | 2513.7                           | 1491.3                   | 1193.3                          | 2684.9                           | 3.4962                   | 1.9962                          | 5.4924 |
| 13                    | 330.93                                | 0.001567                        | 0.012780                         | 1511.1                   | 985.0                           | 2496.1                           | 1531.5                   | 1130.7                          | 2662.2                           | 3.5606                   | 1.8718                          | 5.4323 |
| 14                    | 336.75                                | 0.001611                        | 0.011485                         | 1548.6                   | 928.2                           | 2476.8                           | 1571.1                   | 1066.5                          | 2637.6                           | 3.6232                   | 1.7485                          | 5.3717 |
| 15                    | 342.24                                | 0.001658                        | 0.010337                         | 1585.6                   | 869.8                           | 2455.5                           | 1610.5                   | 1000.0                          | 2610.5                           | 3.6848                   | 1.6249                          | 5.3098 |
| 16                    | 347.44                                | 0.001711                        | 0.009306                         | 1622.7                   | 809.0                           | 2431.7                           | 1650.1                   | 930.6                           | 2580.6                           | 3.7461                   | 1.4994                          | 5.2455 |
| 17                    | 352.37                                | 0.001770                        | 0.008364                         | 1660.2                   | 744.8                           | 2405.0                           | 1690.3                   | 856.9                           | 2547.2                           | 3.8079                   | 1.3698                          | 5.1777 |
| 18                    | 357.06                                | 0.001840                        | 0.007489                         | 1698.9                   | 675.4                           | 2374.3                           | 1732.0                   | 777.1                           | 2509.1                           | 3.8715                   | 1.2329                          | 5.1044 |
| 19                    | 361.54                                | 0.001924                        | 0.006657                         | 1739.9                   | 598.1                           | 2338.1                           | 1776.5                   | 688.0                           | 2464.5                           | 3.9388                   | 1.0839                          | 5.0228 |
| 20                    | 365.81                                | 0.002036                        | 0.005834                         | 1785.6                   | 507.5                           | 2293.0                           | 1826.3                   | 583.4                           | 2409.7                           | 4.0139                   | 0.9130                          | 4.9269 |
| 21                    | 369.89                                | 0.002207                        | 0.004952                         | 1842.1                   | 388.5                           | 2230.6                           | 1888.4                   | 446.2                           | 2334.6                           | 4.1075                   | 0.6938                          | 4.8013 |
| 22                    | 373.80                                | 0.002742                        | 0.003568                         | 1961.9                   | 125.2                           | 2087.1                           | 2022.2                   | 143.4                           | 2165.6                           | 4.3110                   | 0.2216                          | 4.5327 |
| 22.09                 | 374.14                                | 0.003155                        | 0.003155                         | 2029.6                   | 0                               | 2029.6                           | 2099.3                   | 0                               | 2099.3                           | 4.4298                   | 0                               | 4.4298 |

14/-

**TABLE A-6**  
**Superheated water**

| T<br>°C                        | v<br>m³/kg | h<br>kJ/kg | s<br>kJ/(kg · K) | v<br>m³/kg                     | h<br>kJ/kg | s<br>kJ/(kg · K) | v<br>m³/kg | h<br>kJ/kg                     | s<br>kJ/(kg · K) |
|--------------------------------|------------|------------|------------------|--------------------------------|------------|------------------|------------|--------------------------------|------------------|
| <i>P = 0.01 MPa (45.81°C)*</i> |            |            |                  | <i>P = 0.05 MPa (81.33°C)</i>  |            |                  |            | <i>P = 0.10 MPa (99.63°C)</i>  |                  |
| Sal. <sup>t</sup>              | 14.674     | 2437.9     | 2584.7           | 8.1502                         | 3.240      | 2483.9           | 2645.9     | 7.5939                         | 1.6940           |
| 50                             | 14.869     | 2443.9     | 2592.6           | 8.1749                         |            |                  |            |                                | 2506.1           |
| 100                            | 17.196     | 2515.5     | 2687.5           | 8.4479                         | 3.418      | 2511.6           | 2682.5     | 7.6947                         | 2675.5           |
| 150                            | 19.512     | 2587.9     | 2783.0           | 8.6882                         | 3.889      | 2585.6           | 2780.1     | 7.9401                         | 2776.2           |
| 200                            | 21.825     | 2661.3     | 2879.5           | 8.9038                         | 4.356      | 2659.9           | 2877.7     | 8.1580                         | 2875.3           |
| 250                            | 24.136     | 2736.0     | 2977.3           | 9.1002                         | 4.820      | 2735.0           | 2976.0     | 8.3556                         | 2974.3           |
| 300                            | 26.445     | 2812.1     | 3076.5           | 9.2813                         | 5.284      | 2811.3           | 3075.5     | 8.5373                         | 3074.3           |
| 400                            | 31.063     | 2968.9     | 3279.6           | 9.6077                         | 6.209      | 2968.5           | 3278.9     | 8.8642                         | 3278.2           |
| 500                            | 35.679     | 3132.3     | 3489.1           | 9.8978                         | 7.134      | 3132.0           | 3488.7     | 9.1546                         | 3488.1           |
| 600                            | 40.295     | 3302.5     | 3705.4           | 10.1608                        | 8.057      | 3302.2           | 3705.1     | 9.4178                         | 3704.4           |
| 700                            | 44.911     | 3479.6     | 3928.7           | 10.4028                        | 8.981      | 3479.4           | 3928.5     | 9.6599                         | 3925.2           |
| 800                            | 49.526     | 3663.8     | 4159.0           | 10.6281                        | 9.904      | 3663.6           | 4158.9     | 9.8852                         | 4158.6           |
| 900                            | 54.141     | 3855.0     | 4396.4           | 10.8396                        | 10.828     | 3854.9           | 4396.3     | 10.0967                        | 4396.1           |
| 1000                           | 58.757     | 4053.0     | 4640.6           | 11.0393                        | 11.751     | 4052.9           | 4640.5     | 10.2964                        | 4640.3           |
| 1100                           | 63.372     | 4257.5     | 4891.2           | 11.2287                        | 12.674     | 4257.4           | 4891.1     | 10.4859                        | 4891.0           |
| 1200                           | 67.987     | 4467.9     | 5147.8           | 11.4091                        | 13.597     | 4467.8           | 5147.7     | 10.6662                        | 5147.6           |
| 1300                           | 72.602     | 4683.7     | 5409.7           | 11.5811                        | 14.521     | 4683.6           | 5409.6     | 10.8382                        | 5409.5           |
| <i>P = 0.20 MPa (120.23°C)</i> |            |            |                  | <i>P = 0.30 MPa (133.55°C)</i> |            |                  |            | <i>P = 0.40 MPa (143.63°C)</i> |                  |
| Sal.                           | 0.8857     | 2529.5     | 2706.7           | 7.1272                         | 0.6058     | 2543.6           | 2725.3     | 6.9919                         | 0.4625           |
| 150                            | 0.9596     | 2576.9     | 2768.8           | 7.2795                         | 0.6339     | 2570.8           | 2761.0     | 7.0778                         | 0.4708           |
| 200                            | 1.0803     | 2654.4     | 2870.5           | 7.5066                         | 0.7163     | 2650.7           | 2865.6     | 7.3115                         | 0.5342           |
| 250                            | 1.1988     | 2731.2     | 2971.0           | 7.7086                         | 0.7964     | 2728.7           | 2967.6     | 7.5166                         | 0.5951           |
| 300                            | 1.3162     | 2808.6     | 3071.8           | 7.8926                         | 0.8753     | 2806.7           | 3069.3     | 7.7022                         | 0.6548           |
| 400                            | 1.5493     | 2966.7     | 3276.6           | 8.2218                         | 1.0315     | 2965.6           | 3275.0     | 8.0330                         | 0.7726           |
| 500                            | 1.7814     | 3130.8     | 3487.1           | 8.5133                         | 1.1867     | 3130.0           | 3486.0     | 8.3251                         | 0.8893           |
| 600                            | 2.013      | 3301.4     | 3704.0           | 8.7770                         | 1.3414     | 3300.8           | 3703.2     | 8.5892                         | 1.0055           |
| 700                            | 2.244      | 3478.8     | 3927.6           | 9.0194                         | 1.4957     | 3478.4           | 3927.1     | 8.8319                         | 1.1215           |
| 800                            | 2.475      | 3663.1     | 4158.2           | 9.2449                         | 1.6499     | 3662.9           | 4157.8     | 9.0576                         | 1.2372           |
| 900                            | 2.705      | 3854.5     | 4395.8           | 9.4566                         | 1.8041     | 3854.2           | 4395.4     | 9.2692                         | 1.3529           |
| 1000                           | 2.937      | 4052.5     | 4640.0           | 9.6563                         | 1.9581     | 4052.3           | 4639.7     | 9.4690                         | 1.4685           |
| 1100                           | 3.168      | 4257.0     | 4890.7           | 9.8458                         | 2.1121     | 4256.8           | 4890.4     | 9.6585                         | 1.5840           |
| 1200                           | 3.399      | 4467.5     | 5147.5           | 10.0262                        | 2.2661     | 4467.2           | 5147.1     | 9.8389                         | 1.6996           |
| 1300                           | 3.630      | 4683.2     | 5409.3           | 10.1982                        | 2.4201     | 4683.0           | 5409.0     | 10.0110                        | 1.8151           |
| <i>P = 0.50 MPa (151.86°C)</i> |            |            |                  | <i>P = 0.60 MPa (158.85°C)</i> |            |                  |            | <i>P = 0.80 MPa (170.43°C)</i> |                  |
| Sal.                           | 0.3749     | 2561.2     | 2748.7           | 6.8213                         | 0.3157     | 2567.4           | 2756.8     | 6.7600                         | 0.2404           |
| 200                            | 0.4249     | 2642.9     | 2855.4           | 7.0592                         | 0.3520     | 2638.9           | 2850.1     | 6.9665                         | 0.2608           |
| 250                            | 0.4744     | 2723.5     | 2960.7           | 7.2709                         | 0.3938     | 2720.9           | 2957.2     | 7.1816                         | 0.2931           |
| 300                            | 0.5226     | 2802.9     | 3064.2           | 7.4599                         | 0.4344     | 2801.0           | 3061.6     | 7.3724                         | 0.3241           |
| 350                            | 0.5701     | 2882.6     | 3167.7           | 7.6329                         | 0.4742     | 2881.2           | 3165.7     | 7.5464                         | 0.3544           |
| 400                            | 0.6173     | 2963.2     | 3271.9           | 7.7938                         | 0.5137     | 2962.1           | 3270.3     | 7.7079                         | 0.3843           |
| 500                            | 0.7109     | 3128.4     | 3483.9           | 8.0873                         | 0.5920     | 3127.6           | 3482.8     | 8.0021                         | 0.4433           |
| 600                            | 0.8041     | 3299.6     | 3701.7           | 7.3522                         | 0.6697     | 3299.1           | 3700.9     | 8.2674                         | 0.5018           |
| 700                            | 0.8969     | 3477.5     | 3925.9           | 8.5952                         | 0.7472     | 3477.0           | 3925.3     | 8.5107                         | 0.5601           |
| 800                            | 0.9896     | 3662.1     | 4156.9           | 8.8211                         | 0.8245     | 3661.8           | 4156.5     | 8.7367                         | 0.6181           |
| 900                            | 1.0822     | 3853.6     | 4394.7           | 9.0329                         | 0.9017     | 3853.4           | 4394.4     | 8.9486                         | 0.6761           |
| 1000                           | 1.1747     | 4051.8     | 4639.1           | 9.2328                         | 0.9788     | 4051.5           | 4638.8     | 9.1485                         | 0.7340           |
| 1100                           | 1.2672     | 4256.3     | 4889.9           | 9.4224                         | 1.0559     | 4256.1           | 4889.6     | 9.3381                         | 0.7919           |
| 1200                           | 1.3596     | 4466.8     | 5146.6           | 9.6029                         | 1.1330     | 4466.5           | 5146.3     | 9.5185                         | 0.8497           |
| 1300                           | 1.4521     | 4682.5     | 5408.6           | 9.7749                         | 1.2101     | 4682.3           | 5408.3     | 9.6906                         | 0.9076           |

\*The temperature in parentheses is the saturation temperature at the specified pressure.

<sup>t</sup>Properties of saturated vapor at the specified pressure.

**TABLE A-6**  
**Superheated water (Continued)**

| T<br>°C                        | v<br>m³/kg | u<br>kJ/kg | h<br>kJ/kg | s<br>kJ/(kg · K) | v<br>m³/kg | u<br>kJ/kg | h<br>kJ/kg | s<br>kJ/(kg · K) | v<br>m³/kg | u<br>kJ/kg | h<br>kJ/kg | s<br>kJ/(kg · K) |
|--------------------------------|------------|------------|------------|------------------|------------|------------|------------|------------------|------------|------------|------------|------------------|
| <i>P = 1.00 MPa (179.91°C)</i> |            |            |            |                  |            |            |            |                  |            |            |            |                  |
| Sat.                           | 0.19444    | 2583.6     | 2778.1     | 6.5865           | 0.16333    | 2588.8     | 2784.8     | 6.6231           | 0.14084    | 2591.8     | 2790.0     | 6.6891           |
| 200                            | 0.2060     | 2621.9     | 2827.9     | 6.6940           | 0.16930    | 2612.8     | 2815.9     | 6.5898           | 0.14302    | 2603.1     | 2803.3     | 6.4975           |
| 250                            | 0.2327     | 2709.9     | 2942.6     | 6.9247           | 0.19234    | 2704.2     | 2935.0     | 6.8294           | 0.16350    | 2698.3     | 2927.2     | 6.7467           |
| 300                            | 0.2579     | 2793.2     | 3051.2     | 7.1229           | 0.2138     | 2789.2     | 3045.8     | 7.0317           | 0.18228    | 2785.2     | 3040.4     | 6.9534           |
| 350                            | 0.2825     | 2875.2     | 3157.7     | 7.3011           | 0.2345     | 2872.2     | 3153.6     | 7.2121           | 0.2003     | 2869.2     | 3149.5     | 7.1360           |
| 400                            | 0.3066     | 2957.3     | 3263.9     | 7.4651           | 0.2548     | 2954.9     | 3260.7     | 7.3774           | 0.2178     | 2952.5     | 3257.5     | 7.3026           |
| 500                            | 0.3541     | 3124.4     | 3478.5     | 7.7622           | 0.2946     | 3122.8     | 3476.3     | 7.6759           | 0.2521     | 3121.1     | 3474.1     | 7.6027           |
| 600                            | 0.4011     | 3296.8     | 3697.9     | 8.0290           | 0.3339     | 3295.6     | 3696.3     | 7.9435           | 0.2860     | 3294.4     | 3694.8     | 7.8710           |
| 700                            | 0.4478     | 3475.3     | 3923.1     | 8.2731           | 0.3729     | 3474.4     | 3922.0     | 8.1881           | 0.3195     | 3473.6     | 3920.8     | 8.1160           |
| 800                            | 0.4943     | 3660.4     | 4154.7     | 8.4996           | 0.4118     | 3659.7     | 4153.8     | 8.4148           | 0.3528     | 3659.0     | 4153.0     | 8.3431           |
| 900                            | 0.5407     | 3852.2     | 4392.9     | 8.7118           | 0.4505     | 3851.6     | 4392.2     | 8.6272           | 0.3861     | 3851.1     | 4391.5     | 8.5556           |
| 1000                           | 0.5871     | 4050.5     | 4637.6     | 8.9119           | 0.4892     | 4050.0     | 4637.0     | 8.8274           | 0.4192     | 4049.5     | 4636.4     | 8.7559           |
| 1100                           | 0.6335     | 4255.1     | 4888.6     | 9.1017           | 0.5278     | 4254.6     | 4888.0     | 9.0172           | 0.4524     | 4254.1     | 4887.5     | 8.9457           |
| 1200                           | 0.6798     | 4465.6     | 5145.4     | 9.2822           | 0.5665     | 4465.1     | 5144.9     | 9.1977           | 0.4855     | 4464.7     | 5144.4     | 9.1262           |
| 1300                           | 0.7261     | 4681.3     | 5407.4     | 9.4543           | 0.6051     | 4680.9     | 5407.0     | 9.3698           | 0.5186     | 4680.4     | 5406.5     | 9.2984           |
| <i>P = 1.60 MPa (201.41°C)</i> |            |            |            |                  |            |            |            |                  |            |            |            |                  |
| Sat.                           | 0.12380    | 2596.0     | 2794.0     | 6.4218           | 0.11042    | 2598.4     | 2797.1     | 6.3794           | 0.09963    | 2600.3     | 2799.5     | 6.3409           |
| 225                            | 0.13287    | 2644.7     | 2857.3     | 6.5518           | 0.11673    | 2636.6     | 2846.7     | 6.4808           | 0.10377    | 2628.3     | 2835.8     | 6.4147           |
| 250                            | 0.14184    | 2692.3     | 2919.2     | 6.6732           | 0.12497    | 2686.0     | 2911.0     | 6.6066           | 0.11144    | 2679.6     | 2902.5     | 6.5453           |
| 300                            | 0.15862    | 2781.1     | 3034.8     | 6.8844           | 0.14021    | 2776.9     | 3029.2     | 6.8226           | 0.12547    | 2772.6     | 3023.5     | 6.7664           |
| 350                            | 0.17456    | 2866.1     | 3145.4     | 7.0694           | 0.15457    | 2863.0     | 3141.2     | 7.0100           | 0.13857    | 2859.8     | 3137.0     | 6.9563           |
| 400                            | 0.19005    | 2950.1     | 3254.2     | 7.2374           | 0.16847    | 2947.7     | 3250.9     | 7.1794           | 0.15120    | 2945.2     | 3247.6     | 7.1271           |
| 500                            | 0.2203     | 3119.5     | 3472.0     | 7.5390           | 0.19550    | 3117.9     | 3469.8     | 7.4825           | 0.17568    | 3116.2     | 3467.6     | 7.4317           |
| 600                            | 0.2500     | 3293.3     | 3693.2     | 7.8080           | 0.2220     | 3292.1     | 3691.7     | 7.7523           | 0.19960    | 3290.9     | 3690.1     | 7.7024           |
| 700                            | 0.2794     | 3472.7     | 3919.7     | 8.0535           | 0.2482     | 3471.8     | 3918.5     | 7.9983           | 0.2232     | 3470.9     | 3917.4     | 7.9487           |
| 800                            | 0.3086     | 3658.3     | 4152.1     | 8.2808           | 0.2742     | 3657.6     | 4151.2     | 8.2258           | 0.2467     | 3657.0     | 4150.3     | 8.1765           |
| 900                            | 0.3377     | 3850.5     | 4390.8     | 8.4935           | 0.3001     | 3849.9     | 4390.1     | 8.4386           | 0.2700     | 3849.3     | 4389.4     | 8.3895           |
| 1000                           | 0.3668     | 4049.0     | 4635.8     | 8.6938           | 0.3260     | 4048.5     | 4635.2     | 8.6391           | 0.2933     | 4048.0     | 4634.6     | 8.5901           |
| 1100                           | 0.3958     | 4253.7     | 4887.0     | 8.8837           | 0.3518     | 4253.2     | 4886.4     | 8.8290           | 0.3166     | 4252.7     | 4885.9     | 8.7800           |
| 1200                           | 0.4248     | 4464.2     | 5143.9     | 9.0643           | 0.3776     | 4463.7     | 5143.4     | 9.0096           | 0.3398     | 4463.3     | 5142.9     | 8.9607           |
| 1300                           | 0.4538     | 4679.9     | 5406.0     | 9.2364           | 0.4034     | 4679.5     | 5405.6     | 9.1818           | 0.3631     | 4679.0     | 5405.1     | 9.1329           |
| <i>P = 2.50 MPa (223.99°C)</i> |            |            |            |                  |            |            |            |                  |            |            |            |                  |
| Sat.                           | 0.07998    | 2603.1     | 2803.1     | 6.2575           | 0.06668    | 2604.1     | 2804.2     | 6.1869           | 0.05707    | 2603.7     | 2803.4     | 6.1253           |
| 225                            | 0.08027    | 2605.6     | 2806.3     | 6.2639           | 0.07058    | 2644.0     | 2855.8     | 6.2872           | 0.05872    | 2623.7     | 2829.2     | 6.1749           |
| 250                            | 0.08700    | 2662.6     | 2880.1     | 6.4085           | 0.08114    | 2750.1     | 2993.5     | 6.5390           | 0.06842    | 2738.0     | 2977.5     | 6.4461           |
| 300                            | 0.09890    | 2761.6     | 3008.8     | 6.6438           | 0.09053    | 2843.7     | 3115.3     | 6.7428           | 0.07678    | 2835.3     | 3104.0     | 6.6579           |
| 350                            | 0.10976    | 2851.9     | 3126.3     | 6.8403           | 0.09936    | 2932.8     | 3230.9     | 6.9212           | 0.08453    | 2926.4     | 3222.3     | 6.8405           |
| 400                            | 0.12010    | 2939.1     | 3239.3     | 7.0148           | 0.10787    | 3020.4     | 3344.0     | 7.0834           | 0.09196    | 3015.3     | 3337.2     | 7.0052           |
| 500                            | 0.13014    | 3025.5     | 3350.8     | 7.1746           | 0.11619    | 3108.0     | 3456.5     | 7.2338           | 0.09918    | 3103.0     | 3450.9     | 7.1572           |
| 600                            | 0.15930    | 3288.0     | 3686.3     | 7.5960           | 0.13243    | 3285.0     | 3682.3     | 7.5085           | 0.11324    | 3282.1     | 3678.4     | 7.4339           |
| 700                            | 0.17832    | 3468.7     | 3914.5     | 7.8435           | 0.14838    | 3466.5     | 3911.7     | 7.7571           | 0.12699    | 3464.3     | 3908.8     | 7.6837           |
| 800                            | 0.19716    | 3655.3     | 4148.2     | 8.0720           | 0.16414    | 3653.5     | 4145.9     | 7.9862           | 0.14056    | 3651.8     | 4143.7     | 7.9134           |
| 900                            | 0.21590    | 3847.9     | 4387.6     | 8.2853           | 0.17980    | 3846.5     | 4385.9     | 8.1999           | 0.15402    | 3845.0     | 4384.1     | 8.1276           |
| 1000                           | 0.2346     | 4046.7     | 4633.1     | 8.4861           | 0.19541    | 4045.4     | 4631.6     | 8.4009           | 0.16743    | 4044.1     | 4630.1     | 8.3288           |
| 1100                           | 0.2532     | 4251.5     | 4884.6     | 8.6762           | 0.21098    | 4250.3     | 4883.3     | 8.5912           | 0.18080    | 4249.2     | 4881.9     | 8.5192           |
| 1200                           | 0.2718     | 4462.1     | 5141.7     | 8.8569           | 0.22652    | 4460.9     | 5140.5     | 8.7720           | 0.19415    | 4459.8     | 5139.3     | 8.7000           |
| 1300                           | 0.2905     | 4677.8     | 5404.0     | 9.0291           | 0.24206    | 4676.6     | 5402.8     | 8.9442           | 0.20749    | 4675.5     | 5401.7     | 8.8723           |
| <i>P = 3.00 MPa (233.90°C)</i> |            |            |            |                  |            |            |            |                  |            |            |            |                  |
| <i>P = 3.50 MPa (242.60°C)</i> |            |            |            |                  |            |            |            |                  |            |            |            |                  |

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T<sub>p</sub>  
S<sub>v</sub>

## Water (Continued)

|                                  | $\rho$<br>kg/m <sup>3</sup> | $u$<br>kJ/kg | $h$<br>kJ/kg | $s$<br>kJ/(kg · K) | $\rho$<br>kg/m <sup>3</sup> | $u$<br>kJ/kg | $h$<br>kJ/kg | $s$<br>kJ/(kg · K) | $\rho$<br>kg/m <sup>3</sup> | $u$<br>kJ/kg | $h$<br>kJ/kg | $s$<br>kJ/kg |
|----------------------------------|-----------------------------|--------------|--------------|--------------------|-----------------------------|--------------|--------------|--------------------|-----------------------------|--------------|--------------|--------------|
| $P = 4.0 \text{ MPa (250.40°C)}$ |                             |              |              |                    |                             |              |              |                    |                             |              |              |              |
| Sat.                             | 0.04978                     | 2602.3       | 2801.4       | 6.0701             | 0.04406                     | 2600.1       | 2798.3       | 6.0198             | 0.03944                     | 2597.1       | 2794.3       | 5.9734       |
| 275                              | 0.05457                     | 2667.9       | 2886.2       | 6.2285             | 0.04730                     | 2650.3       | 2863.2       | 6.1401             | 0.04141                     | 2631.3       | 2838.3       | 6.0544       |
| 300                              | 0.05884                     | 2725.3       | 2960.7       | 6.3615             | 0.05135                     | 2712.0       | 2943.1       | 6.2828             | 0.04532                     | 2698.0       | 2924.5       | 6.2084       |
| 350                              | 0.06645                     | 2826.7       | 3092.5       | 6.5021             | 0.05840                     | 2817.8       | 3080.6       | 6.5131             | 0.05194                     | 2806.7       | 3068.4       | 6.4493       |
| 400                              | 0.07341                     | 2919.9       | 3213.6       | 6.7690             | 0.06475                     | 2913.3       | 3204.7       | 6.7047             | 0.05781                     | 2906.6       | 3195.7       | 6.6459       |
| 450                              | 0.08002                     | 3010.2       | 3330.3       | 6.9363             | 0.07074                     | 3005.0       | 3323.3       | 6.8746             | 0.06330                     | 2999.7       | 3216.2       | 6.8186       |
| 500                              | 0.08643                     | 3099.5       | 3445.3       | 7.0901             | 0.07651                     | 3095.3       | 3439.6       | 7.0301             | 0.06857                     | 3091.0       | 3433.8       | 6.9759       |
| 600                              | 0.09885                     | 3279.1       | 3674.4       | 7.3688             | 0.08765                     | 3276.0       | 3670.5       | 7.3110             | 0.07869                     | 3273.0       | 3666.5       | 7.2589       |
| 700                              | 0.11095                     | 3462.1       | 3905.9       | 7.6198             | 0.09847                     | 3459.9       | 3903.0       | 7.5631             | 0.08849                     | 3457.6       | 3900.1       | 7.5122       |
| 800                              | 0.12287                     | 3650.0       | 4141.5       | 7.8502             | 0.10911                     | 3648.3       | 4139.3       | 7.7942             | 0.09811                     | 3646.6       | 4137.1       | 7.7440       |
| 900                              | 0.13469                     | 3843.6       | 4382.3       | 8.0647             | 0.11965                     | 3842.2       | 4380.6       | 8.0091             | 0.10762                     | 3840.7       | 4378.8       | 7.9593       |
| 1000                             | 0.14645                     | 4042.9       | 4628.7       | 8.2662             | 0.13013                     | 4041.6       | 4627.2       | 8.2108             | 0.11707                     | 4040.4       | 4625.7       | 8.1612       |
| 1100                             | 0.15817                     | 4248.0       | 4880.6       | 8.4567             | 0.14056                     | 4246.8       | 4879.3       | 8.4015             | 0.12648                     | 4245.6       | 4878.0       | 8.3520       |
| 1200                             | 0.16987                     | 4458.6       | 5138.1       | 8.6376             | 0.15098                     | 4457.5       | 5136.9       | 8.5825             | 0.13587                     | 4456.3       | 5135.7       | 8.5331       |
| 1300                             | 0.18156                     | 4674.3       | 5400.5       | 8.8100             | 0.16139                     | 4673.1       | 5399.4       | 8.7549             | 0.14526                     | 4672.0       | 5398.2       | 8.7055       |
| $P = 6.0 \text{ MPa (275.64°C)}$ |                             |              |              |                    |                             |              |              |                    |                             |              |              |              |
| Sat.                             | 0.03244                     | 2589.7       | 2784.3       | 5.8892             | 0.02737                     | 2580.5       | 2772.1       | 5.8133             | 0.02352                     | 2569.8       | 2758.0       | 5.7432       |
| 300                              | 0.03616                     | 2667.2       | 2884.2       | 6.0674             | 0.02947                     | 2632.2       | 2838.4       | 5.9305             | 0.02426                     | 2590.9       | 2785.0       | 5.7905       |
| 350                              | 0.04223                     | 2789.6       | 3043.0       | 6.3335             | 0.03524                     | 2769.4       | 3016.0       | 6.2283             | 0.02995                     | 2747.7       | 2987.3       | 6.1301       |
| 400                              | 0.04739                     | 2892.9       | 3177.2       | 6.5408             | 0.03993                     | 2878.6       | 3158.1       | 6.4478             | 0.03432                     | 2863.8       | 3138.3       | 6.3634       |
| 450                              | 0.05214                     | 2988.9       | 3301.8       | 6.7193             | 0.04416                     | 2978.0       | 3287.1       | 6.6327             | 0.03817                     | 2966.7       | 3272.0       | 6.5551       |
| 500                              | 0.05665                     | 3082.2       | 3422.2       | 6.8803             | 0.04814                     | 3073.4       | 3410.3       | 6.7975             | 0.04175                     | 3064.3       | 3398.3       | 6.7240       |
| 550                              | 0.06101                     | 3174.6       | 3540.6       | 7.0288             | 0.05195                     | 3167.2       | 3530.9       | 6.9486             | 0.04516                     | 3159.8       | 3521.0       | 6.8778       |
| 600                              | 0.06525                     | 3266.9       | 3658.4       | 7.1677             | 0.05565                     | 3260.7       | 3650.3       | 7.0894             | 0.04645                     | 3254.4       | 3642.0       | 7.0206       |
| 700                              | 0.07352                     | 3453.1       | 3894.2       | 7.4234             | 0.06283                     | 3448.5       | 3888.3       | 7.3476             | 0.05481                     | 3443.9       | 3882.4       | 7.2812       |
| 800                              | 0.08160                     | 3643.1       | 4132.7       | 7.6566             | 0.06981                     | 3639.5       | 4128.2       | 7.5822             | 0.06097                     | 3636.0       | 4123.8       | 7.5172       |
| 900                              | 0.08958                     | 3837.8       | 4375.3       | 7.8727             | 0.07669                     | 3835.0       | 4371.8       | 7.7991             | 0.06702                     | 3832.1       | 4368.3       | 7.7351       |
| 1000                             | 0.09749                     | 4037.8       | 4622.7       | 8.0751             | 0.08350                     | 4035.3       | 4619.8       | 8.0020             | 0.07301                     | 4032.8       | 4616.9       | 7.9384       |
| 1100                             | 0.10536                     | 4243.3       | 4875.4       | 8.2661             | 0.09027                     | 4240.9       | 4872.8       | 8.1933             | 0.07896                     | 4238.6       | 4870.3       | 8.1300       |
| 1200                             | 0.11321                     | 4454.0       | 5133.3       | 8.4474             | 0.09703                     | 4451.7       | 5130.9       | 8.3747             | 0.08489                     | 4449.5       | 5128.5       | 8.3111       |
| 1300                             | 0.12106                     | 4669.6       | 5396.0       | 8.6199             | 0.10377                     | 4667.3       | 5393.7       | 8.5475             | 0.09080                     | 4665.0       | 5391.5       | 8.4841       |
| $P = 9.0 \text{ MPa (303.40°C)}$ |                             |              |              |                    |                             |              |              |                    |                             |              |              |              |
| Sat.                             | 0.02048                     | 2557.8       | 2742.1       | 5.6772             | 0.018026                    | 2544.4       | 2724.7       | 5.6141             | 0.013495                    | 2505.1       | 2673.8       | 5.4621       |
| 325                              | 0.02327                     | 2646.6       | 2856.0       | 5.8712             | 0.019861                    | 2610.4       | 2809.1       | 5.7568             | 0.016126                    | 2624.6       | 2826.2       | 5.7111       |
| 350                              | 0.02580                     | 2724.4       | 2956.6       | 6.0361             | 0.02242                     | 2699.2       | 2923.4       | 5.9443             | 0.02000                     | 2789.3       | 3039.3       | 6.0411       |
| 400                              | 0.02993                     | 2848.4       | 3117.8       | 6.2854             | 0.02641                     | 2832.4       | 3096.5       | 6.2120             | 0.02299                     | 2912.5       | 3199.8       | 6.2711       |
| 450                              | 0.03350                     | 2955.2       | 3256.6       | 6.4844             | 0.02975                     | 2943.4       | 3240.9       | 6.4190             | 0.02560                     | 3021.7       | 3341.8       | 6.4611       |
| 500                              | 0.03677                     | 3055.2       | 3386.1       | 6.6576             | 0.03279                     | 3045.8       | 3373.7       | 6.5966             | 0.02801                     | 3125.0       | 3475.2       | 6.6291       |
| 550                              | 0.03987                     | 3152.2       | 3511.0       | 6.8142             | 0.03564                     | 3144.6       | 3500.9       | 6.7561             | 0.03029                     | 3225.4       | 3604.0       | 6.7811       |
| 600                              | 0.04285                     | 3248.1       | 3633.7       | 6.9589             | 0.03837                     | 3241.7       | 3625.3       | 6.9029             | 0.03248                     | 3324.4       | 3730.4       | 6.9211       |
| 650                              | 0.04574                     | 3343.6       | 3755.3       | 7.0943             | 0.04101                     | 3338.2       | 3748.2       | 7.0398             | 0.03460                     | 3422.9       | 3855.3       | 7.0531       |
| 700                              | 0.04857                     | 3439.3       | 3876.5       | 7.2221             | 0.04358                     | 3434.7       | 3870.5       | 7.1687             | 0.03869                     | 3620.0       | 4103.6       | 7.2961       |
| 800                              | 0.05409                     | 3632.5       | 4119.3       | 7.4596             | 0.04859                     | 3628.9       | 4114.8       | 7.4077             | 0.04267                     | 3819.1       | 4352.5       | 7.5181       |
| 900                              | 0.05950                     | 3829.2       | 4364.8       | 7.6783             | 0.05349                     | 3826.3       | 4361.2       | 7.6272             | 0.04658                     | 4021.6       | 4603.8       | 7.7231       |
| 1000                             | 0.06485                     | 4030.3       | 4614.0       | 7.8821             | 0.05832                     | 4027.8       | 4611.0       | 7.8315             | 0.05045                     | 4228.2       | 4858.8       | 7.9161       |
| 1100                             | 0.07016                     | 4236.3       | 4867.7       | 8.0740             | 0.06312                     | 4234.0       | 4865.1       | 8.0237             | 0.05430                     | 4439.3       | 5118.0       | 8.0931       |
| 1200                             | 0.07544                     | 4447.2       | 5126.2       | 8.2556             | 0.06789                     | 4444.9       | 5123.8       | 8.2055             | 0.05813                     | 4654.8       | 5381.4       | 8.2711       |
| 1300                             | 0.08072                     | 4662.7       | 5389.2       | 8.4284             | 0.07265                     | 4460.5       | 5387.0       | 8.3783             |                             |              |              |              |

**TABLE A-6**  
**Superheated water (Continued)**

| T<br>°C                        | v<br>m³/kg | u<br>kJ/kg | h<br>kJ/kg | s<br>kJ/(kg · K) | v<br>m³/kg                     | u<br>kJ/kg | h<br>kJ/kg | s<br>kJ/(kg · K) | v<br>m³/kg | u<br>kJ/kg                     | h<br>kJ/kg | s<br>kJ/(kg · K) |
|--------------------------------|------------|------------|------------|------------------|--------------------------------|------------|------------|------------------|------------|--------------------------------|------------|------------------|
| <i>P = 15.0 MPa (342.24°C)</i> |            |            |            |                  | <i>P = 17.5 MPa (354.75°C)</i> |            |            |                  |            | <i>P = 20.0 MPa (365.81°C)</i> |            |                  |
| Sat.                           | 0.010337   | 2455.5     | 2610.5     | 5.3098           | 0.007920                       | 2390.2     | 2528.8     | 5.1419           | 0.005334   | 2293.0                         | 2409.7     | 4.9269           |
| 350                            | 0.011470   | 2520.4     | 2692.4     | 5.4421           |                                |            |            |                  |            |                                |            |                  |
| 400                            | 0.015649   | 2740.7     | 2975.5     | 5.8811           | 0.012447                       | 2685.0     | 2902.9     | 5.7213           | 0.009942   | 2619.3                         | 2818.1     | 5.5540           |
| 450                            | 0.018445   | 2879.5     | 3156.2     | 6.1404           | 0.015174                       | 2844.2     | 3109.7     | 6.0184           | 0.012695   | 2806.2                         | 3060.1     | 5.9017           |
| 500                            | 0.02080    | 2996.5     | 3308.6     | 6.3443           | 0.017358                       | 2970.3     | 3274.1     | 6.2383           | 0.014768   | 2942.9                         | 3238.2     | 6.1401           |
| 550                            | 0.02293    | 3104.7     | 3448.6     | 6.5199           | 0.019288                       | 3083.9     | 3421.4     | 6.4230           | 0.016555   | 3062.4                         | 3393.5     | 6.3348           |
| 600                            | 0.02491    | 3208.6     | 3582.3     | 6.6776           | 0.02106                        | 3191.5     | 3560.1     | 6.5866           | 0.018178   | 3174.0                         | 3537.6     | 6.5048           |
| 650                            | 0.02680    | 3310.3     | 3712.3     | 6.8224           | 0.02274                        | 3296.0     | 3693.9     | 6.7357           | 0.019693   | 3281.4                         | 3675.3     | 6.6582           |
| 700                            | 0.02861    | 3410.9     | 3840.1     | 6.9572           | 0.02434                        | 3398.7     | 3824.6     | 6.8736           | 0.02113    | 3386.4                         | 3809.0     | 6.7993           |
| 800                            | 0.03210    | 3610.9     | 4092.4     | 7.2040           | 0.02738                        | 3601.8     | 4081.1     | 7.1244           | 0.02385    | 3592.7                         | 4069.7     | 7.0544           |
| 900                            | 0.03546    | 3811.9     | 4343.8     | 7.4279           | 0.03031                        | 3804.7     | 4335.1     | 7.3507           | 0.02645    | 3797.5                         | 4326.4     | 7.2830           |
| 1000                           | 0.03875    | 4015.4     | 4596.6     | 7.6348           | 0.03316                        | 4009.3     | 4589.5     | 7.5589           | 0.02897    | 4003.1                         | 4582.5     | 7.4925           |
| 1100                           | 0.04200    | 4222.6     | 4852.6     | 7.8283           | 0.03597                        | 4216.9     | 4846.4     | 7.7531           | 0.03145    | 4211.3                         | 4840.2     | 7.6874           |
| 1200                           | 0.04523    | 4433.8     | 5112.3     | 8.0108           | 0.03876                        | 4428.3     | 5106.6     | 7.9360           | 0.03391    | 4422.8                         | 5101.0     | 7.8707           |
| 1300                           | 0.04845    | 4649.1     | 5376.0     | 8.1840           | 0.04154                        | 4643.5     | 5370.5     | 8.1093           | 0.03636    | 4638.0                         | 5365       | 8.0442           |
| <i>P = 25.0 MPa</i>            |            |            |            |                  | <i>P = 30.0 MPa</i>            |            |            |                  |            | <i>P = 35.0 MPa</i>            |            |                  |
| 375                            | 0.0019731  | 1798.7     | 1848.0     | 4.0320           | 0.0017892                      | 1737.8     | 1791.5     | 3.9305           | 0.0017003  | 1702.9                         | 1762.4     | 3.8722           |
| 400                            | 0.006004   | 2430.1     | 2580.2     | 5.1418           | 0.002790                       | 2067.4     | 2151.1     | 4.4728           | 0.002100   | 1914.1                         | 1987.6     | 4.2126           |
| 425                            | 0.007881   | 2609.2     | 2806.3     | 5.4723           | 0.005303                       | 2455.1     | 2614.2     | 5.1504           | 0.003428   | 2253.4                         | 2373.4     | 4.7747           |
| 450                            | 0.009162   | 2720.7     | 2949.7     | 5.6744           | 0.006735                       | 2619.3     | 2821.4     | 5.4424           | 0.004961   | 2498.7                         | 2672.4     | 5.1962           |
| 500                            | 0.011123   | 2884.3     | 3162.4     | 5.9592           | 0.008678                       | 2820.7     | 3081.1     | 5.7905           | 0.006927   | 2751.9                         | 2994.4     | 5.6282           |
| 550                            | 0.012724   | 3017.5     | 3335.6     | 6.1765           | 0.010168                       | 2970.3     | 3275.4     | 6.0342           | 0.008345   | 2921.0                         | 3213.0     | 5.9026           |
| 600                            | 0.014137   | 3137.9     | 3491.4     | 6.3602           | 0.011446                       | 3100.5     | 3443.9     | 6.2331           | 0.009527   | 3062.0                         | 3395.5     | 6.1179           |
| 650                            | 0.015433   | 3251.6     | 3637.4     | 6.5229           | 0.012596                       | 3221.0     | 3598.9     | 6.4058           | 0.010575   | 3189.8                         | 3559.9     | 6.3010           |
| 700                            | 0.016646   | 3361.3     | 3777.5     | 6.6737           | 0.013661                       | 3335.8     | 3745.6     | 6.5606           | 0.011533   | 3309.8                         | 3713.5     | 6.4631           |
| 800                            | 0.018912   | 3574.3     | 4047.1     | 6.9345           | 0.015623                       | 3555.5     | 4024.2     | 6.8332           | 0.013278   | 3536.7                         | 4001.5     | 6.7450           |
| 900                            | 0.021045   | 3783.0     | 4309.1     | 7.1680           | 0.017448                       | 3768.5     | 4291.9     | 7.0718           | 0.014883   | 3754.0                         | 4274.9     | 6.9386           |
| 1000                           | 0.02310    | 3990.9     | 4568.5     | 7.3802           | 0.019196                       | 3978.8     | 4554.7     | 7.2867           | 0.016410   | 3966.7                         | 4541.1     | 7.2064           |
| 1100                           | 0.02512    | 4200.2     | 4828.2     | 7.5765           | 0.020903                       | 4189.2     | 4816.3     | 7.4845           | 0.017895   | 4178.3                         | 4804.6     | 7.4037           |
| 1200                           | 0.02711    | 4412.0     | 5089.9     | 7.7605           | 0.022589                       | 4401.3     | 5079.0     | 7.6692           | 0.019360   | 4390.7                         | 5068.3     | 7.5910           |
| 1300                           | 0.02910    | 4626.9     | 5354.4     | 7.9342           | 0.024266                       | 4616.0     | 5344.0     | 7.8432           | 0.020815   | 4605.1                         | 5333.6     | 7.7653           |
| <i>P = 40.0 MPa</i>            |            |            |            |                  | <i>P = 50.0 MPa</i>            |            |            |                  |            | <i>P = 60.0 MPa</i>            |            |                  |
| 375                            | 0.0016407  | 1677.1     | 1742.6     | 3.8290           | 0.0015594                      | 1638.6     | 1716.6     | 3.7639           | 0.0015028  | 1609.4                         | 1699.5     | 3.7141           |
| 400                            | 0.0019077  | 1854.6     | 1930.9     | 4.1135           | 0.0017309                      | 1788.1     | 1874.6     | 4.0031           | 0.0016335  | 1745.4                         | 1843.4     | 3.9318           |
| 425                            | 0.002532   | 2096.9     | 2198.1     | 4.5029           | 0.002007                       | 1959.7     | 2060.0     | 4.2734           | 0.0018165  | 1892.7                         | 2001.7     | 4.1626           |
| 450                            | 0.003693   | 2365.1     | 2512.8     | 4.9459           | 0.002486                       | 2159.6     | 2284.0     | 4.5884           | 0.002085   | 2053.9                         | 2179.0     | 4.4121           |
| 500                            | 0.005622   | 2678.4     | 2903.3     | 5.4700           | 0.003892                       | 2525.5     | 2720.1     | 5.1726           | 0.002956   | 2390.6                         | 2567.9     | 4.9321           |
| 550                            | 0.006984   | 2869.7     | 3149.1     | 5.7785           | 0.005118                       | 2763.6     | 3019.5     | 5.5485           | 0.003956   | 2658.8                         | 2896.2     | 5.3441           |
| 600                            | 0.008094   | 3022.6     | 3346.4     | 6.0144           | 0.006112                       | 2942.0     | 3247.6     | 5.8178           | 0.004834   | 2861.1                         | 3151.2     | 5.6452           |
| 650                            | 0.009063   | 3158.0     | 3520.6     | 6.2054           | 0.006966                       | 3093.5     | 3441.8     | 6.0342           | 0.005595   | 3028.8                         | 3364.5     | 5.8829           |
| 700                            | 0.009941   | 3283.6     | 3681.2     | 6.3750           | 0.007727                       | 3230.5     | 3616.8     | 6.2189           | 0.006272   | 3177.2                         | 3553.5     | 6.0824           |
| 800                            | 0.011523   | 3517.8     | 3978.7     | 6.6662           | 0.009076                       | 3479.8     | 3933.6     | 6.5290           | 0.007459   | 3441.5                         | 3889.1     | 6.4109           |
| 900                            | 0.012962   | 3739.4     | 4257.9     | 6.9150           | 0.010283                       | 3710.3     | 4224.4     | 6.7882           | 0.008508   | 3681.0                         | 4191.5     | 6.6805           |
| 1000                           | 0.014324   | 3954.6     | 4527.6     | 7.1356           | 0.011411                       | 3930.5     | 4501.1     | 7.0146           | 0.009480   | 3906.4                         | 4475.2     | 6.9127           |
| 1100                           | 0.015642   | 4167.4     | 4793.1     | 7.3364           | 0.012496                       | 4145.7     | 4770.5     | 7.2184           | 0.010409   | 4124.1                         | 4748.6     | 7.1195           |
| 1200                           | 0.016940   | 4380.1     | 5057.7     | 7.5224           | 0.013561                       | 4359.1     | 5037.2     | 7.4058           | 0.011317   | 4338.2                         | 5017.2     | 7.3083           |
| 1300                           | 0.018229   | 4594.3     | 5323.5     | 7.6969           | 0.014616                       | 4572.8     | 5303.6     | 7.5808           | 0.012215   | 4551.4                         | 5284.3     | 7.4837           |

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**APPENDIX A**

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**CONVERSION FACTORS AND  
VALUES OF THE GAS CONSTA**

Because standard reference books contain data in diverse units, we include Table A.1 and A.2 to aid the conversion of values from one set of units to another. Units having no connection with the SI system are enclosed in parentheses. The following definitions are noted:

(ft)  $\equiv$  U.S. defined foot  $\equiv 3.048 \times 10^{-1}$  m

(in)  $\equiv$  U.S. defined inch  $\equiv 2.54 \times 10^{-2}$  m

(lb<sub>m</sub>)  $\equiv$  U.S. defined pound *mass* (avoirdupois)  
 $\equiv 4.5359237 \times 10^{-1}$  kg

(lb<sub>f</sub>)  $\equiv$  force to accelerate 1 (lb<sub>m</sub>) by 32.1740 (ft) s<sup>-2</sup>

(atm)  $\equiv$  standard atmospheric pressure  $\equiv 101,325$  Pa

(psia)  $\equiv$  pounds *force* per square inch absolute pressure

(torr)  $\equiv$  pressure exerted by 1 mm mercury at 0°C and standard gravity

(cal)  $\equiv$  thermochemical calorie

(Btu)  $\equiv$  international steam table British thermal unit

(lb mole)  $\equiv$  mass in pounds *mass* with numerical value equal to the molecular weight

(R)  $\equiv$  absolute temperature in Rankines

The conversion factors of Table A.1 are referred to a single basic unit of the SI system. Conversions between other pairs of units for a given quantity are made as in the following example:

$$1 \text{ bar} = 0.986923(\text{atm}) = 750.061(\text{torr})$$

thus

$$1(\text{atm}) = \frac{750.061}{0.986923} = 760.00(\text{torr})$$

Table A.1: Conversion factors

| Quantity | Conversion  |
|----------|---|
| Length   | $1 \text{ m} = 100 \text{ cm}$<br>$= 3.28084(\text{ft}) = 39.3701(\text{in})$   |
| Mass     | $1 \text{ kg} = 10^3 \text{ g}$<br>$= 2.20462(\text{lb}_m)$   |
| Force    | $1 \text{ N} = 1 \text{ kg m s}^{-2}$<br>$= 10^5(\text{dyne})$<br>$= 0.224809(\text{lbf})$  |
| Pressure | $1 \text{ bar} = 10^5 \text{ kg m}^{-1} \text{s}^{-2} = 10^5 \text{ N m}^{-2}$<br>$= 10^5 \text{ Pa} = 10^2 \text{ kPa}$<br>$= 10^6(\text{dyne}) \text{ cm}^{-2}$<br>$= 0.986923(\text{atm})$<br>$= 14.5038(\text{psia})$<br>$= 750.061(\text{torr})$   |
| Volume   | $1 \text{ m}^3 = 10^6 \text{ cm}^3$<br>$= 35.3147(\text{ft})^3$   |
| Density  | $1 \text{ g cm}^{-3} = 10^3 \text{ kg m}^{-3}$<br>$= 62.4278(\text{lb}_m)(\text{ft})^{-3}$  |
| Energy   | $1 \text{ J} = 1 \text{ kg m}^2 \cdot \text{s}^{-2} = 1 \text{ N m}$<br>$= 1 \text{ m}^3 \text{ Pa} = 10^{-5} \text{ m}^3 \text{ bar} = 10 \text{ cm}^3 \text{ bar}$<br>$= 9.86923 \text{ cm}^3(\text{atm})$<br>$= 10^7(\text{dyne}) \text{ cm} = 10^7(\text{erg})$<br>$= 0.239006(\text{cal})$<br>$= 5.12197 \times 10^{-3}(\text{ft})^3(\text{psia}) = 0.737562(\text{ft})(\text{lbf})$<br>$= 9.47831 \times 10^{-4}(\text{Btu})$ |
| Power    | $1 \text{ kW} = 10^3 \text{ W} = 10^3 \text{ kg m}^2 \text{ s}^{-3} = 10^3 \text{ J s}^{-1}$<br>$= 239.006(\text{cal}) \text{ s}^{-1}$<br>$= 737.562(\text{ft})(\text{lbf}) \text{ s}^{-1}$<br>$= 0.947831(\text{Btu}) \text{ s}^{-1}$<br>$= 1.34102(\text{hp})$  |

Table A.2: Values of the universal gas constant

$$\begin{aligned}
 R &= 8.314 \text{ J mol}^{-1} \text{ K}^{-1} = 8.314 \text{ m}^3 \text{ Pa mol}^{-1} \text{ K}^{-1} \\
 &= 83.14 \text{ cm}^3 \text{ bar mol}^{-1} \text{ K}^{-1} = 8,314 \text{ cm}^3 \text{ kPa mol}^{-1} \text{ K}^{-1} \\
 &= 82.06 \text{ cm}^3(\text{atm}) \text{ mol}^{-1} \text{ K}^{-1} = 62,356 \text{ cm}^3(\text{torr}) \text{ mol}^{-1} \text{ K}^{-1} \\
 &= 1.987(\text{cal}) \text{ mol}^{-1} \text{ K}^{-1} = 1.986(\text{Btu})(\text{lb mole})^{-1}(\text{R})^{-1} \\
 &= 0.7302(\text{ft})^3(\text{atm})(\text{lb mol})^{-1}(\text{R})^{-1} = 10.73(\text{ft})^3(\text{psia})(\text{lb mol})^{-1}(\text{R})^{-1} \\
 &= 1,545(\text{ft})(\text{lb mol})^{-1}(\text{R})^{-1}
 \end{aligned}$$

