

# PROPERTY TABLES AND CHARTS (ENGLISH UNITS)

- Table A-1E** Molar mass, gas constant, and critical-point properties
- Table A-2E** Ideal-gas specific heats of various common gases
- Table A-3E** Properties of common liquids, solids, and foods
- Table A-4E** Saturated water—Temperature table
- Table A-5E** Saturated water—Pressure table
- Table A-6E** Superheated water
- Table A-7E** Compressed liquid water
- Table A-8E** Saturated ice–water vapor
- Figure A-9E**  $T$ - $s$  diagram for water
- Figure A-10E** Mollier diagram for water
- Table A-11E** Saturated refrigerant-134a—Temperature table
- Table A-12E** Saturated refrigerant-134a—Pressure table
- Table A-13E** Superheated refrigerant-134a
- Figure A-14E**  $P$ - $h$  diagram for refrigerant-134a
- Table A-16E** Properties of the atmosphere at high altitude
- Table A-17E** Ideal-gas properties of air
- Table A-18E** Ideal-gas properties of nitrogen,  $N_2$
- Table A-19E** Ideal-gas properties of oxygen,  $O_2$
- Table A-20E** Ideal-gas properties of carbon dioxide,  $CO_2$
- Table A-21E** Ideal-gas properties of carbon monoxide,  $CO$
- Table A-22E** Ideal-gas properties of hydrogen,  $H_2$
- Table A-23E** Ideal-gas properties of water vapor,  $H_2O$
- Table A-26E** Enthalpy of formation, Gibbs function of formation, and absolute entropy at  $77^\circ C$ , 1 atm
- Table A-27E** Properties of some common fuels and hydrocarbons
- Figure A-31E** Psychrometric chart at 1 atm total pressure

TABLE A-1E

Molar mass, gas constant, and critical-point properties

| Substance                      | Formula                           | Molar mass, $M$<br>lbm/lbmol | Gas constant, $R$ |                                  | Critical-point properties |                   |                                   |
|--------------------------------|-----------------------------------|------------------------------|-------------------|----------------------------------|---------------------------|-------------------|-----------------------------------|
|                                |                                   |                              | Btu/<br>lbm·R*    | psia·ft <sup>3</sup> /<br>lbm·R* | Temperature,<br>R         | Pressure,<br>psia | Volume,<br>ft <sup>3</sup> /lbmol |
| Air                            | —                                 | 28.97                        | 0.06855           | 0.3704                           | 238.5                     | 547               | 1.41                              |
| Ammonia                        | NH <sub>3</sub>                   | 17.03                        | 0.1166            | 0.6301                           | 729.8                     | 1636              | 1.16                              |
| Argon                          | Ar                                | 39.948                       | 0.04971           | 0.2686                           | 272                       | 705               | 1.20                              |
| Benzene                        | C <sub>6</sub> H <sub>6</sub>     | 78.115                       | 0.02542           | 0.1374                           | 1012                      | 714               | 4.17                              |
| Bromine                        | Br <sub>2</sub>                   | 159.808                      | 0.01243           | 0.06714                          | 1052                      | 1500              | 2.17                              |
| <i>n</i> -Butane               | C <sub>4</sub> H <sub>10</sub>    | 58.124                       | 0.03417           | 0.1846                           | 765.2                     | 551               | 4.08                              |
| Carbon dioxide                 | CO <sub>2</sub>                   | 44.01                        | 0.04513           | 0.2438                           | 547.5                     | 1071              | 1.51                              |
| Carbon monoxide                | CO                                | 28.011                       | 0.07090           | 0.3831                           | 240                       | 507               | 1.49                              |
| Carbon tetrachloride           | CCl <sub>4</sub>                  | 153.82                       | 0.01291           | 0.06976                          | 1001.5                    | 661               | 4.42                              |
| Chlorine                       | Cl <sub>2</sub>                   | 70.906                       | 0.02801           | 0.1517                           | 751                       | 1120              | 1.99                              |
| Chloroform                     | CHCl <sub>3</sub>                 | 119.38                       | 0.01664           | 0.08988                          | 965.8                     | 794               | 3.85                              |
| Dichlorodifluoromethane (R-12) | CCl <sub>2</sub> F <sub>2</sub>   | 120.91                       | 0.01643           | 0.08874                          | 692.4                     | 582               | 3.49                              |
| Dichlorofluoromethane (R-21)   | CHCl <sub>2</sub> F               | 102.92                       | 0.01930           | 0.1043                           | 813.0                     | 749               | 3.16                              |
| Ethane                         | C <sub>2</sub> H <sub>6</sub>     | 30.020                       | 0.06616           | 0.3574                           | 549.8                     | 708               | 2.37                              |
| Ethyl alcohol                  | C <sub>2</sub> H <sub>5</sub> OH  | 46.07                        | 0.04311           | 0.2329                           | 929.0                     | 926               | 2.68                              |
| Ethylene                       | C <sub>2</sub> H <sub>4</sub>     | 28.054                       | 0.07079           | 0.3825                           | 508.3                     | 742               | 1.99                              |
| Helium                         | He                                | 4.003                        | 0.4961            | 2.6809                           | 9.5                       | 33.2              | 0.926                             |
| <i>n</i> -Hexane               | C <sub>6</sub> H <sub>14</sub>    | 86.178                       | 0.02305           | 0.1245                           | 914.2                     | 439               | 5.89                              |
| Hydrogen (normal)              | H <sub>2</sub>                    | 2.016                        | 0.9851            | 5.3224                           | 59.9                      | 188.1             | 1.04                              |
| Krypton                        | Kr                                | 83.80                        | 0.02370           | 0.1280                           | 376.9                     | 798               | 1.48                              |
| Methane                        | CH <sub>4</sub>                   | 16.043                       | 0.1238            | 0.6688                           | 343.9                     | 673               | 1.59                              |
| Methyl alcohol                 | CH <sub>3</sub> OH                | 32.042                       | 0.06198           | 0.3349                           | 923.7                     | 1154              | 1.89                              |
| Methyl chloride                | CH <sub>3</sub> Cl                | 50.488                       | 0.03934           | 0.2125                           | 749.3                     | 968               | 2.29                              |
| Neon                           | Ne                                | 20.183                       | 0.09840           | 0.5316                           | 80.1                      | 395               | 0.668                             |
| Nitrogen                       | N <sub>2</sub>                    | 28.013                       | 0.07090           | 0.3830                           | 227.1                     | 492               | 1.44                              |
| Nitrous oxide                  | N <sub>2</sub> O                  | 44.013                       | 0.04512           | 0.2438                           | 557.4                     | 1054              | 1.54                              |
| Oxygen                         | O <sub>2</sub>                    | 31.999                       | 0.06206           | 0.3353                           | 278.6                     | 736               | 1.25                              |
| Propane                        | C <sub>3</sub> H <sub>8</sub>     | 44.097                       | 0.04504           | 0.2433                           | 665.9                     | 617               | 3.20                              |
| Propylene                      | C <sub>3</sub> H <sub>6</sub>     | 42.081                       | 0.04719           | 0.2550                           | 656.9                     | 670               | 2.90                              |
| Sulfur dioxide                 | SO <sub>2</sub>                   | 64.063                       | 0.03100           | 1.1675                           | 775.2                     | 1143              | 1.95                              |
| Tetrafluoroethane (R-134a)     | CF <sub>3</sub> CH <sub>2</sub> F | 102.03                       | 0.01946           | 0.1052                           | 673.6                     | 588.7             | 3.19                              |
| Trichlorofluoromethane (R-11)  | CCl <sub>3</sub> F                | 137.37                       | 0.01446           | 0.07811                          | 848.1                     | 635               | 3.97                              |
| Water                          | H <sub>2</sub> O                  | 18.015                       | 0.1102            | 0.5956                           | 1164.8                    | 3200              | 0.90                              |
| Xenon                          | Xe                                | 131.30                       | 0.01513           | 0.08172                          | 521.55                    | 852               | 1.90                              |

\*Calculated from  $R = R_u/M$ , where  $R_u = 1.98588$  Btu/lbmol·R = 10.7316 psia·ft<sup>3</sup>/lbmol·R and  $M$  is the molar mass.Source: K. A. Kobe and R. E. Lynn, Jr., *Chemical Review* 52 (1953), pp. 117–236, and ASHRAE, *Handbook of Fundamentals* (Atlanta, GA: American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., 1993), pp. 16.4 and 36.1.

TABLE A-2E

Ideal-gas specific heats of various common gases  
(a) At 80°F

| Gas             | Formula                        | Gas constant, $R$<br>Btu/lbm·R | $c_p$<br>Btu/lbm·R | $c_v$<br>Btu/lbm·R | $k$   |
|-----------------|--------------------------------|--------------------------------|--------------------|--------------------|-------|
| Air             | —                              | 0.06855                        | 0.240              | 0.171              | 1.400 |
| Argon           | Ar                             | 0.04971                        | 0.1253             | 0.0756             | 1.667 |
| Butane          | C <sub>4</sub> H <sub>10</sub> | 0.03424                        | 0.415              | 0.381              | 1.09  |
| Carbon dioxide  | CO <sub>2</sub>                | 0.04513                        | 0.203              | 0.158              | 1.285 |
| Carbon monoxide | CO                             | 0.07090                        | 0.249              | 0.178              | 1.399 |
| Ethane          | C <sub>2</sub> H <sub>6</sub>  | 0.06616                        | 0.427              | 0.361              | 1.183 |
| Ethylene        | C <sub>2</sub> H <sub>4</sub>  | 0.07079                        | 0.411              | 0.340              | 1.208 |
| Helium          | He                             | 0.4961                         | 1.25               | 0.753              | 1.667 |
| Hydrogen        | H <sub>2</sub>                 | 0.9851                         | 3.43               | 2.44               | 1.404 |
| Methane         | CH <sub>4</sub>                | 0.1238                         | 0.532              | 0.403              | 1.32  |
| Neon            | Ne                             | 0.09840                        | 0.246              | 0.1477             | 1.667 |
| Nitrogen        | N <sub>2</sub>                 | 0.07090                        | 0.248              | 0.177              | 1.400 |
| Octane          | C <sub>8</sub> H <sub>18</sub> | 0.01742                        | 0.409              | 0.392              | 1.044 |
| Oxygen          | O <sub>2</sub>                 | 0.06206                        | 0.219              | 0.157              | 1.395 |
| Propane         | C <sub>3</sub> H <sub>8</sub>  | 0.04504                        | 0.407              | 0.362              | 1.124 |
| Steam           | H <sub>2</sub> O               | 0.1102                         | 0.445              | 0.335              | 1.329 |

Source: Gordon J. Van Wylen and Richard E. Sonntag, *Fundamentals of Classical Thermodynamics*, English/SI Version, 3rd ed. (New York: John Wiley & Sons, 1986), p. 687, Table A-8E.

TABLE A-2E

Ideal-gas specific heats of various common gases (*Continued*)  
 (b) At various temperatures

| Temp.,<br>°F | $c_p$<br>Btu/lbm·R             | $c_v$<br>Btu/lbm·R | $k$   | $c_p$<br>Btu/lbm·R                    | $c_v$<br>Btu/lbm·R | $k$   | $c_p$<br>Btu/lbm·R           | $c_v$<br>Btu/lbm·R | $k$   |
|--------------|--------------------------------|--------------------|-------|---------------------------------------|--------------------|-------|------------------------------|--------------------|-------|
|              | <i>Air</i>                     |                    |       | <i>Carbon dioxide, CO<sub>2</sub></i> |                    |       | <i>Carbon monoxide, CO</i>   |                    |       |
| 40           | 0.240                          | 0.171              | 1.401 | 0.195                                 | 0.150              | 1.300 | 0.248                        | 0.177              | 1.400 |
| 100          | 0.240                          | 0.172              | 1.400 | 0.205                                 | 0.160              | 1.283 | 0.249                        | 0.178              | 1.399 |
| 200          | 0.241                          | 0.173              | 1.397 | 0.217                                 | 0.172              | 1.262 | 0.249                        | 0.179              | 1.397 |
| 300          | 0.243                          | 0.174              | 1.394 | 0.229                                 | 0.184              | 1.246 | 0.251                        | 0.180              | 1.394 |
| 400          | 0.245                          | 0.176              | 1.389 | 0.239                                 | 0.193              | 1.233 | 0.253                        | 0.182              | 1.389 |
| 500          | 0.248                          | 0.179              | 1.383 | 0.247                                 | 0.202              | 1.223 | 0.256                        | 0.185              | 1.384 |
| 600          | 0.250                          | 0.182              | 1.377 | 0.255                                 | 0.210              | 1.215 | 0.259                        | 0.188              | 1.377 |
| 700          | 0.254                          | 0.185              | 1.371 | 0.262                                 | 0.217              | 1.208 | 0.262                        | 0.191              | 1.371 |
| 800          | 0.257                          | 0.188              | 1.365 | 0.269                                 | 0.224              | 1.202 | 0.266                        | 0.195              | 1.364 |
| 900          | 0.259                          | 0.191              | 1.358 | 0.275                                 | 0.230              | 1.197 | 0.269                        | 0.198              | 1.357 |
| 1000         | 0.263                          | 0.195              | 1.353 | 0.280                                 | 0.235              | 1.192 | 0.273                        | 0.202              | 1.351 |
| 1500         | 0.276                          | 0.208              | 1.330 | 0.298                                 | 0.253              | 1.178 | 0.287                        | 0.216              | 1.328 |
| 2000         | 0.286                          | 0.217              | 1.312 | 0.312                                 | 0.267              | 1.169 | 0.297                        | 0.226              | 1.314 |
|              | <i>Hydrogen, H<sub>2</sub></i> |                    |       | <i>Nitrogen, N<sub>2</sub></i>        |                    |       | <i>Oxygen, O<sub>2</sub></i> |                    |       |
| 40           | 3.397                          | 2.412              | 1.409 | 0.248                                 | 0.177              | 1.400 | 0.219                        | 0.156              | 1.397 |
| 100          | 3.426                          | 2.441              | 1.404 | 0.248                                 | 0.178              | 1.399 | 0.220                        | 0.158              | 1.394 |
| 200          | 3.451                          | 2.466              | 1.399 | 0.249                                 | 0.178              | 1.398 | 0.223                        | 0.161              | 1.387 |
| 300          | 3.461                          | 2.476              | 1.398 | 0.250                                 | 0.179              | 1.396 | 0.226                        | 0.164              | 1.378 |
| 400          | 3.466                          | 2.480              | 1.397 | 0.251                                 | 0.180              | 1.393 | 0.230                        | 0.168              | 1.368 |
| 500          | 3.469                          | 2.484              | 1.397 | 0.254                                 | 0.183              | 1.388 | 0.235                        | 0.173              | 1.360 |
| 600          | 3.473                          | 2.488              | 1.396 | 0.256                                 | 0.185              | 1.383 | 0.239                        | 0.177              | 1.352 |
| 700          | 3.477                          | 2.492              | 1.395 | 0.260                                 | 0.189              | 1.377 | 0.242                        | 0.181              | 1.344 |
| 800          | 3.494                          | 2.509              | 1.393 | 0.262                                 | 0.191              | 1.371 | 0.246                        | 0.184              | 1.337 |
| 900          | 3.502                          | 2.519              | 1.392 | 0.265                                 | 0.194              | 1.364 | 0.249                        | 0.187              | 1.331 |
| 1000         | 3.513                          | 2.528              | 1.390 | 0.269                                 | 0.198              | 1.359 | 0.252                        | 0.190              | 1.326 |
| 1500         | 3.618                          | 2.633              | 1.374 | 0.283                                 | 0.212              | 1.334 | 0.263                        | 0.201              | 1.309 |
| 2000         | 3.758                          | 2.773              | 1.355 | 0.293                                 | 0.222              | 1.319 | 0.270                        | 0.208              | 1.298 |

Note: The unit Btu/lbm·R is equivalent to Btu/lbm·°F.

Source: Kenneth Wark, *Thermodynamics*, 4th ed. (New York: McGraw-Hill, 1983), p. 830, Table A-4. Originally published in *Tables of Properties of Gases*, NBS Circular 564, 1955.

TABLE A-2E

Ideal-gas specific heats of various common gases (*Concluded*)  
(c) As a function of temperature

$$\bar{c}_p = a + bT + cT^2 + dT^3$$

( $T$  in R,  $c_p$  in Btu/lbmol·R)

| Substance         | Formula                         | $a$    | $b$                         | $c$                         | $d$                         | Temperature range, R | % error |      |
|-------------------|---------------------------------|--------|-----------------------------|-----------------------------|-----------------------------|----------------------|---------|------|
|                   |                                 |        |                             |                             |                             |                      | Max.    | Avg. |
| Nitrogen          | N <sub>2</sub>                  | 6.903  | -0.02085 × 10 <sup>-2</sup> | 0.05957 × 10 <sup>-5</sup>  | -0.1176 × 10 <sup>-9</sup>  | 491-3240             | 0.59    | 0.34 |
| Oxygen            | O <sub>2</sub>                  | 6.085  | 0.2017 × 10 <sup>-2</sup>   | -0.05275 × 10 <sup>-5</sup> | 0.05372 × 10 <sup>-9</sup>  | 491-3240             | 1.19    | 0.28 |
| Air               | —                               | 6.713  | 0.02609 × 10 <sup>-2</sup>  | 0.03540 × 10 <sup>-5</sup>  | -0.08052 × 10 <sup>-9</sup> | 491-3240             | 0.72    | 0.33 |
| Hydrogen          | H <sub>2</sub>                  | 6.952  | -0.02542 × 10 <sup>-2</sup> | 0.02952 × 10 <sup>-5</sup>  | -0.03565 × 10 <sup>-9</sup> | 491-3240             | 1.02    | 0.26 |
| Carbon monoxide   | CO                              | 6.726  | 0.02222 × 10 <sup>-2</sup>  | 0.03960 × 10 <sup>-5</sup>  | -0.09100 × 10 <sup>-9</sup> | 491-3240             | 0.89    | 0.37 |
| Carbon dioxide    | CO <sub>2</sub>                 | 5.316  | 0.79361 × 10 <sup>-2</sup>  | -0.2581 × 10 <sup>-5</sup>  | 0.3059 × 10 <sup>-9</sup>   | 491-3240             | 0.67    | 0.22 |
| Water vapor       | H <sub>2</sub> O                | 7.700  | 0.02552 × 10 <sup>-2</sup>  | 0.07781 × 10 <sup>-5</sup>  | -0.1472 × 10 <sup>-9</sup>  | 491-3240             | 0.53    | 0.24 |
| Nitric oxide      | NO                              | 7.008  | -0.01247 × 10 <sup>-2</sup> | 0.07185 × 10 <sup>-5</sup>  | -0.1715 × 10 <sup>-9</sup>  | 491-2700             | 0.97    | 0.36 |
| Nitrous oxide     | N <sub>2</sub> O                | 5.758  | 0.7780 × 10 <sup>-2</sup>   | -0.2596 × 10 <sup>-5</sup>  | 0.4331 × 10 <sup>-9</sup>   | 491-2700             | 0.59    | 0.26 |
| Nitrogen dioxide  | NO <sub>2</sub>                 | 5.48   | 0.7583 × 10 <sup>-2</sup>   | -0.260 × 10 <sup>-5</sup>   | 0.322 × 10 <sup>-9</sup>    | 491-2700             | 0.46    | 0.18 |
| Ammonia           | NH <sub>3</sub>                 | 6.5846 | 0.34028 × 10 <sup>-2</sup>  | 0.073034 × 10 <sup>-5</sup> | -0.27402 × 10 <sup>-9</sup> | 491-2700             | 0.91    | 0.36 |
| Sulfur            | S <sub>2</sub>                  | 6.499  | 0.2943 × 10 <sup>-2</sup>   | -0.1200 × 10 <sup>-5</sup>  | 0.1632 × 10 <sup>-9</sup>   | 491-3240             | 0.99    | 0.38 |
| Sulfur dioxide    | SO <sub>2</sub>                 | 6.157  | 0.7689 × 10 <sup>-2</sup>   | -0.2810 × 10 <sup>-5</sup>  | 0.3527 × 10 <sup>-9</sup>   | 491-3240             | 0.45    | 0.24 |
| Sulfur trioxide   | SO <sub>3</sub>                 | 3.918  | 1.935 × 10 <sup>-2</sup>    | -0.8256 × 10 <sup>-5</sup>  | 1.328 × 10 <sup>-9</sup>    | 491-2340             | 0.29    | 0.13 |
| Acetylene         | C <sub>2</sub> H <sub>2</sub>   | 5.21   | 1.2227 × 10 <sup>-2</sup>   | -0.4812 × 10 <sup>-5</sup>  | 0.7457 × 10 <sup>-9</sup>   | 491-2700             | 1.46    | 0.59 |
| Benzene           | C <sub>6</sub> H <sub>6</sub>   | -8.650 | 6.4322 × 10 <sup>-2</sup>   | -2.327 × 10 <sup>-5</sup>   | 3.179 × 10 <sup>-9</sup>    | 491-2700             | 0.34    | 0.20 |
| Methanol          | CH <sub>4</sub> O               | 4.55   | 1.214 × 10 <sup>-2</sup>    | -0.0898 × 10 <sup>-5</sup>  | -0.329 × 10 <sup>-9</sup>   | 491-1800             | 0.18    | 0.08 |
| Ethanol           | C <sub>2</sub> H <sub>6</sub> O | 4.75   | 2.781 × 10 <sup>-2</sup>    | -0.7651 × 10 <sup>-5</sup>  | 0.821 × 10 <sup>-9</sup>    | 491-2700             | 0.40    | 0.22 |
| Hydrogen chloride | HCl                             | 7.244  | -0.1011 × 10 <sup>-2</sup>  | 0.09783 × 10 <sup>-5</sup>  | -0.1776 × 10 <sup>-9</sup>  | 491-2740             | 0.22    | 0.08 |
| Methane           | CH <sub>4</sub>                 | 4.750  | 0.6666 × 10 <sup>-2</sup>   | 0.09352 × 10 <sup>-5</sup>  | -0.4510 × 10 <sup>-9</sup>  | 491-2740             | 1.33    | 0.57 |
| Ethane            | C <sub>2</sub> H <sub>6</sub>   | 1.648  | 2.291 × 10 <sup>-2</sup>    | -0.4722 × 10 <sup>-5</sup>  | 0.2984 × 10 <sup>-9</sup>   | 491-2740             | 0.83    | 0.28 |
| Propane           | C <sub>3</sub> H <sub>8</sub>   | -0.966 | 4.044 × 10 <sup>-2</sup>    | -1.159 × 10 <sup>-5</sup>   | 1.300 × 10 <sup>-9</sup>    | 491-2740             | 0.40    | 0.12 |
| <i>n</i> -Butane  | C <sub>4</sub> H <sub>10</sub>  | 0.945  | 4.929 × 10 <sup>-2</sup>    | -1.352 × 10 <sup>-5</sup>   | 1.433 × 10 <sup>-9</sup>    | 491-2740             | 0.54    | 0.24 |
| <i>i</i> -Butane  | C <sub>4</sub> H <sub>10</sub>  | -1.890 | 5.520 × 10 <sup>-2</sup>    | -1.696 × 10 <sup>-5</sup>   | 2.044 × 10 <sup>-9</sup>    | 491-2740             | 0.25    | 0.13 |
| <i>n</i> -Pentane | C <sub>5</sub> H <sub>12</sub>  | 1.618  | 6.028 × 10 <sup>-2</sup>    | -1.656 × 10 <sup>-5</sup>   | 1.732 × 10 <sup>-9</sup>    | 491-2740             | 0.56    | 0.21 |
| <i>n</i> -Hexane  | C <sub>6</sub> H <sub>14</sub>  | 1.657  | 7.328 × 10 <sup>-2</sup>    | -2.112 × 10 <sup>-5</sup>   | 2.363 × 10 <sup>-9</sup>    | 491-2740             | 0.72    | 0.20 |
| Ethylene          | C <sub>2</sub> H <sub>4</sub>   | 0.944  | 2.075 × 10 <sup>-2</sup>    | -0.6151 × 10 <sup>-5</sup>  | 0.7326 × 10 <sup>-9</sup>   | 491-2740             | 0.54    | 0.13 |
| Propylene         | C <sub>3</sub> H <sub>6</sub>   | 0.753  | 3.162 × 10 <sup>-2</sup>    | -0.8981 × 10 <sup>-5</sup>  | 1.008 × 10 <sup>-9</sup>    | 491-2740             | 0.73    | 0.17 |

Source: *Chemical and Process Thermodynamics 3/E* by Kyle, B. G., © 2000. Adapted by permission of Pearson Education, Inc., Upper Saddle River, NJ.

TABLE A-3E

Properties of common liquids, solids, and foods  
(a) Liquids

| Substance                           | Boiling data at 1 atm    |   | Freezing data      |   | Liquid properties |                                     |                                |
|-------------------------------------|--------------------------|---|--------------------|---|-------------------|-------------------------------------|--------------------------------|
|                                     | Normal boiling point, °F | Latent heat of vaporization, $h_{fg}$ Btu/lbm | Freezing point, °F | Latent heat of fusion, $h_{if}$ Btu/lbm | Temperature, °F   | Density, $\rho$ lbm/ft <sup>3</sup> | Specific heat, $c_p$ Btu/lbm·R |
| Ammonia                             | -27.9                    | 24.54   | -107.9             | 138.6                                   | -27.9             | 42.6                                | 1.06                           |
|                                     |                          |   |                    |   | 0                 | 41.3                                | 1.083                          |
|                                     |                          |   |                    |   | 40                | 39.5                                | 1.103                          |
|                                     |                          |   |                    |   | 80                | 37.5                                | 1.135                          |
| Argon                               | -302.6                   | 69.5  | -308.7             | 12.0                                    | -302.6            | 87.0                                | 0.272                          |
| Benzene                             | 176.4                    | 169.4   | 41.9               | 54.2                                    | 68                | 54.9                                | 0.411                          |
| Brine (20% sodium chloride by mass) | 219.0                    | —   | 0.7                | —                                       | 68                | 71.8                                | 0.743                          |
| <i>n</i> -Butane                    | 31.1                     | 165.6   | -217.3             | 34.5                                    | 31.1              | 37.5                                | 0.552                          |
| Carbon dioxide                      | -109.2*                  | 99.6 (at 32°F)                                | -69.8              | —                                       | 32                | 57.8                                | 0.583                          |
| Ethanol                             | 172.8                    | 360.5   | -173.6             | 46.9                                    | 77                | 48.9                                | 0.588                          |
| Ethyl alcohol                       | 173.5                    | 368   | -248.8             | 46.4                                    | 68                | 49.3                                | 0.678                          |
| Ethylene glycol                     | 388.6                    | 344.0   | 12.6               | 77.9                                    | 68                | 69.2                                | 0.678                          |
| Glycerine                           | 355.8                    | 419   | 66.0               | 86.3                                    | 68                | 78.7                                | 0.554                          |
| Helium                              | -452.1                   | 9.80  | —                  | —                                       | -452.1            | 9.13                                | 5.45                           |
| Hydrogen                            | -423.0                   | 191.7   | -434.5             | 25.6                                    | -423.0            | 4.41                                | 2.39                           |
| Isobutane                           | 10.9                     | 157.8   | -255.5             | 45.5                                    | 10.9              | 37.1                                | 0.545                          |
| Kerosene                            | 399-559                  | 108   | -12.8              | —                                       | 68                | 51.2                                | 0.478                          |
| Mercury                             | 674.1                    | 126.7   | -38.0              | 4.90                                    | 77                | 847                                 | 0.033                          |
| Methane                             | -258.7                   | 219.6   | 296.0              | 25.1                                    | -258.7            | 26.4                                | 0.834                          |
|                                     |                          |   |                    |   | -160              | 20.0                                | 1.074                          |
|                                     |                          |   |                    |   | 77                | 49.1                                | 0.609                          |
| Methanol                            | 148.1                    | 473   | -143.9             | 42.7                                    | 77                | 49.1                                | 0.609                          |
| Nitrogen                            | -320.4                   | 85.4  | -346.0             | 10.9                                    | -320.4            | 50.5                                | 0.492                          |
|                                     |                          |   |                    |   | -260              | 38.2                                | 0.643                          |
|                                     |                          |   |                    |   | 68                | 43.9                                | 0.502                          |
| Octane                              | 256.6                    | 131.7   | -71.5              | 77.9                                    | 68                | 43.9                                | 0.502                          |
| Oil (light)                         | —                        | —   | —                  | —                                       | 77                | 56.8                                | 0.430                          |
| Oxygen                              | -297.3                   | 91.5  | -361.8             | 5.9                                     | -297.3            | 71.2                                | 0.408                          |
| Petroleum                           | —                        | 99-165  | —                  | —                                       | 68                | 40.0                                | 0.478                          |
| Propane                             | -43.7                    | 184.0   | -305.8             | 34.4                                    | -43.7             | 36.3                                | 0.538                          |
|                                     |                          |   |                    |   | 32                | 33.0                                | 0.604                          |
|                                     |                          |   |                    |   | 100               | 29.4                                | 0.673                          |
|                                     |                          |   |                    |   | -40               | 88.5                                | 0.283                          |
| Refrigerant-134a                    | -15.0                    | 93.3  | -141.9             | —                                       | -15               | 86.0                                | 0.294                          |
|                                     |                          |   |                    |   | 32                | 80.9                                | 0.318                          |
|                                     |                          |   |                    |   | 90                | 73.6                                | 0.348                          |
| Water                               | 212                      | 970.1   | 32                 | 143.5                                   | 32                | 62.4                                | 1.01                           |
|                                     |                          |   |                    |   | 90                | 62.1                                | 1.00                           |
|                                     |                          |   |                    |   | 150               | 61.2                                | 1.00                           |
|                                     |                          |   |                    |   | 212               | 59.8                                | 1.01                           |
|                                     |                          |   |                    |   | —                 | —                                   | —                              |

\*Sublimation temperature. (At pressures below the triple-point pressure of 75.1 psia, carbon dioxide exists as a solid or gas. Also, the freezing-point temperature of carbon dioxide is the triple-point temperature of -69.8°F.)

**TABLE A-3E**

Properties of common liquids, solids, and foods (*Concluded*)  
(b) Solids (values are for room temperature unless indicated otherwise)

| Substance                         | Density,<br>$\rho$ lbm/ft <sup>3</sup> | Specific<br>heat, $c_p$<br>Btu/lbm·R | Substance                      | Density,<br>$\rho$ lbm/ft <sup>3</sup> | Specific<br>heat, $c_p$<br>Btu/lbm·R |
|-----------------------------------|--|--------------------------------------|--------------------------------|--|--------------------------------------|
| <b>Metals</b>                     |  |                                      | <b>Nonmetals</b>               |  |                                      |
| Aluminum                          |  |                                      | Asphalt                        | 132                                    | 0.220                                |
| -100°F                            |  | 0.192                                | Brick, common                  | 120                                    | 0.189                                |
| 32°F                              |  | 0.212                                | Brick, fireclay (500°C)        | 144                                    | 0.229                                |
| 100°F                             | 170                                    | 0.218                                | Concrete                       | 144                                    | 0.156                                |
| 200°F                             |  | 0.224                                | Clay                           | 62.4                                   | 0.220                                |
| 300°F                             |  | 0.229                                | Diamond                        | 151                                    | 0.147                                |
| 400°F                             |  | 0.235                                | Glass, window                  | 169                                    | 0.191                                |
| 500°F                             |  | 0.240                                | Glass, pyrex                   | 139                                    | 0.200                                |
| Bronze (76% Cu, 2% Zn,<br>2% Al)  | 517                                    | 0.0955                               | Graphite                       | 156                                    | 0.170                                |
| Brass, yellow (65% Cu,<br>35% Zn) | 519                                    | 0.0955                               | Granite                        | 169                                    | 0.243                                |
| Copper                            |  |                                      | Gypsum or plaster board        | 50                                     | 0.260                                |
| -60°F                             |  | 0.0862                               | Ice                            |  |                                      |
| 0°F                               |  | 0.0893                               | -50°F                          |  | 0.424                                |
| 100°F                             | 555                                    | 0.0925                               | 0°F                            |  | 0.471                                |
| 200°F                             |  | 0.0938                               | 20°F                           |  | 0.491                                |
| 390°F                             |  | 0.0963                               | 32°F                           | 57.5                                   | 0.502                                |
| Iron                              | 490                                    | 0.107                                | Limestone                      | 103                                    | 0.217                                |
| Lead                              | 705                                    | 0.030                                | Marble                         | 162                                    | 0.210                                |
| Magnesium                         | 108                                    | 0.239                                | Plywood (Douglas fir)          | 34.0                                   |                                      |
| Nickel                            | 555                                    | 0.105                                | Rubber (soft)                  | 68.7                                   |                                      |
| Silver                            | 655                                    | 0.056                                | Rubber (hard)                  | 71.8                                   |                                      |
| Steel, mild                       | 489                                    | 0.119                                | Sand                           | 94.9                                   |                                      |
| Tungsten                          | 1211                                   | 0.031                                | Stone                          | 93.6                                   |                                      |
|                                   |  |                                      | Woods, hard (maple, oak, etc.) | 45.0                                   |                                      |
|                                   |  |                                      | Woods, soft (fir, pine, etc.)  | 32.0                                   |                                      |

(c) Foods

| Food          | Water<br>content,<br>% (mass) | Freezing<br>point,<br>°F | Specific heat,<br>Btu/lbm·R |                   | Latent<br>heat of<br>fusion,<br>Btu/lbm | Food           | Water<br>content,<br>% (mass) | Freezing<br>point,<br>°F | Specific heat,<br>Btu/lbm·R |                   | Latent<br>heat of<br>fusion,<br>Btu/lbm |
|---------------|-------------------------------|--------------------------|-----------------------------|-------------------|---|----------------|-------------------------------|--------------------------|-----------------------------|-------------------|---|
|               |                               |                          | Above<br>freezing           | Below<br>freezing |   |                |                               |                          | Above<br>freezing           | Below<br>freezing |   |
| Apples        | 84                            | 30                       | 0.873                       | 0.453             | 121                                     | Lettuce        | 95                            | 32                       | 0.961                       | 0.487             | 136                                     |
| Bananas       | 75                            | 31                       | 0.801                       | 0.426             | 108                                     | Milk, whole    | 88                            | 31                       | 0.905                       | 0.465             | 126                                     |
| Beef round    | 67                            | —                        | 0.737                       | 0.402             | 96                                      | Oranges        | 87                            | 31                       | 0.897                       | 0.462             | 125                                     |
| Broccoli      | 90                            | 31                       | 0.921                       | 0.471             | 129                                     | Potatoes       | 78                            | 31                       | 0.825                       | 0.435             | 112                                     |
| Butter        | 16                            | —                        | —                           | 0.249             | 23                                      | Salmon fish    | 64                            | 28                       | 0.713                       | 0.393             | 92                                      |
| Cheese, Swiss | 39                            | 14                       | 0.513                       | 0.318             | 56                                      | Shrimp         | 83                            | 28                       | 0.865                       | 0.450             | 119                                     |
| Cherries      | 80                            | 29                       | 0.841                       | 0.441             | 115                                     | Spinach        | 93                            | 31                       | 0.945                       | 0.481             | 134                                     |
| Chicken       | 74                            | 27                       | 0.793                       | 0.423             | 106                                     | Strawberries   | 90                            | 31                       | 0.921                       | 0.471             | 129                                     |
| Corn, sweet   | 74                            | 31                       | 0.793                       | 0.423             | 106                                     | Tomatoes, ripe | 94                            | 31                       | 0.953                       | 0.484             | 135                                     |
| Eggs, whole   | 74                            | 31                       | 0.793                       | 0.423             | 106                                     | Turkey         | 64                            | —                        | 0.713                       | 0.393             | 92                                      |
| Ice cream     | 63                            | 22                       | 0.705                       | 0.390             | 90                                      | Watermelon     | 93                            | 31                       | 0.945                       | 0.481             | 134                                     |

Source: Values are obtained from various handbooks and other sources or are calculated. Water content and freezing-point data of foods are from ASHRAE, *Handbook of Fundamentals*, I-P version (Atlanta, GA: American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., 1993), Chap. 30, Table 1. Freezing point is the temperature at which freezing starts for fruits and vegetables, and the average freezing temperature for other foods.

TABLE A-4E

Saturated water—Temperature table

| Temp.,<br>$T$ °F | Sat.<br>press.,<br>$P_{\text{sat}}$ psia | Specific volume,<br>ft <sup>3</sup> /lbm |                         | Internal energy,<br>Btu/lbm |                    |                         | Enthalpy,<br>Btu/lbm     |                    |                         | Entropy,<br>Btu/lbm-R    |                    |                         |
|------------------|--|--|-------------------------|-----------------------------|--------------------|-------------------------|--------------------------|--------------------|-------------------------|--------------------------|--------------------|-------------------------|
|                  |  | 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>$s_g$ |
| 32.018           | 0.08871                                  | 0.01602                                  | 3299.9                  | 0.000                       | 1021.0             | 1021.0                  | 0.000                    | 1075.2             | 1075.2                  | 0.00000                  | 2.18672            | 2.1867                  |
| 35               | 0.09998                                  | 0.01602                                  | 2945.7                  | 3.004                       | 1019.0             | 1022.0                  | 3.004                    | 1073.5             | 1076.5                  | 0.00609                  | 2.17011            | 2.1762                  |
| 40               | 0.12173                                  | 0.01602                                  | 2443.6                  | 8.032                       | 1015.6             | 1023.7                  | 8.032                    | 1070.7             | 1078.7                  | 0.01620                  | 2.14271            | 2.1589                  |
| 45               | 0.14756                                  | 0.01602                                  | 2035.8                  | 13.05                       | 1012.2             | 1025.3                  | 13.05                    | 1067.8             | 1080.9                  | 0.02620                  | 2.11587            | 2.1421                  |
| 50               | 0.17812                                  | 0.01602                                  | 1703.1                  | 18.07                       | 1008.9             | 1026.9                  | 18.07                    | 1065.0             | 1083.1                  | 0.03609                  | 2.08956            | 2.1256                  |
| 55               | 0.21413                                  | 0.01603                                  | 1430.4                  | 23.07                       | 1005.5             | 1028.6                  | 23.07                    | 1062.2             | 1085.3                  | 0.04586                  | 2.06377            | 2.1096                  |
| 60               | 0.25638                                  | 0.01604                                  | 1206.1                  | 28.08                       | 1002.1             | 1030.2                  | 28.08                    | 1059.4             | 1087.4                  | 0.05554                  | 2.03847            | 2.0940                  |
| 65               | 0.30578                                  | 0.01604                                  | 1020.8                  | 33.08                       | 998.76             | 1031.8                  | 33.08                    | 1056.5             | 1089.6                  | 0.06511                  | 2.01366            | 2.0788                  |
| 70               | 0.36334                                  | 0.01605                                  | 867.18                  | 38.08                       | 995.39             | 1033.5                  | 38.08                    | 1053.7             | 1091.8                  | 0.07459                  | 1.98931            | 2.0639                  |
| 75               | 0.43016                                  | 0.01606                                  | 739.27                  | 43.07                       | 992.02             | 1035.1                  | 43.07                    | 1050.9             | 1093.9                  | 0.08398                  | 1.96541            | 2.0494                  |
| 80               | 0.50745                                  | 0.01607                                  | 632.41                  | 48.06                       | 988.65             | 1036.7                  | 48.07                    | 1048.0             | 1096.1                  | 0.09328                  | 1.94196            | 2.0352                  |
| 85               | 0.59659                                  | 0.01609                                  | 542.80                  | 53.06                       | 985.28             | 1038.3                  | 53.06                    | 1045.2             | 1098.3                  | 0.10248                  | 1.91892            | 2.0214                  |
| 90               | 0.69904                                  | 0.01610                                  | 467.40                  | 58.05                       | 981.90             | 1040.0                  | 58.05                    | 1042.4             | 1100.4                  | 0.11161                  | 1.89630            | 2.0079                  |
| 95               | 0.81643                                  | 0.01612                                  | 403.74                  | 63.04                       | 978.52             | 1041.6                  | 63.04                    | 1039.5             | 1102.6                  | 0.12065                  | 1.87408            | 1.9947                  |
| 100              | 0.95052                                  | 0.01613                                  | 349.83                  | 68.03                       | 975.14             | 1043.2                  | 68.03                    | 1036.7             | 1104.7                  | 0.12961                  | 1.85225            | 1.9819                  |
| 110              | 1.2767                                   | 0.01617                                  | 264.96                  | 78.01                       | 968.36             | 1046.4                  | 78.02                    | 1031.0             | 1109.0                  | 0.14728                  | 1.80970            | 1.9570                  |
| 120              | 1.6951                                   | 0.01620                                  | 202.94                  | 88.00                       | 961.56             | 1049.6                  | 88.00                    | 1025.2             | 1113.2                  | 0.16466                  | 1.76856            | 1.9332                  |
| 130              | 2.2260                                   | 0.01625                                  | 157.09                  | 97.99                       | 954.73             | 1052.7                  | 97.99                    | 1019.4             | 1117.4                  | 0.18174                  | 1.72877            | 1.9105                  |
| 140              | 2.8931                                   | 0.01629                                  | 122.81                  | 107.98                      | 947.87             | 1055.9                  | 107.99                   | 1013.6             | 1121.6                  | 0.19855                  | 1.69024            | 1.8888                  |
| 150              | 3.7234                                   | 0.01634                                  | 96.929                  | 117.98                      | 940.98             | 1059.0                  | 117.99                   | 1007.8             | 1125.7                  | 0.21508                  | 1.65291            | 1.8680                  |
| 160              | 4.7474                                   | 0.01639                                  | 77.185                  | 127.98                      | 934.05             | 1062.0                  | 128.00                   | 1001.8             | 1129.8                  | 0.23136                  | 1.61670            | 1.8481                  |
| 170              | 5.9999                                   | 0.01645                                  | 61.982                  | 138.00                      | 927.08             | 1065.1                  | 138.02                   | 995.88             | 1133.9                  | 0.24739                  | 1.58155            | 1.8289                  |
| 180              | 7.5197                                   | 0.01651                                  | 50.172                  | 148.02                      | 920.06             | 1068.1                  | 148.04                   | 989.85             | 1137.9                  | 0.26318                  | 1.54741            | 1.8106                  |
| 190              | 9.3497                                   | 0.01657                                  | 40.920                  | 158.05                      | 912.99             | 1071.0                  | 158.08                   | 983.76             | 1141.8                  | 0.27874                  | 1.51421            | 1.7930                  |
| 200              | 11.538                                   | 0.01663                                  | 33.613                  | 168.10                      | 905.87             | 1074.0                  | 168.13                   | 977.60             | 1145.7                  | 0.29409                  | 1.48191            | 1.7760                  |
| 210              | 14.136                                   | 0.01670                                  | 27.798                  | 178.15                      | 898.68             | 1076.8                  | 178.20                   | 971.35             | 1149.5                  | 0.30922                  | 1.45046            | 1.7597                  |
| 212              | 14.709                                   | 0.01671                                  | 26.782                  | 180.16                      | 897.24             | 1077.4                  | 180.21                   | 970.09             | 1150.3                  | 0.31222                  | 1.44427            | 1.7565                  |
| 220              | 17.201                                   | 0.01677                                  | 23.136                  | 188.22                      | 891.43             | 1079.6                  | 188.28                   | 965.02             | 1153.3                  | 0.32414                  | 1.41980            | 1.7439                  |
| 230              | 20.795                                   | 0.01684                                  | 19.374                  | 198.31                      | 884.10             | 1082.4                  | 198.37                   | 958.59             | 1157.0                  | 0.33887                  | 1.38989            | 1.7288                  |
| 240              | 24.985                                   | 0.01692                                  | 16.316                  | 208.41                      | 876.70             | 1085.1                  | 208.49                   | 952.06             | 1160.5                  | 0.35342                  | 1.36069            | 1.7141                  |
| 250              | 29.844                                   | 0.01700                                  | 13.816                  | 218.54                      | 869.21             | 1087.7                  | 218.63                   | 945.41             | 1164.0                  | 0.36779                  | 1.33216            | 1.6999                  |
| 260              | 35.447                                   | 0.01708                                  | 11.760                  | 228.68                      | 861.62             | 1090.3                  | 228.79                   | 938.65             | 1167.4                  | 0.38198                  | 1.30425            | 1.6862                  |
| 270              | 41.877                                   | 0.01717                                  | 10.059                  | 238.85                      | 853.94             | 1092.8                  | 238.98                   | 931.76             | 1170.7                  | 0.39601                  | 1.27694            | 1.6730                  |
| 280              | 49.222                                   | 0.01726                                  | 8.6439                  | 249.04                      | 846.16             | 1095.2                  | 249.20                   | 924.74             | 1173.9                  | 0.40989                  | 1.25018            | 1.6601                  |
| 290              | 57.573                                   | 0.01735                                  | 7.4607                  | 259.26                      | 838.27             | 1097.5                  | 259.45                   | 917.57             | 1177.0                  | 0.42361                  | 1.22393            | 1.6475                  |
| 300              | 67.028                                   | 0.01745                                  | 6.4663                  | 269.51                      | 830.25             | 1099.8                  | 269.73                   | 910.24             | 1180.0                  | 0.43720                  | 1.19818            | 1.6354                  |
| 310              | 77.691                                   | 0.01755                                  | 5.6266                  | 279.79                      | 822.11             | 1101.9                  | 280.05                   | 902.75             | 1182.8                  | 0.45065                  | 1.17289            | 1.6235                  |
| 320              | 89.667                                   | 0.01765                                  | 4.9144                  | 290.11                      | 813.84             | 1104.0                  | 290.40                   | 895.09             | 1185.5                  | 0.46396                  | 1.14802            | 1.6120                  |
| 330              | 103.07                                   | 0.01776                                  | 4.3076                  | 300.46                      | 805.43             | 1105.9                  | 300.80                   | 887.25             | 1188.1                  | 0.47716                  | 1.12355            | 1.6007                  |
| 340              | 118.02                                   | 0.01787                                  | 3.7885                  | 310.85                      | 796.87             | 1107.7                  | 311.24                   | 879.22             | 1190.5                  | 0.49024                  | 1.09945            | 1.5897                  |
| 350              | 134.63                                   | 0.01799                                  | 3.3425                  | 321.29                      | 788.16             | 1109.4                  | 321.73                   | 870.98             | 1192.7                  | 0.50321                  | 1.07570            | 1.5789                  |
| 360              | 153.03                                   | 0.01811                                  | 2.9580                  | 331.76                      | 779.28             | 1111.0                  | 332.28                   | 862.53             | 1194.8                  | 0.51607                  | 1.05227            | 1.5683                  |
| 370              | 173.36                                   | 0.01823                                  | 2.6252                  | 342.29                      | 770.23             | 1112.5                  | 342.88                   | 853.86             | 1196.7                  | 0.52884                  | 1.02914            | 1.5580                  |
| 380              | 195.74                                   | 0.01836                                  | 2.3361                  | 352.87                      | 761.00             | 1113.9                  | 353.53                   | 844.96             | 1198.5                  | 0.54152                  | 1.00628            | 1.5478                  |
| 390              | 220.33                                   | 0.01850                                  | 2.0842                  | 363.50                      | 751.58             | 1115.1                  | 364.25                   | 835.81             | 1200.1                  | 0.55411                  | 0.98366            | 1.5378                  |



**TABLE A-4E**

Saturated water—Temperature table (*Concluded*)

| Temp.,<br><i>T</i> °F | Sat.<br>press.,<br><i>P</i> <sub>sat</sub> psia | Specific volume,<br>ft <sup>3</sup> /lbm |   | Internal energy,<br>Btu/lbm              |                                  |   | Enthalpy,<br>Btu/lbm                     |                                  |   | Entropy,<br>Btu/lbm·R                    |                                  |   |
|-----------------------|---|--|---|--|----------------------------------|---|--|----------------------------------|---|--|----------------------------------|---|
|                       |   | Sat.<br>liquid,<br><i>v</i> <sub>f</sub> | Sat.<br>vapor,<br><i>v</i> <sub>g</sub> | Sat.<br>liquid,<br><i>u</i> <sub>f</sub> | Evap.,<br><i>u</i> <sub>fg</sub> | Sat.<br>vapor,<br><i>u</i> <sub>g</sub> | Sat.<br>liquid,<br><i>h</i> <sub>f</sub> | Evap.,<br><i>h</i> <sub>fg</sub> | Sat.<br>vapor,<br><i>h</i> <sub>g</sub> | Sat.<br>liquid,<br><i>s</i> <sub>f</sub> | Evap.,<br><i>s</i> <sub>fg</sub> | Sat.<br>vapor,<br><i>s</i> <sub>g</sub> |
| 400                   | 247.26  | 0.01864                                  | 1.8639                                  | 374.19                                   | 741.97                           | 1116.2                                  | 375.04                                   | 826.39                           | 1201.4                                  | 0.56663                                  | 0.96127                          | 1.5279                                  |
| 410                   | 276.69  | 0.01878                                  | 1.6706                                  | 384.94                                   | 732.14                           | 1117.1                                  | 385.90                                   | 816.71                           | 1202.6                                  | 0.57907                                  | 0.93908                          | 1.5182                                  |
| 420                   | 308.76  | 0.01894                                  | 1.5006                                  | 395.76                                   | 722.08                           | 1117.8                                  | 396.84                                   | 806.74                           | 1203.6                                  | 0.59145                                  | 0.91707                          | 1.5085                                  |
| 430                   | 343.64  | 0.01910                                  | 1.3505                                  | 406.65                                   | 711.80                           | 1118.4                                  | 407.86                                   | 796.46                           | 1204.3                                  | 0.60377                                  | 0.89522                          | 1.4990                                  |
| 440                   | 381.49  | 0.01926                                  | 1.2178                                  | 417.61                                   | 701.26                           | 1118.9                                  | 418.97                                   | 785.87                           | 1204.8                                  | 0.61603                                  | 0.87349                          | 1.4895                                  |
| 450                   | 422.47  | 0.01944                                  | 1.0999                                  | 428.66                                   | 690.47                           | 1119.1                                  | 430.18                                   | 774.94                           | 1205.1                                  | 0.62826                                  | 0.85187                          | 1.4801                                  |
| 460                   | 466.75  | 0.01962                                  | 0.99510                                 | 439.79                                   | 679.39                           | 1119.2                                  | 441.48                                   | 763.65                           | 1205.1                                  | 0.64044                                  | 0.83033                          | 1.4708                                  |
| 470                   | 514.52  | 0.01981                                  | 0.90158                                 | 451.01                                   | 668.02                           | 1119.0                                  | 452.90                                   | 751.98                           | 1204.9                                  | 0.65260                                  | 0.80885                          | 1.4615                                  |
| 480                   | 565.96  | 0.02001                                  | 0.81794                                 | 462.34                                   | 656.34                           | 1118.7                                  | 464.43                                   | 739.91                           | 1204.3                                  | 0.66474                                  | 0.78739                          | 1.4521                                  |
| 490                   | 621.24  | 0.02022                                  | 0.74296                                 | 473.77                                   | 644.32                           | 1118.1                                  | 476.09                                   | 727.40                           | 1203.5                                  | 0.67686                                  | 0.76594                          | 1.4428                                  |
| 500                   | 680.56  | 0.02044                                  | 0.67558                                 | 485.32                                   | 631.94                           | 1117.3                                  | 487.89                                   | 714.44                           | 1202.3                                  | 0.68899                                  | 0.74445                          | 1.4334                                  |
| 510                   | 744.11  | 0.02067                                  | 0.61489                                 | 496.99                                   | 619.17                           | 1116.2                                  | 499.84                                   | 700.99                           | 1200.8                                  | 0.70112                                  | 0.72290                          | 1.4240                                  |
| 520                   | 812.11  | 0.02092                                  | 0.56009                                 | 508.80                                   | 605.99                           | 1114.8                                  | 511.94                                   | 687.01                           | 1199.0                                  | 0.71327                                  | 0.70126                          | 1.4145                                  |
| 530                   | 884.74  | 0.02118                                  | 0.51051                                 | 520.76                                   | 592.35                           | 1113.1                                  | 524.23                                   | 672.47                           | 1196.7                                  | 0.72546                                  | 0.67947                          | 1.4049                                  |
| 540                   | 962.24  | 0.02146                                  | 0.46553                                 | 532.88                                   | 578.23                           | 1111.1                                  | 536.70                                   | 657.31                           | 1194.0                                  | 0.73770                                  | 0.65751                          | 1.3952                                  |
| 550                   | 1044.8  | 0.02176                                  | 0.42465                                 | 545.18                                   | 563.58                           | 1108.8                                  | 549.39                                   | 641.47                           | 1190.9                                  | 0.75000                                  | 0.63532                          | 1.3853                                  |
| 560                   | 1132.7  | 0.02207                                  | 0.38740                                 | 557.68                                   | 548.33                           | 1106.0                                  | 562.31                                   | 624.91                           | 1187.2                                  | 0.76238                                  | 0.61284                          | 1.3752                                  |
| 570                   | 1226.2  | 0.02242                                  | 0.35339                                 | 570.40                                   | 532.45                           | 1102.8                                  | 575.49                                   | 607.55                           | 1183.0                                  | 0.77486                                  | 0.59003                          | 1.3649                                  |
| 580                   | 1325.5  | 0.02279                                  | 0.32225                                 | 583.37                                   | 515.84                           | 1099.2                                  | 588.95                                   | 589.29                           | 1178.2                                  | 0.78748                                  | 0.56679                          | 1.3543                                  |
| 590                   | 1430.8  | 0.02319                                  | 0.29367                                 | 596.61                                   | 498.43                           | 1095.0                                  | 602.75                                   | 570.04                           | 1172.8                                  | 0.80026                                  | 0.54306                          | 1.3433                                  |
| 600                   | 1542.5  | 0.02362                                  | 0.26737                                 | 610.18                                   | 480.10                           | 1090.3                                  | 616.92                                   | 549.67                           | 1166.6                                  | 0.81323                                  | 0.51871                          | 1.3319                                  |
| 610                   | 1660.9  | 0.02411                                  | 0.24309                                 | 624.11                                   | 460.73                           | 1084.8                                  | 631.52                                   | 528.03                           | 1159.5                                  | 0.82645                                  | 0.49363                          | 1.3201                                  |
| 620                   | 1786.2  | 0.02464                                  | 0.22061                                 | 638.47                                   | 440.14                           | 1078.6                                  | 646.62                                   | 504.92                           | 1151.5                                  | 0.83998                                  | 0.46765                          | 1.3076                                  |
| 630                   | 1918.9  | 0.02524                                  | 0.19972                                 | 653.35                                   | 418.12                           | 1071.5                                  | 662.32                                   | 480.07                           | 1142.4                                  | 0.85389                                  | 0.44056                          | 1.2944                                  |
| 640                   | 2059.3  | 0.02593                                  | 0.18019                                 | 668.86                                   | 394.36                           | 1063.2                                  | 678.74                                   | 453.14                           | 1131.9                                  | 0.86828                                  | 0.41206                          | 1.2803                                  |
| 650                   | 2207.8  | 0.02673                                  | 0.16184                                 | 685.16                                   | 368.44                           | 1053.6                                  | 696.08                                   | 423.65                           | 1119.7                                  | 0.88332                                  | 0.38177                          | 1.2651                                  |
| 660                   | 2364.9  | 0.02767                                  | 0.14444                                 | 702.48                                   | 339.74                           | 1042.2                                  | 714.59                                   | 390.84                           | 1105.4                                  | 0.89922                                  | 0.34906                          | 1.2483                                  |
| 670                   | 2531.2  | 0.02884                                  | 0.12774                                 | 721.23                                   | 307.22                           | 1028.5                                  | 734.74                                   | 353.54                           | 1088.3                                  | 0.91636                                  | 0.31296                          | 1.2293                                  |
| 680                   | 2707.3  | 0.03035                                  | 0.11134                                 | 742.11                                   | 269.00                           | 1011.1                                  | 757.32                                   | 309.57                           | 1066.9                                  | 0.93541                                  | 0.27163                          | 1.2070                                  |
| 690                   | 2894.1  | 0.03255                                  | 0.09451                                 | 766.81                                   | 220.77                           | 987.6                                   | 784.24                                   | 253.96                           | 1038.2                                  | 0.95797                                  | 0.22089                          | 1.1789                                  |
| 700                   | 3093.0  | 0.03670                                  | 0.07482                                 | 801.75                                   | 146.50                           | 948.3                                   | 822.76                                   | 168.32                           | 991.1                                   | 0.99023                                  | 0.14514                          | 1.1354                                  |
| 705.10                | 3200.1  | 0.04975                                  | 0.04975                                 | 866.61                                   | 0                                | 866.6                                   | 896.07                                   | 0                                | 896.1                                   | 1.05257                                  | 0                                | 1.0526                                  |

Source: Tables A-4E through A-8E are generated using the Engineering Equation Solver (EES) software developed by S. A. Klein and F. L. Alvarado. The routine used in calculations is the highly accurate Steam\_IAPWS, which incorporates the 1995 Formulation for the Thermodynamic Properties of Ordinary Water Substance for General and Scientific Use, issued by The International Association for the Properties of Water and Steam (IAPWS). This formulation replaces the 1984 formulation of Haar, Gallagher, and Kell (NBS/NRC Steam Tables, Hemisphere Publishing Co., 1984), which is also available in EES as the routine STEAM. The new formulation is based on the correlations of Saul and Wagner (J. Phys. Chem. Ref. Data, 16, 893, 1987) with modifications to adjust to the International Temperature Scale of 1990. The modifications are described by Wagner and Pruss (J. Phys. Chem. Ref. Data, 22, 783, 1993). The properties of ice are based on Hyland and Wexler, "Formulations for the Thermodynamic Properties of the Saturated Phases of H<sub>2</sub>O from 173.15 K to 473.15 K," *ASHRAE Trans.*, Part 2A, Paper 2793, 1983.

TABLE A-5E

Saturated water—Pressure table

| Press.,<br><i>P</i> psia | Sat.<br>temp.,<br><i>T</i> <sub>sat</sub> °F | Specific volume,<br>ft <sup>3</sup> /lbm |   | Internal energy,<br>Btu/lbm              |                                  |   | Enthalpy,<br>Btu/lbm                     |                                  |   | Entropy,<br>Btu/lbm-R                    |                                  |   |
|--------------------------|--|--|---|--|----------------------------------|---|--|----------------------------------|---|--|----------------------------------|---|
|                          |  | Sat.<br>liquid,<br><i>v</i> <sub>f</sub> | Sat.<br>vapor,<br><i>v</i> <sub>g</sub> | Sat.<br>liquid,<br><i>u</i> <sub>f</sub> | Evap.,<br><i>u</i> <sub>fg</sub> | Sat.<br>vapor,<br><i>u</i> <sub>g</sub> | Sat.<br>liquid,<br><i>h</i> <sub>f</sub> | Evap.,<br><i>h</i> <sub>fg</sub> | Sat.<br>vapor,<br><i>h</i> <sub>g</sub> | Sat.<br>liquid,<br><i>s</i> <sub>f</sub> | Evap.,<br><i>s</i> <sub>fg</sub> | Sat.<br>vapor,<br><i>s</i> <sub>g</sub> |
| 1                        | 101.69                                       | 0.01614                                  | 333.49                                  | 69.72                                    | 973.99                           | 1043.7                                  | 69.72                                    | 1035.7                           | 1105.4                                  | 0.13262                                  | 1.84495                          | 1.9776                                  |
| 2                        | 126.02                                       | 0.01623                                  | 173.71                                  | 94.02                                    | 957.45                           | 1051.5                                  | 94.02                                    | 1021.7                           | 1115.8                                  | 0.17499                                  | 1.74444                          | 1.9194                                  |
| 3                        | 141.41                                       | 0.01630                                  | 118.70                                  | 109.39                                   | 946.90                           | 1056.3                                  | 109.40                                   | 1012.8                           | 1122.2                                  | 0.20090                                  | 1.68489                          | 1.8858                                  |
| 4                        | 152.91                                       | 0.01636                                  | 90.629                                  | 120.89                                   | 938.97                           | 1059.9                                  | 120.90                                   | 1006.0                           | 1126.9                                  | 0.21985                                  | 1.64225                          | 1.8621                                  |
| 5                        | 162.18                                       | 0.01641                                  | 73.525                                  | 130.17                                   | 932.53                           | 1062.7                                  | 130.18                                   | 1000.5                           | 1130.7                                  | 0.23488                                  | 1.60894                          | 1.8438                                  |
| 6                        | 170.00                                       | 0.01645                                  | 61.982                                  | 138.00                                   | 927.08                           | 1065.1                                  | 138.02                                   | 995.88                           | 1133.9                                  | 0.24739                                  | 1.58155                          | 1.8289                                  |
| 8                        | 182.81                                       | 0.01652                                  | 47.347                                  | 150.83                                   | 918.08                           | 1068.9                                  | 150.86                                   | 988.15                           | 1139.0                                  | 0.26757                                  | 1.53800                          | 1.8056                                  |
| 10                       | 193.16                                       | 0.01659                                  | 38.425                                  | 161.22                                   | 910.75                           | 1072.0                                  | 161.25                                   | 981.82                           | 1143.1                                  | 0.28362                                  | 1.50391                          | 1.7875                                  |
| 14.696                   | 211.95                                       | 0.01671                                  | 26.805                                  | 180.12                                   | 897.27                           | 1077.4                                  | 180.16                                   | 970.12                           | 1150.3                                  | 0.31215                                  | 1.44441                          | 1.7566                                  |
| 15                       | 212.99                                       | 0.01672                                  | 26.297                                  | 181.16                                   | 896.52                           | 1077.7                                  | 181.21                                   | 969.47                           | 1150.7                                  | 0.31370                                  | 1.44441                          | 1.7549                                  |
| 20                       | 227.92                                       | 0.01683                                  | 20.093                                  | 196.21                                   | 885.63                           | 1081.8                                  | 196.27                                   | 959.93                           | 1156.2                                  | 0.33582                                  | 1.39606                          | 1.7319                                  |
| 25                       | 240.03                                       | 0.01692                                  | 16.307                                  | 208.45                                   | 876.67                           | 1085.1                                  | 208.52                                   | 952.03                           | 1160.6                                  | 0.35347                                  | 1.36060                          | 1.7141                                  |
| 30                       | 250.30                                       | 0.01700                                  | 13.749                                  | 218.84                                   | 868.98                           | 1087.8                                  | 218.93                                   | 945.21                           | 1164.1                                  | 0.36821                                  | 1.33132                          | 1.6995                                  |
| 35                       | 259.25                                       | 0.01708                                  | 11.901                                  | 227.92                                   | 862.19                           | 1090.1                                  | 228.03                                   | 939.16                           | 1167.2                                  | 0.38093                                  | 1.30632                          | 1.6872                                  |
| 40                       | 267.22                                       | 0.01715                                  | 10.501                                  | 236.02                                   | 856.09                           | 1092.1                                  | 236.14                                   | 933.69                           | 1169.8                                  | 0.39213                                  | 1.28448                          | 1.6766                                  |
| 45                       | 274.41                                       | 0.01721                                  | 9.4028                                  | 243.34                                   | 850.52                           | 1093.9                                  | 243.49                                   | 928.68                           | 1172.2                                  | 0.40216                                  | 1.26506                          | 1.6672                                  |
| 50                       | 280.99                                       | 0.01727                                  | 8.5175                                  | 250.05                                   | 845.39                           | 1095.4                                  | 250.21                                   | 924.03                           | 1174.2                                  | 0.41125                                  | 1.24756                          | 1.6588                                  |
| 55                       | 287.05                                       | 0.01732                                  | 7.7882                                  | 256.25                                   | 840.61                           | 1096.9                                  | 256.42                                   | 919.70                           | 1176.1                                  | 0.41958                                  | 1.23162                          | 1.6512                                  |
| 60                       | 292.69                                       | 0.01738                                  | 7.1766                                  | 262.01                                   | 836.13                           | 1098.1                                  | 262.20                                   | 915.61                           | 1177.8                                  | 0.42728                                  | 1.21697                          | 1.6442                                  |
| 65                       | 297.95                                       | 0.01743                                  | 6.6560                                  | 267.41                                   | 831.90                           | 1099.3                                  | 267.62                                   | 911.75                           | 1179.4                                  | 0.43443                                  | 1.20341                          | 1.6378                                  |
| 70                       | 302.91                                       | 0.01748                                  | 6.2075                                  | 272.50                                   | 827.90                           | 1100.4                                  | 272.72                                   | 908.08                           | 1180.8                                  | 0.44112                                  | 1.19078                          | 1.6319                                  |
| 75                       | 307.59                                       | 0.01752                                  | 5.8167                                  | 277.31                                   | 824.09                           | 1101.4                                  | 277.55                                   | 904.58                           | 1182.1                                  | 0.44741                                  | 1.17895                          | 1.6264                                  |
| 80                       | 312.02                                       | 0.01757                                  | 5.4733                                  | 281.87                                   | 820.45                           | 1102.3                                  | 282.13                                   | 901.22                           | 1183.4                                  | 0.45335                                  | 1.16783                          | 1.6212                                  |
| 85                       | 316.24                                       | 0.01761                                  | 5.1689                                  | 286.22                                   | 816.97                           | 1103.2                                  | 286.50                                   | 898.00                           | 1184.5                                  | 0.45897                                  | 1.15732                          | 1.6163                                  |
| 90                       | 320.26                                       | 0.01765                                  | 4.8972                                  | 290.38                                   | 813.62                           | 1104.0                                  | 290.67                                   | 894.89                           | 1185.6                                  | 0.46431                                  | 1.14737                          | 1.6117                                  |
| 95                       | 324.11                                       | 0.01770                                  | 4.6532                                  | 294.36                                   | 810.40                           | 1104.8                                  | 294.67                                   | 891.89                           | 1186.6                                  | 0.46941                                  | 1.13791                          | 1.6073                                  |
| 100                      | 327.81                                       | 0.01774                                  | 4.4327                                  | 298.19                                   | 807.29                           | 1105.5                                  | 298.51                                   | 888.99                           | 1187.5                                  | 0.47427                                  | 1.12888                          | 1.6032                                  |
| 110                      | 334.77                                       | 0.01781                                  | 4.0410                                  | 305.41                                   | 801.37                           | 1106.8                                  | 305.78                                   | 883.44                           | 1189.2                                  | 0.48341                                  | 1.11201                          | 1.5954                                  |
| 120                      | 341.25                                       | 0.01789                                  | 3.7289                                  | 312.16                                   | 795.79                           | 1107.9                                  | 312.55                                   | 878.20                           | 1190.8                                  | 0.49187                                  | 1.09646                          | 1.5883                                  |
| 130                      | 347.32                                       | 0.01796                                  | 3.4557                                  | 318.48                                   | 790.51                           | 1109.0                                  | 318.92                                   | 873.21                           | 1192.1                                  | 0.49974                                  | 1.08204                          | 1.5818                                  |
| 140                      | 353.03                                       | 0.01802                                  | 3.2202                                  | 324.45                                   | 785.49                           | 1109.9                                  | 324.92                                   | 868.45                           | 1193.4                                  | 0.50711                                  | 1.06858                          | 1.5757                                  |
| 150                      | 358.42                                       | 0.01809                                  | 3.0150                                  | 330.11                                   | 780.69                           | 1110.8                                  | 330.61                                   | 863.88                           | 1194.5                                  | 0.51405                                  | 1.05595                          | 1.5700                                  |
| 160                      | 363.54                                       | 0.01815                                  | 2.8347                                  | 335.49                                   | 776.10                           | 1111.6                                  | 336.02                                   | 859.49                           | 1195.5                                  | 0.52061                                  | 1.04405                          | 1.5647                                  |
| 170                      | 368.41                                       | 0.01821                                  | 2.6749                                  | 340.62                                   | 771.68                           | 1112.3                                  | 341.19                                   | 855.25                           | 1196.4                                  | 0.52682                                  | 1.03279                          | 1.5596                                  |
| 180                      | 373.07                                       | 0.01827                                  | 2.5322                                  | 345.53                                   | 767.42                           | 1113.0                                  | 346.14                                   | 851.16                           | 1197.3                                  | 0.53274                                  | 1.02210                          | 1.5548                                  |
| 190                      | 377.52                                       | 0.01833                                  | 2.4040                                  | 350.24                                   | 763.31                           | 1113.6                                  | 350.89                                   | 847.19                           | 1198.1                                  | 0.53839                                  | 1.01191                          | 1.5503                                  |
| 200                      | 381.80                                       | 0.01839                                  | 2.2882                                  | 354.78                                   | 759.32                           | 1114.1                                  | 355.46                                   | 843.33                           | 1198.8                                  | 0.54379                                  | 1.00219                          | 1.5460                                  |
| 250                      | 400.97                                       | 0.01865                                  | 1.8440                                  | 375.23                                   | 741.02                           | 1116.3                                  | 376.09                                   | 825.47                           | 1201.6                                  | 0.56784                                  | 0.95912                          | 1.5270                                  |
| 300                      | 417.35                                       | 0.01890                                  | 1.5435                                  | 392.89                                   | 724.77                           | 1117.7                                  | 393.94                                   | 809.41                           | 1203.3                                  | 0.58818                                  | 0.92289                          | 1.5111                                  |
| 350                      | 431.74                                       | 0.01912                                  | 1.3263                                  | 408.55                                   | 709.98                           | 1118.5                                  | 409.79                                   | 794.65                           | 1204.4                                  | 0.60590                                  | 0.89143                          | 1.4973                                  |
| 400                      | 444.62                                       | 0.01934                                  | 1.1617                                  | 422.70                                   | 696.31                           | 1119.0                                  | 424.13                                   | 780.87                           | 1205.0                                  | 0.62168                                  | 0.86350                          | 1.4852                                  |
| 450                      | 456.31                                       | 0.01955                                  | 1.0324                                  | 435.67                                   | 683.52                           | 1119.2                                  | 437.30                                   | 767.86                           | 1205.2                                  | 0.63595                                  | 0.83828                          | 1.4742                                  |
| 500                      | 467.04                                       | 0.01975                                  | 0.92819                                 | 447.68                                   | 671.42                           | 1119.1                                  | 449.51                                   | 755.48                           | 1205.0                                  | 0.64900                                  | 0.81521                          | 1.4642                                  |
| 550                      | 476.97                                       | 0.01995                                  | 0.84228                                 | 458.90                                   | 659.91                           | 1118.8                                  | 460.93                                   | 743.60                           | 1204.5                                  | 0.66107                                  | 0.79388                          | 1.4550                                  |
| 600                      | 486.24                                       | 0.02014                                  | 0.77020                                 | 469.46                                   | 648.88                           | 1118.3                                  | 471.70                                   | 732.15                           | 1203.9                                  | 0.67231                                  | 0.77400                          | 1.4463                                  |

TABLE A-5E

Saturated water—Pressure table (*Concluded*)

| Press.,<br><i>P</i> psia | Sat.<br>temp.,<br>$T_{\text{sat}}$ °F | Specific volume,<br>ft <sup>3</sup> /lbm |                         | Internal energy,<br>Btu/lbm |                    |                         | Enthalpy,<br>Btu/lbm     |                    |                         | Entropy,<br>Btu/lbm·R    |                    |                         |
|--------------------------|---------------------------------------|--|-------------------------|-----------------------------|--------------------|-------------------------|--------------------------|--------------------|-------------------------|--------------------------|--------------------|-------------------------|
|                          |                                       | 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>$s_g$ |
| 700                      | 503.13                                | 0.02051                                  | 0.65589                 | 488.96                      | 627.98             | 1116.9                  | 491.62                   | 710.29             | 1201.9                  | 0.69279                  | 0.73771            | 1.4305                  |
| 800                      | 518.27                                | 0.02087                                  | 0.56920                 | 506.74                      | 608.30             | 1115.0                  | 509.83                   | 689.48             | 1199.3                  | 0.71117                  | 0.70502            | 1.4162                  |
| 900                      | 532.02                                | 0.02124                                  | 0.50107                 | 523.19                      | 589.54             | 1112.7                  | 526.73                   | 669.46             | 1196.2                  | 0.72793                  | 0.67505            | 1.4030                  |
| 1000                     | 544.65                                | 0.02159                                  | 0.44604                 | 538.58                      | 571.49             | 1110.1                  | 542.57                   | 650.03             | 1192.6                  | 0.74341                  | 0.64722            | 1.3906                  |
| 1200                     | 567.26                                | 0.02232                                  | 0.36241                 | 566.89                      | 536.87             | 1103.8                  | 571.85                   | 612.39             | 1184.2                  | 0.77143                  | 0.59632            | 1.3677                  |
| 1400                     | 587.14                                | 0.02307                                  | 0.30161                 | 592.79                      | 503.50             | 1096.3                  | 598.76                   | 575.66             | 1174.4                  | 0.79658                  | 0.54991            | 1.3465                  |
| 1600                     | 604.93                                | 0.02386                                  | 0.25516                 | 616.99                      | 470.69             | 1087.7                  | 624.06                   | 539.18             | 1163.2                  | 0.81972                  | 0.50645            | 1.3262                  |
| 1800                     | 621.07                                | 0.02470                                  | 0.21831                 | 640.03                      | 437.86             | 1077.9                  | 648.26                   | 502.35             | 1150.6                  | 0.84144                  | 0.46482            | 1.3063                  |
| 2000                     | 635.85                                | 0.02563                                  | 0.18815                 | 662.33                      | 404.46             | 1066.8                  | 671.82                   | 464.60             | 1136.4                  | 0.86224                  | 0.42409            | 1.2863                  |
| 2500                     | 668.17                                | 0.02860                                  | 0.13076                 | 717.67                      | 313.53             | 1031.2                  | 730.90                   | 360.79             | 1091.7                  | 0.91311                  | 0.31988            | 1.2330                  |
| 3000                     | 695.41                                | 0.03433                                  | 0.08460                 | 783.39                      | 186.41             | 969.8                   | 802.45                   | 214.32             | 1016.8                  | 0.97321                  | 0.18554            | 1.1587                  |
| 3200.1                   | 705.10                                | 0.04975                                  | 0.04975                 | 866.61                      | 0                  | 866.6                   | 896.07                   | 0                  | 896.1                   | 1.05257                  | 0                  | 1.0526                  |

TABLE A-6E

Superheated water

| $T$<br>°F | $v$<br>ft <sup>3</sup> /lbm | $u$<br>Btu/lbm | $h$<br>Btu/lbm | $s$<br>Btu/<br>lbm·R       | $v$<br>ft <sup>3</sup> /lbm | $u$<br>Btu/lbm | $h$<br>Btu/lbm | $s$<br>Btu/<br>lbm·R      | $v$<br>ft <sup>3</sup> /lbm | $u$<br>Btu/lbm | $h$<br>Btu/lbm | $s$<br>Btu/<br>lbm·R      |  |  |  |
|-----------|-----------------------------|----------------|----------------|----------------------------|-----------------------------|----------------|----------------|---------------------------|-----------------------------|----------------|----------------|---------------------------|--|--|--|
|           |                             |                |                | $P = 1.0$ psia (101.69°F)* |                             |                |                | $P = 5.0$ psia (162.18°F) |                             |                |                | $P = 10$ psia (193.16°F)  |  |  |  |
| Sat.†     | 333.49                      | 1043.7         | 1105.4         | 1.9776                     | 73.525                      | 1062.7         | 1130.7         | 1.8438                    | 38.425                      | 1072.0         | 1143.1         | 1.7875                    |  |  |  |
| 200       | 392.53                      | 1077.5         | 1150.1         | 2.0509                     | 78.153                      | 1076.2         | 1148.5         | 1.8716                    | 38.849                      | 1074.5         | 1146.4         | 1.7926                    |  |  |  |
| 240       | 416.44                      | 1091.2         | 1168.3         | 2.0777                     | 83.009                      | 1090.3         | 1167.1         | 1.8989                    | 41.326                      | 1089.1         | 1165.5         | 1.8207                    |  |  |  |
| 280       | 440.33                      | 1105.0         | 1186.5         | 2.1030                     | 87.838                      | 1104.3         | 1185.6         | 1.9246                    | 43.774                      | 1103.4         | 1184.4         | 1.8469                    |  |  |  |
| 320       | 464.20                      | 1118.9         | 1204.8         | 2.1271                     | 92.650                      | 1118.4         | 1204.1         | 1.9490                    | 46.205                      | 1117.6         | 1203.1         | 1.8716                    |  |  |  |
| 360       | 488.07                      | 1132.9         | 1223.3         | 2.1502                     | 97.452                      | 1132.5         | 1222.6         | 1.9722                    | 48.624                      | 1131.9         | 1221.8         | 1.8950                    |  |  |  |
| 400       | 511.92                      | 1147.1         | 1241.8         | 2.1722                     | 102.25                      | 1146.7         | 1241.3         | 1.9944                    | 51.035                      | 1146.2         | 1240.6         | 1.9174                    |  |  |  |
| 440       | 535.77                      | 1161.3         | 1260.4         | 2.1934                     | 107.03                      | 1160.9         | 1260.0         | 2.0156                    | 53.441                      | 1160.5         | 1259.4         | 1.9388                    |  |  |  |
| 500       | 571.54                      | 1182.8         | 1288.6         | 2.2237                     | 114.21                      | 1182.6         | 1288.2         | 2.0461                    | 57.041                      | 1182.2         | 1287.8         | 1.9693                    |  |  |  |
| 600       | 631.14                      | 1219.4         | 1336.2         | 2.2709                     | 126.15                      | 1219.2         | 1335.9         | 2.0933                    | 63.029                      | 1219.0         | 1335.6         | 2.0167                    |  |  |  |
| 700       | 690.73                      | 1256.8         | 1384.6         | 2.3146                     | 138.09                      | 1256.7         | 1384.4         | 2.1371                    | 69.007                      | 1256.5         | 1384.2         | 2.0605                    |  |  |  |
| 800       | 750.31                      | 1295.1         | 1433.9         | 2.3553                     | 150.02                      | 1294.9         | 1433.7         | 2.1778                    | 74.980                      | 1294.8         | 1433.5         | 2.1013                    |  |  |  |
| 1000      | 869.47                      | 1374.2         | 1535.1         | 2.4299                     | 173.86                      | 1374.2         | 1535.0         | 2.2524                    | 86.913                      | 1374.1         | 1534.9         | 2.1760                    |  |  |  |
| 1200      | 988.62                      | 1457.1         | 1640.0         | 2.4972                     | 197.70                      | 1457.0         | 1640.0         | 2.3198                    | 98.840                      | 1457.0         | 1639.9         | 2.2433                    |  |  |  |
| 1400      | 1107.8                      | 1543.7         | 1748.7         | 2.5590                     | 221.54                      | 1543.7         | 1748.7         | 2.3816                    | 110.762                     | 1543.6         | 1748.6         | 2.3052                    |  |  |  |
|           |                             |                |                | $P = 15$ psia (212.99°F)   |                             |                |                | $P = 20$ psia (227.92°F)  |                             |                |                | $P = 40$ psia (267.22°F)  |  |  |  |
| Sat.      | 26.297                      | 1077.7         | 1150.7         | 1.7549                     | 20.093                      | 1081.8         | 1156.2         | 1.7319                    | 10.501                      | 1092.1         | 1169.8         | 1.6766                    |  |  |  |
| 240       | 27.429                      | 1087.8         | 1163.9         | 1.7742                     | 20.478                      | 1086.5         | 1162.3         | 1.7406                    |                             |                |                |                           |  |  |  |
| 280       | 29.085                      | 1102.4         | 1183.2         | 1.8010                     | 21.739                      | 1101.4         | 1181.9         | 1.7679                    | 10.713                      | 1097.3         | 1176.6         | 1.6858                    |  |  |  |
| 320       | 30.722                      | 1116.9         | 1202.2         | 1.8260                     | 22.980                      | 1116.1         | 1201.2         | 1.7933                    | 11.363                      | 1112.9         | 1197.1         | 1.7128                    |  |  |  |
| 360       | 32.348                      | 1131.3         | 1221.1         | 1.8496                     | 24.209                      | 1130.7         | 1220.2         | 1.8171                    | 11.999                      | 1128.1         | 1216.9         | 1.7376                    |  |  |  |
| 400       | 33.965                      | 1145.7         | 1239.9         | 1.8721                     | 25.429                      | 1145.1         | 1239.3         | 1.8398                    | 12.625                      | 1143.1         | 1236.5         | 1.7610                    |  |  |  |
| 440       | 35.576                      | 1160.1         | 1258.8         | 1.8936                     | 26.644                      | 1159.7         | 1258.3         | 1.8614                    | 13.244                      | 1157.9         | 1256.0         | 1.7831                    |  |  |  |
| 500       | 37.986                      | 1181.9         | 1287.3         | 1.9243                     | 28.458                      | 1181.6         | 1286.9         | 1.8922                    | 14.165                      | 1180.2         | 1285.0         | 1.8143                    |  |  |  |
| 600       | 41.988                      | 1218.7         | 1335.3         | 1.9718                     | 31.467                      | 1218.5         | 1334.9         | 1.9398                    | 15.686                      | 1217.5         | 1333.6         | 1.8625                    |  |  |  |
| 700       | 45.981                      | 1256.3         | 1383.9         | 2.0156                     | 34.467                      | 1256.1         | 1383.7         | 1.9837                    | 17.197                      | 1255.3         | 1382.6         | 1.9067                    |  |  |  |
| 800       | 49.967                      | 1294.6         | 1433.3         | 2.0565                     | 37.461                      | 1294.5         | 1433.1         | 2.0247                    | 18.702                      | 1293.9         | 1432.3         | 1.9478                    |  |  |  |
| 1000      | 57.930                      | 1374.0         | 1534.8         | 2.1312                     | 43.438                      | 1373.8         | 1534.6         | 2.0994                    | 21.700                      | 1373.4         | 1534.1         | 2.0227                    |  |  |  |
| 1200      | 65.885                      | 1456.9         | 1639.8         | 2.1986                     | 49.407                      | 1456.8         | 1639.7         | 2.1668                    | 24.691                      | 1456.5         | 1639.3         | 2.0902                    |  |  |  |
| 1400      | 73.836                      | 1543.6         | 1748.5         | 2.2604                     | 55.373                      | 1543.5         | 1748.4         | 2.2287                    | 27.678                      | 1543.3         | 1748.1         | 2.1522                    |  |  |  |
| 1600      | 81.784                      | 1634.0         | 1861.0         | 2.3178                     | 61.335                      | 1633.9         | 1860.9         | 2.2861                    | 30.662                      | 1633.7         | 1860.7         | 2.2096                    |  |  |  |
|           |                             |                |                | $P = 60$ psia (292.69°F)   |                             |                |                | $P = 80$ psia (312.02°F)  |                             |                |                | $P = 100$ psia (327.81°F) |  |  |  |
| Sat.      | 7.1766                      | 1098.1         | 1177.8         | 1.6442                     | 5.4733                      | 1102.3         | 1183.4         | 1.6212                    | 4.4327                      | 1105.5         | 1187.5         | 1.6032                    |  |  |  |
| 320       | 7.4863                      | 1109.6         | 1192.7         | 1.6636                     | 5.5440                      | 1105.9         | 1187.9         | 1.6271                    |                             |                |                |                           |  |  |  |
| 360       | 7.9259                      | 1125.5         | 1213.5         | 1.6897                     | 5.8876                      | 1122.7         | 1209.9         | 1.6545                    | 4.6628                      | 1119.8         | 1206.1         | 1.6263                    |  |  |  |
| 400       | 8.3548                      | 1140.9         | 1233.7         | 1.7138                     | 6.2187                      | 1138.7         | 1230.8         | 1.6794                    | 4.9359                      | 1136.4         | 1227.8         | 1.6521                    |  |  |  |
| 440       | 8.7766                      | 1156.1         | 1253.6         | 1.7364                     | 6.5420                      | 1154.3         | 1251.2         | 1.7026                    | 5.2006                      | 1152.4         | 1248.7         | 1.6759                    |  |  |  |
| 500       | 9.4005                      | 1178.8         | 1283.1         | 1.7682                     | 7.0177                      | 1177.3         | 1281.2         | 1.7350                    | 5.5876                      | 1175.9         | 1279.3         | 1.7088                    |  |  |  |
| 600       | 10.4256                     | 1216.5         | 1332.2         | 1.8168                     | 7.7951                      | 1215.4         | 1330.8         | 1.7841                    | 6.2167                      | 1214.4         | 1329.4         | 1.7586                    |  |  |  |
| 700       | 11.4401                     | 1254.5         | 1381.6         | 1.8613                     | 8.5616                      | 1253.8         | 1380.5         | 1.8289                    | 6.8344                      | 1253.0         | 1379.5         | 1.8037                    |  |  |  |
| 800       | 12.4484                     | 1293.3         | 1431.5         | 1.9026                     | 9.3218                      | 1292.6         | 1430.6         | 1.8704                    | 7.4457                      | 1292.0         | 1429.8         | 1.8453                    |  |  |  |
| 1000      | 14.4543                     | 1373.0         | 1533.5         | 1.9777                     | 10.8313                     | 1372.6         | 1532.9         | 1.9457                    | 8.6575                      | 1372.2         | 1532.4         | 1.9208                    |  |  |  |
| 1200      | 16.4525                     | 1456.2         | 1638.9         | 2.0454                     | 12.3331                     | 1455.9         | 1638.5         | 2.0135                    | 9.8615                      | 1455.6         | 1638.1         | 1.9887                    |  |  |  |
| 1400      | 18.4464                     | 1543.0         | 1747.8         | 2.1073                     | 13.8306                     | 1542.8         | 1747.5         | 2.0755                    | 11.0612                     | 1542.6         | 1747.2         | 2.0508                    |  |  |  |
| 1600      | 20.438                      | 1633.5         | 1860.5         | 2.1648                     | 15.3257                     | 1633.3         | 1860.2         | 2.1330                    | 12.2584                     | 1633.2         | 1860.0         | 2.1083                    |  |  |  |
| 1800      | 22.428                      | 1727.6         | 1976.6         | 2.2187                     | 16.8192                     | 1727.5         | 1976.5         | 2.1869                    | 13.4541                     | 1727.3         | 1976.3         | 2.1622                    |  |  |  |
| 2000      | 24.417                      | 1825.2         | 2096.3         | 2.2694                     | 18.3117                     | 1825.0         | 2096.1         | 2.2376                    | 14.6487                     | 1824.9         | 2096.0         | 2.2130                    |  |  |  |

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

† Properties of saturated vapor at the specified pressure.

**TABLE A-6E**

Superheated water (*Concluded*)

| <i>T</i><br>°F                 | <i>v</i><br>ft <sup>3</sup> /lbm | <i>u</i><br>Btu/lbm | <i>h</i><br>Btu/lbm | <i>s</i><br>Btu/<br>lbm·R | <i>v</i><br>ft <sup>3</sup> /lbm | <i>u</i><br>Btu/lbm | <i>h</i><br>Btu/lbm | <i>s</i><br>Btu/<br>lbm·R | <i>v</i><br>ft <sup>3</sup> /lbm | <i>u</i><br>Btu/lbm            | <i>h</i><br>Btu/lbm | <i>s</i><br>Btu/<br>lbm·R |  |
|--------------------------------|----------------------------------|---------------------|---------------------|---------------------------|----------------------------------|---------------------|---------------------|---------------------------|----------------------------------|--------------------------------|---------------------|---------------------------|--|
| <i>P</i> = 120 psia (341.25°F) |                                  |                     |                     |                           | <i>P</i> = 140 psia (353.03°F)   |                     |                     |                           |                                  | <i>P</i> = 160 psia (363.54°F) |                     |                           |  |
| Sat.                           | 3.7289                           | 1107.9              | 1190.8              | 1.5883                    | 3.2202                           | 1109.9              | 1193.4              | 1.5757                    | 2.8347                           | 1111.6                         | 1195.5              | 1.5647                    |  |
| 360                            | 3.8446                           | 1116.7              | 1202.1              | 1.6023                    | 3.2584                           | 1113.4              | 1197.8              | 1.5811                    |                                  |                                |                     |                           |  |
| 400                            | 4.0799                           | 1134.0              | 1224.6              | 1.6292                    | 3.4676                           | 1131.5              | 1221.4              | 1.6092                    | 3.0076                           | 1129.0                         | 1218.0              | 1.5914                    |  |
| 450                            | 4.3613                           | 1154.5              | 1251.4              | 1.6594                    | 3.7147                           | 1152.6              | 1248.9              | 1.6403                    | 3.2293                           | 1150.7                         | 1246.3              | 1.6234                    |  |
| 500                            | 4.6340                           | 1174.4              | 1277.3              | 1.6872                    | 3.9525                           | 1172.9              | 1275.3              | 1.6686                    | 3.4412                           | 1171.4                         | 1273.2              | 1.6522                    |  |
| 550                            | 4.9010                           | 1193.9              | 1302.8              | 1.7131                    | 4.1845                           | 1192.7              | 1301.1              | 1.6948                    | 3.6469                           | 1191.4                         | 1299.4              | 1.6788                    |  |
| 600                            | 5.1642                           | 1213.4              | 1328.0              | 1.7375                    | 4.4124                           | 1212.3              | 1326.6              | 1.7195                    | 3.8484                           | 1211.3                         | 1325.2              | 1.7037                    |  |
| 700                            | 5.6829                           | 1252.2              | 1378.4              | 1.7829                    | 4.8604                           | 1251.4              | 1377.3              | 1.7652                    | 4.2434                           | 1250.6                         | 1376.3              | 1.7498                    |  |
| 800                            | 6.1950                           | 1291.4              | 1429.0              | 1.8247                    | 5.3017                           | 1290.8              | 1428.1              | 1.8072                    | 4.6316                           | 1290.2                         | 1427.3              | 1.7920                    |  |
| 1000                           | 7.2083                           | 1371.7              | 1531.8              | 1.9005                    | 6.1732                           | 1371.3              | 1531.3              | 1.8832                    | 5.3968                           | 1370.9                         | 1530.7              | 1.8682                    |  |
| 1200                           | 8.2137                           | 1455.3              | 1637.7              | 1.9684                    | 7.0367                           | 1455.0              | 1637.3              | 1.9512                    | 6.1540                           | 1454.7                         | 1636.9              | 1.9363                    |  |
| 1400                           | 9.2149                           | 1542.3              | 1746.9              | 2.0305                    | 7.8961                           | 1542.1              | 1746.6              | 2.0134                    | 6.9070                           | 1541.8                         | 1746.3              | 1.9986                    |  |
| 1600                           | 10.2135                          | 1633.0              | 1859.8              | 2.0881                    | 8.7529                           | 1632.8              | 1859.5              | 2.0711                    | 7.6574                           | 1632.6                         | 1859.3              | 2.0563                    |  |
| 1800                           | 11.2106                          | 1727.2              | 1976.1              | 2.1420                    | 9.6082                           | 1727.0              | 1975.9              | 2.1250                    | 8.4063                           | 1726.9                         | 1975.7              | 2.1102                    |  |
| 2000                           | 12.2067                          | 1824.8              | 2095.8              | 2.1928                    | 10.4624                          | 1824.6              | 2095.7              | 2.1758                    | 9.1542                           | 1824.5                         | 2095.5              | 2.1610                    |  |
| <i>P</i> = 180 psia (373.07°F) |                                  |                     |                     |                           | <i>P</i> = 200 psia (381.80°F)   |                     |                     |                           |                                  | <i>P</i> = 225 psia (391.80°F) |                     |                           |  |
| Sat.                           | 2.5322                           | 1113.0              | 1197.3              | 1.5548                    | 2.2882                           | 1114.1              | 1198.8              | 1.5460                    | 2.0423                           | 1115.3                         | 1200.3              | 1.5360                    |  |
| 400                            | 2.6490                           | 1126.3              | 1214.5              | 1.5752                    | 2.3615                           | 1123.5              | 1210.9              | 1.5602                    | 2.0728                           | 1119.7                         | 1206.0              | 1.5427                    |  |
| 450                            | 2.8514                           | 1148.7              | 1243.7              | 1.6082                    | 2.5488                           | 1146.7              | 1241.0              | 1.5943                    | 2.2457                           | 1144.1                         | 1237.6              | 1.5783                    |  |
| 500                            | 3.0433                           | 1169.8              | 1271.2              | 1.6376                    | 2.7247                           | 1168.2              | 1269.0              | 1.6243                    | 2.4059                           | 1166.2                         | 1266.3              | 1.6091                    |  |
| 550                            | 3.2286                           | 1190.2              | 1297.7              | 1.6646                    | 2.8939                           | 1188.9              | 1296.0              | 1.6516                    | 2.5590                           | 1187.2                         | 1293.8              | 1.6370                    |  |
| 600                            | 3.4097                           | 1210.2              | 1323.8              | 1.6897                    | 3.0586                           | 1209.1              | 1322.3              | 1.6771                    | 2.7075                           | 1207.7                         | 1320.5              | 1.6628                    |  |
| 700                            | 3.7635                           | 1249.8              | 1375.2              | 1.7361                    | 3.3796                           | 1249.0              | 1374.1              | 1.7238                    | 2.9956                           | 1248.0                         | 1372.7              | 1.7099                    |  |
| 800                            | 4.1104                           | 1289.5              | 1426.5              | 1.7785                    | 3.6934                           | 1288.9              | 1425.6              | 1.7664                    | 3.2765                           | 1288.1                         | 1424.5              | 1.7528                    |  |
| 900                            | 4.4531                           | 1329.7              | 1478.0              | 1.8179                    | 4.0031                           | 1329.2              | 1477.3              | 1.8059                    | 3.5530                           | 1328.5                         | 1476.5              | 1.7925                    |  |
| 1000                           | 4.7929                           | 1370.5              | 1530.1              | 1.8549                    | 4.3099                           | 1370.1              | 1529.6              | 1.8430                    | 3.8268                           | 1369.5                         | 1528.9              | 1.8296                    |  |
| 1200                           | 5.4674                           | 1454.3              | 1636.5              | 1.9231                    | 4.9182                           | 1454.0              | 1636.1              | 1.9113                    | 4.3689                           | 1453.6                         | 1635.6              | 1.8981                    |  |
| 1400                           | 6.1377                           | 1541.6              | 1746.0              | 1.9855                    | 5.5222                           | 1541.4              | 1745.7              | 1.9737                    | 4.9068                           | 1541.1                         | 1745.4              | 1.9606                    |  |
| 1600                           | 6.8054                           | 1632.4              | 1859.1              | 2.0432                    | 6.1238                           | 1632.2              | 1858.8              | 2.0315                    | 5.4422                           | 1632.0                         | 1858.6              | 2.0184                    |  |
| 1800                           | 7.4716                           | 1726.7              | 1975.6              | 2.0971                    | 6.7238                           | 1726.5              | 1975.4              | 2.0855                    | 5.9760                           | 1726.4                         | 1975.2              | 2.0724                    |  |
| 2000                           | 8.1367                           | 1824.4              | 2095.4              | 2.1479                    | 7.3227                           | 1824.3              | 2095.3              | 2.1363                    | 6.5087                           | 1824.1                         | 2095.1              | 2.1232                    |  |
| <i>P</i> = 250 psia (400.97°F) |                                  |                     |                     |                           | <i>P</i> = 275 psia (409.45°F)   |                     |                     |                           |                                  | <i>P</i> = 300 psia (417.35°F) |                     |                           |  |
| Sat.                           | 1.8440                           | 1116.3              | 1201.6              | 1.5270                    | 1.6806                           | 1117.0              | 1202.6              | 1.5187                    | 1.5435                           | 1117.7                         | 1203.3              | 1.5111                    |  |
| 450                            | 2.0027                           | 1141.3              | 1234.0              | 1.5636                    | 1.8034                           | 1138.5              | 1230.3              | 1.5499                    | 1.6369                           | 1135.6                         | 1226.4              | 1.5369                    |  |
| 500                            | 2.1506                           | 1164.1              | 1263.6              | 1.5953                    | 1.9415                           | 1162.0              | 1260.8              | 1.5825                    | 1.7670                           | 1159.8                         | 1257.9              | 1.5706                    |  |
| 550                            | 2.2910                           | 1185.6              | 1291.5              | 1.6237                    | 2.0715                           | 1183.9              | 1289.3              | 1.6115                    | 1.8885                           | 1182.1                         | 1287.0              | 1.6001                    |  |
| 600                            | 2.4264                           | 1206.3              | 1318.6              | 1.6499                    | 2.1964                           | 1204.9              | 1316.7              | 1.6380                    | 2.0046                           | 1203.5                         | 1314.8              | 1.6270                    |  |
| 650                            | 2.5586                           | 1226.8              | 1345.1              | 1.6743                    | 2.3179                           | 1225.6              | 1343.5              | 1.6627                    | 2.1172                           | 1224.4                         | 1341.9              | 1.6520                    |  |
| 700                            | 2.6883                           | 1247.0              | 1371.4              | 1.6974                    | 2.4369                           | 1246.0              | 1370.0              | 1.6860                    | 2.2273                           | 1244.9                         | 1368.6              | 1.6755                    |  |
| 800                            | 2.9429                           | 1287.3              | 1423.5              | 1.7406                    | 2.6699                           | 1286.5              | 1422.4              | 1.7294                    | 2.4424                           | 1285.7                         | 1421.3              | 1.7192                    |  |
| 900                            | 3.1930                           | 1327.9              | 1475.6              | 1.7804                    | 2.8984                           | 1327.3              | 1474.8              | 1.7694                    | 2.6529                           | 1326.6                         | 1473.9              | 1.7593                    |  |
| 1000                           | 3.4403                           | 1369.0              | 1528.2              | 1.8177                    | 3.1241                           | 1368.5              | 1527.4              | 1.8068                    | 2.8605                           | 1367.9                         | 1526.7              | 1.7968                    |  |
| 1200                           | 3.9295                           | 1453.3              | 1635.0              | 1.8863                    | 3.5700                           | 1452.9              | 1634.5              | 1.8755                    | 3.2704                           | 1452.5                         | 1634.0              | 1.8657                    |  |
| 1400                           | 4.4144                           | 1540.8              | 1745.0              | 1.9488                    | 4.0116                           | 1540.5              | 1744.6              | 1.9381                    | 3.6759                           | 1540.2                         | 1744.2              | 1.9284                    |  |
| 1600                           | 4.8969                           | 1631.7              | 1858.3              | 2.0066                    | 4.4507                           | 1631.5              | 1858.0              | 1.9960                    | 4.0789                           | 1631.3                         | 1857.7              | 1.9863                    |  |
| 1800                           | 5.3777                           | 1726.2              | 1974.9              | 2.0607                    | 4.8882                           | 1726.0              | 1974.7              | 2.0501                    | 4.4803                           | 1725.8                         | 1974.5              | 2.0404                    |  |
| 2000                           | 5.8575                           | 1823.9              | 2094.9              | 2.1116                    | 5.3247                           | 1823.8              | 2094.7              | 2.1010                    | 4.8807                           | 1823.6                         | 2094.6              | 2.0913                    |  |

TABLE A-6E

Superheated water (Continued)

| <i>T</i><br>°F                 | <i>v</i><br>ft <sup>3</sup> /lbm | <i>u</i><br>Btu/lbm | <i>h</i><br>Btu/lbm | <i>s</i><br>Btu/<br>lbm-R       | <i>v</i><br>ft <sup>3</sup> /lbm | <i>u</i><br>Btu/lbm | <i>h</i><br>Btu/lbm | <i>s</i><br>Btu/<br>lbm-R       | <i>v</i><br>ft <sup>3</sup> /lbm | <i>u</i><br>Btu/lbm | <i>h</i><br>Btu/lbm | <i>s</i><br>Btu/<br>lbm-R |
|--------------------------------|----------------------------------|---------------------|---------------------|---------------------------------|----------------------------------|---------------------|---------------------|---------------------------------|----------------------------------|---------------------|---------------------|---------------------------|
| <i>P</i> = 350 psia (431.74°F) |                                  |                     |                     | <i>P</i> = 400 psia (444.62°F)  |                                  |                     |                     | <i>P</i> = 450 psia (456.31°F)  |                                  |                     |                     |                           |
| Sat.                           | 1.3263                           | 1118.5              | 1204.4              | 1.4973                          | 1.1617                           | 1119.0              | 1205.0              | 1.4852                          | 1.0324                           | 1119.2              | 1205.2              | 1.4742                    |
| 450                            | 1.3739                           | 1129.3              | 1218.3              | 1.5128                          | 1.1747                           | 1122.5              | 1209.4              | 1.4901                          |                                  |                     |                     |                           |
| 500                            | 1.4921                           | 1155.2              | 1251.9              | 1.5487                          | 1.2851                           | 1150.4              | 1245.6              | 1.5288                          | 1.1233                           | 1145.4              | 1238.9              | 1.5103                    |
| 550                            | 1.6004                           | 1178.6              | 1282.2              | 1.5795                          | 1.3840                           | 1174.9              | 1277.3              | 1.5610                          | 1.2152                           | 1171.1              | 1272.3              | 1.5441                    |
| 600                            | 1.7030                           | 1200.6              | 1310.9              | 1.6073                          | 1.4765                           | 1197.6              | 1306.9              | 1.5897                          | 1.3001                           | 1194.6              | 1302.8              | 1.5737                    |
| 650                            | 1.8018                           | 1221.9              | 1338.6              | 1.6328                          | 1.5650                           | 1219.4              | 1335.3              | 1.6158                          | 1.3807                           | 1216.9              | 1331.9              | 1.6005                    |
| 700                            | 1.8979                           | 1242.8              | 1365.8              | 1.6567                          | 1.6507                           | 1240.7              | 1362.9              | 1.6401                          | 1.4584                           | 1238.5              | 1360.0              | 1.6253                    |
| 800                            | 2.0848                           | 1284.1              | 1419.1              | 1.7009                          | 1.8166                           | 1282.5              | 1417.0              | 1.6849                          | 1.6080                           | 1280.8              | 1414.7              | 1.6706                    |
| 900                            | 2.2671                           | 1325.3              | 1472.2              | 1.7414                          | 1.9777                           | 1324.0              | 1470.4              | 1.7257                          | 1.7526                           | 1322.7              | 1468.6              | 1.7117                    |
| 1000                           | 2.4464                           | 1366.9              | 1525.3              | 1.7791                          | 2.1358                           | 1365.8              | 1523.9              | 1.7636                          | 1.8942                           | 1364.7              | 1522.4              | 1.7499                    |
| 1200                           | 2.7996                           | 1451.7              | 1633.0              | 1.8483                          | 2.4465                           | 1450.9              | 1632.0              | 1.8331                          | 2.1718                           | 1450.1              | 1631.0              | 1.8196                    |
| 1400                           | 3.1484                           | 1539.6              | 1743.5              | 1.9111                          | 2.7527                           | 1539.0              | 1742.7              | 1.8960                          | 2.4450                           | 1538.4              | 1742.0              | 1.8827                    |
| 1600                           | 3.4947                           | 1630.8              | 1857.1              | 1.9691                          | 3.0565                           | 1630.3              | 1856.5              | 1.9541                          | 2.7157                           | 1629.8              | 1856.0              | 1.9409                    |
| 1800                           | 3.8394                           | 1725.4              | 1974.0              | 2.0233                          | 3.3586                           | 1725.0              | 1973.6              | 2.0084                          | 2.9847                           | 1724.6              | 1973.2              | 1.9952                    |
| 2000                           | 4.1830                           | 1823.3              | 2094.2              | 2.0742                          | 3.6597                           | 1823.0              | 2093.9              | 2.0594                          | 3.2527                           | 1822.6              | 2093.5              | 2.0462                    |
| <i>P</i> = 500 psia (467.04°F) |                                  |                     |                     | <i>P</i> = 600 psia (486.24°F)  |                                  |                     |                     | <i>P</i> = 700 psia (503.13°F)  |                                  |                     |                     |                           |
| Sat.                           | 0.92815                          | 1119.1              | 1205.0              | 1.4642                          | 0.77020                          | 1118.3              | 1203.9              | 1.4463                          | 0.65589                          | 1116.9              | 1201.9              | 1.4305                    |
| 500                            | 0.99304                          | 1140.1              | 1231.9              | 1.4928                          | 0.79526                          | 1128.2              | 1216.5              | 1.4596                          |                                  |                     |                     |                           |
| 550                            | 1.07974                          | 1167.1              | 1267.0              | 1.5284                          | 0.87542                          | 1158.7              | 1255.9              | 1.4996                          | 0.72799                          | 1149.5              | 1243.8              | 1.4730                    |
| 600                            | 1.15876                          | 1191.4              | 1298.6              | 1.5590                          | 0.94605                          | 1184.9              | 1289.9              | 1.5325                          | 0.79332                          | 1177.9              | 1280.7              | 1.5087                    |
| 650                            | 1.23312                          | 1214.3              | 1328.4              | 1.5865                          | 1.01133                          | 1209.0              | 1321.3              | 1.5614                          | 0.85242                          | 1203.4              | 1313.8              | 1.5393                    |
| 700                            | 1.30440                          | 1236.4              | 1357.0              | 1.6117                          | 1.07316                          | 1231.9              | 1351.0              | 1.5877                          | 0.90769                          | 1227.2              | 1344.8              | 1.5666                    |
| 800                            | 1.44097                          | 1279.2              | 1412.5              | 1.6576                          | 1.19038                          | 1275.8              | 1408.0              | 1.6348                          | 1.01125                          | 1272.4              | 1403.4              | 1.6150                    |
| 900                            | 1.57252                          | 1321.4              | 1466.9              | 1.6992                          | 1.30230                          | 1318.7              | 1463.3              | 1.6771                          | 1.10921                          | 1316.0              | 1459.7              | 1.6581                    |
| 1000                           | 1.70094                          | 1363.6              | 1521.0              | 1.7376                          | 1.41097                          | 1361.4              | 1518.1              | 1.7160                          | 1.20381                          | 1359.2              | 1515.2              | 1.6974                    |
| 1100                           | 1.82726                          | 1406.2              | 1575.3              | 1.7735                          | 1.51749                          | 1404.4              | 1572.9              | 1.7522                          | 1.29621                          | 1402.5              | 1570.4              | 1.7341                    |
| 1200                           | 1.95211                          | 1449.4              | 1630.0              | 1.8075                          | 1.62252                          | 1447.8              | 1627.9              | 1.7865                          | 1.38709                          | 1446.2              | 1625.9              | 1.7685                    |
| 1400                           | 2.1988                           | 1537.8              | 1741.2              | 1.8708                          | 1.82957                          | 1536.6              | 1739.7              | 1.8501                          | 1.56580                          | 1535.4              | 1738.2              | 1.8324                    |
| 1600                           | 2.4430                           | 1629.4              | 1855.4              | 1.9291                          | 2.0340                           | 1628.4              | 1854.2              | 1.9085                          | 1.74192                          | 1627.5              | 1853.1              | 1.8911                    |
| 1800                           | 2.6856                           | 1724.2              | 1972.7              | 1.9834                          | 2.2369                           | 1723.4              | 1971.8              | 1.9630                          | 1.91643                          | 1722.7              | 1970.9              | 1.9457                    |
| 2000                           | 2.9271                           | 1822.3              | 2093.1              | 2.0345                          | 2.4387                           | 1821.7              | 2092.4              | 2.0141                          | 2.08987                          | 1821.0              | 2091.7              | 1.9969                    |
| <i>P</i> = 800 psia (518.27°F) |                                  |                     |                     | <i>P</i> = 1000 psia (544.65°F) |                                  |                     |                     | <i>P</i> = 1250 psia (572.45°F) |                                  |                     |                     |                           |
| Sat.                           | 0.56920                          | 1115.0              | 1199.3              | 1.4162                          | 0.44604                          | 1110.1              | 1192.6              | 1.3906                          | 0.34549                          | 1102.0              | 1181.9              | 1.3623                    |
| 550                            | 0.61586                          | 1139.4              | 1230.5              | 1.4476                          | 0.45375                          | 1115.2              | 1199.2              | 1.3972                          |                                  |                     |                     |                           |
| 600                            | 0.67799                          | 1170.5              | 1270.9              | 1.4866                          | 0.51431                          | 1154.1              | 1249.3              | 1.4457                          | 0.37894                          | 1129.5              | 1217.2              | 1.3961                    |
| 650                            | 0.73279                          | 1197.6              | 1306.0              | 1.5191                          | 0.56411                          | 1185.1              | 1289.5              | 1.4827                          | 0.42703                          | 1167.5              | 1266.3              | 1.4414                    |
| 700                            | 0.78330                          | 1222.4              | 1338.4              | 1.5476                          | 0.60844                          | 1212.4              | 1325.0              | 1.5140                          | 0.46735                          | 1198.7              | 1306.8              | 1.4771                    |
| 750                            | 0.83102                          | 1246.0              | 1369.1              | 1.5735                          | 0.64944                          | 1237.6              | 1357.8              | 1.5418                          | 0.50344                          | 1226.4              | 1342.9              | 1.5076                    |
| 800                            | 0.87678                          | 1268.9              | 1398.7              | 1.5975                          | 0.68821                          | 1261.7              | 1389.0              | 1.5670                          | 0.53687                          | 1252.2              | 1376.4              | 1.5347                    |
| 900                            | 0.96434                          | 1313.3              | 1456.0              | 1.6413                          | 0.76136                          | 1307.7              | 1448.6              | 1.6126                          | 0.59876                          | 1300.5              | 1439.0              | 1.5826                    |
| 1000                           | 1.04841                          | 1357.0              | 1512.2              | 1.6812                          | 0.83078                          | 1352.5              | 1506.2              | 1.6535                          | 0.65656                          | 1346.7              | 1498.6              | 1.6249                    |
| 1100                           | 1.13024                          | 1400.7              | 1568.0              | 1.7181                          | 0.89783                          | 1396.9              | 1563.1              | 1.6911                          | 0.71184                          | 1392.2              | 1556.8              | 1.6635                    |
| 1200                           | 1.21051                          | 1444.6              | 1623.8              | 1.7528                          | 0.96327                          | 1441.4              | 1619.7              | 1.7263                          | 0.76545                          | 1437.4              | 1614.5              | 1.6993                    |
| 1400                           | 1.36797                          | 1534.2              | 1736.7              | 1.8170                          | 1.09101                          | 1531.8              | 1733.7              | 1.7911                          | 0.86944                          | 1528.7              | 1729.8              | 1.7649                    |
| 1600                           | 1.52283                          | 1626.5              | 1851.9              | 1.8759                          | 1.21610                          | 1624.6              | 1849.6              | 1.8504                          | 0.97072                          | 1622.2              | 1846.7              | 1.8246                    |
| 1800                           | 1.67606                          | 1721.9              | 1970.0              | 1.9306                          | 1.33956                          | 1720.3              | 1968.2              | 1.9053                          | 1.07036                          | 1718.4              | 1966.0              | 1.8799                    |
| 2000                           | 1.82823                          | 1820.4              | 2091.0              | 1.9819                          | 1.46194                          | 1819.1              | 2089.6              | 1.9568                          | 1.16892                          | 1817.5              | 2087.9              | 1.9315                    |

**TABLE A-6E**

Superheated water (*Concluded*)

| <i>T</i><br>°F                  | <i>v</i><br>ft <sup>3</sup> /lbm | <i>u</i><br>Btu/lbm | <i>h</i><br>Btu/lbm | <i>s</i><br>Btu/<br>lbm·R | <i>v</i><br>ft <sup>3</sup> /lbm | <i>u</i><br>Btu/lbm | <i>h</i><br>Btu/lbm | <i>s</i><br>Btu/<br>lbm·R | <i>v</i><br>ft <sup>3</sup> /lbm | <i>u</i><br>Btu/lbm | <i>h</i><br>Btu/lbm | <i>s</i><br>Btu/<br>lbm·R |
|---------------------------------|----------------------------------|---------------------|---------------------|---------------------------|----------------------------------|---------------------|---------------------|---------------------------|----------------------------------|---------------------|---------------------|---------------------------|
| <i>P</i> = 1500 psia (596.26°F) |                                  |                     |                     |                           | <i>P</i> = 1750 psia (617.17°F)  |                     |                     |                           | <i>P</i> = 2000 psia (635.85°F)  |                     |                     |                           |
| Sat.                            | 0.27695                          | 1092.1              | 1169.0              | 1.3362                    | 0.22681                          | 1080.5              | 1153.9              | 1.3112                    | 0.18815                          | 1066.8              | 1136.4              | 1.2863                    |
| 600                             | 0.28189                          | 1097.2              | 1175.4              | 1.3423                    |                                  |                     |                     |                           |                                  |                     |                     |                           |
| 650                             | 0.33310                          | 1147.2              | 1239.7              | 1.4016                    | 0.26292                          | 1122.8              | 1207.9              | 1.3607                    | 0.20586                          | 1091.4              | 1167.6              | 1.3146                    |
| 700                             | 0.37198                          | 1183.6              | 1286.9              | 1.4433                    | 0.30252                          | 1166.8              | 1264.7              | 1.4108                    | 0.24894                          | 1147.6              | 1239.8              | 1.3783                    |
| 750                             | 0.40535                          | 1214.4              | 1326.9              | 1.4771                    | 0.33455                          | 1201.5              | 1309.8              | 1.4489                    | 0.28074                          | 1187.4              | 1291.3              | 1.4218                    |
| 800                             | 0.43550                          | 1242.2              | 1363.1              | 1.5064                    | 0.36266                          | 1231.7              | 1349.1              | 1.4807                    | 0.30763                          | 1220.5              | 1334.3              | 1.4567                    |
| 850                             | 0.46356                          | 1268.2              | 1396.9              | 1.5328                    | 0.38835                          | 1259.3              | 1385.1              | 1.5088                    | 0.33169                          | 1250.0              | 1372.8              | 1.4867                    |
| 900                             | 0.49015                          | 1293.1              | 1429.2              | 1.5569                    | 0.41238                          | 1285.4              | 1419.0              | 1.5341                    | 0.35390                          | 1277.5              | 1408.5              | 1.5134                    |
| 1000                            | 0.54031                          | 1340.9              | 1490.8              | 1.6007                    | 0.45719                          | 1334.9              | 1482.9              | 1.5796                    | 0.39479                          | 1328.7              | 1474.9              | 1.5606                    |
| 1100                            | 0.58781                          | 1387.3              | 1550.5              | 1.6402                    | 0.49917                          | 1382.4              | 1544.1              | 1.6201                    | 0.43266                          | 1377.5              | 1537.6              | 1.6021                    |
| 1200                            | 0.63355                          | 1433.3              | 1609.2              | 1.6767                    | 0.53932                          | 1429.2              | 1603.9              | 1.6572                    | 0.46864                          | 1425.1              | 1598.5              | 1.6400                    |
| 1400                            | 0.72172                          | 1525.7              | 1726.0              | 1.7432                    | 0.61621                          | 1522.6              | 1722.1              | 1.7245                    | 0.53708                          | 1519.5              | 1718.3              | 1.7081                    |
| 1600                            | 0.80714                          | 1619.8              | 1843.8              | 1.8033                    | 0.69031                          | 1617.4              | 1840.9              | 1.7852                    | 0.60269                          | 1615.0              | 1838.0              | 1.7693                    |
| 1800                            | 0.89090                          | 1716.4              | 1963.7              | 1.8589                    | 0.76273                          | 1714.5              | 1961.5              | 1.8410                    | 0.66660                          | 1712.5              | 1959.2              | 1.8255                    |
| 2000                            | 0.97358                          | 1815.9              | 2086.1              | 1.9108                    | 0.83406                          | 1814.2              | 2084.3              | 1.8931                    | 0.72942                          | 1812.6              | 2082.6              | 1.8778                    |
| <i>P</i> = 2500 psia (668.17°F) |                                  |                     |                     |                           | <i>P</i> = 3000 psia (695.41°F)  |                     |                     |                           | <i>P</i> = 3500 psia             |                     |                     |                           |
| Sat.                            | 0.13076                          | 1031.2              | 1091.7              | 1.2330                    | 0.08460                          | 969.8               | 1016.8              | 1.1587                    |                                  |                     |                     |                           |
| 650                             |                                  |                     |                     |                           |                                  |                     |                     |                           | 0.02492                          | 663.7               | 679.9               | 0.8632                    |
| 700                             | 0.16849                          | 1098.4              | 1176.3              | 1.3072                    | 0.09838                          | 1005.3              | 1059.9              | 1.1960                    | 0.03065                          | 760.0               | 779.9               | 0.9511                    |
| 750                             | 0.20327                          | 1154.9              | 1249.0              | 1.3686                    | 0.14840                          | 1114.1              | 1196.5              | 1.3118                    | 0.10460                          | 1057.6              | 1125.4              | 1.2434                    |
| 800                             | 0.22949                          | 1195.9              | 1302.0              | 1.4116                    | 0.17601                          | 1167.5              | 1265.3              | 1.3676                    | 0.13639                          | 1134.3              | 1222.6              | 1.3224                    |
| 850                             | 0.25174                          | 1230.1              | 1346.6              | 1.4463                    | 0.19771                          | 1208.2              | 1317.9              | 1.4086                    | 0.15847                          | 1183.8              | 1286.5              | 1.3721                    |
| 900                             | 0.27165                          | 1260.7              | 1386.4              | 1.4761                    | 0.21640                          | 1242.8              | 1362.9              | 1.4423                    | 0.17659                          | 1223.4              | 1337.8              | 1.4106                    |
| 950                             | 0.29001                          | 1289.1              | 1423.3              | 1.5028                    | 0.23321                          | 1273.9              | 1403.3              | 1.4716                    | 0.19245                          | 1257.8              | 1382.4              | 1.4428                    |
| 1000                            | 0.30726                          | 1316.1              | 1458.2              | 1.5271                    | 0.24876                          | 1302.8              | 1440.9              | 1.4978                    | 0.20687                          | 1289.0              | 1423.0              | 1.4711                    |
| 1100                            | 0.33949                          | 1367.3              | 1524.4              | 1.5710                    | 0.27732                          | 1356.8              | 1510.8              | 1.5441                    | 0.23289                          | 1346.1              | 1496.9              | 1.5201                    |
| 1200                            | 0.36966                          | 1416.6              | 1587.6              | 1.6103                    | 0.30367                          | 1408.0              | 1576.6              | 1.5850                    | 0.25654                          | 1399.3              | 1565.4              | 1.5627                    |
| 1400                            | 0.42631                          | 1513.3              | 1710.5              | 1.6802                    | 0.35249                          | 1507.0              | 1702.7              | 1.6567                    | 0.29978                          | 1500.7              | 1694.8              | 1.6364                    |
| 1600                            | 0.48004                          | 1610.1              | 1832.2              | 1.7424                    | 0.39830                          | 1605.3              | 1826.4              | 1.7199                    | 0.33994                          | 1600.4              | 1820.5              | 1.7006                    |
| 1800                            | 0.53205                          | 1708.6              | 1954.8              | 1.7991                    | 0.44237                          | 1704.7              | 1950.3              | 1.7773                    | 0.37833                          | 1700.8              | 1945.8              | 1.7586                    |
| 2000                            | 0.58295                          | 1809.4              | 2079.1              | 1.8518                    | 0.48532                          | 1806.1              | 2075.6              | 1.8304                    | 0.41561                          | 1802.9              | 2072.1              | 1.8121                    |
| <i>P</i> = 4000 psia            |                                  |                     |                     |                           | <i>P</i> = 5000 psia             |                     |                     |                           | <i>P</i> = 6000 psia             |                     |                     |                           |
| 650                             | 0.02448                          | 657.9               | 676.1               | 0.8577                    | 0.02379                          | 648.3               | 670.3               | 0.8485                    | 0.02325                          | 640.3               | 666.1               | 0.8408                    |
| 700                             | 0.02871                          | 742.3               | 763.6               | 0.9347                    | 0.02678                          | 721.8               | 746.6               | 0.9156                    | 0.02564                          | 708.1               | 736.5               | 0.9028                    |
| 750                             | 0.06370                          | 962.1               | 1009.2              | 1.1410                    | 0.03373                          | 821.8               | 853.0               | 1.0054                    | 0.02981                          | 788.7               | 821.8               | 0.9747                    |
| 800                             | 0.10520                          | 1094.2              | 1172.1              | 1.2734                    | 0.05937                          | 986.9               | 1041.8              | 1.1581                    | 0.03949                          | 897.1               | 941.0               | 1.0711                    |
| 850                             | 0.12848                          | 1156.7              | 1251.8              | 1.3355                    | 0.08551                          | 1092.4              | 1171.5              | 1.2593                    | 0.05815                          | 1018.6              | 1083.1              | 1.1819                    |
| 900                             | 0.14647                          | 1202.5              | 1310.9              | 1.3799                    | 0.10390                          | 1155.9              | 1252.1              | 1.3198                    | 0.07584                          | 1103.5              | 1187.7              | 1.2603                    |
| 950                             | 0.16176                          | 1240.7              | 1360.5              | 1.4157                    | 0.11863                          | 1203.9              | 1313.6              | 1.3643                    | 0.09010                          | 1163.7              | 1263.7              | 1.3153                    |
| 1000                            | 0.17538                          | 1274.6              | 1404.4              | 1.4463                    | 0.13128                          | 1244.0              | 1365.5              | 1.4004                    | 0.10208                          | 1211.4              | 1324.7              | 1.3578                    |
| 1100                            | 0.19957                          | 1335.1              | 1482.8              | 1.4983                    | 0.15298                          | 1312.2              | 1453.8              | 1.4590                    | 0.12211                          | 1288.4              | 1424.0              | 1.4237                    |
| 1200                            | 0.22121                          | 1390.3              | 1554.1              | 1.5426                    | 0.17185                          | 1372.1              | 1531.1              | 1.5070                    | 0.13911                          | 1353.4              | 1507.8              | 1.4758                    |
| 1300                            | 0.24128                          | 1443.0              | 1621.6              | 1.5821                    | 0.18902                          | 1427.8              | 1602.7              | 1.5490                    | 0.15434                          | 1412.5              | 1583.8              | 1.5203                    |
| 1400                            | 0.26028                          | 1494.3              | 1687.0              | 1.6182                    | 0.20508                          | 1481.4              | 1671.1              | 1.5868                    | 0.16841                          | 1468.4              | 1655.4              | 1.5598                    |
| 1600                            | 0.29620                          | 1595.5              | 1814.7              | 1.6835                    | 0.23505                          | 1585.6              | 1803.1              | 1.6542                    | 0.19438                          | 1575.7              | 1791.5              | 1.6294                    |
| 1800                            | 0.33033                          | 1696.8              | 1941.4              | 1.7422                    | 0.26320                          | 1689.0              | 1932.5              | 1.7142                    | 0.21853                          | 1681.1              | 1923.7              | 1.6907                    |
| 2000                            | 0.36335                          | 1799.7              | 2068.6              | 1.7961                    | 0.29023                          | 1793.2              | 2061.7              | 1.7689                    | 0.24155                          | 1786.7              | 2054.9              | 1.7463                    |

TABLE A-7E

Compressed liquid water

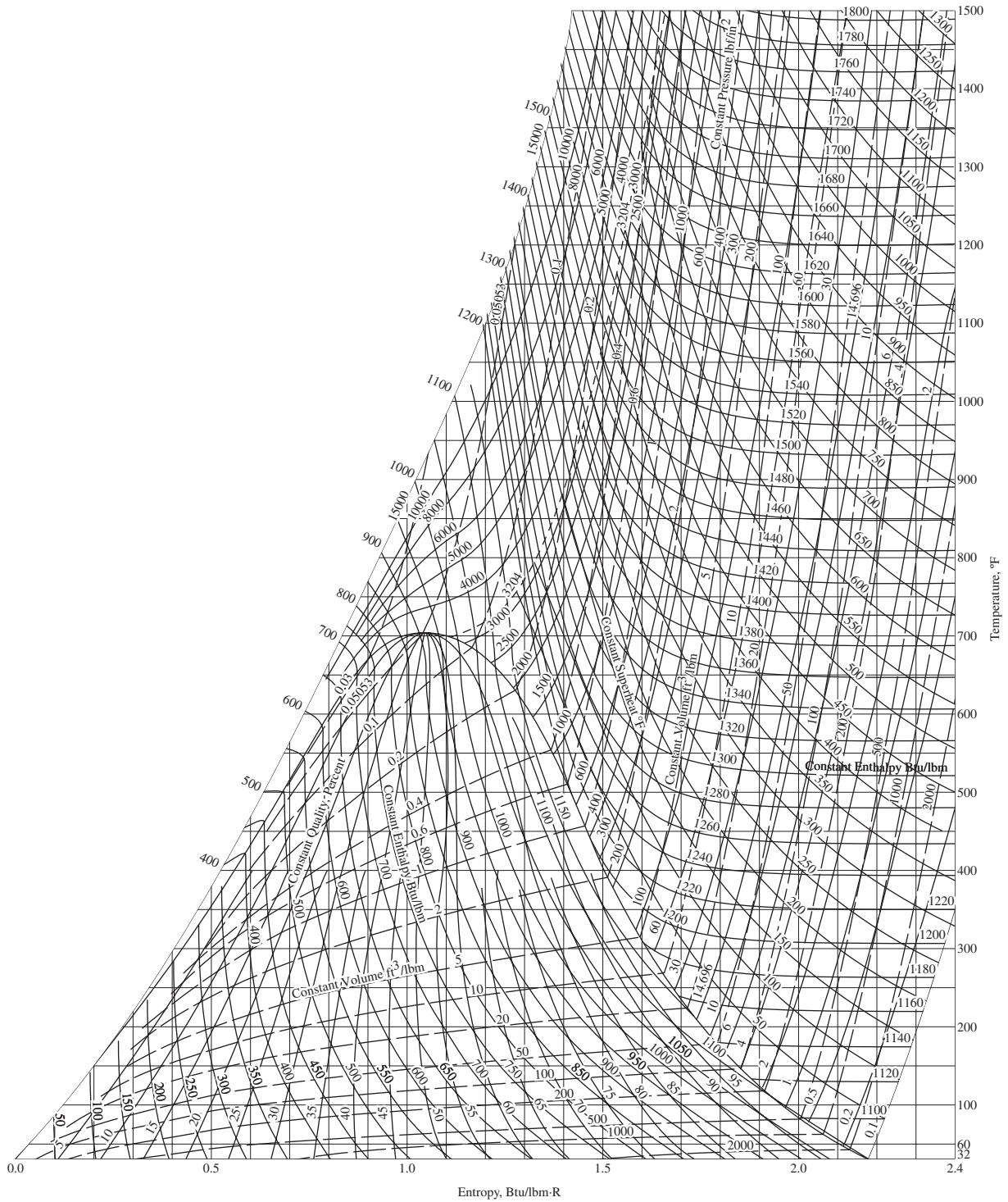
| <i>T</i><br>°F                  | <i>v</i><br>ft <sup>3</sup> /lbm | <i>u</i><br>Btu/lbm | <i>h</i><br>Btu/lbm | <i>s</i><br>Btu/lbm-R           | <i>v</i><br>ft <sup>3</sup> /lbm | <i>u</i><br>Btu/lbm | <i>h</i><br>Btu/lbm | <i>s</i><br>Btu/lbm-R           | <i>v</i><br>ft <sup>3</sup> /lbm | <i>u</i><br>Btu/lbm | <i>h</i><br>Btu/lbm | <i>s</i><br>Btu/lbm-R |
|---------------------------------|----------------------------------|---------------------|---------------------|---------------------------------|----------------------------------|---------------------|---------------------|---------------------------------|----------------------------------|---------------------|---------------------|-----------------------|
| <i>P</i> = 500 psia (467.04°F)  |                                  |                     |                     | <i>P</i> = 1000 psia (544.65°F) |                                  |                     |                     | <i>P</i> = 1500 psia (596.26°F) |                                  |                     |                     |                       |
| Sat.                            | 0.019750                         | 447.68              | 449.51              | 0.64900                         | 0.021595                         | 538.58              | 542.57              | 0.74341                         | 0.023456                         | 605.07              | 611.58              | 0.80836               |
| 32                              | 0.015994                         | 0.01                | 1.49                | 0.00001                         | 0.015966                         | 0.03                | 2.99                | 0.00005                         | 0.015939                         | 0.05                | 4.48                | 0.00008               |
| 50                              | 0.015998                         | 18.03               | 19.51               | 0.03601                         | 0.015972                         | 17.99               | 20.95               | 0.03593                         | 0.015946                         | 17.95               | 22.38               | 0.03584               |
| 100                             | 0.016107                         | 67.86               | 69.35               | 0.12930                         | 0.016083                         | 67.69               | 70.67               | 0.12899                         | 0.016059                         | 67.53               | 71.98               | 0.12869               |
| 150                             | 0.016317                         | 117.70              | 119.21              | 0.21462                         | 0.016292                         | 117.42              | 120.43              | 0.21416                         | 0.016267                         | 117.14              | 121.66              | 0.21369               |
| 200                             | 0.016607                         | 167.70              | 169.24              | 0.29349                         | 0.016580                         | 167.31              | 170.38              | 0.29289                         | 0.016553                         | 166.92              | 171.52              | 0.29229               |
| 250                             | 0.016972                         | 218.04              | 219.61              | 0.36708                         | 0.016941                         | 217.51              | 220.65              | 0.36634                         | 0.016911                         | 217.00              | 221.69              | 0.36560               |
| 300                             | 0.017417                         | 268.92              | 270.53              | 0.43641                         | 0.017380                         | 268.24              | 271.46              | 0.43551                         | 0.017345                         | 267.57              | 272.39              | 0.43463               |
| 350                             | 0.017954                         | 320.64              | 322.30              | 0.50240                         | 0.017910                         | 319.77              | 323.08              | 0.50132                         | 0.017866                         | 318.91              | 323.87              | 0.50025               |
| 400                             | 0.018609                         | 373.61              | 375.33              | 0.56595                         | 0.018552                         | 372.48              | 375.91              | 0.56463                         | 0.018496                         | 371.37              | 376.51              | 0.56333               |
| 450                             | 0.019425                         | 428.44              | 430.24              | 0.62802                         | 0.019347                         | 426.93              | 430.51              | 0.62635                         | 0.019271                         | 425.47              | 430.82              | 0.62472               |
| 500                             |                                  |                     |                     |                                 | 0.020368                         | 484.03              | 487.80              | 0.68764                         | 0.020258                         | 482.01              | 487.63              | 0.68550               |
| 550                             |                                  |                     |                     |                                 |                                  |                     |                     |                                 | 0.021595                         | 542.50              | 548.50              | 0.74731               |
| <i>P</i> = 2000 psia (635.85°F) |                                  |                     |                     | <i>P</i> = 3000 psia (695.41°F) |                                  |                     |                     | <i>P</i> = 5000 psia            |                                  |                     |                     |                       |
| Sat.                            | 0.025634                         | 662.33              | 671.82              | 0.86224                         | 0.034335                         | 783.39              | 802.45              | 0.97321                         |                                  |                     |                     |                       |
| 32                              | 0.015912                         | 0.07                | 5.96                | 0.00010                         | 0.015859                         | 0.10                | 8.90                | 0.00011                         | 0.015756                         | 0.13                | 14.71               | 0.00002               |
| 50                              | 0.015921                         | 17.91               | 23.80               | 0.03574                         | 0.015870                         | 17.83               | 26.64               | 0.03554                         | 0.015773                         | 17.65               | 32.25               | 0.03505               |
| 100                             | 0.016035                         | 67.36               | 73.30               | 0.12838                         | 0.015988                         | 67.04               | 75.91               | 0.12776                         | 0.015897                         | 66.41               | 81.12               | 0.12652               |
| 200                             | 0.016527                         | 166.54              | 172.66              | 0.29170                         | 0.016475                         | 165.79              | 174.94              | 0.29053                         | 0.016375                         | 164.36              | 179.51              | 0.28824               |
| 300                             | 0.017310                         | 266.92              | 273.33              | 0.43376                         | 0.017242                         | 265.65              | 275.22              | 0.43204                         | 0.017112                         | 263.24              | 279.07              | 0.42874               |
| 400                             | 0.018442                         | 370.30              | 377.12              | 0.56205                         | 0.018338                         | 368.22              | 378.41              | 0.55959                         | 0.018145                         | 364.35              | 381.14              | 0.55492               |
| 450                             | 0.019199                         | 424.06              | 431.16              | 0.62314                         | 0.019062                         | 421.36              | 431.94              | 0.62010                         | 0.018812                         | 416.40              | 433.80              | 0.61445               |
| 500                             | 0.020154                         | 480.08              | 487.54              | 0.68346                         | 0.019960                         | 476.45              | 487.53              | 0.67958                         | 0.019620                         | 469.94              | 488.10              | 0.67254               |
| 560                             | 0.021739                         | 552.21              | 560.26              | 0.75692                         | 0.021405                         | 546.59              | 558.47              | 0.75126                         | 0.020862                         | 537.08              | 556.38              | 0.74154               |
| 600                             | 0.023317                         | 605.77              | 614.40              | 0.80898                         | 0.022759                         | 597.42              | 610.06              | 0.80086                         | 0.021943                         | 584.42              | 604.72              | 0.78803               |
| 640                             |                                  |                     |                     |                                 | 0.024765                         | 654.52              | 668.27              | 0.85476                         | 0.023358                         | 634.95              | 656.56              | 0.83603               |
| 680                             |                                  |                     |                     |                                 | 0.028821                         | 728.63              | 744.64              | 0.92288                         | 0.025366                         | 690.67              | 714.14              | 0.88745               |
| 700                             |                                  |                     |                     |                                 |                                  |                     |                     |                                 | 0.026777                         | 721.78              | 746.56              | 0.91564               |



TABLE A-8E

Saturated ice—water vapor

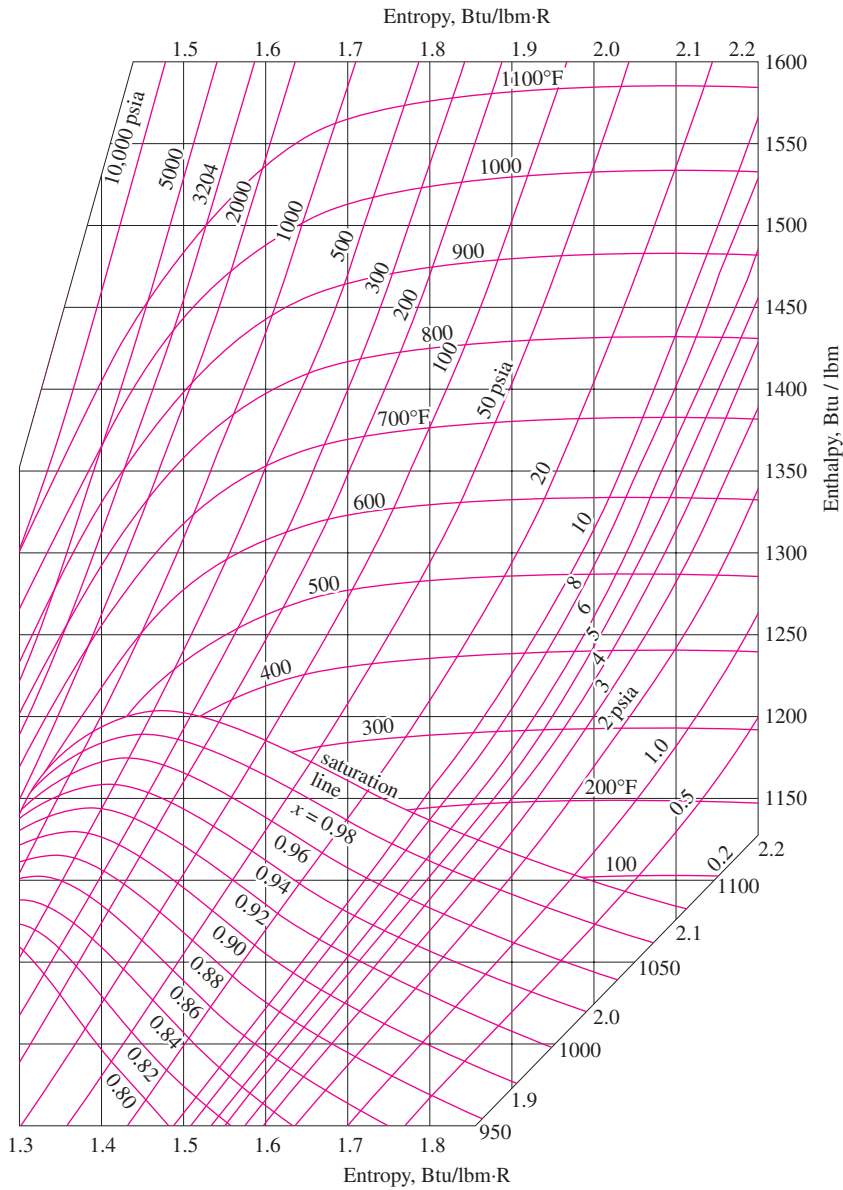
| Temp.,<br><i>T</i> °F | Sat.<br>press.,<br><i>P</i> <sub>sat</sub><br>psia | Specific volume,<br>ft <sup>3</sup> /lbm |   | Internal energy,<br>Btu/lbm           |                                  |   | Enthalpy,<br>Btu/lbm                  |                                  |   | Entropy,<br>Btu/lbm-R                 |                                  |   |
|-----------------------|--|--|---|---------------------------------------|----------------------------------|---|---------------------------------------|----------------------------------|---|---------------------------------------|----------------------------------|---|
|                       |  | Sat.<br>ice,<br><i>v</i> <sub>i</sub>    | Sat.<br>vapor,<br><i>v</i> <sub>g</sub> | Sat.<br>ice,<br><i>u</i> <sub>i</sub> | Subl.,<br><i>u</i> <sub>ig</sub> | Sat.<br>vapor,<br><i>u</i> <sub>g</sub> | Sat.<br>ice,<br><i>h</i> <sub>i</sub> | Subl.,<br><i>h</i> <sub>ig</sub> | Sat.<br>vapor,<br><i>h</i> <sub>g</sub> | Sat.<br>ice,<br><i>s</i> <sub>i</sub> | Subl.,<br><i>s</i> <sub>ig</sub> | Sat.<br>vapor,<br><i>s</i> <sub>g</sub> |
| 32.018                | 0.08871  | 0.01747                                  | 3299.6                                  | -143.34                               | 1164.2                           | 1020.9                                  | -143.34                               | 1218.3                           | 1075.0                                  | -0.29146                              | 2.4779                           | 2.1864                                  |
| 32                    | 0.08864  | 0.01747                                  | 3302.6                                  | -143.35                               | 1164.2                           | 1020.9                                  | -143.35                               | 1218.4                           | 1075.0                                  | -0.29148                              | 2.4779                           | 2.1865                                  |
| 30                    | 0.08086  | 0.01747                                  | 3605.8                                  | -144.35                               | 1164.6                           | 1020.2                                  | -144.35                               | 1218.5                           | 1074.2                                  | -0.29353                              | 2.4883                           | 2.1948                                  |
| 25                    | 0.06405  | 0.01746                                  | 4505.8                                  | -146.85                               | 1165.4                           | 1018.6                                  | -146.85                               | 1218.8                           | 1072.0                                  | -0.29865                              | 2.5146                           | 2.2160                                  |
| 20                    | 0.05049  | 0.01746                                  | 5657.6                                  | -149.32                               | 1166.2                           | 1016.9                                  | -149.32                               | 1219.1                           | 1069.8                                  | -0.30377                              | 2.5414                           | 2.2376                                  |
| 15                    | 0.03960  | 0.01745                                  | 7138.9                                  | -151.76                               | 1167.0                           | 1015.2                                  | -151.76                               | 1219.3                           | 1067.6                                  | -0.30889                              | 2.5687                           | 2.2598                                  |
| 10                    | 0.03089  | 0.01744                                  | 9054.0                                  | -154.18                               | 1167.8                           | 1013.6                                  | -154.18                               | 1219.5                           | 1065.4                                  | -0.31401                              | 2.5965                           | 2.2825                                  |
| 5                     | 0.02397  | 0.01743                                  | 11,543                                  | -156.57                               | 1168.5                           | 1011.9                                  | -156.57                               | 1219.7                           | 1063.1                                  | -0.31913                              | 2.6248                           | 2.3057                                  |
| 0                     | 0.01850  | 0.01743                                  | 14,797                                  | -158.94                               | 1169.2                           | 1010.3                                  | -158.94                               | 1219.9                           | 1060.9                                  | -0.32426                              | 2.6537                           | 2.3295                                  |
| -5                    | 0.01420  | 0.01742                                  | 19,075                                  | -161.28                               | 1169.9                           | 1008.6                                  | -161.28                               | 1220.0                           | 1058.7                                  | -0.32938                              | 2.6832                           | 2.3538                                  |
| -10                   | 0.01083  | 0.01741                                  | 24,731                                  | -163.60                               | 1170.6                           | 1007.0                                  | -163.60                               | 1220.1                           | 1056.5                                  | -0.33451                              | 2.7133                           | 2.3788                                  |
| -15                   | 0.00821  | 0.01740                                  | 32,257                                  | -165.90                               | 1171.2                           | 1005.3                                  | -165.90                               | 1220.2                           | 1054.3                                  | -0.33964                              | 2.7440                           | 2.4044                                  |
| -20                   | 0.00619  | 0.01740                                  | 42,335                                  | -168.16                               | 1171.8                           | 1003.6                                  | -168.16                               | 1220.3                           | 1052.1                                  | -0.34478                              | 2.7754                           | 2.4306                                  |
| -25                   | 0.00463  | 0.01739                                  | 55,917                                  | -170.41                               | 1172.4                           | 1002.0                                  | -170.41                               | 1220.3                           | 1049.9                                  | -0.34991                              | 2.8074                           | 2.4575                                  |
| -30                   | 0.00344  | 0.01738                                  | 74,345                                  | -172.63                               | 1173.0                           | 1000.3                                  | -172.63                               | 1220.3                           | 1047.7                                  | -0.35505                              | 2.8401                           | 2.4850                                  |
| -35                   | 0.00254  | 0.01738                                  | 99,526                                  | -174.83                               | 1173.5                           | 998.7                                   | -174.83                               | 1220.3                           | 1045.5                                  | -0.36019                              | 2.8735                           | 2.5133                                  |
| -40                   | 0.00186  | 0.01737                                  | 134,182                                 | -177.00                               | 1174.0                           | 997.0                                   | -177.00                               | 1220.3                           | 1043.3                                  | -0.36534                              | 2.9076                           | 2.5423                                  |



**FIGURE A-9E**

T-s diagram for water.

Source: Joseph H. Keenan, Frederick G. Keyes, Philip G. Hill, and Joan G. Moore, *Steam Tables* (New York: John Wiley & Sons, 1969).



**FIGURE A-10E**  
Mollier diagram for water.

Source: Joseph H. Keenan, Frederick G. Keyes, Philip G. Hill, and Joan G. Moore, *Steam Tables* (New York: John Wiley & Sons, 1969).

TABLE A-11E

Saturated refrigerant-134a—Temperature table

| Temp.,<br>T °F | Sat.<br>press.,<br>P <sub>sat</sub> psia | Specific volume,<br>ft <sup>3</sup> /lbm |                                  | Internal energy,<br>Btu/lbm       |                           | Enthalpy,<br>Btu/lbm             |                                   |                           |                                  | Entropy,<br>Btu/lbm·R             |                           |                                  |
|----------------|--|--|----------------------------------|-----------------------------------|---------------------------|----------------------------------|-----------------------------------|---------------------------|----------------------------------|-----------------------------------|---------------------------|----------------------------------|
|                |  | Sat.<br>liquid,<br>v <sub>f</sub>        | Sat.<br>vapor,<br>v <sub>g</sub> | Sat.<br>liquid,<br>u <sub>f</sub> | Evap.,<br>u <sub>fg</sub> | Sat.<br>vapor,<br>u <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> |
| -40            | 7.432                                    | 0.01130                                  | 5.7796                           | -0.016                            | 89.167                    | 89.15                            | 0.000                             | 97.100                    | 97.10                            | 0.00000                           | 0.23135                   | 0.23135                          |
| -35            | 8.581                                    | 0.01136                                  | 5.0509                           | 1.484                             | 88.352                    | 89.84                            | 1.502                             | 96.354                    | 97.86                            | 0.00355                           | 0.22687                   | 0.23043                          |
| -30            | 9.869                                    | 0.01143                                  | 4.4300                           | 2.990                             | 87.532                    | 90.52                            | 3.011                             | 95.601                    | 98.61                            | 0.00708                           | 0.22248                   | 0.22956                          |
| -25            | 11.306                                   | 0.01150                                  | 3.8988                           | 4.502                             | 86.706                    | 91.21                            | 4.526                             | 94.839                    | 99.36                            | 0.01058                           | 0.21817                   | 0.22875                          |
| -20            | 12.906                                   | 0.01156                                  | 3.4426                           | 6.019                             | 85.874                    | 91.89                            | 6.047                             | 94.068                    | 100.12                           | 0.01405                           | 0.21394                   | 0.22798                          |
| -15            | 14.680                                   | 0.01163                                  | 3.0494                           | 7.543                             | 85.036                    | 92.58                            | 7.574                             | 93.288                    | 100.86                           | 0.01749                           | 0.20978                   | 0.22727                          |
| -10            | 16.642                                   | 0.01171                                  | 2.7091                           | 9.073                             | 84.191                    | 93.26                            | 9.109                             | 92.498                    | 101.61                           | 0.02092                           | 0.20569                   | 0.22660                          |
| -5             | 18.806                                   | 0.01178                                  | 2.4137                           | 10.609                            | 83.339                    | 93.95                            | 10.650                            | 91.698                    | 102.35                           | 0.02431                           | 0.20166                   | 0.22598                          |
| 0              | 21.185                                   | 0.01185                                  | 2.1564                           | 12.152                            | 82.479                    | 94.63                            | 12.199                            | 90.886                    | 103.08                           | 0.02769                           | 0.19770                   | 0.22539                          |
| 5              | 23.793                                   | 0.01193                                  | 1.9316                           | 13.702                            | 81.610                    | 95.31                            | 13.755                            | 90.062                    | 103.82                           | 0.03104                           | 0.19380                   | 0.22485                          |
| 10             | 26.646                                   | 0.01201                                  | 1.7345                           | 15.259                            | 80.733                    | 95.99                            | 15.318                            | 89.226                    | 104.54                           | 0.03438                           | 0.18996                   | 0.22434                          |
| 15             | 29.759                                   | 0.01209                                  | 1.5612                           | 16.823                            | 79.846                    | 96.67                            | 16.889                            | 88.377                    | 105.27                           | 0.03769                           | 0.18617                   | 0.22386                          |
| 20             | 33.147                                   | 0.01217                                  | 1.4084                           | 18.394                            | 78.950                    | 97.34                            | 18.469                            | 87.514                    | 105.98                           | 0.04098                           | 0.18243                   | 0.22341                          |
| 25             | 36.826                                   | 0.01225                                  | 1.2732                           | 19.973                            | 78.043                    | 98.02                            | 20.056                            | 86.636                    | 106.69                           | 0.04426                           | 0.17874                   | 0.22300                          |
| 30             | 40.813                                   | 0.01234                                  | 1.1534                           | 21.560                            | 77.124                    | 98.68                            | 21.653                            | 85.742                    | 107.40                           | 0.04752                           | 0.17509                   | 0.22260                          |
| 35             | 45.124                                   | 0.01242                                  | 1.0470                           | 23.154                            | 76.195                    | 99.35                            | 23.258                            | 84.833                    | 108.09                           | 0.05076                           | 0.17148                   | 0.22224                          |
| 40             | 49.776                                   | 0.01251                                  | 0.95205                          | 24.757                            | 75.253                    | 100.01                           | 24.873                            | 83.907                    | 108.78                           | 0.05398                           | 0.16791                   | 0.22189                          |
| 45             | 54.787                                   | 0.01261                                  | 0.86727                          | 26.369                            | 74.298                    | 100.67                           | 26.497                            | 82.963                    | 109.46                           | 0.05720                           | 0.16437                   | 0.22157                          |
| 50             | 60.175                                   | 0.01270                                  | 0.79136                          | 27.990                            | 73.329                    | 101.32                           | 28.131                            | 82.000                    | 110.13                           | 0.06039                           | 0.16087                   | 0.22127                          |
| 55             | 65.957                                   | 0.01280                                  | 0.72323                          | 29.619                            | 72.346                    | 101.97                           | 29.775                            | 81.017                    | 110.79                           | 0.06358                           | 0.15740                   | 0.22098                          |
| 60             | 72.152                                   | 0.01290                                  | 0.66195                          | 31.258                            | 71.347                    | 102.61                           | 31.431                            | 80.013                    | 111.44                           | 0.06675                           | 0.15396                   | 0.22070                          |
| 65             | 78.780                                   | 0.01301                                  | 0.60671                          | 32.908                            | 70.333                    | 103.24                           | 33.097                            | 78.988                    | 112.09                           | 0.06991                           | 0.15053                   | 0.22044                          |
| 70             | 85.858                                   | 0.01312                                  | 0.55681                          | 34.567                            | 69.301                    | 103.87                           | 34.776                            | 77.939                    | 112.71                           | 0.07306                           | 0.14713                   | 0.22019                          |
| 75             | 93.408                                   | 0.01323                                  | 0.51165                          | 36.237                            | 68.251                    | 104.49                           | 36.466                            | 76.866                    | 113.33                           | 0.07620                           | 0.14375                   | 0.21995                          |
| 80             | 101.45                                   | 0.01334                                  | 0.47069                          | 37.919                            | 67.181                    | 105.10                           | 38.169                            | 75.767                    | 113.94                           | 0.07934                           | 0.14038                   | 0.21972                          |
| 85             | 110.00                                   | 0.01347                                  | 0.43348                          | 39.612                            | 66.091                    | 105.70                           | 39.886                            | 74.641                    | 114.53                           | 0.08246                           | 0.13703                   | 0.21949                          |
| 90             | 119.08                                   | 0.01359                                  | 0.39959                          | 41.317                            | 64.979                    | 106.30                           | 41.617                            | 73.485                    | 115.10                           | 0.08559                           | 0.13368                   | 0.21926                          |
| 95             | 128.72                                   | 0.01372                                  | 0.36869                          | 43.036                            | 63.844                    | 106.88                           | 43.363                            | 72.299                    | 115.66                           | 0.08870                           | 0.13033                   | 0.21904                          |
| 100            | 138.93                                   | 0.01386                                  | 0.34045                          | 44.768                            | 62.683                    | 107.45                           | 45.124                            | 71.080                    | 116.20                           | 0.09182                           | 0.12699                   | 0.21881                          |
| 105            | 149.73                                   | 0.01400                                  | 0.31460                          | 46.514                            | 61.496                    | 108.01                           | 46.902                            | 69.825                    | 116.73                           | 0.09493                           | 0.12365                   | 0.21858                          |
| 110            | 161.16                                   | 0.01415                                  | 0.29090                          | 48.276                            | 60.279                    | 108.56                           | 48.698                            | 68.533                    | 117.23                           | 0.09804                           | 0.12029                   | 0.21834                          |
| 115            | 173.23                                   | 0.01430                                  | 0.26913                          | 50.054                            | 59.031                    | 109.08                           | 50.512                            | 67.200                    | 117.71                           | 0.10116                           | 0.11693                   | 0.21809                          |
| 120            | 185.96                                   | 0.01446                                  | 0.24909                          | 51.849                            | 57.749                    | 109.60                           | 52.346                            | 65.823                    | 118.17                           | 0.10428                           | 0.11354                   | 0.21782                          |
| 130            | 213.53                                   | 0.01482                                  | 0.21356                          | 55.495                            | 55.071                    | 110.57                           | 56.080                            | 62.924                    | 119.00                           | 0.11054                           | 0.10670                   | 0.21724                          |
| 140            | 244.06                                   | 0.01521                                  | 0.18315                          | 59.226                            | 52.216                    | 111.44                           | 59.913                            | 59.801                    | 119.71                           | 0.11684                           | 0.09971                   | 0.21655                          |
| 150            | 277.79                                   | 0.01567                                  | 0.15692                          | 63.059                            | 49.144                    | 112.20                           | 63.864                            | 56.405                    | 120.27                           | 0.12321                           | 0.09251                   | 0.21572                          |
| 160            | 314.94                                   | 0.01619                                  | 0.13410                          | 67.014                            | 45.799                    | 112.81                           | 67.958                            | 52.671                    | 120.63                           | 0.12970                           | 0.08499                   | 0.21469                          |
| 170            | 355.80                                   | 0.01681                                  | 0.11405                          | 71.126                            | 42.097                    | 113.22                           | 72.233                            | 48.499                    | 120.73                           | 0.13634                           | 0.07701                   | 0.21335                          |
| 180            | 400.66                                   | 0.01759                                  | 0.09618                          | 75.448                            | 37.899                    | 113.35                           | 76.752                            | 43.726                    | 120.48                           | 0.14323                           | 0.06835                   | 0.21158                          |
| 190            | 449.90                                   | 0.01860                                  | 0.07990                          | 80.082                            | 32.950                    | 113.03                           | 81.631                            | 38.053                    | 119.68                           | 0.15055                           | 0.05857                   | 0.20911                          |
| 200            | 504.00                                   | 0.02009                                  | 0.06441                          | 85.267                            | 26.651                    | 111.92                           | 87.140                            | 30.785                    | 117.93                           | 0.15867                           | 0.04666                   | 0.20533                          |
| 210            | 563.76                                   | 0.02309                                  | 0.04722                          | 91.986                            | 16.498                    | 108.48                           | 94.395                            | 19.015                    | 113.41                           | 0.16922                           | 0.02839                   | 0.19761                          |

Source: Tables A-11E through A-13E are generated using the Engineering Equation Solver (EES) software developed by S. A. Klein and F. L. Alvarado. The routine used in calculations is the R134a, which is based on the fundamental equation of state developed by R. Tillner-Roth and H.D. Baehr, "An International Standard Formulation for the Thermodynamic Properties of 1,1,1,2-Tetrafluoroethane (HFC-134a) for Temperatures from 170 K to 455 K and Pressures up to 70 MPa," *J. Phys. Chem. Ref. Data*, Vol. 23, No. 5, 1994. The enthalpy and entropy values of saturated liquid are set to zero at -40°C (and -40°F).

**TABLE A-12E**

Saturated refrigerant-134a—Pressure table

| Press.,<br><i>P</i> psia | Sat.<br>temp.,<br><i>T</i> °F | Specific volume,<br>ft <sup>3</sup> /lbm |  | Internal energy,<br>Btu/lbm             |                                 |  | Enthalpy,<br>Btu/lbm                    |                                 |  | Entropy,<br>Btu/lbm-R                   |                                 |  |
|--------------------------|-------------------------------|--|--|---|---------------------------------|--|---|---------------------------------|--|---|---------------------------------|--|
|                          |                               | 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> |
| 5                        | -53.09                        | 0.01113                                  | 8.3785                                 | -3.918                                  | 91.280                          | 87.36                                  | -3.907                                  | 99.022                          | 95.11                                  | -0.00945                                | 0.24353                         | 0.23408                                |
| 10                       | -29.52                        | 0.01144                                  | 4.3753                                 | 3.135                                   | 87.453                          | 90.59                                  | 3.156                                   | 95.528                          | 98.68                                  | 0.00742                                 | 0.22206                         | 0.22948                                |
| 15                       | -14.15                        | 0.01165                                  | 2.9880                                 | 7.803                                   | 84.893                          | 92.70                                  | 7.835                                   | 93.155                          | 100.99                                 | 0.01808                                 | 0.20908                         | 0.22715                                |
| 20                       | -2.43                         | 0.01182                                  | 2.2772                                 | 11.401                                  | 82.898                          | 94.30                                  | 11.445                                  | 91.282                          | 102.73                                 | 0.02605                                 | 0.19962                         | 0.22567                                |
| 25                       | 7.17                          | 0.01196                                  | 1.8429                                 | 14.377                                  | 81.231                          | 95.61                                  | 14.432                                  | 89.701                          | 104.13                                 | 0.03249                                 | 0.19213                         | 0.22462                                |
| 30                       | 15.37                         | 0.01209                                  | 1.5492                                 | 16.939                                  | 79.780                          | 96.72                                  | 17.006                                  | 88.313                          | 105.32                                 | 0.03793                                 | 0.18589                         | 0.22383                                |
| 35                       | 22.57                         | 0.01221                                  | 1.3369                                 | 19.205                                  | 78.485                          | 97.69                                  | 19.284                                  | 87.064                          | 106.35                                 | 0.04267                                 | 0.18053                         | 0.22319                                |
| 40                       | 29.01                         | 0.01232                                  | 1.1760                                 | 21.246                                  | 77.307                          | 98.55                                  | 21.337                                  | 85.920                          | 107.26                                 | 0.04688                                 | 0.17580                         | 0.22268                                |
| 45                       | 34.86                         | 0.01242                                  | 1.0497                                 | 23.110                                  | 76.221                          | 99.33                                  | 23.214                                  | 84.858                          | 108.07                                 | 0.05067                                 | 0.17158                         | 0.22225                                |
| 50                       | 40.23                         | 0.01252                                  | 0.94791                                | 24.832                                  | 75.209                          | 100.04                                 | 24.948                                  | 83.863                          | 108.81                                 | 0.05413                                 | 0.16774                         | 0.22188                                |
| 55                       | 45.20                         | 0.01261                                  | 0.86400                                | 26.435                                  | 74.258                          | 100.69                                 | 26.564                                  | 82.924                          | 109.49                                 | 0.05733                                 | 0.16423                         | 0.22156                                |
| 60                       | 49.84                         | 0.01270                                  | 0.79361                                | 27.939                                  | 73.360                          | 101.30                                 | 28.080                                  | 82.030                          | 110.11                                 | 0.06029                                 | 0.16098                         | 0.22127                                |
| 65                       | 54.20                         | 0.01279                                  | 0.73370                                | 29.357                                  | 72.505                          | 101.86                                 | 29.510                                  | 81.176                          | 110.69                                 | 0.06307                                 | 0.15796                         | 0.22102                                |
| 70                       | 58.30                         | 0.01287                                  | 0.68205                                | 30.700                                  | 71.688                          | 102.39                                 | 30.867                                  | 80.357                          | 111.22                                 | 0.06567                                 | 0.15512                         | 0.22080                                |
| 75                       | 62.19                         | 0.01295                                  | 0.63706                                | 31.979                                  | 70.905                          | 102.88                                 | 32.159                                  | 79.567                          | 111.73                                 | 0.06813                                 | 0.15245                         | 0.22059                                |
| 80                       | 65.89                         | 0.01303                                  | 0.59750                                | 33.201                                  | 70.151                          | 103.35                                 | 33.394                                  | 78.804                          | 112.20                                 | 0.07047                                 | 0.14993                         | 0.22040                                |
| 85                       | 69.41                         | 0.01310                                  | 0.56244                                | 34.371                                  | 69.424                          | 103.79                                 | 34.577                                  | 78.064                          | 112.64                                 | 0.07269                                 | 0.14753                         | 0.22022                                |
| 90                       | 72.78                         | 0.01318                                  | 0.53113                                | 35.495                                  | 68.719                          | 104.21                                 | 35.715                                  | 77.345                          | 113.06                                 | 0.07481                                 | 0.14525                         | 0.22006                                |
| 95                       | 76.02                         | 0.01325                                  | 0.50301                                | 36.578                                  | 68.035                          | 104.61                                 | 36.811                                  | 76.645                          | 113.46                                 | 0.07684                                 | 0.14307                         | 0.21991                                |
| 100                      | 79.12                         | 0.01332                                  | 0.47760                                | 37.623                                  | 67.371                          | 104.99                                 | 37.869                                  | 75.962                          | 113.83                                 | 0.07879                                 | 0.14097                         | 0.21976                                |
| 110                      | 85.00                         | 0.01347                                  | 0.43347                                | 39.612                                  | 66.091                          | 105.70                                 | 39.886                                  | 74.641                          | 114.53                                 | 0.08246                                 | 0.13703                         | 0.21949                                |
| 120                      | 90.49                         | 0.01360                                  | 0.39644                                | 41.485                                  | 64.869                          | 106.35                                 | 41.787                                  | 73.371                          | 115.16                                 | 0.08589                                 | 0.13335                         | 0.21924                                |
| 130                      | 95.64                         | 0.01374                                  | 0.36491                                | 43.258                                  | 63.696                          | 106.95                                 | 43.589                                  | 72.144                          | 115.73                                 | 0.08911                                 | 0.12990                         | 0.21901                                |
| 140                      | 100.51                        | 0.01387                                  | 0.33771                                | 44.945                                  | 62.564                          | 107.51                                 | 45.304                                  | 70.954                          | 116.26                                 | 0.09214                                 | 0.12665                         | 0.21879                                |
| 150                      | 105.12                        | 0.01400                                  | 0.31401                                | 46.556                                  | 61.467                          | 108.02                                 | 46.945                                  | 69.795                          | 116.74                                 | 0.09501                                 | 0.12357                         | 0.21857                                |
| 160                      | 109.50                        | 0.01413                                  | 0.29316                                | 48.101                                  | 60.401                          | 108.50                                 | 48.519                                  | 68.662                          | 117.18                                 | 0.09774                                 | 0.12062                         | 0.21836                                |
| 170                      | 113.69                        | 0.01426                                  | 0.27466                                | 49.586                                  | 59.362                          | 108.95                                 | 50.035                                  | 67.553                          | 117.59                                 | 0.10034                                 | 0.11781                         | 0.21815                                |
| 180                      | 117.69                        | 0.01439                                  | 0.25813                                | 51.018                                  | 58.345                          | 109.36                                 | 51.497                                  | 66.464                          | 117.96                                 | 0.10284                                 | 0.11511                         | 0.21795                                |
| 190                      | 121.53                        | 0.01452                                  | 0.24327                                | 52.402                                  | 57.349                          | 109.75                                 | 52.912                                  | 65.392                          | 118.30                                 | 0.10524                                 | 0.11250                         | 0.21774                                |
| 200                      | 125.22                        | 0.01464                                  | 0.22983                                | 53.743                                  | 56.371                          | 110.11                                 | 54.285                                  | 64.335                          | 118.62                                 | 0.10754                                 | 0.10998                         | 0.21753                                |
| 220                      | 132.21                        | 0.01490                                  | 0.20645                                | 56.310                                  | 54.458                          | 110.77                                 | 56.917                                  | 62.256                          | 119.17                                 | 0.11192                                 | 0.10517                         | 0.21710                                |
| 240                      | 138.73                        | 0.01516                                  | 0.18677                                | 58.746                                  | 52.591                          | 111.34                                 | 59.419                                  | 60.213                          | 119.63                                 | 0.11603                                 | 0.10061                         | 0.21665                                |
| 260                      | 144.85                        | 0.01543                                  | 0.16996                                | 61.071                                  | 50.757                          | 111.83                                 | 61.813                                  | 58.192                          | 120.00                                 | 0.11992                                 | 0.09625                         | 0.21617                                |
| 280                      | 150.62                        | 0.01570                                  | 0.15541                                | 63.301                                  | 48.945                          | 112.25                                 | 64.115                                  | 56.184                          | 120.30                                 | 0.12362                                 | 0.09205                         | 0.21567                                |
| 300                      | 156.09                        | 0.01598                                  | 0.14266                                | 65.452                                  | 47.143                          | 112.60                                 | 66.339                                  | 54.176                          | 120.52                                 | 0.12715                                 | 0.08797                         | 0.21512                                |
| 350                      | 168.64                        | 0.01672                                  | 0.11664                                | 70.554                                  | 42.627                          | 113.18                                 | 71.638                                  | 49.099                          | 120.74                                 | 0.13542                                 | 0.07814                         | 0.21356                                |
| 400                      | 179.86                        | 0.01757                                  | 0.09642                                | 75.385                                  | 37.963                          | 113.35                                 | 76.686                                  | 43.798                          | 120.48                                 | 0.14314                                 | 0.06848                         | 0.21161                                |
| 450                      | 190.02                        | 0.01860                                  | 0.07987                                | 80.092                                  | 32.939                          | 113.03                                 | 81.641                                  | 38.041                          | 119.68                                 | 0.15056                                 | 0.05854                         | 0.20911                                |
| 500                      | 199.29                        | 0.01995                                  | 0.06551                                | 84.871                                  | 27.168                          | 112.04                                 | 86.718                                  | 31.382                          | 118.10                                 | 0.15805                                 | 0.04762                         | 0.20566                                |

TABLE A-13E

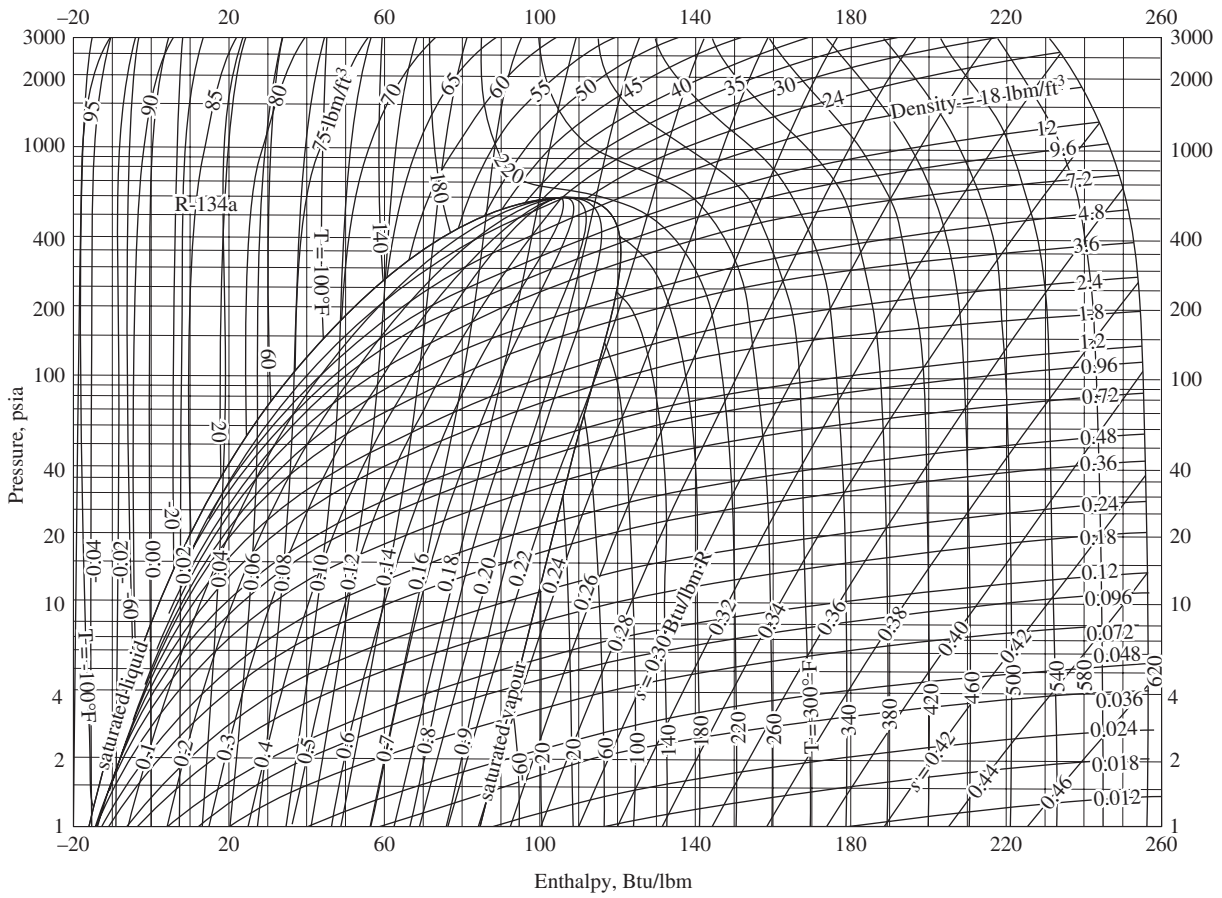
Superheated refrigerant-134a

| $T$<br>°F  | $v$<br>ft <sup>3</sup> /lbm | $u$<br>Btu/lbm | $h$<br>Btu/lbm | $s$<br>Btu/<br>lbm·R   | $v$<br>ft <sup>3</sup> /lbm | $u$<br>Btu/lbm | $h$<br>Btu/lbm | $s$<br>Btu/<br>lbm·R  | $v$<br>ft <sup>3</sup> /lbm | $u$<br>Btu/lbm | $h$<br>Btu/lbm | $s$<br>Btu/<br>lbm·R |
|--|-----------------------------|----------------|----------------|--|-----------------------------|----------------|----------------|---|-----------------------------|----------------|----------------|----------------------|
| $P = 10 \text{ psia } (T_{\text{sat}} = -29.52^\circ\text{F})$ |                             |                |                | $P = 15 \text{ psia } (T_{\text{sat}} = -14.15^\circ\text{F})$ |                             |                |                | $P = 20 \text{ psia } (T_{\text{sat}} = -2.43^\circ\text{F})$ |                             |                |                |                      |
| Sat.   | 4.3753                      | 90.59          | 98.68          | 0.22948  | 2.9880                      | 92.70          | 100.99         | 0.22715   | 2.2772                      | 94.30          | 102.73         | 0.22567              |
| -20  | 4.4856                      | 92.13          | 100.43         | 0.23350  |                             |                |                |   |                             |                |                |                      |
| 0  | 4.7135                      | 95.41          | 104.14         | 0.24174  | 3.1001                      | 95.08          | 103.68         | 0.23310   | 2.2922                      | 94.72          | 103.20         | 0.22671              |
| 20   | 4.9380                      | 98.77          | 107.91         | 0.24976  | 3.2551                      | 98.48          | 107.52         | 0.24127   | 2.4130                      | 98.19          | 107.12         | 0.23504              |
| 40   | 5.1600                      | 102.20         | 111.75         | 0.25761  | 3.4074                      | 101.95         | 111.41         | 0.24922   | 2.5306                      | 101.70         | 111.07         | 0.24311              |
| 60   | 5.3802                      | 105.72         | 115.67         | 0.26531  | 3.5577                      | 105.50         | 115.38         | 0.25700   | 2.6461                      | 105.28         | 115.07         | 0.25097              |
| 80   | 5.5989                      | 109.32         | 119.68         | 0.27288  | 3.7064                      | 109.13         | 119.42         | 0.26463   | 2.7600                      | 108.93         | 119.15         | 0.25866              |
| 100  | 5.8165                      | 113.01         | 123.78         | 0.28033  | 3.8540                      | 112.84         | 123.54         | 0.27212   | 2.8726                      | 112.66         | 123.29         | 0.26621              |
| 120  | 6.0331                      | 116.79         | 127.96         | 0.28767  | 4.0006                      | 116.63         | 127.74         | 0.27950   | 2.9842                      | 116.47         | 127.52         | 0.27363              |
| 140  | 6.2490                      | 120.66         | 132.22         | 0.29490  | 4.1464                      | 120.51         | 132.02         | 0.28677   | 3.0950                      | 120.37         | 131.82         | 0.28093              |
| 160  | 6.4642                      | 124.61         | 136.57         | 0.30203  | 4.2915                      | 124.48         | 136.39         | 0.29393   | 3.2051                      | 124.35         | 136.21         | 0.28812              |
| 180  | 6.6789                      | 128.65         | 141.01         | 0.30908  | 4.4361                      | 128.53         | 140.84         | 0.30100   | 3.3146                      | 128.41         | 140.67         | 0.29521              |
| 200  | 6.8930                      | 132.77         | 145.53         | 0.31604  | 4.5802                      | 132.66         | 145.37         | 0.30798   | 3.4237                      | 132.55         | 145.22         | 0.30221              |
| 220  | 7.1068                      | 136.98         | 150.13         | 0.32292  | 4.7239                      | 136.88         | 149.99         | 0.31487   | 3.5324                      | 136.78         | 149.85         | 0.30912              |
| $P = 30 \text{ psia } (T_{\text{sat}} = 15.37^\circ\text{F})$  |                             |                |                | $P = 40 \text{ psia } (T_{\text{sat}} = 29.01^\circ\text{F})$  |                             |                |                | $P = 50 \text{ psia } (T_{\text{sat}} = 40.23^\circ\text{F})$ |                             |                |                |                      |
| Sat.   | 1.5492                      | 96.72          | 105.32         | 0.22383  | 1.1760                      | 98.55          | 107.26         | 0.22268   | 0.9479                      | 100.04         | 108.81         | 0.22188              |
| 20   | 1.5691                      | 97.56          | 106.27         | 0.22581  |                             |                |                |   |                             |                |                |                      |
| 40   | 1.6528                      | 101.17         | 110.35         | 0.23414  | 1.2126                      | 100.61         | 109.58         | 0.22738   |                             |                |                |                      |
| 60   | 1.7338                      | 104.82         | 114.45         | 0.24219  | 1.2768                      | 104.34         | 113.79         | 0.23565   | 1.0019                      | 103.84         | 113.11         | 0.23031              |
| 80   | 1.8130                      | 108.53         | 118.59         | 0.25002  | 1.3389                      | 108.11         | 118.02         | 0.24363   | 1.0540                      | 107.68         | 117.43         | 0.23847              |
| 100  | 1.8908                      | 112.30         | 122.80         | 0.25767  | 1.3995                      | 111.93         | 122.29         | 0.25140   | 1.1043                      | 111.55         | 121.77         | 0.24637              |
| 120  | 1.9675                      | 116.15         | 127.07         | 0.26517  | 1.4588                      | 115.82         | 126.62         | 0.25900   | 1.1534                      | 115.48         | 126.16         | 0.25406              |
| 140  | 2.0434                      | 120.08         | 131.42         | 0.27254  | 1.5173                      | 119.78         | 131.01         | 0.26644   | 1.2015                      | 119.47         | 130.59         | 0.26159              |
| 160  | 2.1185                      | 124.08         | 135.84         | 0.27979  | 1.5750                      | 123.81         | 135.47         | 0.27375   | 1.2488                      | 123.53         | 135.09         | 0.26896              |
| 180  | 2.1931                      | 128.16         | 140.34         | 0.28693  | 1.6321                      | 127.91         | 140.00         | 0.28095   | 1.2955                      | 127.66         | 139.65         | 0.27621              |
| 200  | 2.2671                      | 132.32         | 144.91         | 0.29398  | 1.6887                      | 132.10         | 144.60         | 0.28803   | 1.3416                      | 131.87         | 144.28         | 0.28333              |
| 220  | 2.3408                      | 136.57         | 149.56         | 0.30092  | 1.7449                      | 136.36         | 149.27         | 0.29501   | 1.3873                      | 136.15         | 148.98         | 0.29036              |
| 240  | 2.4141                      | 140.89         | 154.29         | 0.30778  | 1.8007                      | 140.70         | 154.03         | 0.30190   | 1.4326                      | 140.50         | 153.76         | 0.29728              |
| 260  | 2.4871                      | 145.30         | 159.10         | 0.31456  | 1.8562                      | 145.12         | 158.86         | 0.30871   | 1.4776                      | 144.93         | 158.60         | 0.30411              |
| 280  | 2.5598                      | 149.78         | 163.99         | 0.32126  | 1.9114                      | 149.61         | 163.76         | 0.31543   | 1.5223                      | 149.44         | 163.53         | 0.31086              |
| $P = 60 \text{ psia } (T_{\text{sat}} = 49.84^\circ\text{F})$  |                             |                |                | $P = 70 \text{ psia } (T_{\text{sat}} = 58.30^\circ\text{F})$  |                             |                |                | $P = 80 \text{ psia } (T_{\text{sat}} = 65.89^\circ\text{F})$ |                             |                |                |                      |
| Sat.   | 0.7936                      | 101.30         | 110.11         | 0.22127  | 0.6821                      | 102.39         | 111.22         | 0.22080   | 0.59750                     | 103.35         | 112.20         | 0.22040              |
| 60   | 0.8179                      | 103.31         | 112.39         | 0.22570  | 0.6857                      | 102.73         | 111.62         | 0.22155   |                             |                |                |                      |
| 80   | 0.8636                      | 107.23         | 116.82         | 0.23407  | 0.7271                      | 106.76         | 116.18         | 0.23016   | 0.62430                     | 106.26         | 115.51         | 0.22661              |
| 100  | 0.9072                      | 111.16         | 121.24         | 0.24211  | 0.7662                      | 110.76         | 120.68         | 0.23836   | 0.66009                     | 110.34         | 120.11         | 0.23499              |
| 120  | 0.9495                      | 115.14         | 125.68         | 0.24991  | 0.8037                      | 114.78         | 125.19         | 0.24628   | 0.69415                     | 114.42         | 124.69         | 0.24304              |
| 140  | 0.9908                      | 119.16         | 130.16         | 0.25751  | 0.8401                      | 118.85         | 129.73         | 0.25398   | 0.72698                     | 118.52         | 129.29         | 0.25083              |
| 160  | 1.0312                      | 123.25         | 134.70         | 0.26496  | 0.8756                      | 122.97         | 134.31         | 0.26149   | 0.75888                     | 122.68         | 133.91         | 0.25841              |
| 180  | 1.0709                      | 127.41         | 139.30         | 0.27226  | 0.9105                      | 127.15         | 138.94         | 0.26885   | 0.79003                     | 126.89         | 138.58         | 0.26583              |
| 200  | 1.1101                      | 131.63         | 143.96         | 0.27943  | 0.9447                      | 131.40         | 143.63         | 0.27607   | 0.82059                     | 131.16         | 143.31         | 0.27310              |
| 220  | 1.1489                      | 135.93         | 148.69         | 0.28649  | 0.9785                      | 135.71         | 148.39         | 0.28317   | 0.85065                     | 135.49         | 148.09         | 0.28024              |
| 240  | 1.1872                      | 140.30         | 153.48         | 0.29344  | 1.0118                      | 140.10         | 153.21         | 0.29015   | 0.88030                     | 139.90         | 152.93         | 0.28726              |
| 260  | 1.2252                      | 144.75         | 158.35         | 0.30030  | 1.0449                      | 144.56         | 158.10         | 0.29704   | 0.90961                     | 144.37         | 157.84         | 0.29418              |
| 280  | 1.2629                      | 149.27         | 163.29         | 0.30707  | 1.0776                      | 149.10         | 163.06         | 0.30384   | 0.93861                     | 148.92         | 162.82         | 0.30100              |
| 300  | 1.3004                      | 153.87         | 168.31         | 0.31376  | 1.1101                      | 153.71         | 168.09         | 0.31055   | 0.96737                     | 153.54         | 167.86         | 0.30773              |
| 320  | 1.3377                      | 158.54         | 173.39         | 0.32037  | 1.1424                      | 158.39         | 173.19         | 0.31718   | 0.99590                     | 158.24         | 172.98         | 0.31438              |

TABLE A-13E

Superheated refrigerant-134a (Concluded)

| <i>T</i><br>°F  | <i>v</i><br>ft <sup>3</sup> /lbm | <i>u</i><br>Btu/lbm | <i>h</i><br>Btu/lbm | <i>s</i><br>Btu/<br>lbm·R                                 | <i>v</i><br>ft <sup>3</sup> /lbm | <i>u</i><br>Btu/lbm | <i>h</i><br>Btu/lbm | <i>s</i><br>Btu/<br>lbm·R                                 | <i>v</i><br>ft <sup>3</sup> /lbm | <i>u</i><br>Btu/lbm | <i>h</i><br>Btu/lbm | <i>s</i><br>Btu/<br>lbm·R |
|---|----------------------------------|---------------------|---------------------|---|----------------------------------|---------------------|---------------------|---|----------------------------------|---------------------|---------------------|---------------------------|
| <i>P</i> = 90 psia ( <i>T</i> <sub>sat</sub> = 72.78°F)   |                                  |                     |                     | <i>P</i> = 100 psia ( <i>T</i> <sub>sat</sub> = 79.12°F)  |                                  |                     |                     | <i>P</i> = 120 psia ( <i>T</i> <sub>sat</sub> = 90.49°F)  |                                  |                     |                     |                           |
| Sat.  | 0.53113                          | 104.21              | 113.06              | 0.22006   | 0.47760                          | 104.99              | 113.83              | 0.21976   | 0.39644                          | 106.35              | 115.16              | 0.21924                   |
| 80  | 0.54388                          | 105.74              | 114.80              | 0.22330   | 0.47906                          | 105.18              | 114.05              | 0.22016   |                                  |                     |                     |                           |
| 100   | 0.57729                          | 109.91              | 119.52              | 0.23189   | 0.51076                          | 109.45              | 118.90              | 0.22900   | 0.41013                          | 108.48              | 117.59              | 0.22362                   |
| 120   | 0.60874                          | 114.04              | 124.18              | 0.24008   | 0.54022                          | 113.66              | 123.65              | 0.23733   | 0.43692                          | 112.84              | 122.54              | 0.23232                   |
| 140   | 0.63885                          | 118.19              | 128.83              | 0.24797   | 0.56821                          | 117.86              | 128.37              | 0.24534   | 0.46190                          | 117.15              | 127.41              | 0.24058                   |
| 160   | 0.66796                          | 122.38              | 133.51              | 0.25563   | 0.59513                          | 122.08              | 133.09              | 0.25309   | 0.48563                          | 121.46              | 132.25              | 0.24851                   |
| 180   | 0.69629                          | 126.62              | 138.22              | 0.26311   | 0.62122                          | 126.35              | 137.85              | 0.26063   | 0.50844                          | 125.79              | 137.09              | 0.25619                   |
| 200   | 0.72399                          | 130.92              | 142.97              | 0.27043   | 0.64667                          | 130.67              | 142.64              | 0.26801   | 0.53054                          | 130.17              | 141.95              | 0.26368                   |
| 220   | 0.75119                          | 135.27              | 147.78              | 0.27762   | 0.67158                          | 135.05              | 147.47              | 0.27523   | 0.55206                          | 134.59              | 146.85              | 0.27100                   |
| 240   | 0.77796                          | 139.69              | 152.65              | 0.28468   | 0.69605                          | 139.49              | 152.37              | 0.28233   | 0.57312                          | 139.07              | 151.80              | 0.27817                   |
| 260   | 0.80437                          | 144.19              | 157.58              | 0.29162   | 0.72016                          | 143.99              | 157.32              | 0.28931   | 0.59379                          | 143.61              | 156.79              | 0.28521                   |
| 280   | 0.83048                          | 148.75              | 162.58              | 0.29847   | 0.74396                          | 148.57              | 162.34              | 0.29618   | 0.61413                          | 148.21              | 161.85              | 0.29214                   |
| 300   | 0.85633                          | 153.38              | 167.64              | 0.30522   | 0.76749                          | 153.21              | 167.42              | 0.30296   | 0.63420                          | 152.88              | 166.96              | 0.29896                   |
| 320   | 0.88195                          | 158.08              | 172.77              | 0.31189   | 0.79079                          | 157.93              | 172.56              | 0.30964   | 0.65402                          | 157.62              | 172.14              | 0.30569                   |
| <i>P</i> = 140 psia ( <i>T</i> <sub>sat</sub> = 100.50°F) |                                  |                     |                     | <i>P</i> = 160 psia ( <i>T</i> <sub>sat</sub> = 109.50°F) |                                  |                     |                     | <i>P</i> = 180 psia ( <i>T</i> <sub>sat</sub> = 117.69°F) |                                  |                     |                     |                           |
| Sat.  | 0.33771                          | 107.51              | 116.26              | 0.21879   | 0.29316                          | 108.50              | 117.18              | 0.21836   | 0.25813                          | 109.36              | 117.96              | 0.21795                   |
| 120   | 0.36243                          | 111.96              | 121.35              | 0.22773   | 0.30578                          | 111.01              | 120.06              | 0.22337   | 0.26083                          | 109.94              | 118.63              | 0.21910                   |
| 140   | 0.38551                          | 116.41              | 126.40              | 0.23628   | 0.32774                          | 115.62              | 125.32              | 0.23230   | 0.28231                          | 114.77              | 124.17              | 0.22850                   |
| 160   | 0.40711                          | 120.81              | 131.36              | 0.24443   | 0.34790                          | 120.13              | 130.43              | 0.24069   | 0.30154                          | 119.42              | 129.46              | 0.23718                   |
| 180   | 0.42766                          | 125.22              | 136.30              | 0.25227   | 0.36686                          | 124.62              | 135.49              | 0.24871   | 0.31936                          | 124.00              | 134.64              | 0.24540                   |
| 200   | 0.44743                          | 129.65              | 141.24              | 0.25988   | 0.38494                          | 129.12              | 140.52              | 0.25645   | 0.33619                          | 128.57              | 139.77              | 0.25330                   |
| 220   | 0.46657                          | 134.12              | 146.21              | 0.26730   | 0.40234                          | 133.64              | 145.55              | 0.26397   | 0.35228                          | 133.15              | 144.88              | 0.26094                   |
| 240   | 0.48522                          | 138.64              | 151.21              | 0.27455   | 0.41921                          | 138.20              | 150.62              | 0.27131   | 0.36779                          | 137.76              | 150.01              | 0.26837                   |
| 260   | 0.50345                          | 143.21              | 156.26              | 0.28166   | 0.43564                          | 142.81              | 155.71              | 0.27849   | 0.38284                          | 142.40              | 155.16              | 0.27562                   |
| 280   | 0.52134                          | 147.85              | 161.35              | 0.28864   | 0.45171                          | 147.48              | 160.85              | 0.28554   | 0.39751                          | 147.10              | 160.34              | 0.28273                   |
| 300   | 0.53895                          | 152.54              | 166.50              | 0.29551   | 0.46748                          | 152.20              | 166.04              | 0.29246   | 0.41186                          | 151.85              | 165.57              | 0.28970                   |
| 320   | 0.55630                          | 157.30              | 171.71              | 0.30228   | 0.48299                          | 156.98              | 171.28              | 0.29927   | 0.42594                          | 156.66              | 170.85              | 0.29656                   |
| 340   | 0.57345                          | 162.13              | 176.98              | 0.30896   | 0.49828                          | 161.83              | 176.58              | 0.30598   | 0.43980                          | 161.53              | 176.18              | 0.30331                   |
| 360   | 0.59041                          | 167.02              | 182.32              | 0.31555   | 0.51338                          | 166.74              | 181.94              | 0.31260   | 0.45347                          | 166.46              | 181.56              | 0.30996                   |
| <i>P</i> = 200 psia ( <i>T</i> <sub>sat</sub> = 125.22°F) |                                  |                     |                     | <i>P</i> = 300 psia ( <i>T</i> <sub>sat</sub> = 156.09°F) |                                  |                     |                     | <i>P</i> = 400 psia ( <i>T</i> <sub>sat</sub> = 179.86°F) |                                  |                     |                     |                           |
| Sat.  | 0.22983                          | 110.11              | 118.62              | 0.21753   | 0.14266                          | 112.60              | 120.52              | 0.21512   | 0.09642                          | 113.35              | 120.48              | 0.21161                   |
| 140   | 0.24541                          | 113.85              | 122.93              | 0.22481   |                                  |                     |                     |   |                                  |                     |                     |                           |
| 160   | 0.26412                          | 118.66              | 128.44              | 0.23384   | 0.14656                          | 113.82              | 121.95              | 0.21745   |                                  |                     |                     |                           |
| 180   | 0.28115                          | 123.35              | 133.76              | 0.24229   | 0.16355                          | 119.52              | 128.60              | 0.22802   | 0.09658                          | 113.41              | 120.56              | 0.21173                   |
| 200   | 0.29704                          | 128.00              | 138.99              | 0.25035   | 0.17776                          | 124.78              | 134.65              | 0.23733   | 0.11440                          | 120.52              | 128.99              | 0.22471                   |
| 220   | 0.31212                          | 132.64              | 144.19              | 0.25812   | 0.19044                          | 129.85              | 140.42              | 0.24594   | 0.12746                          | 126.44              | 135.88              | 0.23500                   |
| 240   | 0.32658                          | 137.30              | 149.38              | 0.26565   | 0.20211                          | 134.83              | 146.05              | 0.25410   | 0.13853                          | 131.95              | 142.20              | 0.24418                   |
| 260   | 0.34054                          | 141.99              | 154.59              | 0.27298   | 0.21306                          | 139.77              | 151.59              | 0.26192   | 0.14844                          | 137.26              | 148.25              | 0.25270                   |
| 280   | 0.35410                          | 146.72              | 159.82              | 0.28015   | 0.22347                          | 144.70              | 157.11              | 0.26947   | 0.15756                          | 142.48              | 154.14              | 0.26077                   |
| 300   | 0.36733                          | 151.50              | 165.09              | 0.28718   | 0.23346                          | 149.65              | 162.61              | 0.27681   | 0.16611                          | 147.65              | 159.94              | 0.26851                   |
| 320   | 0.38029                          | 156.33              | 170.40              | 0.29408   | 0.24310                          | 154.63              | 168.12              | 0.28398   | 0.17423                          | 152.80              | 165.70              | 0.27599                   |
| 340   | 0.39300                          | 161.22              | 175.77              | 0.30087   | 0.25246                          | 159.64              | 173.66              | 0.29098   | 0.18201                          | 157.97              | 171.44              | 0.28326                   |
| 360   | 0.40552                          | 166.17              | 181.18              | 0.30756   | 0.26159                          | 164.70              | 179.22              | 0.29786   | 0.18951                          | 163.15              | 177.18              | 0.29035                   |



**FIGURE A-14E**

*P-h* diagram for refrigerant-134a.

Reprinted by permission of American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., Atlanta, GA.



**TABLE A-16E**

Properties of the atmosphere at high altitude

| Altitude, ft | Temperature, °F | Pressure, psia | Gravity, g, ft/s <sup>2</sup> | Speed of sound, ft/s | Density, lbm/ft <sup>3</sup> | Viscosity, $\mu$ , lbm/ft-s | Thermal conductivity, Btu/h-ft-R |
|--------------|-----------------|----------------|-------------------------------|----------------------|------------------------------|-----------------------------|----------------------------------|
| 0            | 59.00           | 14.7           | 32.174                        | 1116                 | 0.07647                      | $1.202 \times 10^{-5}$      | 0.0146                           |
| 500          | 57.22           | 14.4           | 32.173                        | 1115                 | 0.07536                      | $1.199 \times 10^{-5}$      | 0.0146                           |
| 1000         | 55.43           | 14.2           | 32.171                        | 1113                 | 0.07426                      | $1.196 \times 10^{-5}$      | 0.0146                           |
| 1500         | 53.65           | 13.9           | 32.169                        | 1111                 | 0.07317                      | $1.193 \times 10^{-5}$      | 0.0145                           |
| 2000         | 51.87           | 13.7           | 32.168                        | 1109                 | 0.07210                      | $1.190 \times 10^{-5}$      | 0.0145                           |
| 2500         | 50.09           | 13.4           | 32.166                        | 1107                 | 0.07104                      | $1.186 \times 10^{-5}$      | 0.0144                           |
| 3000         | 48.30           | 13.2           | 32.165                        | 1105                 | 0.06998                      | $1.183 \times 10^{-5}$      | 0.0144                           |
| 3500         | 46.52           | 12.9           | 32.163                        | 1103                 | 0.06985                      | $1.180 \times 10^{-5}$      | 0.0143                           |
| 4000         | 44.74           | 12.7           | 32.162                        | 1101                 | 0.06792                      | $1.177 \times 10^{-5}$      | 0.0143                           |
| 4500         | 42.96           | 12.5           | 32.160                        | 1099                 | 0.06690                      | $1.173 \times 10^{-5}$      | 0.0142                           |
| 5000         | 41.17           | 12.2           | 32.159                        | 1097                 | 0.06590                      | $1.170 \times 10^{-5}$      | 0.0142                           |
| 5500         | 39.39           | 12.0           | 32.157                        | 1095                 | 0.06491                      | $1.167 \times 10^{-5}$      | 0.0141                           |
| 6000         | 37.61           | 11.8           | 32.156                        | 1093                 | 0.06393                      | $1.164 \times 10^{-5}$      | 0.0141                           |
| 6500         | 35.83           | 11.6           | 32.154                        | 1091                 | 0.06296                      | $1.160 \times 10^{-5}$      | 0.0141                           |
| 7000         | 34.05           | 11.3           | 32.152                        | 1089                 | 0.06200                      | $1.157 \times 10^{-5}$      | 0.0140                           |
| 7500         | 32.26           | 11.1           | 32.151                        | 1087                 | 0.06105                      | $1.154 \times 10^{-5}$      | 0.0140                           |
| 8000         | 30.48           | 10.9           | 32.149                        | 1085                 | 0.06012                      | $1.150 \times 10^{-5}$      | 0.0139                           |
| 8500         | 28.70           | 10.7           | 32.148                        | 1083                 | 0.05919                      | $1.147 \times 10^{-5}$      | 0.0139                           |
| 9000         | 26.92           | 10.5           | 32.146                        | 1081                 | 0.05828                      | $1.144 \times 10^{-5}$      | 0.0138                           |
| 9500         | 25.14           | 10.3           | 32.145                        | 1079                 | 0.05738                      | $1.140 \times 10^{-5}$      | 0.0138                           |
| 10,000       | 23.36           | 10.1           | 32.145                        | 1077                 | 0.05648                      | $1.137 \times 10^{-5}$      | 0.0137                           |
| 11,000       | 19.79           | 9.72           | 32.140                        | 1073                 | 0.05473                      | $1.130 \times 10^{-5}$      | 0.0136                           |
| 12,000       | 16.23           | 9.34           | 32.137                        | 1069                 | 0.05302                      | $1.124 \times 10^{-5}$      | 0.0136                           |
| 13,000       | 12.67           | 8.99           | 32.134                        | 1065                 | 0.05135                      | $1.117 \times 10^{-5}$      | 0.0135                           |
| 14,000       | 9.12            | 8.63           | 32.131                        | 1061                 | 0.04973                      | $1.110 \times 10^{-5}$      | 0.0134                           |
| 15,000       | 5.55            | 8.29           | 32.128                        | 1057                 | 0.04814                      | $1.104 \times 10^{-5}$      | 0.0133                           |
| 16,000       | +1.99           | 7.97           | 32.125                        | 1053                 | 0.04659                      | $1.097 \times 10^{-5}$      | 0.0132                           |
| 17,000       | -1.58           | 7.65           | 32.122                        | 1049                 | 0.04508                      | $1.090 \times 10^{-5}$      | 0.0132                           |
| 18,000       | -5.14           | 7.34           | 32.119                        | 1045                 | 0.04361                      | $1.083 \times 10^{-5}$      | 0.0130                           |
| 19,000       | -8.70           | 7.05           | 32.115                        | 1041                 | 0.04217                      | $1.076 \times 10^{-5}$      | 0.0129                           |
| 20,000       | -12.2           | 6.76           | 32.112                        | 1037                 | 0.04077                      | $1.070 \times 10^{-5}$      | 0.0128                           |
| 22,000       | -19.4           | 6.21           | 32.106                        | 1029                 | 0.03808                      | $1.056 \times 10^{-5}$      | 0.0126                           |
| 24,000       | -26.5           | 5.70           | 32.100                        | 1020                 | 0.03553                      | $1.042 \times 10^{-5}$      | 0.0124                           |
| 26,000       | -33.6           | 5.22           | 32.094                        | 1012                 | 0.03311                      | $1.028 \times 10^{-5}$      | 0.0122                           |
| 28,000       | -40.7           | 4.78           | 32.088                        | 1003                 | 0.03082                      | $1.014 \times 10^{-5}$      | 0.0121                           |
| 30,000       | -47.8           | 4.37           | 32.082                        | 995                  | 0.02866                      | $1.000 \times 10^{-5}$      | 0.0119                           |
| 32,000       | -54.9           | 3.99           | 32.08                         | 987                  | 0.02661                      | $0.986 \times 10^{-5}$      | 0.0117                           |
| 34,000       | -62.0           | 3.63           | 32.07                         | 978                  | 0.02468                      | $0.971 \times 10^{-5}$      | 0.0115                           |
| 36,000       | -69.2           | 3.30           | 32.06                         | 969                  | 0.02285                      | $0.956 \times 10^{-5}$      | 0.0113                           |
| 38,000       | -69.7           | 3.05           | 32.06                         | 968                  | 0.02079                      | $0.955 \times 10^{-5}$      | 0.0113                           |
| 40,000       | -69.7           | 2.73           | 32.05                         | 968                  | 0.01890                      | $0.955 \times 10^{-5}$      | 0.0113                           |
| 45,000       | -69.7           | 2.148          | 32.04                         | 968                  | 0.01487                      | $0.955 \times 10^{-5}$      | 0.0113                           |
| 50,000       | -69.7           | 1.691          | 32.02                         | 968                  | 0.01171                      | $0.955 \times 10^{-5}$      | 0.0113                           |
| 55,000       | -69.7           | 1.332          | 32.00                         | 968                  | 0.00922                      | $0.955 \times 10^{-5}$      | 0.0113                           |
| 60,000       | -69.7           | 1.048          | 31.99                         | 968                  | 0.00726                      | $0.955 \times 10^{-5}$      | 0.0113                           |

Source: U.S. Standard Atmosphere Supplements, U.S. Government Printing Office, 1966. Based on year-round mean conditions at 45° latitude and varies with the time of the year and the weather patterns. The conditions at sea level ( $z = 0$ ) are taken to be  $P = 14.696$  psia,  $T = 59^\circ\text{F}$ ,  $\rho = 0.076474$  lbm/ft<sup>3</sup>,  $g = 32.1741$  ft/s<sup>2</sup>.

TABLE A-17E

Ideal-gas properties of air

| $T$<br>R | $h$<br>Btu/lbm | $P_r$  | $u$<br>Btu/lbm | $v_r$  | $s^\circ$<br>Btu/lbm-R | $T$<br>R | $h$<br>Btu/lbm | $P_r$  | $u$<br>Btu/lbm | $v_r$  | $s^\circ$<br>Btu/lbm-R |
|----------|----------------|--------|----------------|--------|------------------------|----------|----------------|--------|----------------|--------|------------------------|
| 360      | 85.97          | 0.3363 | 61.29          | 396.6  | 0.50369                | 1600     | 395.74         | 71.13  | 286.06         | 8.263  | 0.87130                |
| 380      | 90.75          | 0.4061 | 64.70          | 346.6  | 0.51663                | 1650     | 409.13         | 80.89  | 296.03         | 7.556  | 0.87954                |
| 400      | 95.53          | 0.4858 | 68.11          | 305.0  | 0.52890                | 1700     | 422.59         | 90.95  | 306.06         | 6.924  | 0.88758                |
| 420      | 100.32         | 0.5760 | 71.52          | 270.1  | 0.54058                | 1750     | 436.12         | 101.98 | 316.16         | 6.357  | 0.89542                |
| 440      | 105.11         | 0.6776 | 74.93          | 240.6  | 0.55172                | 1800     | 449.71         | 114.0  | 326.32         | 5.847  | 0.90308                |
| 460      | 109.90         | 0.7913 | 78.36          | 215.33 | 0.56235                | 1850     | 463.37         | 127.2  | 336.55         | 5.388  | 0.91056                |
| 480      | 114.69         | 0.9182 | 81.77          | 193.65 | 0.57255                | 1900     | 477.09         | 141.5  | 346.85         | 4.974  | 0.91788                |
| 500      | 119.48         | 1.0590 | 85.20          | 174.90 | 0.58233                | 1950     | 490.88         | 157.1  | 357.20         | 4.598  | 0.92504                |
| 520      | 124.27         | 1.2147 | 88.62          | 158.58 | 0.59173                | 2000     | 504.71         | 174.0  | 367.61         | 4.258  | 0.93205                |
| 537      | 128.10         | 1.3593 | 91.53          | 146.34 | 0.59945                | 2050     | 518.71         | 192.3  | 378.08         | 3.949  | 0.93891                |
| 540      | 129.06         | 1.3860 | 92.04          | 144.32 | 0.60078                | 2100     | 532.55         | 212.1  | 388.60         | 3.667  | 0.94564                |
| 560      | 133.86         | 1.5742 | 95.47          | 131.78 | 0.60950                | 2150     | 546.54         | 223.5  | 399.17         | 3.410  | 0.95222                |
| 580      | 138.66         | 1.7800 | 98.90          | 120.70 | 0.61793                | 2200     | 560.59         | 256.6  | 409.78         | 3.176  | 0.95919                |
| 600      | 143.47         | 2.005  | 102.34         | 110.88 | 0.62607                | 2250     | 574.69         | 281.4  | 420.46         | 2.961  | 0.96501                |
| 620      | 148.28         | 2.249  | 105.78         | 102.12 | 0.63395                | 2300     | 588.82         | 308.1  | 431.16         | 2.765  | 0.97123                |
| 640      | 153.09         | 2.514  | 109.21         | 94.30  | 0.64159                | 2350     | 603.00         | 336.8  | 441.91         | 2.585  | 0.97732                |
| 660      | 157.92         | 2.801  | 112.67         | 87.27  | 0.64902                | 2400     | 617.22         | 367.6  | 452.70         | 2.419  | 0.98331                |
| 680      | 162.73         | 3.111  | 116.12         | 80.96  | 0.65621                | 2450     | 631.48         | 400.5  | 463.54         | 2.266  | 0.98919                |
| 700      | 167.56         | 3.446  | 119.58         | 75.25  | 0.66321                | 2500     | 645.78         | 435.7  | 474.40         | 2.125  | 0.99497                |
| 720      | 172.39         | 3.806  | 123.04         | 70.07  | 0.67002                | 2550     | 660.12         | 473.3  | 485.31         | 1.996  | 1.00064                |
| 740      | 177.23         | 4.193  | 126.51         | 65.38  | 0.67665                | 2600     | 674.49         | 513.5  | 496.26         | 1.876  | 1.00623                |
| 760      | 182.08         | 4.607  | 129.99         | 61.10  | 0.68312                | 2650     | 688.90         | 556.3  | 507.25         | 1.765  | 1.01172                |
| 780      | 186.94         | 5.051  | 133.47         | 57.20  | 0.68942                | 2700     | 703.35         | 601.9  | 518.26         | 1.662  | 1.01712                |
| 800      | 191.81         | 5.526  | 136.97         | 53.63  | 0.69558                | 2750     | 717.83         | 650.4  | 529.31         | 1.566  | 1.02244                |
| 820      | 196.69         | 6.033  | 140.47         | 50.35  | 0.70160                | 2800     | 732.33         | 702.0  | 540.40         | 1.478  | 1.02767                |
| 840      | 201.56         | 6.573  | 143.98         | 47.34  | 0.70747                | 2850     | 746.88         | 756.7  | 551.52         | 1.395  | 1.03282                |
| 860      | 206.46         | 7.149  | 147.50         | 44.57  | 0.71323                | 2900     | 761.45         | 814.8  | 562.66         | 1.318  | 1.03788                |
| 880      | 211.35         | 7.761  | 151.02         | 42.01  | 0.71886                | 2950     | 776.05         | 876.4  | 573.84         | 1.247  | 1.04288                |
| 900      | 216.26         | 8.411  | 154.57         | 39.64  | 0.72438                | 3000     | 790.68         | 941.4  | 585.04         | 1.180  | 1.04779                |
| 920      | 221.18         | 9.102  | 158.12         | 37.44  | 0.72979                | 3050     | 805.34         | 1011   | 596.28         | 1.118  | 1.05264                |
| 940      | 226.11         | 9.834  | 161.68         | 35.41  | 0.73509                | 3100     | 820.03         | 1083   | 607.53         | 1.060  | 1.05741                |
| 960      | 231.06         | 10.61  | 165.26         | 33.52  | 0.74030                | 3150     | 834.75         | 1161   | 618.82         | 1.006  | 1.06212                |
| 980      | 236.02         | 11.43  | 168.83         | 31.76  | 0.74540                | 3200     | 849.48         | 1242   | 630.12         | 0.955  | 1.06676                |
| 1000     | 240.98         | 12.30  | 172.43         | 30.12  | 0.75042                | 3250     | 864.24         | 1328   | 641.46         | 0.907  | 1.07134                |
| 1040     | 250.95         | 14.18  | 179.66         | 27.17  | 0.76019                | 3300     | 879.02         | 1418   | 652.81         | 0.8621 | 1.07585                |
| 1080     | 260.97         | 16.28  | 186.93         | 24.58  | 0.76964                | 3350     | 893.83         | 1513   | 664.20         | 0.8202 | 1.08031                |
| 1120     | 271.03         | 18.60  | 194.25         | 22.30  | 0.77880                | 3400     | 908.66         | 1613   | 675.60         | 0.7807 | 1.08470                |
| 1160     | 281.14         | 21.18  | 201.63         | 20.29  | 0.78767                | 3450     | 923.52         | 1719   | 687.04         | 0.7436 | 1.08904                |
| 1200     | 291.30         | 24.01  | 209.05         | 18.51  | 0.79628                | 3500     | 938.40         | 1829   | 698.48         | 0.7087 | 1.09332                |
| 1240     | 301.52         | 27.13  | 216.53         | 16.93  | 0.80466                | 3550     | 953.30         | 1946   | 709.95         | 0.6759 | 1.09755                |
| 1280     | 311.79         | 30.55  | 224.05         | 15.52  | 0.81280                | 3600     | 968.21         | 2068   | 721.44         | 0.6449 | 1.10172                |
| 1320     | 322.11         | 34.31  | 231.63         | 14.25  | 0.82075                | 3650     | 983.15         | 2196   | 732.95         | 0.6157 | 1.10584                |
| 1360     | 332.48         | 38.41  | 239.25         | 13.12  | 0.82848                | 3700     | 998.11         | 2330   | 744.48         | 0.5882 | 1.10991                |
| 1400     | 342.90         | 42.88  | 246.93         | 12.10  | 0.83604                | 3750     | 1013.1         | 2471   | 756.04         | 0.5621 | 1.11393                |
| 1440     | 353.37         | 47.75  | 254.66         | 11.17  | 0.84341                | 3800     | 1028.1         | 2618   | 767.60         | 0.5376 | 1.11791                |
| 1480     | 363.89         | 53.04  | 262.44         | 10.34  | 0.85062                | 3850     | 1043.1         | 2773   | 779.19         | 0.5143 | 1.12183                |
| 1520     | 374.47         | 58.78  | 270.26         | 9.578  | 0.85767                | 3900     | 1058.1         | 2934   | 790.80         | 0.4923 | 1.12571                |
| 1560     | 385.08         | 65.00  | 278.13         | 8.890  | 0.86456                | 3950     | 1073.2         | 3103   | 802.43         | 0.4715 | 1.12955                |

TABLE A-17E

Ideal-gas properties of air (*Concluded*)

| $T$<br>R | $h$<br>Btu/lbm | $P_r$ | $u$<br>Btu/lbm | $v_r$  | $s^\circ$<br>Btu/lbm·R | $T$<br>R | $h$<br>Btu/lbm | $P_r$  | $u$<br>Btu/lbm | $v_r$  | $s^\circ$<br>Btu/lbm·R |
|----------|----------------|-------|----------------|--------|------------------------|----------|----------------|--------|----------------|--------|------------------------|
| 4000     | 1088.3         | 3280  | 814.06         | 0.4518 | 1.13334                | 4600     | 1270.4         | 6089   | 955.04         | 0.2799 | 1.17575                |
| 4050     | 1103.4         | 3464  | 825.72         | 0.4331 | 1.13709                | 4700     | 1300.9         | 6701   | 978.73         | 0.2598 | 1.18232                |
| 4100     | 1118.5         | 3656  | 837.40         | 0.4154 | 1.14079                | 4800     | 1331.5         | 7362   | 1002.5         | 0.2415 | 1.18876                |
| 4150     | 1133.6         | 3858  | 849.09         | 0.3985 | 1.14446                | 4900     | 1362.2         | 8073   | 1026.3         | 0.2248 | 1.19508                |
| 4200     | 1148.7         | 4067  | 860.81         | 0.3826 | 1.14809                | 5000     | 1392.9         | 8837   | 1050.1         | 0.2096 | 1.20129                |
| 4300     | 1179.0         | 4513  | 884.28         | 0.3529 | 1.15522                | 5100     | 1423.6         | 9658   | 1074.0         | 0.1956 | 1.20738                |
| 4400     | 1209.4         | 4997  | 907.81         | 0.3262 | 1.16221                | 5200     | 1454.4         | 10,539 | 1098.0         | 0.1828 | 1.21336                |
| 4500     | 1239.9         | 5521  | 931.39         | 0.3019 | 1.16905                | 5300     | 1485.3         | 11,481 | 1122.0         | 0.1710 | 1.21923                |

Note: The properties  $P_r$  (relative pressure) and  $v_r$  (relative specific volume) are dimensionless quantities used in the analysis of isentropic processes, and should not be confused with the properties pressure and specific volume.

Source: Kenneth Wark, *Thermodynamics*, 4th ed. (New York: McGraw-Hill, 1983), pp. 832–33, Table A-5. Originally published in J. H. Keenan and J. Kaye, *Gas Tables* (New York: John Wiley & Sons, 1948).

TABLE A-18E

Ideal-gas properties of nitrogen,  $N_2$ 

| $T$<br>R | $\bar{h}$<br>Btu/lbmol | $\bar{u}$<br>Btu/lbmol | $\bar{s}^\circ$<br>Btu/lbmol·R | $T$<br>R | $\bar{h}$<br>Btu/lbmol | $\bar{u}$<br>Btu/lbmol | $\bar{s}^\circ$<br>Btu/lbmol·R |
|----------|------------------------|------------------------|--------------------------------|----------|------------------------|------------------------|--------------------------------|
| 300      | 2,082.0                | 1,486.2                | 41.695                         | 1080     | 7,551.0                | 5,406.2                | 50.651                         |
| 320      | 2,221.0                | 1,585.5                | 42.143                         | 1100     | 7,695.0                | 5,510.5                | 50.783                         |
| 340      | 2,360.0                | 1,684.4                | 42.564                         | 1120     | 7,839.3                | 5,615.2                | 50.912                         |
| 360      | 2,498.9                | 1,784.0                | 42.962                         | 1140     | 7,984.0                | 5,720.1                | 51.040                         |
| 380      | 2,638.0                | 1,883.4                | 43.337                         | 1160     | 8,129.0                | 5,825.4                | 51.167                         |
| 400      | 2,777.0                | 1,982.6                | 43.694                         | 1180     | 8,274.4                | 5,931.0                | 51.291                         |
| 420      | 2,916.1                | 2,082.0                | 44.034                         | 1200     | 8,420.0                | 6,037.0                | 51.143                         |
| 440      | 3,055.1                | 2,181.3                | 44.357                         | 1220     | 8,566.1                | 6,143.4                | 51.534                         |
| 460      | 3,194.1                | 2,280.6                | 44.665                         | 1240     | 8,712.6                | 6,250.1                | 51.653                         |
| 480      | 3,333.1                | 2,379.9                | 44.962                         | 1260     | 8,859.3                | 6,357.2                | 51.771                         |
| 500      | 3,472.2                | 2,479.3                | 45.246                         | 1280     | 9,006.4                | 6,464.5                | 51.887                         |
| 520      | 3,611.3                | 2,578.6                | 45.519                         | 1300     | 9,153.9                | 6,572.3                | 51.001                         |
| 537      | 3,729.5                | 2,663.1                | 45.743                         | 1320     | 9,301.8                | 6,680.4                | 52.114                         |
| 540      | 3,750.3                | 2,678.0                | 45.781                         | 1340     | 9,450.0                | 6,788.9                | 52.225                         |
| 560      | 3,889.5                | 2,777.4                | 46.034                         | 1360     | 9,598.6                | 6,897.8                | 52.335                         |
| 580      | 4,028.7                | 2,876.9                | 46.278                         | 1380     | 9,747.5                | 7,007.0                | 52.444                         |
| 600      | 4,167.9                | 2,976.4                | 46.514                         | 1400     | 9,896.9                | 7,116.7                | 52.551                         |
| 620      | 4,307.1                | 3,075.9                | 46.742                         | 1420     | 10,046.6               | 7,226.7                | 52.658                         |
| 640      | 4,446.4                | 3,175.5                | 46.964                         | 1440     | 10,196.6               | 7,337.0                | 52.763                         |
| 660      | 4,585.8                | 3,275.2                | 47.178                         | 1460     | 10,347.0               | 7,447.6                | 52.867                         |
| 680      | 4,725.3                | 3,374.9                | 47.386                         | 1480     | 10,497.8               | 7,558.7                | 52.969                         |
| 700      | 4,864.9                | 3,474.8                | 47.588                         | 1500     | 10,648.0               | 7,670.1                | 53.071                         |
| 720      | 5,004.5                | 3,574.7                | 47.785                         | 1520     | 10,800.4               | 7,781.9                | 53.171                         |
| 740      | 5,144.3                | 3,674.7                | 47.977                         | 1540     | 10,952.2               | 7,893.9                | 53.271                         |
| 760      | 5,284.1                | 3,774.9                | 48.164                         | 1560     | 11,104.3               | 8,006.4                | 53.369                         |
| 780      | 5,424.2                | 3,875.2                | 48.345                         | 1580     | 11,256.9               | 8,119.2                | 53.465                         |
| 800      | 5,564.4                | 3,975.7                | 48.522                         | 1600     | 11,409.7               | 8,232.3                | 53.561                         |
| 820      | 5,704.7                | 4,076.3                | 48.696                         | 1620     | 11,562.8               | 8,345.7                | 53.656                         |
| 840      | 5,845.3                | 4,177.1                | 48.865                         | 1640     | 11,716.4               | 8,459.6                | 53.751                         |
| 860      | 5,985.9                | 4,278.1                | 49.031                         | 1660     | 11,870.2               | 8,573.6                | 53.844                         |
| 880      | 6,126.9                | 4,379.4                | 49.193                         | 1680     | 12,024.3               | 8,688.1                | 53.936                         |
| 900      | 6,268.1                | 4,480.8                | 49.352                         | 1700     | 12,178.9               | 8,802.9                | 54.028                         |
| 920      | 6,409.6                | 4,582.6                | 49.507                         | 1720     | 12,333.7               | 8,918.0                | 54.118                         |
| 940      | 6,551.2                | 4,684.5                | 49.659                         | 1740     | 12,488.8               | 9,033.4                | 54.208                         |
| 960      | 6,693.1                | 4,786.7                | 49.808                         | 1760     | 12,644.3               | 9,149.2                | 54.297                         |
| 980      | 6,835.4                | 4,889.3                | 49.955                         | 1780     | 12,800.2               | 9,265.3                | 54.385                         |
| 1000     | 6,977.9                | 4,992.0                | 50.099                         | 1800     | 12,956.3               | 9,381.7                | 54.472                         |
| 1020     | 7,120.7                | 5,095.1                | 50.241                         | 1820     | 13,112.7               | 9,498.4                | 54.559                         |
| 1040     | 7,263.8                | 5,198.5                | 50.380                         | 1840     | 13,269.5               | 9,615.5                | 54.645                         |
| 1060     | 7,407.2                | 5,302.2                | 50.516                         | 1860     | 13,426.5               | 9,732.8                | 54.729                         |

TABLE A-18E

Ideal-gas properties of nitrogen,  $N_2$  (Concluded)

| $T$<br>R | $\bar{h}$<br>Btu/lbmol | $\bar{u}$<br>Btu/lbmol | $\bar{s}^\circ$<br>Btu/lbmol·R | $T$<br>R | $\bar{h}$<br>Btu/lbmol | $\bar{u}$<br>Btu/lbmol | $\bar{s}^\circ$<br>Btu/lbmol·R |
|----------|------------------------|------------------------|--------------------------------|----------|------------------------|------------------------|--------------------------------|
| 1900     | 13,742                 | 9,968                  | 54.896                         | 3500     | 27,016                 | 20,065                 | 59.944                         |
| 1940     | 14,058                 | 10,205                 | 55.061                         | 3540     | 27,359                 | 20,329                 | 60.041                         |
| 1980     | 14,375                 | 10,443                 | 55.223                         | 3580     | 27,703                 | 20,593                 | 60.138                         |
| 2020     | 14,694                 | 10,682                 | 55.383                         | 3620     | 28,046                 | 20,858                 | 60.234                         |
| 2060     | 15,013                 | 10,923                 | 55.540                         | 3660     | 28,391                 | 21,122                 | 60.328                         |
| 2100     | 15,334                 | 11,164                 | 55.694                         | 3700     | 28,735                 | 21,387                 | 60.422                         |
| 2140     | 15,656                 | 11,406                 | 55.846                         | 3740     | 29,080                 | 21,653                 | 60.515                         |
| 2180     | 15,978                 | 11,649                 | 55.995                         | 3780     | 29,425                 | 21,919                 | 60.607                         |
| 2220     | 16,302                 | 11,893                 | 56.141                         | 3820     | 29,771                 | 22,185                 | 60.698                         |
| 2260     | 16,626                 | 12,138                 | 56.286                         | 3860     | 30,117                 | 22,451                 | 60.788                         |
| 2300     | 16,951                 | 12,384                 | 56.429                         | 3900     | 30,463                 | 22,718                 | 60.877                         |
| 2340     | 17,277                 | 12,630                 | 56.570                         | 3940     | 30,809                 | 22,985                 | 60.966                         |
| 2380     | 17,604                 | 12,878                 | 56.708                         | 3980     | 31,156                 | 23,252                 | 61.053                         |
| 2420     | 17,932                 | 13,126                 | 56.845                         | 4020     | 31,503                 | 23,520                 | 61.139                         |
| 2460     | 18,260                 | 13,375                 | 56.980                         | 4060     | 31,850                 | 23,788                 | 61.225                         |
| 2500     | 18,590                 | 13,625                 | 57.112                         | 4100     | 32,198                 | 24,056                 | 61.310                         |
| 2540     | 18,919                 | 13,875                 | 57.243                         | 4140     | 32,546                 | 24,324                 | 61.395                         |
| 2580     | 19,250                 | 14,127                 | 57.372                         | 4180     | 32,894                 | 24,593                 | 61.479                         |
| 2620     | 19,582                 | 14,379                 | 57.499                         | 4220     | 33,242                 | 24,862                 | 61.562                         |
| 2660     | 19,914                 | 14,631                 | 57.625                         | 4260     | 33,591                 | 25,131                 | 61.644                         |
| 2700     | 20,246                 | 14,885                 | 57.750                         | 4300     | 33,940                 | 25,401                 | 61.726                         |
| 2740     | 20,580                 | 15,139                 | 57.872                         | 4340     | 34,289                 | 25,670                 | 61.806                         |
| 2780     | 20,914                 | 15,393                 | 57.993                         | 4380     | 34,638                 | 25,940                 | 61.887                         |
| 2820     | 21,248                 | 15,648                 | 58.113                         | 4420     | 34,988                 | 26,210                 | 61.966                         |
| 2860     | 21,584                 | 15,905                 | 58.231                         | 4460     | 35,338                 | 26,481                 | 62.045                         |
| 2900     | 21,920                 | 16,161                 | 58.348                         | 4500     | 35,688                 | 26,751                 | 62.123                         |
| 2940     | 22,256                 | 16,417                 | 58.463                         | 4540     | 36,038                 | 27,022                 | 62.201                         |
| 2980     | 22,593                 | 16,675                 | 58.576                         | 4580     | 36,389                 | 27,293                 | 62.278                         |
| 3020     | 22,930                 | 16,933                 | 58.688                         | 4620     | 36,739                 | 27,565                 | 62.354                         |
| 3060     | 23,268                 | 17,192                 | 58.800                         | 4660     | 37,090                 | 27,836                 | 62.429                         |
| 3100     | 23,607                 | 17,451                 | 58.910                         | 4700     | 37,441                 | 28,108                 | 62.504                         |
| 3140     | 23,946                 | 17,710                 | 59.019                         | 4740     | 37,792                 | 28,379                 | 62.578                         |
| 3180     | 24,285                 | 17,970                 | 59.126                         | 4780     | 38,144                 | 28,651                 | 62.652                         |
| 3220     | 24,625                 | 18,231                 | 59.232                         | 4820     | 38,495                 | 28,924                 | 62.725                         |
| 3260     | 24,965                 | 18,491                 | 59.338                         | 4860     | 38,847                 | 29,196                 | 62.798                         |
| 3300     | 25,306                 | 18,753                 | 59.442                         | 4900     | 39,199                 | 29,468                 | 62.870                         |
| 3340     | 25,647                 | 19,014                 | 59.544                         | 5000     | 40,080                 | 30,151                 | 63.049                         |
| 3380     | 25,989                 | 19,277                 | 59.646                         | 5100     | 40,962                 | 30,834                 | 63.223                         |
| 3420     | 26,331                 | 19,539                 | 59.747                         | 5200     | 41,844                 | 31,518                 | 63.395                         |
| 3460     | 26,673                 | 19,802                 | 59.846                         | 5300     | 42,728                 | 32,203                 | 63.563                         |

Source: Tables A-18E through A-23E are adapted from Kenneth Wark, *Thermodynamics*, 4th ed. (New York: McGraw-Hill, 1983), pp. 834-44. Originally published in J. H. Keenan and J. Kaye, *Gas Tables* (New York: John Wiley & Sons, 1945).

TABLE A-19E

Ideal-gas properties of oxygen, O<sub>2</sub>

| $T$<br>R | $\bar{h}$<br>Btu/lbmol | $\bar{u}$<br>Btu/lbmol | $\bar{s}^\circ$<br>Btu/lbmol·R | $T$<br>R | $\bar{h}$<br>Btu/lbmol | $\bar{u}$<br>Btu/lbmol | $\bar{s}^\circ$<br>Btu/lbmol·R |
|----------|------------------------|------------------------|--------------------------------|----------|------------------------|------------------------|--------------------------------|
| 300      | 2,073.5                | 1,477.8                | 44.927                         | 1080     | 7,696.8                | 5,552.1                | 54.064                         |
| 320      | 2,212.6                | 1,577.1                | 45.375                         | 1100     | 7,850.4                | 5,665.9                | 54.204                         |
| 340      | 2,351.7                | 1,676.5                | 45.797                         | 1120     | 8,004.5                | 5,780.3                | 54.343                         |
| 360      | 2,490.8                | 1,775.9                | 46.195                         | 1140     | 8,159.1                | 5,895.2                | 54.480                         |
| 380      | 2,630.0                | 1,875.3                | 46.571                         | 1160     | 8,314.2                | 6,010.6                | 54.614                         |
| 400      | 2,769.1                | 1,974.8                | 46.927                         | 1180     | 8,469.8                | 6,126.5                | 54.748                         |
| 420      | 2,908.3                | 2,074.3                | 47.267                         | 1200     | 8,625.8                | 6,242.8                | 54.879                         |
| 440      | 3,047.5                | 2,173.8                | 47.591                         | 1220     | 8,782.4                | 6,359.6                | 55.008                         |
| 460      | 3,186.9                | 2,273.4                | 47.900                         | 1240     | 8,939.4                | 6,476.9                | 55.136                         |
| 480      | 3,326.5                | 2,373.3                | 48.198                         | 1260     | 9,096.7                | 6,594.5                | 55.262                         |
| 500      | 3,466.2                | 2,473.2                | 48.483                         | 1280     | 9,254.6                | 6,712.7                | 55.386                         |
| 520      | 3,606.1                | 2,573.4                | 48.757                         | 1300     | 9,412.9                | 6,831.3                | 55.508                         |
| 537      | 3,725.1                | 2,658.7                | 48.982                         | 1320     | 9,571.9                | 6,950.2                | 55.630                         |
| 540      | 3,746.2                | 2,673.8                | 49.021                         | 1340     | 9,730.7                | 7,069.6                | 55.750                         |
| 560      | 3,886.6                | 2,774.5                | 49.276                         | 1360     | 9,890.2                | 7,189.4                | 55.867                         |
| 580      | 4,027.3                | 2,875.5                | 49.522                         | 1380     | 10,050.1               | 7,309.6                | 55.984                         |
| 600      | 4,168.3                | 2,976.8                | 49.762                         | 1400     | 10,210.4               | 7,430.1                | 56.099                         |
| 620      | 4,309.7                | 3,078.4                | 49.993                         | 1420     | 10,371.0               | 7,551.1                | 56.213                         |
| 640      | 4,451.4                | 3,180.4                | 50.218                         | 1440     | 10,532.0               | 7,672.4                | 56.326                         |
| 660      | 4,593.5                | 3,282.9                | 50.437                         | 1460     | 10,693.3               | 7,793.9                | 56.437                         |
| 680      | 4,736.2                | 3,385.8                | 50.650                         | 1480     | 10,855.1               | 7,916.0                | 56.547                         |
| 700      | 4,879.3                | 3,489.2                | 50.858                         | 1500     | 11,017.1               | 8,038.3                | 56.656                         |
| 720      | 5,022.9                | 3,593.1                | 51.059                         | 1520     | 11,179.6               | 8,161.1                | 56.763                         |
| 740      | 5,167.0                | 3,697.4                | 51.257                         | 1540     | 11,342.4               | 8,284.2                | 56.869                         |
| 760      | 5,311.4                | 3,802.4                | 51.450                         | 1560     | 11,505.4               | 8,407.4                | 56.975                         |
| 780      | 5,456.4                | 3,907.5                | 51.638                         | 1580     | 11,668.8               | 8,531.1                | 57.079                         |
| 800      | 5,602.0                | 4,013.3                | 51.821                         | 1600     | 11,832.5               | 8,655.1                | 57.182                         |
| 820      | 5,748.1                | 4,119.7                | 52.002                         | 1620     | 11,996.6               | 8,779.5                | 57.284                         |
| 840      | 5,894.8                | 4,226.6                | 52.179                         | 1640     | 12,160.9               | 8,904.1                | 57.385                         |
| 860      | 6,041.9                | 4,334.1                | 52.352                         | 1660     | 12,325.5               | 9,029.0                | 57.484                         |
| 880      | 6,189.6                | 4,442.0                | 52.522                         | 1680     | 12,490.4               | 9,154.1                | 57.582                         |
| 900      | 6,337.9                | 4,550.6                | 52.688                         | 1700     | 12,655.6               | 9,279.6                | 57.680                         |
| 920      | 6,486.7                | 4,659.7                | 52.852                         | 1720     | 12,821.1               | 9,405.4                | 57.777                         |
| 940      | 6,636.1                | 4,769.4                | 53.012                         | 1740     | 12,986.9               | 9,531.5                | 57.873                         |
| 960      | 6,786.0                | 4,879.5                | 53.170                         | 1760     | 13,153.0               | 9,657.9                | 57.968                         |
| 980      | 6,936.4                | 4,990.3                | 53.326                         | 1780     | 13,319.2               | 9,784.4                | 58.062                         |
| 1000     | 7,087.5                | 5,101.6                | 53.477                         | 1800     | 13,485.8               | 9,911.2                | 58.155                         |
| 1020     | 7,238.9                | 5,213.3                | 53.628                         | 1820     | 13,652.5               | 10,038.2               | 58.247                         |
| 1040     | 7,391.0                | 5,325.7                | 53.775                         | 1840     | 13,819.6               | 10,165.6               | 58.339                         |
| 1060     | 7,543.6                | 5,438.6                | 53.921                         | 1860     | 13,986.8               | 10,293.1               | 58.428                         |

**TABLE A-19E**

Ideal-gas properties of oxygen, O<sub>2</sub> (Concluded)

| <i>T</i><br>R | $\bar{h}$<br>Btu/lbmol | $\bar{u}$<br>Btu/lbmol | $\bar{s}^\circ$<br>Btu/lbmol·R | <i>T</i><br>R | $\bar{h}$<br>Btu/lbmol | $\bar{u}$<br>Btu/lbmol | $\bar{s}^\circ$<br>Btu/lbmol·R |
|---------------|------------------------|------------------------|--------------------------------|---------------|------------------------|------------------------|--------------------------------|
| 1900          | 14,322                 | 10,549                 | 58.607                         | 3500          | 28,273                 | 21,323                 | 63.914                         |
| 1940          | 14,658                 | 10,806                 | 58.782                         | 3540          | 28,633                 | 21,603                 | 64.016                         |
| 1980          | 14,995                 | 11,063                 | 58.954                         | 3580          | 28,994                 | 21,884                 | 64.114                         |
| 2020          | 15,333                 | 11,321                 | 59.123                         | 3620          | 29,354                 | 22,165                 | 64.217                         |
| 2060          | 15,672                 | 11,581                 | 59.289                         | 3660          | 29,716                 | 22,447                 | 64.316                         |
| 2100          | 16,011                 | 11,841                 | 59.451                         | 3700          | 30,078                 | 22,730                 | 64.415                         |
| 2140          | 16,351                 | 12,101                 | 59.612                         | 3740          | 30,440                 | 23,013                 | 64.512                         |
| 2180          | 16,692                 | 12,363                 | 59.770                         | 3780          | 30,803                 | 23,296                 | 64.609                         |
| 2220          | 17,036                 | 12,625                 | 59.926                         | 3820          | 31,166                 | 23,580                 | 64.704                         |
| 2260          | 17,376                 | 12,888                 | 60.077                         | 3860          | 31,529                 | 23,864                 | 64.800                         |
| 2300          | 17,719                 | 13,151                 | 60.228                         | 3900          | 31,894                 | 24,149                 | 64.893                         |
| 2340          | 18,062                 | 13,416                 | 60.376                         | 3940          | 32,258                 | 24,434                 | 64.986                         |
| 2380          | 18,407                 | 13,680                 | 60.522                         | 3980          | 32,623                 | 24,720                 | 65.078                         |
| 2420          | 18,572                 | 13,946                 | 60.666                         | 4020          | 32,989                 | 25,006                 | 65.169                         |
| 2460          | 19,097                 | 14,212                 | 60.808                         | 4060          | 33,355                 | 25,292                 | 65.260                         |
| 2500          | 19,443                 | 14,479                 | 60.946                         | 4100          | 33,722                 | 25,580                 | 65.350                         |
| 2540          | 19,790                 | 14,746                 | 61.084                         | 4140          | 34,089                 | 25,867                 | 64.439                         |
| 2580          | 20,138                 | 15,014                 | 61.220                         | 4180          | 34,456                 | 26,155                 | 65.527                         |
| 2620          | 20,485                 | 15,282                 | 61.354                         | 4220          | 34,824                 | 26,144                 | 65.615                         |
| 2660          | 20,834                 | 15,551                 | 61.486                         | 4260          | 35,192                 | 26,733                 | 65.702                         |
| 2700          | 21,183                 | 15,821                 | 61.616                         | 4300          | 35,561                 | 27,022                 | 65.788                         |
| 2740          | 21,533                 | 16,091                 | 61.744                         | 4340          | 35,930                 | 27,312                 | 65.873                         |
| 2780          | 21,883                 | 16,362                 | 61.871                         | 4380          | 36,300                 | 27,602                 | 65.958                         |
| 2820          | 22,232                 | 16,633                 | 61.996                         | 4420          | 36,670                 | 27,823                 | 66.042                         |
| 2860          | 22,584                 | 16,905                 | 62.120                         | 4460          | 37,041                 | 28,184                 | 66.125                         |
| 2900          | 22,936                 | 17,177                 | 62.242                         | 4500          | 37,412                 | 28,475                 | 66.208                         |
| 2940          | 23,288                 | 17,450                 | 62.363                         | 4540          | 37,783                 | 28,768                 | 66.290                         |
| 2980          | 23,641                 | 17,723                 | 62.483                         | 4580          | 38,155                 | 29,060                 | 66.372                         |
| 3020          | 23,994                 | 17,997                 | 62.599                         | 4620          | 38,528                 | 29,353                 | 66.453                         |
| 3060          | 24,348                 | 18,271                 | 62.716                         | 4660          | 38,900                 | 29,646                 | 66.533                         |
| 3100          | 24,703                 | 18,546                 | 62.831                         | 4700          | 39,274                 | 29,940                 | 66.613                         |
| 3140          | 25,057                 | 18,822                 | 62.945                         | 4740          | 39,647                 | 30,234                 | 66.691                         |
| 3180          | 25,413                 | 19,098                 | 63.057                         | 4780          | 40,021                 | 30,529                 | 66.770                         |
| 3220          | 25,769                 | 19,374                 | 63.169                         | 4820          | 40,396                 | 30,824                 | 66.848                         |
| 3260          | 26,175                 | 19,651                 | 63.279                         | 4860          | 40,771                 | 31,120                 | 66.925                         |
| 3300          | 26,412                 | 19,928                 | 63.386                         | 4900          | 41,146                 | 31,415                 | 67.003                         |
| 3340          | 26,839                 | 20,206                 | 63.494                         | 5000          | 42,086                 | 32,157                 | 67.193                         |
| 3380          | 27,197                 | 20,485                 | 63.601                         | 5100          | 43,021                 | 32,901                 | 67.380                         |
| 3420          | 27,555                 | 20,763                 | 63.706                         | 5200          | 43,974                 | 33,648                 | 67.562                         |
| 3460          | 27,914                 | 21,043                 | 63.811                         | 5300          | 44,922                 | 34,397                 | 67.743                         |

TABLE A-20E

Ideal-gas properties of carbon dioxide, CO<sub>2</sub>

| $T$<br>R | $\bar{h}$<br>Btu/lbmol | $\bar{u}$<br>Btu/lbmol | $\bar{s}^\circ$<br>Btu/lbmol·R | $T$<br>R | $\bar{h}$<br>Btu/lbmol | $\bar{u}$<br>Btu/lbmol | $\bar{s}^\circ$<br>Btu/lbmol·R |
|----------|------------------------|------------------------|--------------------------------|----------|------------------------|------------------------|--------------------------------|
| 300      | 2,108.2                | 1,512.4                | 46.353                         | 1080     | 9,575.8                | 7,431.1                | 58.072                         |
| 320      | 2,256.6                | 1,621.1                | 46.832                         | 1100     | 9,802.6                | 7,618.1                | 58.281                         |
| 340      | 2,407.3                | 1,732.1                | 47.289                         | 1120     | 10,030.6               | 7,806.4                | 58.485                         |
| 360      | 2,560.5                | 1,845.6                | 47.728                         | 1140     | 10,260.1               | 7,996.2                | 58.689                         |
| 380      | 2,716.4                | 1,961.8                | 48.148                         | 1160     | 10,490.6               | 8,187.0                | 58.889                         |
| 400      | 2,874.7                | 2,080.4                | 48.555                         | 1180     | 10,722.3               | 8,379.0                | 59.088                         |
| 420      | 3,035.7                | 2,201.7                | 48.947                         | 1200     | 10,955.3               | 8,572.3                | 59.283                         |
| 440      | 3,199.4                | 2,325.6                | 49.329                         | 1220     | 11,189.4               | 8,766.6                | 59.477                         |
| 460      | 3,365.7                | 2,452.2                | 49.698                         | 1240     | 11,424.6               | 8,962.1                | 59.668                         |
| 480      | 3,534.7                | 2,581.5                | 50.058                         | 1260     | 11,661.0               | 9,158.8                | 59.858                         |
| 500      | 3,706.2                | 2,713.3                | 50.408                         | 1280     | 11,898.4               | 9,356.5                | 60.044                         |
| 520      | 3,880.3                | 2,847.7                | 50.750                         | 1300     | 12,136.9               | 9,555.3                | 60.229                         |
| 537      | 4,027.5                | 2,963.8                | 51.032                         | 1320     | 12,376.4               | 9,755.0                | 60.412                         |
| 540      | 4,056.8                | 2,984.4                | 51.082                         | 1340     | 12,617.0               | 9,955.9                | 60.593                         |
| 560      | 4,235.8                | 3,123.7                | 51.408                         | 1360     | 12,858.5               | 10,157.7               | 60.772                         |
| 580      | 4,417.2                | 3,265.4                | 51.726                         | 1380     | 13,101.0               | 10,360.5               | 60.949                         |
| 600      | 4,600.9                | 3,409.4                | 52.038                         | 1400     | 13,344.7               | 10,564.5               | 61.124                         |
| 620      | 4,786.6                | 3,555.6                | 52.343                         | 1420     | 13,589.1               | 10,769.2               | 61.298                         |
| 640      | 4,974.9                | 3,704.0                | 52.641                         | 1440     | 13,834.5               | 10,974.8               | 61.469                         |
| 660      | 5,165.2                | 3,854.6                | 52.934                         | 1460     | 14,080.8               | 11,181.4               | 61.639                         |
| 680      | 5,357.6                | 4,007.2                | 53.225                         | 1480     | 14,328.0               | 11,388.9               | 61.800                         |
| 700      | 5,552.0                | 4,161.9                | 53.503                         | 1500     | 14,576.0               | 11,597.2               | 61.974                         |
| 720      | 5,748.4                | 4,318.6                | 53.780                         | 1520     | 14,824.9               | 11,806.4               | 62.138                         |
| 740      | 5,946.8                | 4,477.3                | 54.051                         | 1540     | 15,074.7               | 12,016.5               | 62.302                         |
| 760      | 6,147.0                | 4,637.9                | 54.319                         | 1560     | 15,325.3               | 12,227.3               | 62.464                         |
| 780      | 6,349.1                | 4,800.1                | 54.582                         | 1580     | 15,576.7               | 12,439.0               | 62.624                         |
| 800      | 6,552.9                | 4,964.2                | 54.839                         | 1600     | 15,829.0               | 12,651.6               | 62.783                         |
| 820      | 6,758.3                | 5,129.9                | 55.093                         | 1620     | 16,081.9               | 12,864.8               | 62.939                         |
| 840      | 6,965.7                | 5,297.6                | 55.343                         | 1640     | 16,335.7               | 13,078.9               | 63.095                         |
| 860      | 7,174.7                | 5,466.9                | 55.589                         | 1660     | 16,590.2               | 13,293.7               | 63.250                         |
| 880      | 7,385.3                | 5,637.7                | 55.831                         | 1680     | 16,845.5               | 13,509.2               | 63.403                         |
| 900      | 7,597.6                | 5,810.3                | 56.070                         | 1700     | 17,101.4               | 13,725.4               | 63.555                         |
| 920      | 7,811.4                | 5,984.4                | 56.305                         | 1720     | 17,358.1               | 13,942.4               | 63.704                         |
| 940      | 8,026.8                | 6,160.1                | 56.536                         | 1740     | 17,615.5               | 14,160.1               | 63.853                         |
| 960      | 8,243.8                | 6,337.4                | 56.765                         | 1760     | 17,873.5               | 14,378.4               | 64.001                         |
| 980      | 8,462.2                | 6,516.1                | 56.990                         | 1780     | 18,132.2               | 14,597.4               | 64.147                         |
| 1000     | 8,682.1                | 6,696.2                | 57.212                         | 1800     | 18,391.5               | 14,816.9               | 64.292                         |
| 1020     | 8,903.4                | 6,877.8                | 57.432                         | 1820     | 18,651.5               | 15,037.2               | 64.435                         |
| 1040     | 9,126.2                | 7,060.9                | 57.647                         | 1840     | 18,912.2               | 15,258.2               | 64.578                         |
| 1060     | 9,350.3                | 7,245.3                | 57.861                         | 1860     | 19,173.4               | 15,479.7               | 64.719                         |



**TABLE A-20E**

Ideal-gas properties of carbon dioxide, CO<sub>2</sub> (Concluded)

| $T$<br>R | $\bar{h}$<br>Btu/lbmol | $\bar{u}$<br>Btu/lbmol | $\bar{s}^\circ$<br>Btu/lbmol·R | $T$<br>R | $\bar{h}$<br>Btu/lbmol | $\bar{u}$<br>Btu/lbmol | $\bar{s}^\circ$<br>Btu/lbmol·R |
|----------|------------------------|------------------------|--------------------------------|----------|------------------------|------------------------|--------------------------------|
| 1900     | 19,698                 | 15,925                 | 64.999                         | 3500     | 41,965                 | 35,015                 | 73.462                         |
| 1940     | 20,224                 | 16,372                 | 65.272                         | 3540     | 42,543                 | 35,513                 | 73.627                         |
| 1980     | 20,753                 | 16,821                 | 65.543                         | 3580     | 43,121                 | 36,012                 | 73.789                         |
| 2020     | 21,284                 | 17,273                 | 65.809                         | 3620     | 43,701                 | 36,512                 | 73.951                         |
| 2060     | 21,818                 | 17,727                 | 66.069                         | 3660     | 44,280                 | 37,012                 | 74.110                         |
| 2100     | 22,353                 | 18,182                 | 66.327                         | 3700     | 44,861                 | 37,513                 | 74.267                         |
| 2140     | 22,890                 | 18,640                 | 66.581                         | 3740     | 45,442                 | 38,014                 | 74.423                         |
| 2180     | 23,429                 | 19,101                 | 66.830                         | 3780     | 46,023                 | 38,517                 | 74.578                         |
| 2220     | 23,970                 | 19,561                 | 67.076                         | 3820     | 46,605                 | 39,019                 | 74.732                         |
| 2260     | 24,512                 | 20,024                 | 67.319                         | 3860     | 47,188                 | 39,522                 | 74.884                         |
| 2300     | 25,056                 | 20,489                 | 67.557                         | 3900     | 47,771                 | 40,026                 | 75.033                         |
| 2340     | 25,602                 | 20,955                 | 67.792                         | 3940     | 48,355                 | 40,531                 | 75.182                         |
| 2380     | 26,150                 | 21,423                 | 68.025                         | 3980     | 48,939                 | 41,035                 | 75.330                         |
| 2420     | 26,699                 | 21,893                 | 68.253                         | 4020     | 49,524                 | 41,541                 | 75.477                         |
| 2460     | 27,249                 | 22,364                 | 68.479                         | 4060     | 50,109                 | 42,047                 | 75.622                         |
| 2500     | 27,801                 | 22,837                 | 68.702                         | 4100     | 50,695                 | 42,553                 | 75.765                         |
| 2540     | 28,355                 | 23,310                 | 68.921                         | 4140     | 51,282                 | 43,060                 | 75.907                         |
| 2580     | 28,910                 | 23,786                 | 69.138                         | 4180     | 51,868                 | 43,568                 | 76.048                         |
| 2620     | 29,465                 | 24,262                 | 69.352                         | 4220     | 52,456                 | 44,075                 | 76.188                         |
| 2660     | 30,023                 | 24,740                 | 69.563                         | 4260     | 53,044                 | 44,584                 | 76.327                         |
| 2700     | 30,581                 | 25,220                 | 69.771                         | 4300     | 53,632                 | 45,093                 | 76.464                         |
| 2740     | 31,141                 | 25,701                 | 69.977                         | 4340     | 54,221                 | 45,602                 | 76.601                         |
| 2780     | 31,702                 | 26,181                 | 70.181                         | 4380     | 54,810                 | 46,112                 | 76.736                         |
| 2820     | 32,264                 | 26,664                 | 70.382                         | 4420     | 55,400                 | 46,622                 | 76.870                         |
| 2860     | 32,827                 | 27,148                 | 70.580                         | 4460     | 55,990                 | 47,133                 | 77.003                         |
| 2900     | 33,392                 | 27,633                 | 70.776                         | 4500     | 56,581                 | 47,645                 | 77.135                         |
| 2940     | 33,957                 | 28,118                 | 70.970                         | 4540     | 57,172                 | 48,156                 | 77.266                         |
| 2980     | 34,523                 | 28,605                 | 71.160                         | 4580     | 57,764                 | 48,668                 | 77.395                         |
| 3020     | 35,090                 | 29,093                 | 71.350                         | 4620     | 58,356                 | 49,181                 | 77.581                         |
| 3060     | 35,659                 | 29,582                 | 71.537                         | 4660     | 58,948                 | 49,694                 | 77.652                         |
| 3100     | 36,228                 | 30,072                 | 71.722                         | 4700     | 59,541                 | 50,208                 | 77.779                         |
| 3140     | 36,798                 | 30,562                 | 71.904                         | 4740     | 60,134                 | 50,721                 | 77.905                         |
| 3180     | 37,369                 | 31,054                 | 72.085                         | 4780     | 60,728                 | 51,236                 | 78.029                         |
| 3220     | 37,941                 | 31,546                 | 72.264                         | 4820     | 61,322                 | 51,750                 | 78.153                         |
| 3260     | 38,513                 | 32,039                 | 72.441                         | 4860     | 61,916                 | 52,265                 | 78.276                         |
| 3300     | 39,087                 | 32,533                 | 72.616                         | 4900     | 62,511                 | 52,781                 | 78.398                         |
| 3340     | 39,661                 | 33,028                 | 72.788                         | 5000     | 64,000                 | 54,071                 | 78.698                         |
| 3380     | 40,236                 | 33,524                 | 72.960                         | 5100     | 65,491                 | 55,363                 | 78.994                         |
| 3420     | 40,812                 | 34,020                 | 73.129                         | 5200     | 66,984                 | 56,658                 | 79.284                         |
| 3460     | 41,388                 | 34,517                 | 73.297                         | 5300     | 68,471                 | 57,954                 | 79.569                         |

TABLE A-21E

Ideal-gas properties of carbon monoxide, CO

| $T$<br>R | $\bar{h}$<br>Btu/lbmol | $\bar{u}$<br>Btu/lbmol | $\bar{s}^\circ$<br>Btu/lbmol·R | $T$<br>R | $\bar{h}$<br>Btu/lbmol | $\bar{u}$<br>Btu/lbmol | $\bar{s}^\circ$<br>Btu/lbmol·R |
|----------|------------------------|------------------------|--------------------------------|----------|------------------------|------------------------|--------------------------------|
| 300      | 2,081.9                | 1,486.1                | 43.223                         | 1080     | 7,571.1                | 5,426.4                | 52.203                         |
| 320      | 2,220.9                | 1,585.4                | 43.672                         | 1100     | 7,716.8                | 5,532.3                | 52.337                         |
| 340      | 2,359.9                | 1,684.7                | 44.093                         | 1120     | 7,862.9                | 5,638.7                | 52.468                         |
| 360      | 2,498.8                | 1,783.9                | 44.490                         | 1140     | 8,009.2                | 5,745.4                | 52.598                         |
| 380      | 2,637.9                | 1,883.3                | 44.866                         | 1160     | 8,156.1                | 5,851.5                | 52.726                         |
| 400      | 2,776.9                | 1,982.6                | 45.223                         | 1180     | 8,303.3                | 5,960.0                | 52.852                         |
| 420      | 2,916.0                | 2,081.9                | 45.563                         | 1200     | 8,450.8                | 6,067.8                | 52.976                         |
| 440      | 3,055.0                | 2,181.2                | 45.886                         | 1220     | 8,598.8                | 6,176.0                | 53.098                         |
| 460      | 3,194.0                | 2,280.5                | 46.194                         | 1240     | 8,747.2                | 6,284.7                | 53.218                         |
| 480      | 3,333.0                | 2,379.8                | 46.491                         | 1260     | 8,896.0                | 6,393.8                | 53.337                         |
| 500      | 3,472.1                | 2,479.2                | 46.775                         | 1280     | 9,045.0                | 6,503.1                | 53.455                         |
| 520      | 3,611.2                | 2,578.6                | 47.048                         | 1300     | 9,194.6                | 6,613.0                | 53.571                         |
| 537      | 3,725.1                | 2,663.1                | 47.272                         | 1320     | 9,344.6                | 6,723.2                | 53.685                         |
| 540      | 3,750.3                | 2,677.9                | 47.310                         | 1340     | 9,494.8                | 6,833.7                | 53.799                         |
| 560      | 3,889.5                | 2,777.4                | 47.563                         | 1360     | 9,645.5                | 6,944.7                | 53.910                         |
| 580      | 4,028.7                | 2,876.9                | 47.807                         | 1380     | 9,796.6                | 7,056.1                | 54.021                         |
| 600      | 4,168.0                | 2,976.5                | 48.044                         | 1400     | 9,948.1                | 7,167.9                | 54.129                         |
| 620      | 4,307.4                | 3,076.2                | 48.272                         | 1420     | 10,100.0               | 7,280.1                | 54.237                         |
| 640      | 4,446.9                | 3,175.9                | 48.494                         | 1440     | 10,252.2               | 7,392.6                | 54.344                         |
| 660      | 4,586.6                | 3,275.8                | 48.709                         | 1460     | 10,404.8               | 7,505.4                | 54.448                         |
| 680      | 4,726.2                | 3,375.8                | 48.917                         | 1480     | 10,557.8               | 7,618.7                | 54.522                         |
| 700      | 4,886.0                | 3,475.9                | 49.120                         | 1500     | 10,711.1               | 7,732.3                | 54.665                         |
| 720      | 5,006.1                | 3,576.3                | 49.317                         | 1520     | 10,864.9               | 7,846.4                | 54.757                         |
| 740      | 5,146.4                | 3,676.9                | 49.509                         | 1540     | 11,019.0               | 7,960.8                | 54.858                         |
| 760      | 5,286.8                | 3,777.5                | 49.697                         | 1560     | 11,173.4               | 8,075.4                | 54.958                         |
| 780      | 5,427.4                | 3,878.4                | 49.880                         | 1580     | 11,328.2               | 8,190.5                | 55.056                         |
| 800      | 5,568.2                | 3,979.5                | 50.058                         | 1600     | 11,483.4               | 8,306.0                | 55.154                         |
| 820      | 5,709.4                | 4,081.0                | 50.232                         | 1620     | 11,638.9               | 8,421.8                | 55.251                         |
| 840      | 5,850.7                | 4,182.6                | 50.402                         | 1640     | 11,794.7               | 8,537.9                | 55.347                         |
| 860      | 5,992.3                | 4,284.5                | 50.569                         | 1660     | 11,950.9               | 8,654.4                | 55.411                         |
| 880      | 6,134.2                | 4,386.6                | 50.732                         | 1680     | 12,107.5               | 8,771.2                | 55.535                         |
| 900      | 6,276.4                | 4,489.1                | 50.892                         | 1700     | 12,264.3               | 8,888.3                | 55.628                         |
| 920      | 6,419.0                | 4,592.0                | 51.048                         | 1720     | 12,421.4               | 9,005.7                | 55.720                         |
| 940      | 6,561.7                | 4,695.0                | 51.202                         | 1740     | 12,579.0               | 9,123.6                | 55.811                         |
| 960      | 6,704.9                | 4,798.5                | 51.353                         | 1760     | 12,736.7               | 9,241.6                | 55.900                         |
| 980      | 6,848.4                | 4,902.3                | 51.501                         | 1780     | 12,894.9               | 9,360.0                | 55.990                         |
| 1000     | 6,992.2                | 5,006.3                | 51.646                         | 1800     | 13,053.2               | 9,478.6                | 56.078                         |
| 1020     | 7,136.4                | 5,110.8                | 51.788                         | 1820     | 13,212.0               | 9,597.7                | 56.166                         |
| 1040     | 7,281.0                | 5,215.7                | 51.929                         | 1840     | 13,371.0               | 9,717.0                | 56.253                         |
| 1060     | 7,425.9                | 5,320.9                | 52.067                         | 1860     | 13,530.2               | 9,836.5                | 56.339                         |

TABLE A-21E

Ideal-gas properties of carbon monoxide, CO (Concluded)

| $T$<br>R | $\bar{h}$<br>Btu/lbmol | $\bar{u}$<br>Btu/lbmol | $\bar{s}^\circ$<br>Btu/lbmol·R | $T$<br>R | $\bar{h}$<br>Btu/lbmol | $\bar{u}$<br>Btu/lbmol | $\bar{s}^\circ$<br>Btu/lbmol·R |
|----------|------------------------|------------------------|--------------------------------|----------|------------------------|------------------------|--------------------------------|
| 1900     | 13,850                 | 10,077                 | 56.509                         | 3500     | 27,262                 | 20,311                 | 61.612                         |
| 1940     | 14,170                 | 10,318                 | 56.677                         | 3540     | 27,608                 | 20,576                 | 61.710                         |
| 1980     | 14,492                 | 10,560                 | 56.841                         | 3580     | 27,954                 | 20,844                 | 61.807                         |
| 2020     | 14,815                 | 10,803                 | 57.007                         | 3620     | 28,300                 | 21,111                 | 61.903                         |
| 2060     | 15,139                 | 11,048                 | 57.161                         | 3660     | 28,647                 | 21,378                 | 61.998                         |
| 2100     | 15,463                 | 11,293                 | 57.317                         | 3700     | 28,994                 | 21,646                 | 62.093                         |
| 2140     | 15,789                 | 11,539                 | 57.470                         | 3740     | 29,341                 | 21,914                 | 62.186                         |
| 2180     | 16,116                 | 11,787                 | 57.621                         | 3780     | 29,688                 | 22,182                 | 62.279                         |
| 2220     | 16,443                 | 12,035                 | 57.770                         | 3820     | 30,036                 | 22,450                 | 62.370                         |
| 2260     | 16,722                 | 12,284                 | 57.917                         | 3860     | 30,384                 | 22,719                 | 62.461                         |
| 2300     | 17,101                 | 12,534                 | 58.062                         | 3900     | 30,733                 | 22,988                 | 62.511                         |
| 2340     | 17,431                 | 12,784                 | 58.204                         | 3940     | 31,082                 | 23,257                 | 62.640                         |
| 2380     | 17,762                 | 13,035                 | 58.344                         | 3980     | 31,431                 | 23,527                 | 62.728                         |
| 2420     | 18,093                 | 13,287                 | 58.482                         | 4020     | 31,780                 | 23,797                 | 62.816                         |
| 2460     | 18,426                 | 13,541                 | 58.619                         | 4060     | 32,129                 | 24,067                 | 62.902                         |
| 2500     | 18,759                 | 13,794                 | 58.754                         | 4100     | 32,479                 | 24,337                 | 62.988                         |
| 2540     | 19,093                 | 14,048                 | 58.885                         | 4140     | 32,829                 | 24,608                 | 63.072                         |
| 2580     | 19,427                 | 14,303                 | 59.016                         | 4180     | 33,179                 | 24,878                 | 63.156                         |
| 2620     | 19,762                 | 14,559                 | 59.145                         | 4220     | 33,530                 | 25,149                 | 63.240                         |
| 2660     | 20,098                 | 14,815                 | 59.272                         | 4260     | 33,880                 | 25,421                 | 63.323                         |
| 2700     | 20,434                 | 15,072                 | 59.398                         | 4300     | 34,231                 | 25,692                 | 63.405                         |
| 2740     | 20,771                 | 15,330                 | 59.521                         | 4340     | 34,582                 | 25,934                 | 63.486                         |
| 2780     | 21,108                 | 15,588                 | 59.644                         | 4380     | 34,934                 | 26,235                 | 63.567                         |
| 2820     | 21,446                 | 15,846                 | 59.765                         | 4420     | 35,285                 | 26,508                 | 63.647                         |
| 2860     | 21,785                 | 16,105                 | 59.884                         | 4460     | 35,637                 | 26,780                 | 63.726                         |
| 2900     | 22,124                 | 16,365                 | 60.002                         | 4500     | 35,989                 | 27,052                 | 63.805                         |
| 2940     | 22,463                 | 16,225                 | 60.118                         | 4540     | 36,341                 | 27,325                 | 63.883                         |
| 2980     | 22,803                 | 16,885                 | 60.232                         | 4580     | 36,693                 | 27,598                 | 63.960                         |
| 3020     | 23,144                 | 17,146                 | 60.346                         | 4620     | 37,046                 | 27,871                 | 64.036                         |
| 3060     | 23,485                 | 17,408                 | 60.458                         | 4660     | 37,398                 | 28,144                 | 64.113                         |
| 3100     | 23,826                 | 17,670                 | 60.569                         | 4700     | 37,751                 | 28,417                 | 64.188                         |
| 3140     | 24,168                 | 17,932                 | 60.679                         | 4740     | 38,104                 | 28,691                 | 64.263                         |
| 3180     | 24,510                 | 18,195                 | 60.787                         | 4780     | 38,457                 | 28,965                 | 64.337                         |
| 3220     | 24,853                 | 18,458                 | 60.894                         | 4820     | 38,811                 | 29,239                 | 64.411                         |
| 3260     | 25,196                 | 18,722                 | 61.000                         | 4860     | 39,164                 | 29,513                 | 64.484                         |
| 3300     | 25,539                 | 18,986                 | 61.105                         | 4900     | 39,518                 | 29,787                 | 64.556                         |
| 3340     | 25,883                 | 19,250                 | 61.209                         | 5000     | 40,403                 | 30,473                 | 64.735                         |
| 3380     | 26,227                 | 19,515                 | 61.311                         | 5100     | 41,289                 | 31,161                 | 64.910                         |
| 3420     | 26,572                 | 19,780                 | 61.412                         | 5200     | 42,176                 | 31,849                 | 65.082                         |
| 3460     | 26,917                 | 20,045                 | 61.513                         | 5300     | 43,063                 | 32,538                 | 65.252                         |

TABLE A-22E

Ideal-gas properties of hydrogen, H<sub>2</sub>

| $T$<br>R | $\bar{h}$<br>Btu/lbmol | $\bar{u}$<br>Btu/lbmol | $\bar{s}^\circ$<br>Btu/lbmol·R | $T$<br>R | $\bar{h}$<br>Btu/lbmol | $\bar{u}$<br>Btu/lbmol | $\bar{s}^\circ$<br>Btu/lbmol·R |
|----------|------------------------|------------------------|--------------------------------|----------|------------------------|------------------------|--------------------------------|
| 300      | 2,063.5                | 1,467.7                | 27.337                         | 1400     | 9,673.8                | 6,893.6                | 37.883                         |
| 320      | 2,189.4                | 1,553.9                | 27.742                         | 1500     | 10,381.5               | 7,402.7                | 38.372                         |
| 340      | 2,317.2                | 1,642.0                | 28.130                         | 1600     | 11,092.5               | 7,915.1                | 38.830                         |
| 360      | 2,446.8                | 1,731.9                | 28.501                         | 1700     | 11,807.4               | 8,431.4                | 39.264                         |
| 380      | 2,577.8                | 1,823.2                | 28.856                         | 1800     | 12,526.8               | 8,952.2                | 39.675                         |
| 400      | 2,710.2                | 1,915.8                | 29.195                         | 1900     | 13,250.9               | 9,477.8                | 40.067                         |
| 420      | 2,843.7                | 2,009.6                | 29.520                         | 2000     | 13,980.1               | 10,008.4               | 40.441                         |
| 440      | 2,978.1                | 2,104.3                | 29.833                         | 2100     | 14,714.5               | 10,544.2               | 40.799                         |
| 460      | 3,113.5                | 2,200.0                | 30.133                         | 2200     | 15,454.4               | 11,085.5               | 41.143                         |
| 480      | 3,249.4                | 2,296.2                | 30.424                         | 2300     | 16,199.8               | 11,632.3               | 41.475                         |
| 500      | 3,386.1                | 2,393.2                | 30.703                         | 2400     | 16,950.6               | 12,184.5               | 41.794                         |
| 520      | 3,523.2                | 2,490.6                | 30.972                         | 2500     | 17,707.3               | 12,742.6               | 42.104                         |
| 537      | 3,640.3                | 2,573.9                | 31.194                         | 2600     | 18,469.7               | 13,306.4               | 42.403                         |
| 540      | 3,660.9                | 2,588.5                | 31.232                         | 2700     | 19,237.8               | 13,876.0               | 42.692                         |
| 560      | 3,798.8                | 2,686.7                | 31.482                         | 2800     | 20,011.8               | 14,451.4               | 42.973                         |
| 580      | 3,937.1                | 2,785.3                | 31.724                         | 2900     | 20,791.5               | 15,032.5               | 43.247                         |
| 600      | 4,075.6                | 2,884.1                | 31.959                         | 3000     | 21,576.9               | 15,619.3               | 43.514                         |
| 620      | 4,214.3                | 2,983.1                | 32.187                         | 3100     | 22,367.7               | 16,211.5               | 43.773                         |
| 640      | 4,353.1                | 3,082.1                | 32.407                         | 3200     | 23,164.1               | 16,809.3               | 44.026                         |
| 660      | 4,492.1                | 3,181.4                | 32.621                         | 3300     | 23,965.5               | 17,412.1               | 44.273                         |
| 680      | 4,631.1                | 3,280.7                | 32.829                         | 3400     | 24,771.9               | 18,019.9               | 44.513                         |
| 700      | 4,770.2                | 3,380.1                | 33.031                         | 3500     | 25,582.9               | 18,632.4               | 44.748                         |
| 720      | 4,909.5                | 3,479.6                | 33.226                         | 3600     | 26,398.5               | 19,249.4               | 44.978                         |
| 740      | 5,048.8                | 3,579.2                | 33.417                         | 3700     | 27,218.5               | 19,870.8               | 45.203                         |
| 760      | 5,188.1                | 3,678.8                | 33.603                         | 3800     | 28,042.8               | 20,496.5               | 45.423                         |
| 780      | 5,327.6                | 3,778.6                | 33.784                         | 3900     | 28,871.1               | 21,126.2               | 45.638                         |
| 800      | 5,467.1                | 3,878.4                | 33.961                         | 4000     | 29,703.5               | 21,760.0               | 45.849                         |
| 820      | 5,606.7                | 3,978.3                | 34.134                         | 4100     | 30,539.8               | 22,397.7               | 46.056                         |
| 840      | 5,746.3                | 4,078.2                | 34.302                         | 4200     | 31,379.8               | 23,039.2               | 46.257                         |
| 860      | 5,885.9                | 4,178.0                | 34.466                         | 4300     | 32,223.5               | 23,684.3               | 46.456                         |
| 880      | 6,025.6                | 4,278.0                | 34.627                         | 4400     | 33,070.9               | 24,333.1               | 46.651                         |
| 900      | 6,165.3                | 4,378.0                | 34.784                         | 4500     | 33,921.6               | 24,985.2               | 46.842                         |
| 920      | 6,305.1                | 4,478.1                | 34.938                         | 4600     | 34,775.7               | 25,640.7               | 47.030                         |
| 940      | 6,444.9                | 4,578.1                | 35.087                         | 4700     | 35,633.0               | 26,299.4               | 47.215                         |
| 960      | 6,584.7                | 4,678.3                | 35.235                         | 4800     | 36,493.4               | 26,961.2               | 47.396                         |
| 980      | 6,724.6                | 4,778.4                | 35.379                         | 4900     | 35,356.9               | 27,626.1               | 47.574                         |
| 1000     | 6,864.5                | 4,878.6                | 35.520                         | 5000     | 38,223.3               | 28,294.0               | 47.749                         |
| 1100     | 7,564.6                | 5,380.1                | 36.188                         | 5100     | 39,092.8               | 28,964.9               | 47.921                         |
| 1200     | 8,265.8                | 5,882.8                | 36.798                         | 5200     | 39,965.1               | 29,638.6               | 48.090                         |
| 1300     | 8,968.7                | 6,387.1                | 37.360                         | 5300     | 40,840.2               | 30,315.1               | 48.257                         |

TABLE A-23E

Ideal-gas properties of water vapor, H<sub>2</sub>O

| $T$<br>R | $\bar{h}$<br>Btu/lbmol | $\bar{u}$<br>Btu/lbmol | $\bar{s}^\circ$<br>Btu/lbmol·R | $T$<br>R | $\bar{h}$<br>Btu/lbmol | $\bar{u}$<br>Btu/lbmol | $\bar{s}^\circ$<br>Btu/lbmol·R |
|----------|------------------------|------------------------|--------------------------------|----------|------------------------|------------------------|--------------------------------|
| 300      | 2,367.6                | 1,771.8                | 40.439                         | 1080     | 8,768.2                | 6,623.5                | 50.854                         |
| 320      | 2,526.8                | 1,891.3                | 40.952                         | 1100     | 8,942.0                | 6,757.5                | 51.013                         |
| 340      | 2,686.0                | 2,010.8                | 41.435                         | 1120     | 9,116.4                | 6,892.2                | 51.171                         |
| 360      | 2,845.1                | 2,130.2                | 41.889                         | 1140     | 9,291.4                | 7,027.5                | 51.325                         |
| 380      | 3,004.4                | 2,249.8                | 42.320                         | 1160     | 9,467.1                | 7,163.5                | 51.478                         |
| 400      | 3,163.8                | 2,369.4                | 42.728                         | 1180     | 9,643.4                | 7,300.1                | 51.360                         |
| 420      | 3,323.2                | 2,489.1                | 43.117                         | 1200     | 9,820.4                | 7,437.4                | 51.777                         |
| 440      | 3,482.7                | 2,608.9                | 43.487                         | 1220     | 9,998.0                | 7,575.2                | 51.925                         |
| 460      | 3,642.3                | 2,728.8                | 43.841                         | 1240     | 10,176.1               | 7,713.6                | 52.070                         |
| 480      | 3,802.0                | 2,848.8                | 44.182                         | 1260     | 10,354.9               | 7,852.7                | 52.212                         |
| 500      | 3,962.0                | 2,969.1                | 44.508                         | 1280     | 10,534.4               | 7,992.5                | 52.354                         |
| 520      | 4,122.0                | 3,089.4                | 44.821                         | 1300     | 10,714.5               | 8,132.9                | 52.494                         |
| 537      | 4,258.0                | 3,191.9                | 45.079                         | 1320     | 10,895.3               | 8,274.0                | 52.631                         |
| 540      | 4,282.4                | 3,210.0                | 45.124                         | 1340     | 11,076.6               | 8,415.5                | 52.768                         |
| 560      | 4,442.8                | 3,330.7                | 45.415                         | 1360     | 11,258.7               | 8,557.9                | 52.903                         |
| 580      | 4,603.7                | 3,451.9                | 45.696                         | 1380     | 11,441.4               | 8,700.9                | 53.037                         |
| 600      | 4,764.7                | 3,573.2                | 45.970                         | 1400     | 11,624.8               | 8,844.6                | 53.168                         |
| 620      | 4,926.1                | 3,694.9                | 46.235                         | 1420     | 11,808.8               | 8,988.9                | 53.299                         |
| 640      | 5,087.8                | 3,816.8                | 46.492                         | 1440     | 11,993.4               | 9,133.8                | 53.428                         |
| 660      | 5,250.0                | 3,939.3                | 46.741                         | 1460     | 12,178.8               | 9,279.4                | 53.556                         |
| 680      | 5,412.5                | 4,062.1                | 46.984                         | 1480     | 12,364.8               | 9,425.7                | 53.682                         |
| 700      | 5,575.4                | 4,185.3                | 47.219                         | 1500     | 12,551.4               | 9,572.7                | 53.808                         |
| 720      | 5,738.8                | 4,309.0                | 47.450                         | 1520     | 12,738.8               | 9,720.3                | 53.932                         |
| 740      | 5,902.6                | 4,433.1                | 47.673                         | 1540     | 12,926.8               | 9,868.6                | 54.055                         |
| 760      | 6,066.9                | 4,557.6                | 47.893                         | 1560     | 13,115.6               | 10,017.6               | 54.117                         |
| 780      | 6,231.7                | 4,682.7                | 48.106                         | 1580     | 13,305.0               | 10,167.3               | 54.298                         |
| 800      | 6,396.9                | 4,808.2                | 48.316                         | 1600     | 13,494.4               | 10,317.6               | 54.418                         |
| 820      | 6,562.6                | 4,934.2                | 48.520                         | 1620     | 13,685.7               | 10,468.6               | 54.535                         |
| 840      | 6,728.9                | 5,060.8                | 48.721                         | 1640     | 13,877.0               | 10,620.2               | 54.653                         |
| 860      | 6,895.6                | 5,187.8                | 48.916                         | 1660     | 14,069.2               | 10,772.7               | 54.770                         |
| 880      | 7,062.9                | 5,315.3                | 49.109                         | 1680     | 14,261.9               | 10,925.6               | 54.886                         |
| 900      | 7,230.9                | 5,443.6                | 49.298                         | 1700     | 14,455.4               | 11,079.4               | 54.999                         |
| 920      | 7,399.4                | 5,572.4                | 49.483                         | 1720     | 14,649.5               | 11,233.8               | 55.113                         |
| 940      | 7,568.4                | 5,701.7                | 49.665                         | 1740     | 14,844.3               | 11,388.9               | 55.226                         |
| 960      | 7,738.0                | 5,831.6                | 49.843                         | 1760     | 15,039.8               | 11,544.7               | 55.339                         |
| 980      | 7,908.2                | 5,962.0                | 50.019                         | 1780     | 15,236.1               | 11,701.2               | 55.449                         |
| 1000     | 8,078.2                | 6,093.0                | 50.191                         | 1800     | 15,433.0               | 11,858.4               | 55.559                         |
| 1020     | 8,250.4                | 6,224.8                | 50.360                         | 1820     | 15,630.6               | 12,016.3               | 55.668                         |
| 1040     | 8,422.4                | 6,357.1                | 50.528                         | 1840     | 15,828.7               | 12,174.7               | 55.777                         |
| 1060     | 8,595.0                | 6,490.0                | 50.693                         | 1860     | 16,027.6               | 12,333.9               | 55.884                         |

TABLE A-23E

Ideal-gas properties of water vapor, H<sub>2</sub>O (Continued)

| $T$<br>R | $\bar{h}$<br>Btu/lbmol | $\bar{u}$<br>Btu/lbmol | $\bar{s}^\circ$<br>Btu/lbmol·R | $T$<br>R | $\bar{h}$<br>Btu/lbmol | $\bar{u}$<br>Btu/lbmol | $\bar{s}^\circ$<br>Btu/lbmol·R |
|----------|------------------------|------------------------|--------------------------------|----------|------------------------|------------------------|--------------------------------|
| 1900     | 16,428                 | 12,654                 | 56.097                         | 3500     | 34,324                 | 27,373                 | 62.876                         |
| 1940     | 16,830                 | 12,977                 | 56.307                         | 3540     | 34,809                 | 27,779                 | 63.015                         |
| 1980     | 17,235                 | 13,303                 | 56.514                         | 3580     | 35,296                 | 28,187                 | 63.153                         |
| 2020     | 17,643                 | 13,632                 | 56.719                         | 3620     | 35,785                 | 28,596                 | 63.288                         |
| 2060     | 18,054                 | 13,963                 | 56.920                         | 3660     | 36,274                 | 29,006                 | 63.423                         |
| 2100     | 18,467                 | 14,297                 | 57.119                         | 3700     | 36,765                 | 29,418                 | 63.557                         |
| 2140     | 18,883                 | 14,633                 | 57.315                         | 3740     | 37,258                 | 29,831                 | 63.690                         |
| 2180     | 19,301                 | 14,972                 | 57.509                         | 3780     | 37,752                 | 30,245                 | 63.821                         |
| 2220     | 19,722                 | 15,313                 | 57.701                         | 3820     | 38,247                 | 30,661                 | 63.952                         |
| 2260     | 20,145                 | 15,657                 | 57.889                         | 3860     | 38,743                 | 31,077                 | 64.082                         |
| 2300     | 20,571                 | 16,003                 | 58.077                         | 3900     | 39,240                 | 31,495                 | 64.210                         |
| 2340     | 20,999                 | 16,352                 | 58.261                         | 3940     | 39,739                 | 31,915                 | 64.338                         |
| 2380     | 21,429                 | 16,703                 | 58.445                         | 3980     | 40,239                 | 32,335                 | 64.465                         |
| 2420     | 21,862                 | 17,057                 | 58.625                         | 4020     | 40,740                 | 32,757                 | 64.591                         |
| 2460     | 22,298                 | 17,413                 | 58.803                         | 4060     | 41,242                 | 33,179                 | 64.715                         |
| 2500     | 22,735                 | 17,771                 | 58.980                         | 4100     | 41,745                 | 33,603                 | 64.839                         |
| 2540     | 23,175                 | 18,131                 | 59.155                         | 4140     | 42,250                 | 34,028                 | 64.962                         |
| 2580     | 23,618                 | 18,494                 | 59.328                         | 4180     | 42,755                 | 34,454                 | 65.084                         |
| 2620     | 24,062                 | 18,859                 | 59.500                         | 4220     | 43,267                 | 34,881                 | 65.204                         |
| 2660     | 24,508                 | 19,226                 | 59.669                         | 4260     | 43,769                 | 35,310                 | 65.325                         |
| 2700     | 24,957                 | 19,595                 | 59.837                         | 4300     | 44,278                 | 35,739                 | 65.444                         |
| 2740     | 25,408                 | 19,967                 | 60.003                         | 4340     | 44,788                 | 36,169                 | 65.563                         |
| 2780     | 25,861                 | 20,340                 | 60.167                         | 4380     | 45,298                 | 36,600                 | 65.680                         |
| 2820     | 26,316                 | 20,715                 | 60.330                         | 4420     | 45,810                 | 37,032                 | 65.797                         |
| 2860     | 26,773                 | 21,093                 | 60.490                         | 4460     | 46,322                 | 37,465                 | 65.913                         |
| 2900     | 27,231                 | 21,472                 | 60.650                         | 4500     | 46,836                 | 37,900                 | 66.028                         |
| 2940     | 27,692                 | 21,853                 | 60.809                         | 4540     | 47,350                 | 38,334                 | 66.142                         |
| 2980     | 28,154                 | 22,237                 | 60.965                         | 4580     | 47,866                 | 38,770                 | 66.255                         |
| 3020     | 28,619                 | 22,621                 | 61.120                         | 4620     | 48,382                 | 39,207                 | 66.368                         |
| 3060     | 29,085                 | 23,085                 | 61.274                         | 4660     | 48,899                 | 39,645                 | 66.480                         |
| 3100     | 29,553                 | 23,397                 | 61.426                         | 4700     | 49,417                 | 40,083                 | 66.591                         |
| 3140     | 30,023                 | 23,787                 | 61.577                         | 4740     | 49,936                 | 40,523                 | 66.701                         |
| 3180     | 30,494                 | 24,179                 | 61.727                         | 4780     | 50,455                 | 40,963                 | 66.811                         |
| 3220     | 30,967                 | 24,572                 | 61.874                         | 4820     | 50,976                 | 41,404                 | 66.920                         |
| 3260     | 31,442                 | 24,968                 | 62.022                         | 4860     | 51,497                 | 41,856                 | 67.028                         |
| 3300     | 31,918                 | 25,365                 | 62.167                         | 4900     | 52,019                 | 42,288                 | 67.135                         |
| 3340     | 32,396                 | 25,763                 | 62.312                         | 5000     | 53,327                 | 43,398                 | 67.401                         |
| 3380     | 32,876                 | 26,164                 | 62.454                         | 5100     | 54,640                 | 44,512                 | 67.662                         |
| 3420     | 33,357                 | 26,565                 | 62.597                         | 5200     | 55,957                 | 45,631                 | 67.918                         |
| 3460     | 33,839                 | 26,968                 | 62.738                         | 5300     | 57,279                 | 46,754                 | 68.172                         |

TABLE A-26E

Enthalpy of formation, Gibbs function of formation, and absolute entropy at 77°F, 1 atm

| Substance          | Formula                             | $\bar{h}_f^\circ$<br>Btu/lbmol | $\bar{g}_f^\circ$<br>Btu/lbmol | $\bar{s}^\circ$<br>Btu/lbmol-R |
|--------------------|-------------------------------------|--------------------------------|--------------------------------|--------------------------------|
| Carbon             | C(s)                                | 0                              | 0                              | 1.36                           |
| Hydrogen           | H <sub>2</sub> (g)                  | 0                              | 0                              | 31.21                          |
| Nitrogen           | N <sub>2</sub> (g)                  | 0                              | 0                              | 45.77                          |
| Oxygen             | O <sub>2</sub> (g)                  | 0                              | 0                              | 49.00                          |
| Carbon monoxide    | CO(g)                               | -47,540                        | -59,010                        | 47.21                          |
| Carbon dioxide     | CO <sub>2</sub> (g)                 | -169,300                       | -169,680                       | 51.07                          |
| Water vapor        | H <sub>2</sub> O(g)                 | -104,040                       | -98,350                        | 45.11                          |
| Water              | H <sub>2</sub> O(l)                 | -122,970                       | -102,040                       | 16.71                          |
| Hydrogen peroxide  | H <sub>2</sub> O <sub>2</sub> (g)   | -58,640                        | -45,430                        | 55.60                          |
| Ammonia            | NH <sub>3</sub> (g)                 | -19,750                        | -7,140                         | 45.97                          |
| Methane            | CH <sub>4</sub> (g)                 | -32,210                        | -21,860                        | 44.49                          |
| Acetylene          | C <sub>2</sub> H <sub>2</sub> (g)   | +97,540                        | +87,990                        | 48.00                          |
| Ethylene           | C <sub>2</sub> H <sub>4</sub> (g)   | +22,490                        | +29,306                        | 52.54                          |
| Ethane             | C <sub>2</sub> H <sub>6</sub> (g)   | -36,420                        | -14,150                        | 54.85                          |
| Propylene          | C <sub>3</sub> H <sub>6</sub> (g)   | +8,790                         | +26,980                        | 63.80                          |
| Propane            | C <sub>3</sub> H <sub>8</sub> (g)   | -44,680                        | -10,105                        | 64.51                          |
| <i>n</i> -Butane   | C <sub>4</sub> H <sub>10</sub> (g)  | -54,270                        | -6,760                         | 74.11                          |
| <i>n</i> -Octane   | C <sub>8</sub> H <sub>18</sub> (g)  | -89,680                        | +7,110                         | 111.55                         |
| <i>n</i> -Octane   | C <sub>8</sub> H <sub>18</sub> (l)  | -107,530                       | +2,840                         | 86.23                          |
| <i>n</i> -Dodecane | C <sub>12</sub> H <sub>26</sub> (g) | -125,190                       | +21,570                        | 148.86                         |
| Benzene            | C <sub>6</sub> H <sub>6</sub> (g)   | +35,680                        | +55,780                        | 64.34                          |
| Methyl alcohol     | CH <sub>3</sub> OH(g)               | -86,540                        | -69,700                        | 57.29                          |
| Methyl alcohol     | CH <sub>3</sub> OH(l)               | -102,670                       | -71,570                        | 30.30                          |
| Ethyl alcohol      | C <sub>2</sub> H <sub>5</sub> OH(g) | -101,230                       | -72,520                        | 67.54                          |
| Ethyl alcohol      | C <sub>2</sub> H <sub>5</sub> OH(l) | -119,470                       | -75,240                        | 38.40                          |
| Oxygen             | O(g)                                | +107,210                       | +99,710                        | 38.47                          |
| Hydrogen           | H(g)                                | +93,780                        | +87,460                        | 27.39                          |
| Nitrogen           | N(g)                                | +203,340                       | +195,970                       | 36.61                          |
| Hydroxyl           | OH(g)                               | +16,790                        | +14,750                        | 43.92                          |

Source: From JANAF, *Thermochemical Tables* (Midland, MI: Dow Chemical Co., 1971), *Selected Values of Chemical Thermodynamic Properties*, NBS Technical Note 270-3, 1968; and *API Research Project 44* (Carnegie Press, 1953).

TABLE A-27E

Properties of some common fuels and hydrocarbons

| Fuel (phase)        | Formula  | Molar mass, lbm/lbmol | Density, <sup>1</sup> lbm/ft <sup>3</sup> | Enthalpy of vaporization, <sup>2</sup> Btu/lbm | Specific heat, <sup>1</sup> $c_p$ Btu/lbm·°F | Higher heating value, <sup>3</sup> Btu/lbm | Lower heating value, <sup>3</sup> Btu/lbm |
|---------------------|--|-----------------------|---|--|--|--|---|
| Carbon (s)          | C  | 12.011                | 125                                       | —  | 0.169  | 14,100                                     | 14,100                                    |
| Hydrogen (g)        | H <sub>2</sub>                                     | 2.016                 | —   | —  | 3.44   | 60,970                                     | 51,600                                    |
| Carbon monoxide (g) | CO   | 28.013                | —   | —  | 0.251  | 4,340                                      | 4,340                                     |
| Methane (g)         | CH <sub>4</sub>                                    | 16.043                | —   | 219  | 0.525  | 23,880                                     | 21,520                                    |
| Methanol (ℓ)        | CH <sub>4</sub> O                                  | 32.042                | 49.3                                      | 502  | 0.604  | 9,740                                      | 8,570                                     |
| Acetylene (g)       | C <sub>2</sub> H <sub>2</sub>                      | 26.038                | —   | —  | 0.404  | 21,490                                     | 20,760                                    |
| Ethane (g)          | C <sub>2</sub> H <sub>6</sub>                      | 30.070                | —   | 74   | 0.418  | 22,320                                     | 20,430                                    |
| Ethanol (ℓ)         | C <sub>2</sub> H <sub>6</sub> O                    | 46.069                | 49.3                                      | 395  | 0.583  | 12,760                                     | 11,530                                    |
| Propane (ℓ)         | C <sub>3</sub> H <sub>8</sub>                      | 44.097                | 31.2                                      | 144  | 0.662  | 21,640                                     | 19,930                                    |
| Butane (ℓ)          | C <sub>4</sub> H <sub>10</sub>                     | 58.123                | 36.1                                      | 156  | 0.578  | 21,130                                     | 19,510                                    |
| 1-Pentene (ℓ)       | C <sub>5</sub> H <sub>10</sub>                     | 70.134                | 40.0                                      | 156  | 0.525  | 20,540                                     | 19,190                                    |
| Isopentane (ℓ)      | C <sub>5</sub> H <sub>12</sub>                     | 72.150                | 39.1                                      | —  | 0.554  | 20,890                                     | 19,310                                    |
| Benzene (ℓ)         | C <sub>6</sub> H <sub>6</sub>                      | 78.114                | 54.7                                      | 186  | 0.411  | 17,970                                     | 17,240                                    |
| Hexene (ℓ)          | C <sub>6</sub> H <sub>12</sub>                     | 84.161                | 42.0                                      | 169  | 0.439  | 20,430                                     | 19,090                                    |
| Hexane (ℓ)          | C <sub>6</sub> H <sub>14</sub>                     | 86.177                | 41.2                                      | 157  | 0.542  | 20,770                                     | 19,240                                    |
| Toluene (ℓ)         | C <sub>7</sub> H <sub>8</sub>                      | 92.141                | 54.1                                      | 177  | 0.408  | 18,230                                     | 17,420                                    |
| Heptane (ℓ)         | C <sub>7</sub> H <sub>16</sub>                     | 100.204               | 42.7                                      | 157  | 0.535  | 20,680                                     | 19,180                                    |
| Octane (ℓ)          | C <sub>8</sub> H <sub>18</sub>                     | 114.231               | 43.9                                      | 156  | 0.533  | 20,590                                     | 19,100                                    |
| Decane (ℓ)          | C <sub>10</sub> H <sub>22</sub>                    | 142.285               | 45.6                                      | 155  | 0.528  | 20,490                                     | 19,020                                    |
| Gasoline (ℓ)        | C <sub>n</sub> H <sub>1.87n</sub>                  | 100–110               | 45–49                                     | 151  | 0.57   | 20,300                                     | 18,900                                    |
| Light diesel (ℓ)    | C <sub>n</sub> H <sub>1.8n</sub>                   | 170                   | 49–52                                     | 116  | 0.53   | 19,800                                     | 18,600                                    |
| Heavy diesel (ℓ)    | C <sub>n</sub> H <sub>1.7n</sub>                   | 200                   | 51–55                                     | 99   | 0.45   | 19,600                                     | 18,400                                    |
| Natural gas (g)     | C <sub>n</sub> H <sub>3.8n</sub> N <sub>0.1n</sub> | 18                    | —   | —  | 0.48   | 21,500                                     | 19,400                                    |

<sup>1</sup>At 1 atm and 68°F.<sup>2</sup>At 77°F for liquid fuels, and 1 atm and normal boiling temperature for gaseous fuels.<sup>3</sup>At 77°F. Multiply by molar mass to obtain heating values in Btu/lbmol.





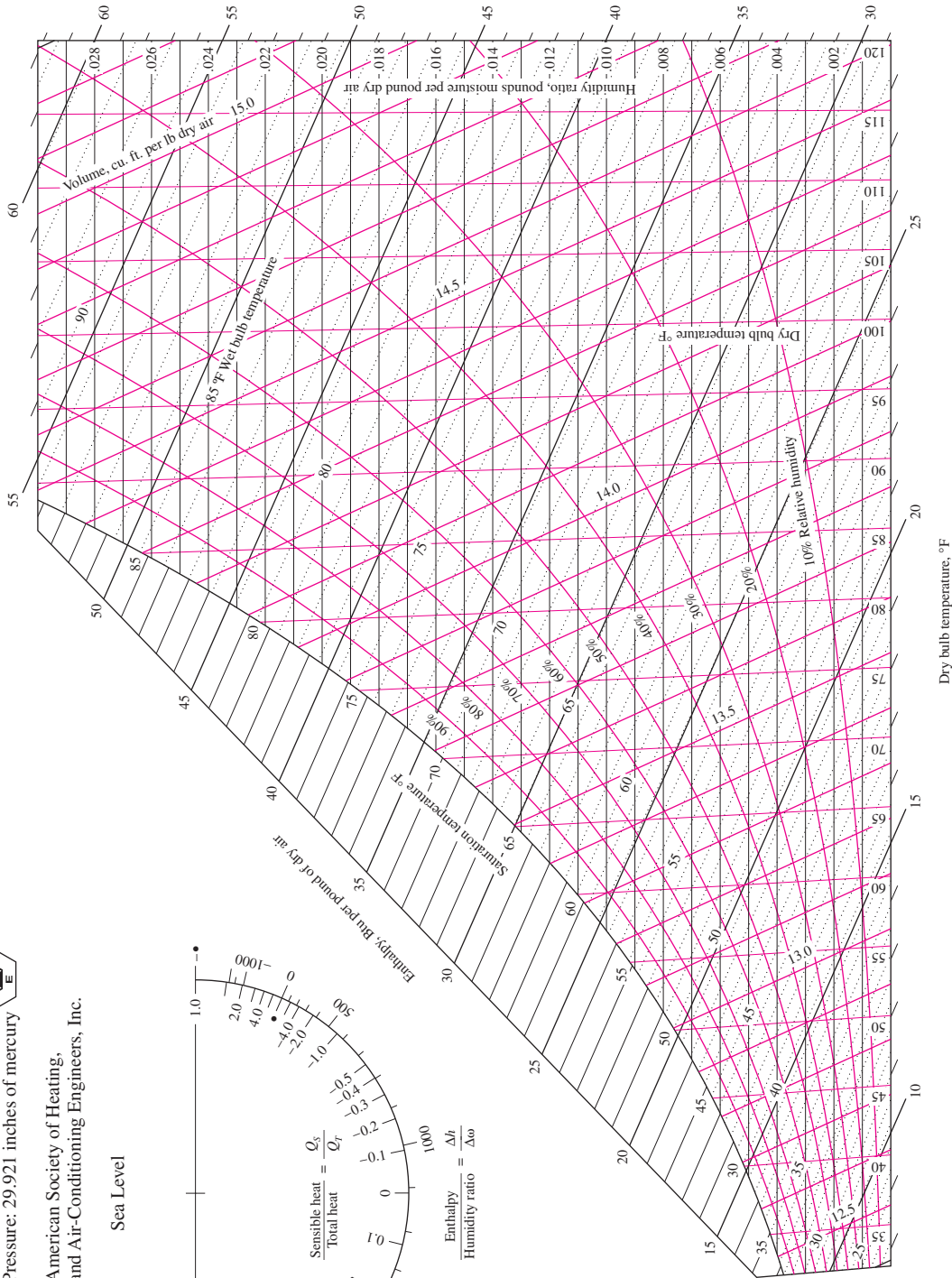
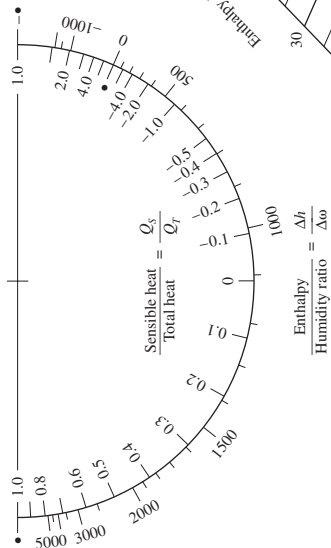
**ASHRAE Psychrometric Chart No. 1**

Normal Temperature

Barometric Pressure: 29.921 inches of mercury

© 1992 American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

Sea Level



Prepared by Center for Applied Thermodynamic Studies, University of Idaho.

**FIGURE A-31E**

Psychrometric chart at 1 atm total pressure.

From the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, GA: used with permission.

