

# APÊNDICE

## TABELAS, FIGURAS E DIAGRAMAS



**Tabela A.1 — Propriedades termodinâmicas da água**

**Tabela A.1.1 — Água saturada: tabela em função da temperatura**

| Temp.<br>°C<br><i>T</i> | Pressão<br>kPa<br><i>p</i> | Volume específico<br>m³/kg              |                                       | Energia interna<br>kJ/kg                |                               |                                       | Entalpia<br>kJ/kg                       |                               |                                       | Entropia<br>kJ/kg K                     |                               |                                       |
|-------------------------|----------------------------|-----------------------------------------|---------------------------------------|-----------------------------------------|-------------------------------|---------------------------------------|-----------------------------------------|-------------------------------|---------------------------------------|-----------------------------------------|-------------------------------|---------------------------------------|
|                         |                            | Líquido<br>sat.<br><i>v<sub>l</sub></i> | Vapor<br>sat.<br><i>v<sub>v</sub></i> | Líquido<br>sat.<br><i>u<sub>l</sub></i> | Evap.<br><i>u<sub>h</sub></i> | Vapor<br>sat.<br><i>u<sub>v</sub></i> | Líquido<br>sat.<br><i>h<sub>l</sub></i> | Evap.<br><i>h<sub>h</sub></i> | Vapor<br>sat.<br><i>h<sub>v</sub></i> | Líquido<br>sat.<br><i>s<sub>l</sub></i> | Evap.<br><i>s<sub>h</sub></i> | Vapor<br>sat.<br><i>s<sub>v</sub></i> |
| 0,01                    | 0,6113                     | 0,001000                                | 206,132                               | 0,00                                    | 2375,3                        | 2375,3                                | 0,00                                    | 2501,3                        | 2501,3                                | 0,0000                                  | 9,1562                        | 9,1562                                |
| 5                       | 0,8721                     | 0,001000                                | 147,118                               | 20,97                                   | 2361,3                        | 2382,2                                | 20,98                                   | 2489,6                        | 2510,5                                | 0,0761                                  | 8,9496                        | 9,0257                                |
| 10                      | 1,2276                     | 0,001000                                | 106,377                               | 41,99                                   | 2347,2                        | 2389,2                                | 41,99                                   | 2477,7                        | 2519,7                                | 0,1510                                  | 8,7498                        | 8,9007                                |
| 15                      | 1,7051                     | 0,001001                                | 77,925                                | 62,98                                   | 2333,1                        | 2396,0                                | 62,98                                   | 2465,9                        | 2528,9                                | 0,2245                                  | 9,5569                        | 8,7813                                |
| <b>20</b>               | <b>2,3385</b>              | <b>0,001002</b>                         | <b>57,790</b>                         | <b>83,94</b>                            | <b>2319,0</b>                 | <b>2402,9</b>                         | <b>83,94</b>                            | <b>2454,1</b>                 | <b>2538,1</b>                         | <b>0,2966</b>                           | <b>8,3706</b>                 | <b>8,6671</b>                         |
| 25                      | 3,1691                     | 0,001003                                | 43,359                                | 104,86                                  | 2304,9                        | 2409,8                                | 104,87                                  | 2442,3                        | 2547,2                                | 0,3673                                  | 8,1905                        | 8,5579                                |
| 30                      | 4,2461                     | 0,001004                                | 32,893                                | 125,77                                  | 2290,8                        | 2416,6                                | 125,77                                  | 2430,5                        | 2556,2                                | 0,4369                                  | 8,0164                        | 8,4533                                |
| 35                      | 5,6280                     | 0,001006                                | 25,216                                | 146,65                                  | 2276,7                        | 2423,4                                | 146,66                                  | 2418,6                        | 2565,3                                | 0,5052                                  | 7,8478                        | 8,3530                                |
| 40                      | 7,3837                     | 0,001008                                | 19,523                                | 167,53                                  | 2262,6                        | 2430,1                                | 167,54                                  | 2406,7                        | 2574,3                                | 0,5724                                  | 7,6845                        | 8,2569                                |
| <b>45</b>               | <b>9,5934</b>              | <b>0,001010</b>                         | <b>15,258</b>                         | <b>188,41</b>                           | <b>2248,4</b>                 | <b>2436,8</b>                         | <b>188,42</b>                           | <b>2394,8</b>                 | <b>2583,2</b>                         | <b>0,6386</b>                           | <b>7,5261</b>                 | <b>8,1647</b>                         |
| 50                      | 12,350                     | 0,001012                                | 12,032                                | 209,30                                  | 2234,2                        | 2443,5                                | 209,31                                  | 2382,7                        | 2592,1                                | 0,7037                                  | 7,3725                        | 8,0762                                |
| 55                      | 15,758                     | 0,001015                                | 9,568                                 | 230,19                                  | 2219,9                        | 2450,1                                | 230,20                                  | 2370,7                        | 2600,9                                | 0,7679                                  | 7,2234                        | 7,9912                                |
| 60                      | 19,941                     | 0,001017                                | 7,671                                 | 251,09                                  | 2205,5                        | 2456,6                                | 251,11                                  | 2358,5                        | 2609,6                                | 0,8311                                  | 7,0784                        | 7,9095                                |
| 65                      | 25,033                     | 0,001020                                | 6,197                                 | 272,00                                  | 2191,1                        | 2463,1                                | 272,03                                  | 2346,2                        | 2618,2                                | 0,8934                                  | 6,9375                        | 7,8309                                |
| <b>70</b>               | <b>31,188</b>              | <b>0,001023</b>                         | <b>5,042</b>                          | <b>292,93</b>                           | <b>2176,6</b>                 | <b>2469,5</b>                         | <b>292,96</b>                           | <b>2333,8</b>                 | <b>2626,8</b>                         | <b>0,9548</b>                           | <b>6,8004</b>                 | <b>7,7552</b>                         |
| 75                      | 38,578                     | 0,001026                                | 4,131                                 | 313,87                                  | 2162,0                        | 2475,9                                | 313,91                                  | 2321,4                        | 2635,3                                | 1,0154                                  | 6,6670                        | 7,6824                                |
| 80                      | 47,390                     | 0,001029                                | 3,407                                 | 334,84                                  | 2147,4                        | 2482,2                                | 334,88                                  | 2308,8                        | 2643,7                                | 1,0752                                  | 6,5369                        | 7,6121                                |
| 85                      | 57,834                     | 0,001032                                | 2,828                                 | 355,82                                  | 2132,6                        | 2488,4                                | 355,88                                  | 2296,0                        | 2651,9                                | 1,1342                                  | 6,4102                        | 7,5444                                |
| 90                      | 70,139                     | 0,001036                                | 2,361                                 | 376,82                                  | 2117,7                        | 2494,5                                | 376,90                                  | 2283,2                        | 2660,1                                | 1,1924                                  | 6,2866                        | 7,4790                                |
| <b>95</b>               | <b>84,554</b>              | <b>0,001040</b>                         | <b>1,982</b>                          | <b>397,86</b>                           | <b>2102,7</b>                 | <b>2500,6</b>                         | <b>397,94</b>                           | <b>2270,2</b>                 | <b>2668,1</b>                         | <b>1,2500</b>                           | <b>6,1659</b>                 | <b>7,4158</b>                         |
| <b>MPa</b>              |                            |                                         |                                       |                                         |                               |                                       |                                         |                               |                                       |                                         |                               |                                       |
| 100                     | 0,10135                    | 0,001044                                | 1,6729                                | 418,91                                  | 2087,6                        | 2506,5                                | 419,02                                  | 2257,0                        | 2676,0                                | 1,3068                                  | 6,0480                        | 7,3548                                |
| 105                     | 0,12082                    | 0,001047                                | 1,4194                                | 440,00                                  | 2072,3                        | 2512,3                                | 440,13                                  | 2243,7                        | 2683,8                                | 1,3629                                  | 5,9328                        | 7,2958                                |
| 110                     | 0,14328                    | 0,001052                                | 1,2102                                | 461,12                                  | 2057,0                        | 2518,1                                | 461,27                                  | 2230,2                        | 2691,5                                | 1,4184                                  | 5,8202                        | 7,2386                                |
| 115                     | 0,16906                    | 0,001056                                | 1,0366                                | 482,28                                  | 2041,4                        | 2523,7                                | 482,46                                  | 2216,5                        | 2699,0                                | 1,4733                                  | 5,7100                        | 7,1832                                |
| <b>120</b>              | <b>0,19853</b>             | <b>0,001060</b>                         | <b>0,8919</b>                         | <b>503,48</b>                           | <b>2025,8</b>                 | <b>2529,2</b>                         | <b>503,69</b>                           | <b>2202,6</b>                 | <b>2706,3</b>                         | <b>1,5275</b>                           | <b>5,6020</b>                 | <b>7,1295</b>                         |
| 125                     | 0,2321                     | 0,001065                                | 0,77059                               | 524,72                                  | 2009,9                        | 2534,6                                | 524,96                                  | 2188,5                        | 2713,5                                | 1,5812                                  | 5,4962                        | 7,0774                                |
| 130                     | 0,2701                     | 0,001070                                | 0,66850                               | 546,00                                  | 1993,9                        | 2539,9                                | 546,29                                  | 2174,2                        | 2720,5                                | 1,6343                                  | 5,3925                        | 7,0269                                |
| 135                     | 0,3130                     | 0,001075                                | 0,58217                               | 567,34                                  | 1977,7                        | 2545,0                                | 567,67                                  | 2159,6                        | 2727,3                                | 1,6869                                  | 5,2907                        | 6,9777                                |
| 140                     | 0,3613                     | 0,001080                                | 0,50885                               | 588,72                                  | 1961,3                        | 2550,0                                | 589,11                                  | 2144,8                        | 2733,9                                | 1,7390                                  | 5,1908                        | 6,9298                                |
| <b>145</b>              | <b>0,4154</b>              | <b>0,001085</b>                         | <b>0,44632</b>                        | <b>610,16</b>                           | <b>1944,7</b>                 | <b>2554,9</b>                         | <b>610,61</b>                           | <b>2129,6</b>                 | <b>2740,3</b>                         | <b>1,7906</b>                           | <b>5,0926</b>                 | <b>6,8832</b>                         |
| 150                     | 0,4759                     | 0,001090                                | 0,39278                               | 631,66                                  | 1927,9                        | 2559,5                                | 632,18                                  | 2114,3                        | 2746,4                                | 1,8417                                  | 4,9960                        | 6,8378                                |
| 155                     | 0,5431                     | 0,001096                                | 0,34676                               | 653,23                                  | 1910,8                        | 2564,0                                | 653,82                                  | 2098,6                        | 2752,4                                | 1,8924                                  | 4,9010                        | 6,7934                                |

Tabela A.1.1 (Continuação) — Água saturada: tabela em função da temperatura

| Temp.<br>°C<br>$T$ | Pressão<br>MPa<br>$p$ | Volume específico<br>m <sup>3</sup> /kg |                        | Energia interna<br>kJ/kg |                   |                        | Entalpia<br>kJ/kg        |                   |                        | Entropia<br>kJ/kg K      |                   |                        |
|--------------------|-----------------------|-----------------------------------------|------------------------|--------------------------|-------------------|------------------------|--------------------------|-------------------|------------------------|--------------------------|-------------------|------------------------|
|                    |                       | Líquido<br>sat.<br>$v_f$                | Vapor<br>sat.<br>$v_g$ | Líquido<br>sat.<br>$u_f$ | Evap.<br>$u_{fg}$ | Vapor<br>sat.<br>$u_g$ | Líquido<br>sat.<br>$h_f$ | Evap.<br>$h_{fg}$ | Vapor<br>sat.<br>$h_g$ | Líquido<br>sat.<br>$s_f$ | Evap.<br>$s_{fg}$ | Vapor<br>sat.<br>$s_g$ |
| 160                | 0,6178                | 0,001102                                | 0,30706                | 674,85                   | 1893,5            | 2568,4                 | 675,53                   | 2082,6            | 2758,1                 | 1,9426                   | 4,8075            | 6,7501                 |
| 165                | 0,7005                | 0,001108                                | 0,27269                | 696,55                   | 1876,0            | 2572,5                 | 697,32                   | 2066,2            | 2763,5                 | 1,9924                   | 4,7153            | 6,7078                 |
| 170                | 0,7917                | 0,001114                                | 0,24283                | 718,31                   | 1858,1            | 2576,5                 | 719,20                   | 2049,5            | 2768,7                 | 2,0418                   | 4,6244            | 6,6663                 |
| 175                | 0,8920                | 0,001121                                | 0,21680                | 740,16                   | 1840,0            | 2580,2                 | 741,16                   | 2032,4            | 2773,6                 | 2,0909                   | 4,5347            | 6,6256                 |
| <b>180</b>         | <b>1,0022</b>         | <b>0,001127</b>                         | <b>0,19405</b>         | <b>762,08</b>            | <b>1821,6</b>     | <b>2583,7</b>          | <b>763,21</b>            | <b>2015,0</b>     | <b>2778,2</b>          | <b>2,1395</b>            | <b>4,4461</b>     | <b>6,5857</b>          |
| 185                | 1,1227                | 0,001134                                | 0,17409                | 784,08                   | 1802,9            | 2587,0                 | 785,36                   | 1997,1            | 2782,4                 | 2,1878                   | 4,3586            | 6,5464                 |
| 190                | 1,2544                | 0,001141                                | 0,15654                | 806,17                   | 1783,8            | 2590,0                 | 807,61                   | 1978,8            | 2786,4                 | 2,2358                   | 4,2720            | 6,5078                 |
| 195                | 1,3978                | 0,001149                                | 0,14105                | 828,36                   | 1764,4            | 2592,8                 | 829,96                   | 1960,0            | 2790,0                 | 2,2835                   | 4,1863            | 6,4697                 |
| 200                | 1,5538                | 0,001156                                | 0,12736                | 850,64                   | 1744,7            | 2595,3                 | 852,43                   | 1940,7            | 2793,2                 | 2,3308                   | 4,1014            | 6,4322                 |
| <b>205</b>         | <b>1,7230</b>         | <b>0,001164</b>                         | <b>0,11521</b>         | <b>873,02</b>            | <b>1724,5</b>     | <b>2597,5</b>          | <b>875,03</b>            | <b>1921,0</b>     | <b>2796,0</b>          | <b>2,3779</b>            | <b>4,0172</b>     | <b>6,3951</b>          |
| 210                | 1,9063                | 0,001173                                | 0,10441                | 895,51                   | 1703,9            | 2599,4                 | 897,75                   | 1900,7            | 2798,5                 | 2,4247                   | 3,9337            | 6,3584                 |
| 215                | 2,1042                | 0,001181                                | 0,09479                | 918,12                   | 1682,9            | 2601,1                 | 920,61                   | 1879,9            | 2800,5                 | 2,4713                   | 3,8507            | 6,3221                 |
| 220                | 2,3178                | 0,001190                                | 0,08619                | 940,85                   | 1661,5            | 2602,3                 | 943,61                   | 1858,5            | 2802,1                 | 2,5177                   | 3,7683            | 6,2860                 |
| 225                | 2,5477                | 0,001199                                | 0,07849                | 963,72                   | 1639,6            | 2603,3                 | 966,77                   | 1836,5            | 2803,3                 | 2,5639                   | 3,6863            | 6,2502                 |
| <b>230</b>         | <b>2,7949</b>         | <b>0,001209</b>                         | <b>0,07158</b>         | <b>986,72</b>            | <b>1617,2</b>     | <b>2603,9</b>          | <b>990,10</b>            | <b>1813,8</b>     | <b>2803,9</b>          | <b>2,6099</b>            | <b>3,6047</b>     | <b>6,2146</b>          |
| 235                | 3,0601                | 0,001219                                | 0,06536                | 1009,88                  | 1594,2            | 2604,1                 | 1013,61                  | 1790,5            | 2804,1                 | 2,6557                   | 3,5233            | 6,1791                 |
| 240                | 3,3442                | 0,001229                                | 0,05976                | 1033,19                  | 1570,8            | 2603,9                 | 1037,31                  | 1766,5            | 2803,8                 | 2,7015                   | 3,4422            | 6,1436                 |
| 245                | 3,6482                | 0,001240                                | 0,05470                | 1056,69                  | 1546,7            | 2603,4                 | 1061,21                  | 1741,7            | 2802,9                 | 2,7471                   | 3,3612            | 6,1083                 |
| 250                | 3,9730                | 0,001251                                | 0,05013                | 1080,37                  | 1522,0            | 2602,4                 | 1085,34                  | 1716,2            | 2801,5                 | 2,7927                   | 3,2802            | 6,0729                 |
| <b>255</b>         | <b>4,3195</b>         | <b>0,001263</b>                         | <b>0,04598</b>         | <b>1104,26</b>           | <b>1496,7</b>     | <b>2600,9</b>          | <b>1109,72</b>           | <b>1689,8</b>     | <b>2799,5</b>          | <b>2,8382</b>            | <b>3,1992</b>     | <b>6,0374</b>          |
| 260                | 4,6886                | 0,001276                                | 0,04220                | 1128,37                  | 1470,6            | 2599,0                 | 1134,35                  | 1662,5            | 2796,9                 | 2,8837                   | 3,1181            | 6,0018                 |
| 265                | 5,0813                | 0,001289                                | 0,03877                | 1152,72                  | 1443,9            | 2596,6                 | 1159,27                  | 1634,3            | 2793,6                 | 2,9293                   | 3,0368            | 5,9661                 |
| 270                | 5,4987                | 0,001302                                | 0,03564                | 1177,33                  | 1416,3            | 2593,7                 | 1184,49                  | 1605,2            | 2789,7                 | 2,9750                   | 2,9551            | 5,9301                 |
| 275                | 5,9418                | 0,001317                                | 0,03279                | 1202,23                  | 1387,9            | 2590,2                 | 1210,05                  | 1574,9            | 2785,0                 | 3,0208                   | 2,8730            | 5,8937                 |
| <b>280</b>         | <b>6,4117</b>         | <b>0,001332</b>                         | <b>0,03017</b>         | <b>1227,43</b>           | <b>1358,7</b>     | <b>2586,1</b>          | <b>1235,97</b>           | <b>1543,6</b>     | <b>2779,5</b>          | <b>3,0667</b>            | <b>2,7903</b>     | <b>5,8570</b>          |
| 285                | 6,9094                | 0,001348                                | 0,02777                | 1252,98                  | 1328,4            | 2581,4                 | 1262,29                  | 1511,0            | 2773,3                 | 3,1129                   | 2,7069            | 5,8198                 |
| 290                | 7,4360                | 0,001366                                | 0,02557                | 1278,89                  | 1297,1            | 2576,0                 | 1289,04                  | 1477,1            | 2766,1                 | 3,1593                   | 2,6227            | 5,7821                 |
| 295                | 7,9928                | 0,001384                                | 0,02354                | 1305,21                  | 1264,7            | 2569,9                 | 1316,27                  | 1441,8            | 2758,0                 | 3,2061                   | 2,5375            | 5,7436                 |
| 300                | 8,5810                | 0,001404                                | 0,02167                | 1331,97                  | 1231,0            | 2563,0                 | 1344,01                  | 1404,9            | 2748,9                 | 3,2533                   | 2,4511            | 5,7044                 |
| <b>305</b>         | <b>9,2018</b>         | <b>0,001425</b>                         | <b>0,01995</b>         | <b>1359,22</b>           | <b>1195,9</b>     | <b>2555,2</b>          | <b>1372,33</b>           | <b>1366,4</b>     | <b>2738,7</b>          | <b>3,3009</b>            | <b>2,3633</b>     | <b>5,6642</b>          |
| 310                | 9,8566                | 0,001447                                | 0,01835                | 1387,03                  | 1159,4            | 2546,4                 | 1401,29                  | 1326,0            | 2727,3                 | 3,3492                   | 2,2737            | 5,6229                 |
| 315                | 10,547                | 0,001472                                | 0,01687                | 1415,44                  | 1121,1            | 2536,6                 | 1430,97                  | 1283,5            | 2714,4                 | 3,3981                   | 2,1821            | 5,5803                 |
| 320                | 11,274                | 0,001499                                | 0,01549                | 1444,55                  | 1080,9            | 2525,5                 | 1461,45                  | 1238,6            | 2700,1                 | 3,4479                   | 2,0882            | 5,5361                 |
| 330                | 12,845                | 0,001561                                | 0,012996               | 1505,24                  | 993,7             | 2498,9                 | 1525,29                  | 1140,6            | 2665,8                 | 3,5506                   | 1,8909            | 5,4416                 |
| <b>340</b>         | <b>14,586</b>         | <b>0,001638</b>                         | <b>0,010797</b>        | <b>1570,26</b>           | <b>894,3</b>      | <b>2464,5</b>          | <b>1594,15</b>           | <b>1027,9</b>     | <b>2622,0</b>          | <b>3,6593</b>            | <b>1,6763</b>     | <b>5,3356</b>          |
| 350                | 16,514                | 0,001740                                | 0,008813               | 1641,81                  | 776,6             | 2418,4                 | 1670,54                  | 893,4             | 2563,9                 | 3,7776                   | 1,4336            | 5,2111                 |
| 360                | 18,651                | 0,001892                                | 0,006945               | 1725,19                  | 626,3             | 2351,5                 | 1760,48                  | 720,5             | 2481,0                 | 3,9146                   | 1,1379            | 5,0525                 |
| 370                | 21,028                | 0,002213                                | 0,004926               | 1843,84                  | 384,7             | 2228,5                 | 1890,37                  | 441,8             | 2332,1                 | 4,1104                   | 0,6868            | 4,7972                 |
| 374,14             | 22,089                | 0,003155                                | 0,003155               | 2029,58                  | 0,0               | 2029,6                 | 2099,26                  | 0,0               | 2099,3                 | 4,4297                   | 0,0000            | 4,4297                 |

Tabela A.1.2 — Água saturada: tabela em função da pressão

| Pressão<br>kPa<br><i>p</i> | Temp.<br>°C<br><i>T</i> | Volume específico<br>m <sup>3</sup> /kg |                                       | Energia interna<br>kJ/kg                |                                |                                       | Entalpia<br>kJ/kg                       |                                |                                       | Entropia<br>kJ/kg K                     |                                |                                       |
|----------------------------|-------------------------|-----------------------------------------|---------------------------------------|-----------------------------------------|--------------------------------|---------------------------------------|-----------------------------------------|--------------------------------|---------------------------------------|-----------------------------------------|--------------------------------|---------------------------------------|
|                            |                         | Líquido<br>sat.<br><i>v<sub>f</sub></i> | Vapor<br>sat.<br><i>v<sub>g</sub></i> | Líquido<br>sat.<br><i>u<sub>f</sub></i> | Evap.<br><i>u<sub>fg</sub></i> | Vapor<br>sat.<br><i>u<sub>g</sub></i> | Líquido<br>sat.<br><i>h<sub>f</sub></i> | Evap.<br><i>h<sub>fg</sub></i> | Vapor<br>sat.<br><i>h<sub>g</sub></i> | Líquido<br>sat.<br><i>s<sub>f</sub></i> | Evap.<br><i>s<sub>fg</sub></i> | Vapor<br>sat.<br><i>s<sub>g</sub></i> |
| 0,6113                     | 0,01                    | 0,001000                                | 206,132                               | 0,00                                    | 2375,3                         | 2375,3                                | 0,00                                    | 2501,3                         | 2501,3                                | 0,0000                                  | 9,1562                         | 9,1562                                |
| 1,0                        | 6,98                    | 0,001000                                | 129,208                               | 29,29                                   | 2355,7                         | 2385,0                                | 29,29                                   | 2484,9                         | 2514,2                                | 0,1059                                  | 8,8697                         | 8,9756                                |
| 1,5                        | 13,03                   | 0,001001                                | 87,980                                | 54,70                                   | 2338,6                         | 2393,3                                | 54,70                                   | 2470,6                         | 2525,3                                | 0,1956                                  | 8,6322                         | 8,8278                                |
| 2,0                        | 17,50                   | 0,001001                                | 67,004                                | 73,41                                   | 2326,0                         | 2399,5                                | 73,47                                   | 2460,0                         | 2533,5                                | 0,2607                                  | 8,4629                         | 8,7236                                |
| <b>2,5</b>                 | <b>21,08</b>            | <b>0,001002</b>                         | <b>54,254</b>                         | <b>88,47</b>                            | <b>2315,9</b>                  | <b>2404,4</b>                         | <b>88,47</b>                            | <b>2451,6</b>                  | <b>2540,0</b>                         | <b>0,3120</b>                           | <b>8,3311</b>                  | <b>8,6431</b>                         |
| 3,0                        | 24,08                   | 0,001003                                | 45,665                                | 101,03                                  | 2307,5                         | 2408,5                                | 101,03                                  | 2444,5                         | 2545,5                                | 0,3545                                  | 8,2231                         | 8,5775                                |
| 4,0                        | 28,96                   | 0,001004                                | 34,800                                | 121,44                                  | 2293,7                         | 2415,2                                | 121,44                                  | 2432,9                         | 2554,4                                | 0,4226                                  | 8,0520                         | 8,4746                                |
| 5,0                        | 32,88                   | 0,001005                                | 28,193                                | 137,79                                  | 2282,7                         | 2420,5                                | 137,79                                  | 2423,7                         | 2561,4                                | 0,4763                                  | 7,9187                         | 8,3950                                |
| 7,5                        | 40,29                   | 0,001008                                | 19,238                                | 168,76                                  | 2261,7                         | 2430,5                                | 168,77                                  | 2406,0                         | 2574,8                                | 0,5763                                  | 7,6751                         | 8,2514                                |
| <b>10,0</b>                | <b>45,81</b>            | <b>0,001010</b>                         | <b>14,674</b>                         | <b>191,79</b>                           | <b>2246,1</b>                  | <b>2437,9</b>                         | <b>191,81</b>                           | <b>2392,8</b>                  | <b>2584,6</b>                         | <b>0,6492</b>                           | <b>7,5010</b>                  | <b>8,1501</b>                         |
| 15,0                       | 53,97                   | 0,001014                                | 10,022                                | 225,90                                  | 2222,8                         | 2448,7                                | 225,91                                  | 2373,1                         | 2599,1                                | 0,7548                                  | 7,2536                         | 8,0084                                |
| 20,0                       | 60,06                   | 0,001017                                | 7,649                                 | 251,35                                  | 2205,4                         | 2456,7                                | 251,38                                  | 2358,3                         | 2609,7                                | 0,8319                                  | 7,0766                         | 7,9085                                |
| 25,0                       | 64,97                   | 0,001020                                | 6,204                                 | 271,88                                  | 2191,2                         | 2463,1                                | 271,90                                  | 2346,3                         | 2618,2                                | 0,8930                                  | 6,9383                         | 7,8313                                |
| 30,0                       | 69,10                   | 0,001022                                | 5,229                                 | 289,18                                  | 2179,2                         | 2468,4                                | 289,21                                  | 2336,1                         | 2625,3                                | 0,9439                                  | 6,8247                         | 7,7686                                |
| <b>40,0</b>                | <b>75,87</b>            | <b>0,001026</b>                         | <b>3,993</b>                          | <b>317,51</b>                           | <b>2159,5</b>                  | <b>2477,0</b>                         | <b>317,55</b>                           | <b>2319,2</b>                  | <b>2636,7</b>                         | <b>1,0258</b>                           | <b>6,6441</b>                  | <b>7,6700</b>                         |
| 50,0                       | 81,33                   | 0,001030                                | 3,240                                 | 340,42                                  | 2143,4                         | 2483,8                                | 340,47                                  | 2305,4                         | 2645,9                                | 1,0910                                  | 6,5029                         | 7,5939                                |
| 75,0                       | 91,77                   | 0,001037                                | 2,217                                 | 384,29                                  | 2112,4                         | 2496,7                                | 384,36                                  | 2278,6                         | 2663,0                                | 1,2129                                  | 6,2434                         | 7,4563                                |
| MPa                        |                         |                                         |                                       |                                         |                                |                                       |                                         |                                |                                       |                                         |                                |                                       |
| 0,100                      | 99,62                   | 0,001043                                | 1,6940                                | 417,33                                  | 2088,7                         | 2506,1                                | 417,44                                  | 2258,0                         | 2675,5                                | 1,3025                                  | 6,0568                         | 7,3593                                |
| 0,125                      | 105,99                  | 0,001048                                | 1,3749                                | 444,16                                  | 2069,3                         | 2513,5                                | 444,30                                  | 2241,1                         | 2685,3                                | 1,3739                                  | 5,9104                         | 7,2843                                |
| 0,150                      | 111,37                  | 0,001053                                | 1,1593                                | 466,92                                  | 2052,7                         | 2519,6                                | 467,08                                  | 2226,5                         | 2693,5                                | 1,4335                                  | 5,7897                         | 7,2232                                |
| 0,175                      | 116,06                  | 0,001057                                | 1,0036                                | 486,78                                  | 2038,1                         | 2524,9                                | 486,97                                  | 2213,6                         | 2700,5                                | 1,4848                                  | 5,6868                         | 7,1717                                |
| <b>0,200</b>               | <b>120,23</b>           | <b>0,001061</b>                         | <b>0,8857</b>                         | <b>504,47</b>                           | <b>2025,0</b>                  | <b>2529,5</b>                         | <b>504,68</b>                           | <b>2202,0</b>                  | <b>2706,6</b>                         | <b>1,5300</b>                           | <b>5,5970</b>                  | <b>7,1271</b>                         |
| 0,225                      | 124,00                  | 0,001064                                | 0,7933                                | 520,45                                  | 2013,1                         | 2533,6                                | 520,69                                  | 2191,3                         | 2712,0                                | 1,5705                                  | 5,5173                         | 7,0878                                |
| 0,250                      | 127,43                  | 0,001067                                | 0,7187                                | 535,08                                  | 2002,1                         | 2537,2                                | 535,34                                  | 2181,5                         | 2716,9                                | 1,6072                                  | 5,4455                         | 7,0526                                |
| 0,275                      | 130,60                  | 0,001070                                | 0,6573                                | 548,57                                  | 1992,0                         | 2540,5                                | 548,87                                  | 2172,4                         | 2721,3                                | 1,6407                                  | 5,3801                         | 7,0208                                |
| 0,300                      | 133,55                  | 0,001073                                | 0,6058                                | 561,13                                  | 1982,4                         | 2543,6                                | 561,45                                  | 2163,9                         | 2725,3                                | 1,6717                                  | 5,3201                         | 6,9918                                |
| <b>0,325</b>               | <b>136,30</b>           | <b>0,001076</b>                         | <b>0,5620</b>                         | <b>572,88</b>                           | <b>1973,5</b>                  | <b>2546,3</b>                         | <b>573,23</b>                           | <b>2155,8</b>                  | <b>2729,0</b>                         | <b>1,7005</b>                           | <b>5,2646</b>                  | <b>6,9651</b>                         |
| 0,350                      | 138,88                  | 0,001079                                | 0,5243                                | 583,93                                  | 1965,0                         | 2548,9                                | 584,31                                  | 2148,1                         | 2732,4                                | 1,7274                                  | 5,2130                         | 6,9404                                |
| 0,375                      | 141,32                  | 0,001081                                | 0,4914                                | 594,38                                  | 1956,9                         | 2551,3                                | 594,79                                  | 2140,8                         | 2735,6                                | 1,7527                                  | 5,1647                         | 6,9174                                |
| 0,40                       | 143,63                  | 0,001084                                | 0,4625                                | 604,29                                  | 1949,3                         | 2553,6                                | 604,73                                  | 2133,8                         | 2738,5                                | 1,7766                                  | 5,1193                         | 6,8958                                |
| 0,45                       | 147,93                  | 0,001088                                | 0,4140                                | 622,75                                  | 1934,9                         | 2557,6                                | 623,24                                  | 2120,7                         | 2743,9                                | 1,8206                                  | 5,0359                         | 6,8565                                |
| <b>0,50</b>                | <b>151,86</b>           | <b>0,001093</b>                         | <b>0,3749</b>                         | <b>639,66</b>                           | <b>1921,6</b>                  | <b>2561,2</b>                         | <b>640,21</b>                           | <b>2108,5</b>                  | <b>2748,7</b>                         | <b>1,8606</b>                           | <b>4,9606</b>                  | <b>6,8212</b>                         |
| 0,55                       | 155,48                  | 0,001097                                | 0,3427                                | 655,30                                  | 1909,2                         | 2564,5                                | 655,91                                  | 2097,0                         | 2752,9                                | 1,8972                                  | 4,8920                         | 6,7892                                |
| 0,60                       | 158,85                  | 0,001101                                | 0,3157                                | 669,88                                  | 1897,5                         | 2567,4                                | 670,54                                  | 2086,3                         | 2756,8                                | 1,9311                                  | 4,8289                         | 6,7600                                |
| 0,65                       | 162,01                  | 0,001104                                | 0,2927                                | 683,55                                  | 1886,5                         | 2570,1                                | 684,26                                  | 2076,0                         | 2760,3                                | 1,9627                                  | 4,7704                         | 6,7330                                |
| 0,70                       | 164,97                  | 0,001108                                | 0,2729                                | 696,43                                  | 1876,1                         | 2572,5                                | 697,20                                  | 2066,3                         | 2763,5                                | 1,9922                                  | 4,7158                         | 6,7080                                |
| <b>0,75</b>                | <b>167,77</b>           | <b>0,001111</b>                         | <b>0,2556</b>                         | <b>708,62</b>                           | <b>1866,1</b>                  | <b>2574,7</b>                         | <b>709,45</b>                           | <b>2057,0</b>                  | <b>2766,4</b>                         | <b>2,0199</b>                           | <b>4,6647</b>                  | <b>6,6846</b>                         |
| 0,80                       | 170,43                  | 0,001115                                | 0,2404                                | 720,20                                  | 1856,6                         | 2576,8                                | 721,10                                  | 2048,0                         | 2769,1                                | 2,0461                                  | 4,6166                         | 6,6627                                |
| 0,85                       | 172,96                  | 0,001118                                | 0,2270                                | 731,25                                  | 1847,4                         | 2578,7                                | 732,20                                  | 2039,4                         | 2771,6                                | 2,0709                                  | 4,5711                         | 6,6421                                |
| 0,90                       | 175,38                  | 0,001121                                | 0,2150                                | 741,81                                  | 1838,7                         | 2580,5                                | 742,82                                  | 2031,1                         | 2773,9                                | 2,0946                                  | 4,5280                         | 6,6225                                |
| 0,95                       | 177,69                  | 0,001124                                | 0,2042                                | 751,94                                  | 1830,2                         | 2582,1                                | 753,00                                  | 2023,1                         | 2776,1                                | 2,1171                                  | 4,4869                         | 6,6040                                |
| <b>1,00</b>                | <b>179,91</b>           | <b>0,001127</b>                         | <b>0,19444</b>                        | <b>761,67</b>                           | <b>1822,0</b>                  | <b>2583,6</b>                         | <b>762,79</b>                           | <b>2015,3</b>                  | <b>2778,1</b>                         | <b>2,1386</b>                           | <b>4,4478</b>                  | <b>6,5864</b>                         |

Tabela A.1.2 (Continuação) — Água saturada: tabela em função da pressão

| Pressão<br>MPa<br>$p$ | Temp.<br>°C<br>$T$ | Volume específico<br>m³/kg |                        | Energia interna<br>kJ/kg |                   |                        | Entalpia<br>kJ/kg        |                   |                        | Entropia<br>kJ/kg K      |                   |                        |
|-----------------------|--------------------|----------------------------|------------------------|--------------------------|-------------------|------------------------|--------------------------|-------------------|------------------------|--------------------------|-------------------|------------------------|
|                       |                    | Líquido<br>sat.<br>$v_f$   | Vapor<br>sat.<br>$v_g$ | Líquido<br>sat.<br>$u_f$ | Evap.<br>$u_{fg}$ | Vapor<br>sat.<br>$u_g$ | Líquido<br>sat.<br>$h_f$ | Evap.<br>$h_{fg}$ | Vapor<br>sat.<br>$h_g$ | Líquido<br>sat.<br>$s_f$ | Evap.<br>$s_{fg}$ | Vapor<br>sat.<br>$s_g$ |
| 1.10                  | 184.09             | 0.001133                   | 0.17753                | 780.08                   | 1806.3            | 2586.4                 | 781.32                   | 2000.4            | 2781.7                 | 2.1791                   | 4.3744            | 6.5535                 |
| 1.20                  | 187.99             | 0.001139                   | 0.16333                | 797.27                   | 1791.6            | 2588.8                 | 798.64                   | 1986.2            | 2784.8                 | 2.2165                   | 4.3067            | 6.5233                 |
| 1.30                  | 191.64             | 0.001144                   | 0.15125                | 813.42                   | 1777.5            | 2590.9                 | 814.91                   | 1972.7            | 2787.6                 | 2.2514                   | 4.2438            | 6.4953                 |
| 1.40                  | 195.07             | 0.001149                   | 0.14084                | 828.68                   | 1764.1            | 2592.8                 | 830.29                   | 1959.7            | 2790.0                 | 2.2842                   | 4.1850            | 6.4692                 |
| <b>1.50</b>           | <b>198,32</b>      | <b>0,001154</b>            | <b>0,13177</b>         | <b>843,14</b>            | <b>1751,3</b>     | <b>2594,5</b>          | <b>844,87</b>            | <b>1947,3</b>     | <b>2792,1</b>          | <b>2,3150</b>            | <b>4,1298</b>     | <b>6,4448</b>          |
| 1.75                  | 205.76             | 0.001166                   | 0.11349                | 876.44                   | 1721.4            | 2597.8                 | 878.48                   | 1918.0            | 2796.4                 | 2.3851                   | 4.0044            | 6.3895                 |
| 2.00                  | 212.42             | 0.001177                   | 0.09963                | 906.42                   | 1693.8            | 2600.3                 | 908.77                   | 1890.7            | 2799.5                 | 2.4473                   | 3.8935            | 6.3408                 |
| 2.25                  | 218.45             | 0.001187                   | 0.08875                | 933.81                   | 1668.2            | 2602.0                 | 936.48                   | 1865.2            | 2801.7                 | 2.5034                   | 3.7938            | 6.2971                 |
| 2.50                  | 223.99             | 0.001197                   | 0.07998                | 959.09                   | 1644.0            | 2603.1                 | 962.09                   | 1841.0            | 2803.1                 | 2.5546                   | 3.7028            | 6.2574                 |
| <b>2.75</b>           | <b>229,12</b>      | <b>0,001207</b>            | <b>0,07275</b>         | <b>982,65</b>            | <b>1621,2</b>     | <b>2603,8</b>          | <b>985,97</b>            | <b>1817,9</b>     | <b>2803,9</b>          | <b>2,6018</b>            | <b>3,6190</b>     | <b>6,2208</b>          |
| 3.00                  | 233.90             | 0.001216                   | 0.06668                | 1004.76                  | 1599.3            | 2604.1                 | 1008.41                  | 1795.7            | 2804.1                 | 2.6456                   | 3.5412            | 6.1869                 |
| 3.25                  | 238.38             | 0.001226                   | 0.06152                | 1025.62                  | 1578.4            | 2604.0                 | 1029.60                  | 1774.4            | 2804.0                 | 2.6866                   | 3.4685            | 6.1551                 |
| 3.50                  | 242.60             | 0.001235                   | 0.05707                | 1045.41                  | 1558.3            | 2603.7                 | 1049.73                  | 1753.7            | 2803.4                 | 2.7252                   | 3.4000            | 6.1252                 |
| 4.0                   | 250.40             | 0.001252                   | 0.049778               | 1082.28                  | 1520.0            | 2602.3                 | 1087.29                  | 1714.1            | 2801.4                 | 2.7963                   | 3.2737            | 6.0700                 |
| <b>5,0</b>            | <b>263,99</b>      | <b>0,001286</b>            | <b>0,039441</b>        | <b>1147,78</b>           | <b>1449,3</b>     | <b>2597,1</b>          | <b>1154,21</b>           | <b>1640,1</b>     | <b>2794,3</b>          | <b>2,9201</b>            | <b>3,0532</b>     | <b>5,9733</b>          |
| 6.0                   | 275.64             | 0.001319                   | 0.032440               | 1205.41                  | 1384.3            | 2589.7                 | 1213.32                  | 1571.0            | 2784.3                 | 3.0266                   | 2.8625            | 5.8891                 |
| 7.0                   | 285.88             | 0.001351                   | 0.027370               | 1257.51                  | 1323.0            | 2580.5                 | 1266.97                  | 1505.1            | 2772.1                 | 3.1210                   | 2.6922            | 5.8132                 |
| 8.0                   | 295.06             | 0.001384                   | 0.023518               | 1305.54                  | 1264.3            | 2569.8                 | 1316.61                  | 1441.3            | 2757.9                 | 3.2067                   | 2.5365            | 5.7431                 |
| 9.0                   | 303.40             | 0.001418                   | 0.020484               | 1350.47                  | 1207.3            | 2557.8                 | 1363.23                  | 1378.9            | 2742.1                 | 3.2857                   | 2.3915            | 5.6771                 |
| <b>10,0</b>           | <b>311,06</b>      | <b>0,001452</b>            | <b>0,018026</b>        | <b>1393,00</b>           | <b>1151,4</b>     | <b>2544,4</b>          | <b>1407,53</b>           | <b>1317,1</b>     | <b>2724,7</b>          | <b>3,3595</b>            | <b>2,2545</b>     | <b>5,6140</b>          |
| 11.0                  | 318.15             | 0.001489                   | 0.015987               | 1433.68                  | 1056.1            | 2529.7                 | 1450.05                  | 1255.5            | 2705.6                 | 3.4294                   | 2.1233            | 5.5527                 |
| 12.0                  | 324.75             | 0.001527                   | 0.014263               | 1472.92                  | 1040.8            | 2513.7                 | 1491.24                  | 1193.6            | 2684.8                 | 3.4961                   | 1.9962            | 5.4923                 |
| 13.0                  | 330.93             | 0.001567                   | 0.012780               | 1511.09                  | 985.0             | 2496.1                 | 1531.46                  | 1130.8            | 2662.2                 | 3.5604                   | 1.8718            | 5.4323                 |
| 14.0                  | 336.75             | 0.001611                   | 0.011485               | 1548.53                  | 928.2             | 2476.8                 | 1571.08                  | 1066.5            | 2637.5                 | 3.6231                   | 1.7485            | 5.3716                 |
| <b>15,0</b>           | <b>342,24</b>      | <b>0,001658</b>            | <b>0,010338</b>        | <b>1585,58</b>           | <b>869,8</b>      | <b>2455,4</b>          | <b>1610,45</b>           | <b>1000,0</b>     | <b>2610,5</b>          | <b>3,6847</b>            | <b>1,6250</b>     | <b>5,3097</b>          |
| 16.0                  | 347.43             | 0.001711                   | 0.009306               | 1622.63                  | 809.1             | 2431.7                 | 1650.00                  | 930.6             | 2580.6                 | 3.7460                   | 1.4995            | 5.2454                 |
| 17.0                  | 352.37             | 0.001770                   | 0.008365               | 1660.16                  | 744.8             | 2405.0                 | 1690.25                  | 856.9             | 2547.2                 | 3.8078                   | 1.3698            | 5.1776                 |
| 18.0                  | 357.06             | 0.001840                   | 0.007490               | 1698.86                  | 675.4             | 2374.3                 | 1731.97                  | 777.1             | 2509.1                 | 3.8713                   | 1.2330            | 5.1044                 |
| 19.0                  | 361.54             | 0.001924                   | 0.006657               | 1739.87                  | 598.2             | 2338.1                 | 1776.43                  | 688.1             | 2464.5                 | 3.9387                   | 1.0841            | 5.0227                 |
| <b>20,0</b>           | <b>365,81</b>      | <b>0,002035</b>            | <b>0,005834</b>        | <b>1785,47</b>           | <b>507,6</b>      | <b>2293,1</b>          | <b>1826,18</b>           | <b>583,6</b>      | <b>2409,7</b>          | <b>4,0137</b>            | <b>0,9132</b>     | <b>4,9269</b>          |
| 21.0                  | 369.89             | 0.002206                   | 0.004953               | 1841.97                  | 388.7             | 2230.7                 | 1888.30                  | 446.4             | 2334.7                 | 4.1073                   | 0.6942            | 4.8015                 |
| 22.0                  | 373.80             | 0.002808                   | 0.003526               | 1973.16                  | 108.2             | 2081.4                 | 2034.92                  | 124.0             | 2159.0                 | 4.3307                   | 0.1917            | 4.5224                 |
| 22,09                 | 374.14             | 0.003155                   | 0.003155               | 2029.58                  | 0.0               | 2029.6                 | 2099.26                  | 0.0               | 2099.3                 | 4.4297                   | 0.0000            | 4.4297                 |

Tabela A.1.3 — Vapor d'água superaquecido (as unidades são as mesmas da Tabela anterior)

| <i>T</i>    | <i>p</i> = 10 kPa (45,81)   |               |               |                | <i>p</i> = 50 kPa (81,33)   |               |               |                | <i>p</i> = 100 kPa (99,62)  |               |               |                |
|-------------|-----------------------------|---------------|---------------|----------------|-----------------------------|---------------|---------------|----------------|-----------------------------|---------------|---------------|----------------|
|             | <i>v</i>                    | <i>u</i>      | <i>h</i>      | <i>s</i>       | <i>v</i>                    | <i>u</i>      | <i>h</i>      | <i>s</i>       | <i>v</i>                    | <i>u</i>      | <i>h</i>      | <i>s</i>       |
| Sat.        | 14,674                      | 2437,9        | 2584,6        | 8,1501         | 3,240                       | 2483,8        | 2645,9        | 7,5939         | 1,6940                      | 2506,1        | 2675,5        | 7,3593         |
| 50          | 14,869                      | 2443,9        | 2592,6        | 8,1749         | —                           | —             | —             | —              | —                           | —             | —             | —              |
| 100         | 17,196                      | 2515,5        | 2687,5        | 8,4479         | 3,418                       | 2511,6        | 2682,5        | 7,6947         | 1,6958                      | 2506,6        | 2676,2        | 7,3614         |
| 150         | 19,513                      | 2587,9        | 2783,0        | 8,6881         | 3,889                       | 2585,6        | 2780,1        | 7,9400         | 1,9364                      | 2582,7        | 2776,4        | 7,6133         |
| <b>200</b>  | <b>21,825</b>               | <b>2661,3</b> | <b>2879,5</b> | <b>8,9037</b>  | <b>4,356</b>                | <b>2659,8</b> | <b>2877,6</b> | <b>8,1579</b>  | <b>2,1723</b>               | <b>2658,0</b> | <b>2875,3</b> | <b>7,8342</b>  |
| 250         | 24,136                      | 2736,0        | 2977,3        | 9,1002         | 4,821                       | 2735,0        | 2976,0        | 8,3555         | 2,4060                      | 2733,7        | 2974,3        | 8,0332         |
| 300         | 26,445                      | 2812,1        | 3076,5        | 9,2812         | 5,284                       | 2811,3        | 3075,5        | 8,5372         | 2,6388                      | 2810,4        | 3074,3        | 8,2157         |
| 400         | 31,063                      | 2968,9        | 3279,5        | 9,6076         | 6,209                       | 2968,4        | 3278,9        | 8,8641         | 3,1026                      | 2967,8        | 3278,1        | 8,5434         |
| 500         | 35,679                      | 3132,3        | 3489,0        | 9,8977         | 7,134                       | 3131,9        | 3488,6        | 9,1545         | 3,5655                      | 3131,5        | 3488,1        | 8,8341         |
| <b>600</b>  | <b>40,295</b>               | <b>3302,5</b> | <b>3705,4</b> | <b>10,1608</b> | <b>8,058</b>                | <b>3302,2</b> | <b>3705,1</b> | <b>9,4177</b>  | <b>4,0278</b>               | <b>3301,9</b> | <b>3704,7</b> | <b>9,0975</b>  |
| 700         | 44,911                      | 3479,6        | 3928,7        | 10,4028        | 8,981                       | 3479,5        | 3928,5        | 9,6599         | 4,4899                      | 3479,2        | 3928,2        | 9,3398         |
| 800         | 49,526                      | 3663,8        | 4159,1        | 10,6281        | 9,904                       | 3663,7        | 4158,9        | 9,8852         | 4,9517                      | 3663,5        | 4158,7        | 9,5652         |
| 900         | 54,141                      | 3855,0        | 4396,4        | 10,8395        | 10,828                      | 3854,9        | 4396,3        | 10,0967        | 5,4135                      | 3854,8        | 4396,1        | 9,7767         |
| 1000        | 58,757                      | 4053,0        | 4640,6        | 11,0392        | 11,751                      | 4052,9        | 4640,5        | 10,2964        | 5,8753                      | 4052,8        | 4640,3        | 9,9764         |
| <b>1100</b> | <b>63,372</b>               | <b>4257,5</b> | <b>4891,2</b> | <b>11,2287</b> | <b>12,674</b>               | <b>4257,4</b> | <b>4891,1</b> | <b>10,4858</b> | <b>6,3370</b>               | <b>4257,3</b> | <b>4890,9</b> | <b>10,1658</b> |
| 1200        | 67,987                      | 4467,9        | 5147,8        | 11,4090        | 13,597                      | 4467,8        | 5147,7        | 10,6662        | 6,7986                      | 4467,7        | 5147,6        | 10,3462        |
| 1300        | 72,603                      | 4683,7        | 5409,7        | 11,5810        | 14,521                      | 4683,6        | 5409,6        | 10,8382        | 7,2603                      | 4683,5        | 5409,5        | 10,5182        |
| <i>T</i>    | <i>p</i> = 200 kPa (120,23) |               |               |                | <i>p</i> = 300 kPa (133,55) |               |               |                | <i>p</i> = 400 kPa (143,63) |               |               |                |
|             | <i>v</i>                    | <i>u</i>      | <i>h</i>      | <i>s</i>       | <i>v</i>                    | <i>u</i>      | <i>h</i>      | <i>s</i>       | <i>v</i>                    | <i>u</i>      | <i>h</i>      | <i>s</i>       |
| Sat.        | 0,88573                     | 2529,5        | 2706,6        | 7,1271         | 0,60582                     | 2543,6        | 2725,3        | 6,9918         | 0,46246                     | 2553,6        | 2738,5        | 6,8958         |
| 150         | 0,95964                     | 2576,9        | 2768,8        | 7,2795         | 0,63388                     | 2570,8        | 2761,0        | 7,0778         | 0,47084                     | 2564,5        | 2752,8        | 6,9299         |
| 200         | 1,08034                     | 2654,4        | 2870,5        | 7,5066         | 0,71629                     | 2650,7        | 2865,5        | 7,3115         | 0,53422                     | 2646,8        | 2860,5        | 7,1706         |
| 250         | 1,19880                     | 2731,2        | 2971,0        | 7,7085         | 0,79636                     | 2728,7        | 2967,6        | 7,5165         | 0,59512                     | 2726,1        | 2964,2        | 7,3788         |
| <b>300</b>  | <b>1,31616</b>              | <b>2808,6</b> | <b>3071,8</b> | <b>7,8926</b>  | <b>0,87529</b>              | <b>2806,7</b> | <b>3069,3</b> | <b>7,7022</b>  | <b>0,65484</b>              | <b>2804,8</b> | <b>3066,7</b> | <b>7,5661</b>  |
| 400         | 1,54930                     | 2966,7        | 3276,5        | 8,2217         | 1,03151                     | 2965,5        | 3275,0        | 8,0329         | 0,77262                     | 2964,4        | 3273,4        | 7,8984         |
| 500         | 1,78139                     | 3130,7        | 3487,0        | 8,5132         | 1,18669                     | 3130,0        | 3486,0        | 8,3250         | 0,88934                     | 3129,2        | 3484,9        | 8,1912         |
| 600         | 2,01297                     | 3301,4        | 3704,0        | 8,7769         | 1,34136                     | 3300,8        | 3703,2        | 8,5892         | 1,00555                     | 3300,2        | 3702,4        | 8,4557         |
| 700         | 2,24426                     | 3478,8        | 3927,7        | 9,0194         | 1,49573                     | 3478,4        | 3927,1        | 8,8319         | 1,12147                     | 3477,9        | 3926,5        | 8,6987         |
| <b>800</b>  | <b>2,47539</b>              | <b>3663,2</b> | <b>4158,3</b> | <b>9,2450</b>  | <b>1,64994</b>              | <b>3662,9</b> | <b>4157,8</b> | <b>9,0575</b>  | <b>1,23722</b>              | <b>3662,5</b> | <b>4157,4</b> | <b>8,9244</b>  |
| 900         | 2,70643                     | 3854,5        | 4395,8        | 9,4565         | 1,80406                     | 3854,2        | 4395,4        | 9,2691         | 1,35288                     | 3853,9        | 4395,1        | 9,1361         |
| 1000        | 2,93740                     | 4052,5        | 4640,0        | 9,6563         | 1,95812                     | 4052,3        | 4639,7        | 9,4689         | 1,46847                     | 4052,0        | 4639,4        | 9,3360         |
| 1100        | 3,16834                     | 4257,0        | 4890,7        | 9,8458         | 2,11214                     | 4256,8        | 4890,4        | 9,6585         | 1,58404                     | 4256,5        | 4890,1        | 9,5255         |
| 1200        | 3,39927                     | 4467,5        | 5147,3        | 10,0262        | 2,26614                     | 4467,2        | 5147,1        | 9,8389         | 1,69958                     | 4467,0        | 5146,8        | 9,7059         |
| <b>1300</b> | <b>3,63018</b>              | <b>4683,2</b> | <b>5409,3</b> | <b>10,1982</b> | <b>2,42013</b>              | <b>4683,0</b> | <b>5409,0</b> | <b>10,0109</b> | <b>1,81511</b>              | <b>4682,8</b> | <b>5408,8</b> | <b>9,8780</b>  |
| <i>T</i>    | <i>p</i> = 500 kPa (151,86) |               |               |                | <i>p</i> = 600 kPa (158,85) |               |               |                | <i>p</i> = 800 kPa (170,43) |               |               |                |
|             | <i>v</i>                    | <i>u</i>      | <i>h</i>      | <i>s</i>       | <i>v</i>                    | <i>u</i>      | <i>h</i>      | <i>s</i>       | <i>v</i>                    | <i>u</i>      | <i>h</i>      | <i>s</i>       |
| Sat.        | 0,37489                     | 2561,2        | 2748,7        | 6,8212         | 0,31567                     | 2567,4        | 2756,8        | 6,7600         | 0,24043                     | 2576,8        | 2769,1        | 6,6627         |
| 200         | 0,42492                     | 2642,9        | 2855,4        | 7,0592         | 0,35202                     | 2638,9        | 2850,1        | 6,9665         | 0,26080                     | 2630,6        | 2839,2        | 6,8158         |
| 250         | 0,47436                     | 2723,5        | 2960,7        | 7,2708         | 0,39383                     | 2720,9        | 2957,2        | 7,1816         | 0,29314                     | 2715,5        | 2950,0        | 7,0384         |
| 300         | 0,52256                     | 2802,9        | 3064,2        | 7,4598         | 0,43437                     | 2801,0        | 3061,6        | 7,3723         | 0,32411                     | 2797,1        | 3056,4        | 7,2327         |
| <b>350</b>  | <b>0,57012</b>              | <b>2882,6</b> | <b>3167,6</b> | <b>7,6328</b>  | <b>0,47424</b>              | <b>2881,1</b> | <b>3165,7</b> | <b>7,5463</b>  | <b>0,35439</b>              | <b>2878,2</b> | <b>3161,7</b> | <b>7,4088</b>  |
| 400         | 0,61728                     | 2963,2        | 3271,8        | 7,7937         | 0,51372                     | 2962,0        | 3270,2        | 7,7078         | 0,38426                     | 2959,7        | 3267,1        | 7,5715         |
| 500         | 0,71093                     | 3128,4        | 3483,8        | 8,0872         | 0,59199                     | 3127,6        | 3482,7        | 8,0020         | 0,44331                     | 3125,9        | 3480,6        | 7,8672         |
| 600         | 0,80406                     | 3299,6        | 3701,7        | 8,3521         | 0,66974                     | 3299,1        | 3700,9        | 8,2673         | 0,50184                     | 3297,9        | 3699,4        | 8,1332         |
| 700         | 0,89691                     | 3477,5        | 3926,0        | 8,5952         | 0,74720                     | 3477,1        | 3925,4        | 8,5107         | 0,56007                     | 3476,2        | 3924,3        | 8,3770         |
| <b>800</b>  | <b>0,98959</b>              | <b>3662,2</b> | <b>4157,0</b> | <b>8,8211</b>  | <b>0,82450</b>              | <b>3661,8</b> | <b>4156,5</b> | <b>8,7367</b>  | <b>0,61813</b>              | <b>3661,1</b> | <b>4155,7</b> | <b>8,6033</b>  |
| 900         | 1,08217                     | 3853,6        | 4394,7        | 9,0329         | 0,90169                     | 3853,3        | 4394,4        | 8,9485         | 0,67610                     | 3852,8        | 4393,6        | 8,8153         |
| 1000        | 1,17469                     | 4051,8        | 4639,1        | 9,2328         | 0,97883                     | 4051,5        | 4638,8        | 9,1484         | 0,73401                     | 4051,0        | 4638,2        | 9,0153         |

Tabela A.1.3 (Continuação) — Vapor d'água superaquecido

| <i>T</i>                     | <i>p</i> = 500 kPa (151,86) |          |          |          | <i>p</i> = 600 kPa (158,85)  |          |          |          | <i>p</i> = 800 kPa (170,43)  |          |          |          |
|------------------------------|-----------------------------|----------|----------|----------|------------------------------|----------|----------|----------|------------------------------|----------|----------|----------|
|                              | <i>v</i>                    | <i>u</i> | <i>h</i> | <i>s</i> | <i>v</i>                     | <i>u</i> | <i>h</i> | <i>s</i> | <i>v</i>                     | <i>u</i> | <i>h</i> | <i>s</i> |
| 1100                         | 1,26718                     | 4256,3   | 4889,9   | 9,4224   | 1,05594                      | 4256,1   | 4889,6   | 9,3381   | 0,79188                      | 4255,6   | 4889,1   | 9,2049   |
| 1200                         | 1,35964                     | 4466,8   | 5146,6   | 9,6028   | 1,13302                      | 4466,5   | 5146,3   | 9,5185   | 0,84974                      | 4466,1   | 5145,8   | 9,3854   |
| 1300                         | 1,45210                     | 4682,5   | 5408,6   | 9,7749   | 1,21009                      | 4682,3   | 5408,3   | 9,6906   | 0,90758                      | 4681,8   | 5407,9   | 9,5575   |
| <i>p</i> = 1,00 MPa (179,91) |                             |          |          |          | <i>p</i> = 1,20 MPa (187,99) |          |          |          | <i>p</i> = 1,40 MPa (195,07) |          |          |          |
| Sat.                         | 0,19444                     | 2583,6   | 2778,1   | 6,5864   | 0,16333                      | 2588,8   | 2784,8   | 6,5233   | 0,14084                      | 2592,8   | 2790,0   | 6,4692   |
| 200                          | 0,20596                     | 2621,9   | 2827,9   | 6,6939   | 0,16930                      | 2612,7   | 2815,9   | 6,5898   | 0,14302                      | 2603,1   | 2803,3   | 6,4975   |
| 250                          | 0,23268                     | 2709,9   | 2942,6   | 6,9246   | 0,19235                      | 2704,2   | 2935,0   | 6,8293   | 0,16350                      | 2698,3   | 2927,2   | 6,7467   |
| 300                          | 0,25794                     | 2793,2   | 3051,2   | 7,1228   | 0,21382                      | 2789,2   | 3045,8   | 7,0316   | 0,18228                      | 2785,2   | 3040,4   | 6,9533   |
| 350                          | 0,28247                     | 2875,2   | 3157,7   | 7,3010   | 0,23452                      | 2872,2   | 3153,6   | 7,2120   | 0,20026                      | 2869,1   | 3149,5   | 7,1359   |
| 400                          | 0,30659                     | 2957,3   | 3263,9   | 7,4650   | 0,25480                      | 2954,9   | 3260,7   | 7,3773   | 0,21780                      | 2952,5   | 3257,4   | 7,3025   |
| 500                          | 0,35411                     | 3124,3   | 3478,4   | 7,7621   | 0,29463                      | 3122,7   | 3476,3   | 7,6758   | 0,25215                      | 3121,1   | 3474,1   | 7,6026   |
| 600                          | 0,40109                     | 3296,8   | 3697,9   | 8,0289   | 0,33393                      | 3295,6   | 3696,3   | 7,9434   | 0,28596                      | 3294,4   | 3694,8   | 7,8710   |
| 700                          | 0,44779                     | 3475,4   | 3923,1   | 8,2731   | 0,37294                      | 3474,5   | 3922,0   | 8,1881   | 0,31947                      | 3473,6   | 3920,9   | 8,1160   |
| 800                          | 0,49432                     | 3660,5   | 4154,8   | 8,4996   | 0,41177                      | 3659,8   | 4153,9   | 8,4149   | 0,35281                      | 3659,1   | 4153,0   | 8,3431   |
| 900                          | 0,54075                     | 3852,2   | 4392,9   | 8,7118   | 0,45051                      | 3851,6   | 4392,2   | 8,6272   | 0,38606                      | 3851,0   | 4391,5   | 8,5555   |
| 1000                         | 0,58712                     | 4050,5   | 4637,6   | 8,9119   | 0,48919                      | 4050,0   | 4637,0   | 8,8274   | 0,41924                      | 4049,5   | 4636,4   | 8,7558   |
| 1100                         | 0,63345                     | 4255,1   | 4888,5   | 9,1016   | 0,52783                      | 4254,6   | 4888,0   | 9,0171   | 0,45239                      | 4254,1   | 4887,5   | 8,9456   |
| 1200                         | 0,67977                     | 4465,6   | 5145,4   | 9,2821   | 0,56646                      | 4465,1   | 5144,9   | 9,1977   | 0,48552                      | 4464,6   | 5144,4   | 9,1262   |
| 1300                         | 0,72608                     | 4681,3   | 5407,4   | 9,4542   | 0,60507                      | 4680,9   | 5406,9   | 9,3698   | 0,51864                      | 4680,4   | 5406,5   | 9,2983   |
| <i>p</i> = 1,60 MPa (201,40) |                             |          |          |          | <i>p</i> = 1,80 MPa (207,15) |          |          |          | <i>p</i> = 2,00 MPa (212,42) |          |          |          |
| Sat.                         | 0,12380                     | 2595,9   | 2794,0   | 6,4217   | 0,11042                      | 2598,4   | 2797,1   | 6,3793   | 0,09963                      | 2600,3   | 2799,5   | 6,3408   |
| 225                          | 0,13287                     | 2644,6   | 2857,2   | 6,5518   | 0,11673                      | 2636,6   | 2846,7   | 6,4807   | 0,10377                      | 2628,3   | 2835,8   | 6,4146   |
| 250                          | 0,14184                     | 2692,3   | 2919,2   | 6,6732   | 0,12497                      | 2686,0   | 2911,0   | 6,6066   | 0,11144                      | 2679,6   | 2902,5   | 6,5452   |
| 300                          | 0,15862                     | 2781,0   | 3034,8   | 6,8844   | 0,14021                      | 2776,8   | 3029,2   | 6,8226   | 0,12547                      | 2772,6   | 3023,5   | 6,7663   |
| 350                          | 0,17456                     | 2866,0   | 3145,4   | 7,0693   | 0,15457                      | 2862,9   | 3141,2   | 7,0099   | 0,13857                      | 2859,8   | 3137,0   | 6,9562   |
| 400                          | 0,19005                     | 2950,1   | 3254,2   | 7,2373   | 0,16847                      | 2947,7   | 3250,9   | 7,1793   | 0,15120                      | 2945,2   | 3247,6   | 7,1270   |
| 500                          | 0,22029                     | 3119,5   | 3471,9   | 7,5389   | 0,19550                      | 3117,8   | 3469,7   | 7,4824   | 0,17568                      | 3116,2   | 3467,6   | 7,4316   |
| 600                          | 0,24998                     | 3293,3   | 3693,2   | 7,8080   | 0,22199                      | 3292,1   | 3691,7   | 7,7523   | 0,19960                      | 3290,9   | 3690,1   | 7,7023   |
| 700                          | 0,27937                     | 3472,7   | 3919,7   | 8,0535   | 0,24818                      | 3471,9   | 3918,6   | 7,9983   | 0,22323                      | 3471,0   | 3917,5   | 7,9487   |
| 800                          | 0,30859                     | 3658,4   | 4152,1   | 8,2808   | 0,27420                      | 3657,7   | 4151,3   | 8,2258   | 0,24668                      | 3657,0   | 4150,4   | 8,1766   |
| 900                          | 0,33772                     | 3850,5   | 4390,8   | 8,4934   | 0,30012                      | 3849,9   | 4390,1   | 8,4386   | 0,27004                      | 3849,3   | 4389,4   | 8,3895   |
| 1000                         | 0,36678                     | 4049,0   | 4635,8   | 8,6938   | 0,32598                      | 4048,4   | 4635,2   | 8,6390   | 0,29333                      | 4047,9   | 4634,6   | 8,5900   |
| 1100                         | 0,39581                     | 4253,7   | 4887,0   | 8,8837   | 0,35180                      | 4253,2   | 4886,4   | 8,8290   | 0,31659                      | 4252,7   | 4885,9   | 8,7800   |
| 1200                         | 0,42482                     | 4464,2   | 5143,9   | 9,0642   | 0,37761                      | 4463,7   | 5143,4   | 9,0096   | 0,33984                      | 4463,2   | 5142,9   | 8,9606   |
| 1300                         | 0,45382                     | 4679,9   | 5406,0   | 9,2364   | 0,40340                      | 4679,4   | 5405,6   | 9,1817   | 0,36306                      | 4679,0   | 5405,1   | 9,1328   |
| <i>p</i> = 2,50 MPa (223,99) |                             |          |          |          | <i>p</i> = 3,00 MPa (233,90) |          |          |          | <i>p</i> = 3,50 MPa (242,60) |          |          |          |
| Sat.                         | 0,07998                     | 2603,1   | 2803,1   | 6,2574   | 0,06668                      | 2604,1   | 2804,1   | 6,1869   | 0,05707                      | 2603,7   | 2803,4   | 6,1252   |
| 225                          | 0,08027                     | 2605,6   | 2806,3   | 6,2638   | —                            | —        | —        | —        | —                            | —        | —        | —        |
| 250                          | 0,08700                     | 2662,5   | 2880,1   | 6,4084   | 0,07058                      | 2644,0   | 2855,8   | 6,2871   | 0,05873                      | 2623,7   | 2829,2   | 6,1748   |
| 300                          | 0,09890                     | 2761,6   | 3008,8   | 6,6437   | 0,08114                      | 2750,0   | 2993,5   | 6,5389   | 0,06842                      | 2738,0   | 2977,5   | 6,4460   |
| 350                          | 0,10976                     | 2851,8   | 3126,2   | 6,8402   | 0,09053                      | 2843,7   | 3115,3   | 6,7427   | 0,07678                      | 2835,3   | 3104,0   | 6,6578   |
| 400                          | 0,12010                     | 2939,0   | 3239,3   | 7,0147   | 0,09936                      | 2932,7   | 3230,8   | 6,9211   | 0,08453                      | 2926,4   | 3222,2   | 6,8404   |
| 450                          | 0,13014                     | 3025,4   | 3350,8   | 7,1745   | 0,10787                      | 3020,4   | 3344,0   | 7,0833   | 0,09196                      | 3015,3   | 3337,2   | 7,0051   |
| 500                          | 0,13998                     | 3112,1   | 3462,0   | 7,3233   | 0,11619                      | 3107,9   | 3456,5   | 7,2337   | 0,09918                      | 3103,7   | 3450,9   | 7,1571   |
| 600                          | 0,15930                     | 3288,0   | 3686,2   | 7,5960   | 0,13243                      | 3285,0   | 3682,3   | 7,5084   | 0,11324                      | 3282,1   | 3678,4   | 7,4338   |

Tabela A.1.3 (Continuação) — Vapor d'água superaquecido

| T           | p = 2,50 MPa (223,99) |               |               |               | p = 3,00 MPa (233,90)  |               |               |               | p = 3,50 MPa (242,60)  |               |               |               |
|-------------|-----------------------|---------------|---------------|---------------|------------------------|---------------|---------------|---------------|------------------------|---------------|---------------|---------------|
|             | v                     | u             | h             | s             | v                      | u             | h             | s             | v                      | u             | h             | s             |
| 700         | 0.17832               | 3468,8        | 3914,6        | 7.8435        | 0.14838                | 3466,6        | 3911,7        | 7.7571        | 0.12699                | 3464,4        | 3908,8        | 7.6837        |
| 800         | 0.19716               | 3655,3        | 4148,2        | 8.0720        | 0.16414                | 3653,6        | 4146,0        | 7.9862        | 0.14056                | 3651,8        | 4143,8        | 7.9135        |
| 900         | 0.21590               | 3847,9        | 4387,6        | 8.2853        | 0.17980                | 3846,5        | 4385,9        | 8.1999        | 0.15402                | 3845,0        | 4384,1        | 8.1275        |
| 1000        | 0.23458               | 4046,7        | 4633,1        | 8.4860        | 0.19541                | 4045,4        | 4631,6        | 8.4009        | 0.16743                | 4044,1        | 4630,1        | 8.3288        |
| <b>1100</b> | <b>0,25322</b>        | <b>4251,5</b> | <b>4884,6</b> | <b>8,6761</b> | <b>0,21098</b>         | <b>4250,3</b> | <b>4883,3</b> | <b>8,5911</b> | <b>0,18080</b>         | <b>4249,1</b> | <b>4881,9</b> | <b>8,5191</b> |
| 1200        | 0.27185               | 4462,1        | 5141,7        | 8.8569        | 0.22652                | 4460,9        | 5140,5        | 8.7719        | 0.19415                | 4459,8        | 5139,3        | 8.7000        |
| 1300        | 0.29046               | 4677,8        | 5404,0        | 9.0291        | 0.24206                | 4676,6        | 5402,8        | 8.9442        | 0.20749                | 4675,5        | 5401,7        | 8.8723        |
| T           | p = 4,00 MPa (250,40) |               |               |               | p = 4,50 MPa (257,48)  |               |               |               | p = 5,00 MPa (263,99)  |               |               |               |
|             | v                     | u             | h             | s             | v                      | u             | h             | s             | v                      | u             | h             | s             |
| Sat.        | 0.04978               | 2602,3        | 2801,4        | 6.0700        | 0.04406                | 2600,0        | 2798,3        | 6.0198        | 0.03944                | 2597,1        | 2794,3        | 5.9733        |
| 275         | 0.05457               | 2667,9        | 2886,2        | 6.2284        | 0.04730                | 2650,3        | 2863,1        | 6.1401        | 0.04141                | 2631,2        | 2838,3        | 6.0543        |
| 300         | 0.05884               | 2725,3        | 2960,7        | 6.3614        | 0.05135                | 2712,0        | 2943,1        | 6.2827        | 0.04532                | 2697,9        | 2924,5        | 6.2083        |
| 350         | 0.06645               | 2826,6        | 3092,4        | 6.5820        | 0.05840                | 2817,8        | 3080,6        | 6.5130        | 0.05194                | 2808,7        | 3068,4        | 6.4492        |
| <b>400</b>  | <b>0,07341</b>        | <b>2919,9</b> | <b>3213,5</b> | <b>6,7689</b> | <b>0,06475</b>         | <b>2913,3</b> | <b>3204,7</b> | <b>6,7046</b> | <b>0,05781</b>         | <b>2906,6</b> | <b>3195,6</b> | <b>6,6458</b> |
| 450         | 0.08003               | 3010,1        | 3330,2        | 6.9362        | 0.07074                | 3004,9        | 3323,2        | 6.8745        | 0.06330                | 2999,6        | 3316,1        | 6.8185        |
| 500         | 0.08643               | 3099,5        | 3445,2        | 7.0900        | 0.07651                | 3095,2        | 3439,5        | 7.0300        | 0.06857                | 3090,9        | 3433,8        | 6.9758        |
| 600         | 0.09885               | 3279,1        | 3674,4        | 7.3688        | 0.08765                | 3276,0        | 3670,5        | 7.3109        | 0.07869                | 3273,0        | 3666,5        | 7.2588        |
| 700         | 0.11095               | 3462,1        | 3905,9        | 7.6198        | 0.09847                | 3459,9        | 3903,0        | 7.5631        | 0.08849                | 3457,7        | 3900,1        | 7.5122        |
| <b>800</b>  | <b>0,12287</b>        | <b>3650,1</b> | <b>4141,6</b> | <b>7,8502</b> | <b>0,10911</b>         | <b>3648,4</b> | <b>4139,4</b> | <b>7,7942</b> | <b>0,09811</b>         | <b>3646,6</b> | <b>4137,2</b> | <b>7,7440</b> |
| 900         | 0.13469               | 3843,6        | 4382,3        | 8.0647        | 0.11965                | 3842,1        | 4380,6        | 8.0091        | 0.10762                | 3840,7        | 4378,8        | 7.9593        |
| 1000        | 0.14645               | 4042,9        | 4628,7        | 8.2661        | 0.13013                | 4041,6        | 4627,2        | 8.2108        | 0.11707                | 4040,3        | 4625,7        | 8.1612        |
| 1100        | 0.15817               | 4248,0        | 4880,6        | 8.4566        | 0.14056                | 4246,8        | 4879,3        | 8.4014        | 0.12648                | 4245,6        | 4878,0        | 8.3519        |
| 1200        | 0.16987               | 4458,6        | 5138,1        | 8.6376        | 0.15098                | 4457,4        | 5136,9        | 8.5824        | 0.13587                | 4456,3        | 5135,7        | 8.5330        |
| <b>1300</b> | <b>0,18156</b>        | <b>4674,3</b> | <b>5400,5</b> | <b>8,8099</b> | <b>0,16139</b>         | <b>4673,1</b> | <b>5399,4</b> | <b>8,7548</b> | <b>0,14526</b>         | <b>4672,0</b> | <b>5398,2</b> | <b>8,7055</b> |
| T           | p = 6,00 MPa (275,64) |               |               |               | p = 7,00 MPa (285,88)  |               |               |               | p = 8,00 MPa (295,06)  |               |               |               |
|             | v                     | u             | h             | s             | v                      | u             | h             | s             | v                      | u             | h             | s             |
| Sat.        | 0.03244               | 2589,7        | 2784,3        | 5.8891        | 0.02737                | 2580,5        | 2772,1        | 5.8132        | 0.02352                | 2569,8        | 2757,9        | 5.7431        |
| 300         | 0.03616               | 2667,2        | 2884,2        | 6.0673        | 0.02947                | 2632,1        | 2838,4        | 5.9304        | 0.02426                | 2590,9        | 2785,0        | 5.7905        |
| 350         | 0.04223               | 2789,6        | 3043,0        | 6.3334        | 0.03524                | 2769,3        | 3016,0        | 6.2282        | 0.02995                | 2747,7        | 2987,3        | 6.1300        |
| 400         | 0.04739               | 2892,8        | 3177,2        | 6.5407        | 0.03993                | 2878,6        | 3158,1        | 6.4477        | 0.03432                | 2863,8        | 3138,3        | 6.3633        |
| 450         | 0.05214               | 2988,9        | 3301,8        | 6.7192        | 0.04416                | 2977,9        | 3287,0        | 6.6326        | 0.03817                | 2966,7        | 3272,0        | 6.5550        |
| 500         | 0.05665               | 3082,2        | 3422,1        | 6.8802        | 0.04814                | 3073,3        | 3410,3        | 6.7974        | 0.04175                | 3064,3        | 3398,3        | 6.7239        |
| 550         | 0.06101               | 3174,6        | 3540,6        | 7.0287        | 0.05195                | 3167,2        | 3530,9        | 6.9486        | 0.04516                | 3159,8        | 3521,0        | 6.8778        |
| 600         | 0.06525               | 3266,9        | 3658,4        | 7.1676        | 0.05565                | 3260,7        | 3650,3        | 7.0894        | 0.04845                | 3254,4        | 3642,0        | 7.0205        |
| 700         | 0.07352               | 3453,2        | 3894,3        | 7.4234        | 0.06283                | 3448,6        | 3888,4        | 7.3476        | 0.05481                | 3444,0        | 3882,5        | 7.2812        |
| <b>800</b>  | <b>0,08160</b>        | <b>3643,1</b> | <b>4132,7</b> | <b>7,6566</b> | <b>0,06981</b>         | <b>3639,6</b> | <b>4128,3</b> | <b>7,5822</b> | <b>0,06097</b>         | <b>3636,1</b> | <b>4123,8</b> | <b>7,5173</b> |
| 900         | 0.08958               | 3837,8        | 4375,3        | 7.8727        | 0.07669                | 3835,0        | 4371,8        | 7.7991        | 0.06702                | 3832,1        | 4368,3        | 7.7350        |
| 1000        | 0.09749               | 4037,8        | 4622,7        | 8.0751        | 0.08350                | 4035,3        | 4619,8        | 8.0020        | 0.07301                | 4032,8        | 4616,9        | 7.9384        |
| 1100        | 0.10536               | 4243,3        | 4875,4        | 8.2661        | 0.09027                | 4240,9        | 4872,8        | 8.1933        | 0.07896                | 4238,6        | 4870,3        | 8.1299        |
| 1200        | 0.11321               | 4454,0        | 5133,3        | 8.4473        | 0.09703                | 4451,7        | 5130,9        | 8.3747        | 0.08489                | 4449,4        | 5128,5        | 8.3115        |
| <b>1300</b> | <b>0,12106</b>        | <b>4669,6</b> | <b>5396,0</b> | <b>8,6199</b> | <b>0,10377</b>         | <b>4667,3</b> | <b>5393,7</b> | <b>8,5472</b> | <b>0,09080</b>         | <b>4665,0</b> | <b>5391,5</b> | <b>8,4842</b> |
| T           | p = 9,00 MPa (303,40) |               |               |               | p = 10,00 MPa (311,06) |               |               |               | p = 12,50 MPa (327,89) |               |               |               |
|             | v                     | u             | h             | s             | v                      | u             | h             | s             | v                      | u             | h             | s             |
| Sat.        | 0.02048               | 2557,8        | 2742,1        | 5.6771        | 0.01803                | 2544,4        | 2724,7        | 5.6140        | 0.01350                | 2505,1        | 2673,8        | 5.4623        |
| 325         | 0.02327               | 2646,5        | 2855,9        | 5.8711        | 0.01986                | 2610,4        | 2809,0        | 5.7568        | —                      | —             | —             | —             |
| 350         | 0.02580               | 2724,4        | 2956,5        | 6.0361        | 0.02242                | 2699,2        | 2923,4        | 5.9442        | 0.01613                | 2624,6        | 2826,2        | 5.7117        |
| 400         | 0.02993               | 2848,4        | 3117,8        | 6.2853        | 0.02641                | 2832,4        | 3096,5        | 6.2119        | 0.02000                | 2789,3        | 3039,3        | 6.0416        |
| <b>450</b>  | <b>0,03350</b>        | <b>2955,1</b> | <b>3256,6</b> | <b>6,4843</b> | <b>0,02975</b>         | <b>2943,3</b> | <b>3240,8</b> | <b>6,4189</b> | <b>0,02299</b>         | <b>2912,4</b> | <b>3199,8</b> | <b>6,2718</b> |

Tabela A.1.3 (Continuação) — Vapor d'água superaquecido

| <i>T</i>    | <i>p</i> = 9,00 MPa (303,40) |               |               |               | <i>p</i> = 10,00 MPa (311,06) |               |               |               | <i>p</i> = 12,50 MPa (327,89) |               |               |               |
|-------------|------------------------------|---------------|---------------|---------------|-------------------------------|---------------|---------------|---------------|-------------------------------|---------------|---------------|---------------|
|             | <i>v</i>                     | <i>u</i>      | <i>h</i>      | <i>s</i>      | <i>v</i>                      | <i>u</i>      | <i>h</i>      | <i>s</i>      | <i>v</i>                      | <i>u</i>      | <i>h</i>      | <i>s</i>      |
| 500         | 0,03677                      | 3055,1        | 3386,1        | 6,6575        | 0,03279                       | 3045,8        | 3373,6        | 6,5965        | 0,02560                       | 3021,7        | 3341,7        | 6,4617        |
| 550         | 0,03987                      | 3152,2        | 3511,0        | 6,8141        | 0,03564                       | 3144,5        | 3500,9        | 6,7561        | 0,02801                       | 3124,9        | 3475,1        | 6,6289        |
| 600         | 0,04285                      | 3248,1        | 3633,7        | 6,9588        | 0,03837                       | 3241,7        | 3625,3        | 6,9028        | 0,03029                       | 3225,4        | 3604,0        | 6,7810        |
| 650         | 0,04574                      | 3343,7        | 3755,3        | 7,0943        | 0,04101                       | 3338,2        | 3748,3        | 7,0397        | 0,03248                       | 3324,4        | 3730,4        | 6,9218        |
| <b>700</b>  | <b>0,04857</b>               | <b>3439,4</b> | <b>3876,5</b> | <b>7,2221</b> | <b>0,04358</b>                | <b>3434,7</b> | <b>3870,5</b> | <b>7,1687</b> | <b>0,03460</b>                | <b>3422,9</b> | <b>3855,4</b> | <b>7,0536</b> |
| 800         | 0,05409                      | 3632,5        | 4119,4        | 7,4597        | 0,04859                       | 3629,0        | 4114,9        | 7,4077        | 0,03869                       | 3620,0        | 4103,7        | 7,2965        |
| 900         | 0,05950                      | 3829,2        | 4364,7        | 7,6782        | 0,05349                       | 3826,3        | 4361,2        | 7,6272        | 0,04267                       | 3819,1        | 4352,5        | 7,5181        |
| 1000        | 0,06485                      | 4030,3        | 4613,9        | 7,8821        | 0,05832                       | 4027,8        | 4611,0        | 7,8315        | 0,04658                       | 4021,6        | 4603,8        | 7,7237        |
| 1100        | 0,07016                      | 4236,3        | 4867,7        | 8,0739        | 0,06312                       | 4234,0        | 4865,1        | 8,0236        | 0,05045                       | 4228,2        | 4858,8        | 7,9165        |
| <b>1200</b> | <b>0,07544</b>               | <b>4447,2</b> | <b>5126,2</b> | <b>8,2556</b> | <b>0,06789</b>                | <b>4444,9</b> | <b>5123,8</b> | <b>8,2054</b> | <b>0,05430</b>                | <b>4439,3</b> | <b>5118,0</b> | <b>8,0987</b> |
| 1300        | 0,08072                      | 4662,7        | 5389,2        | 8,4283        | 0,07265                       | 4660,4        | 5387,0        | 8,3783        | 0,05813                       | 4654,8        | 5381,4        | 8,2717        |
| <i>T</i>    | <i>p</i> = 15 MPa (342,24)   |               |               |               | <i>p</i> = 17,5 MPa (354,75)  |               |               |               | <i>p</i> = 20 MPa (365,81)    |               |               |               |
|             | <i>v</i>                     | <i>u</i>      | <i>h</i>      | <i>s</i>      | <i>v</i>                      | <i>u</i>      | <i>h</i>      | <i>s</i>      | <i>v</i>                      | <i>u</i>      | <i>h</i>      | <i>s</i>      |
| Sat.        | 0,10338                      | 2455,4        | 2610,5        | 5,3097        | 0,079204                      | 2390,2        | 2528,8        | 5,1418        | 0,058342                      | 2293,1        | 2409,7        | 4,9269        |
| 350         | 0,11470                      | 2520,4        | 2692,4        | 5,4420        | —                             | —             | —             | —             | —                             | —             | —             | —             |
| 400         | 0,15649                      | 2740,7        | 2975,4        | 5,8810        | 0,124477                      | 2685,0        | 2902,8        | 5,7212        | 0,099423                      | 2619,2        | 2818,1        | 5,5539        |
| 450         | 0,18446                      | 2879,5        | 3156,2        | 6,1403        | 0,151740                      | 2844,2        | 3109,7        | 6,0182        | 0,126953                      | 2806,2        | 3060,1        | 5,9016        |
| <b>500</b>  | <b>0,20800</b>               | <b>2996,5</b> | <b>3308,5</b> | <b>6,3442</b> | <b>0,173585</b>               | <b>2970,3</b> | <b>3274,0</b> | <b>6,2382</b> | <b>0,147683</b>               | <b>2942,8</b> | <b>3238,2</b> | <b>6,1400</b> |
| 550         | 0,22927                      | 3104,7        | 3448,6        | 6,5198        | 0,192877                      | 3083,8        | 3421,4        | 6,4229        | 0,165553                      | 3062,3        | 3393,5        | 6,3347        |
| 600         | 0,24911                      | 3208,6        | 3582,3        | 6,6775        | 0,210640                      | 3191,5        | 3560,1        | 6,5866        | 0,181781                      | 3174,0        | 3537,6        | 6,5048        |
| 650         | 0,26797                      | 3310,4        | 3712,3        | 6,8223        | 0,227372                      | 3296,0        | 3693,9        | 6,7356        | 0,196929                      | 3281,5        | 3675,3        | 6,6582        |
| 700         | 0,28612                      | 3410,9        | 3840,1        | 6,9572        | 0,243365                      | 3398,8        | 3824,7        | 6,8736        | 0,211311                      | 3386,5        | 3809,1        | 6,7993        |
| <b>800</b>  | <b>0,32096</b>               | <b>3611,0</b> | <b>4092,4</b> | <b>7,2040</b> | <b>0,273849</b>               | <b>3601,9</b> | <b>4081,1</b> | <b>7,1245</b> | <b>0,238532</b>               | <b>3592,7</b> | <b>4069,8</b> | <b>7,0544</b> |
| 900         | 0,35457                      | 3811,9        | 4343,8        | 7,4279        | 0,303071                      | 3804,7        | 4335,1        | 7,3507        | 0,264463                      | 3797,4        | 4326,4        | 7,2830        |
| 1000        | 0,38748                      | 4015,4        | 4596,6        | 7,6347        | 0,331580                      | 4009,3        | 4589,5        | 7,5588        | 0,289666                      | 4003,1        | 4582,5        | 7,4925        |
| 1100        | 0,42001                      | 4222,6        | 4852,6        | 7,8282        | 0,359695                      | 4216,9        | 4846,4        | 7,7530        | 0,314471                      | 4211,3        | 4840,2        | 7,6874        |
| 1200        | 0,45233                      | 4433,8        | 5112,3        | 8,0108        | 0,387605                      | 4428,3        | 5106,6        | 7,9359        | 0,339071                      | 4422,8        | 5101,0        | 7,8706        |
| <b>1300</b> | <b>0,48455</b>               | <b>4649,1</b> | <b>5375,9</b> | <b>8,1839</b> | <b>0,415417</b>               | <b>4643,5</b> | <b>5370,5</b> | <b>8,1093</b> | <b>0,363574</b>               | <b>4638,0</b> | <b>5365,1</b> | <b>8,0441</b> |
| <i>T</i>    | <i>p</i> = 25 MPa            |               |               |               | <i>p</i> = 30 MPa             |               |               |               | <i>p</i> = 35 MPa             |               |               |               |
|             | <i>v</i>                     | <i>u</i>      | <i>h</i>      | <i>s</i>      | <i>v</i>                      | <i>u</i>      | <i>h</i>      | <i>s</i>      | <i>v</i>                      | <i>u</i>      | <i>h</i>      | <i>s</i>      |
| 375         | 0,001973                     | 1798,6        | 1847,9        | 4,0319        | 0,001789                      | 1737,8        | 1791,4        | 3,9303        | 0,001700                      | 1702,9        | 1762,4        | 3,8721        |
| 400         | 0,006004                     | 2430,1        | 2580,2        | 5,1418        | 0,002790                      | 2067,3        | 2151,0        | 4,4728        | 0,002100                      | 1914,0        | 1987,5        | 4,2124        |
| 425         | 0,007882                     | 2609,2        | 2806,3        | 5,4722        | 0,005304                      | 2455,1        | 2614,2        | 5,1503        | 0,003428                      | 2253,4        | 2373,4        | 4,7747        |
| 450         | 0,009162                     | 2720,7        | 2949,7        | 5,6743        | 0,006735                      | 2619,3        | 2821,4        | 5,4423        | 0,004962                      | 2498,7        | 2672,4        | 5,1962        |
| <b>500</b>  | <b>0,011124</b>              | <b>2884,3</b> | <b>3162,4</b> | <b>5,9592</b> | <b>0,008679</b>               | <b>2820,7</b> | <b>3081,0</b> | <b>5,7904</b> | <b>0,006927</b>               | <b>2751,9</b> | <b>2994,3</b> | <b>5,6281</b> |
| 550         | 0,012724                     | 3017,5        | 3335,6        | 6,1764        | 0,010168                      | 2970,3        | 3275,4        | 6,0342        | 0,008345                      | 2920,9        | 3213,0        | 5,9025        |
| 600         | 0,014138                     | 3137,9        | 3491,4        | 6,3602        | 0,011446                      | 3100,5        | 3443,9        | 6,2330        | 0,009527                      | 3062,0        | 3395,5        | 6,1178        |
| 650         | 0,015433                     | 3251,6        | 3637,5        | 6,5229        | 0,012596                      | 3221,0        | 3598,9        | 6,4057        | 0,010575                      | 3189,8        | 3559,9        | 6,3010        |
| 700         | 0,016647                     | 3361,4        | 3777,6        | 6,6707        | 0,013661                      | 3335,8        | 3745,7        | 6,5606        | 0,011533                      | 3309,9        | 3713,5        | 6,4631        |
| <b>800</b>  | <b>0,018913</b>              | <b>3574,3</b> | <b>4047,1</b> | <b>6,9345</b> | <b>0,015623</b>               | <b>3555,6</b> | <b>4024,3</b> | <b>6,8332</b> | <b>0,013278</b>               | <b>3536,8</b> | <b>4001,5</b> | <b>6,7450</b> |
| 900         | 0,021045                     | 3783,0        | 4309,1        | 7,1679        | 0,017448                      | 3768,5        | 4291,9        | 7,0717        | 0,014883                      | 3754,0        | 4274,9        | 6,9886        |
| 1000        | 0,023102                     | 3990,9        | 4568,5        | 7,3801        | 0,019196                      | 3978,8        | 4554,7        | 7,2867        | 0,016410                      | 3966,7        | 4541,1        | 7,2063        |
| 1100        | 0,025119                     | 4200,2        | 4828,2        | 7,5765        | 0,020903                      | 4189,2        | 4816,3        | 7,4845        | 0,017895                      | 4178,3        | 4804,6        | 7,4056        |
| 1200        | 0,027115                     | 4412,0        | 5089,9        | 7,7604        | 0,022589                      | 4401,3        | 5079,0        | 7,6691        | 0,019360                      | 4390,7        | 5068,4        | 7,5910        |
| <b>1300</b> | <b>0,029101</b>              | <b>4626,9</b> | <b>5354,4</b> | <b>7,9342</b> | <b>0,024266</b>               | <b>4616,0</b> | <b>5344,0</b> | <b>7,8432</b> | <b>0,020815</b>               | <b>4605,1</b> | <b>5333,6</b> | <b>7,7652</b> |



Tabela A.1.3 (Continuação) — Vapor d'água superaquecido

| T          | p = 40 MPa      |               |               |               | p = 50 MPa      |               |               |               | p = 60 MPa      |               |               |               |
|------------|-----------------|---------------|---------------|---------------|-----------------|---------------|---------------|---------------|-----------------|---------------|---------------|---------------|
|            | v               | u             | h             | s             | v               | u             | h             | s             | v               | u             | h             | s             |
| 375        | .0016406        | 1677,1        | 1742,7        | 3,8289        | .0015593        | 1638,6        | 1716,5        | 3,7638        | .0015027        | 1609,3        | 1699,5        | 3,7140        |
| 400        | .0019077        | 1854,5        | 1930,8        | 4,1134        | .0017309        | 1788,0        | 1874,6        | 4,0030        | .0016335        | 1745,3        | 1843,4        | 3,9317        |
| 425        | .0025319        | 2096,8        | 2198,1        | 4,5028        | .0020071        | 1959,6        | 2060,0        | 4,2733        | .0018165        | 1892,7        | 2001,7        | 4,1625        |
| 450        | .0036931        | 2365,1        | 2512,8        | 4,9459        | .0024862        | 2159,6        | 2283,9        | 4,5883        | .0020850        | 2053,9        | 2179,0        | 4,4119        |
| <b>500</b> | <b>.0056225</b> | <b>2678,4</b> | <b>2903,3</b> | <b>5,4699</b> | <b>.0038924</b> | <b>2525,5</b> | <b>2720,1</b> | <b>5,1725</b> | <b>.0029557</b> | <b>2390,5</b> | <b>2567,9</b> | <b>4,9320</b> |
| 600        | .0080943        | 3022,6        | 3346,4        | 6,0113        | .0061123        | 2942,0        | 3247,6        | 5,8177        | .0048345        | 2861,1        | 3151,2        | 5,6451        |
| 650        | .0090636        | 3158,0        | 3520,6        | 6,2054        | .0069657        | 3093,6        | 3441,8        | 6,0342        | .0055953        | 3028,8        | 3364,6        | 5,8829        |
| 700        | .0099415        | 3283,6        | 3681,3        | 6,3750        | .0077274        | 3230,5        | 3616,9        | 6,2189        | .0062719        | 3177,3        | 3553,6        | 6,0824        |
| 800        | .0115228        | 3517,9        | 3978,8        | 6,6662        | .0090761        | 3479,8        | 3933,6        | 6,5290        | .0074588        | 3441,6        | 3889,1        | 6,4110        |
| <b>900</b> | <b>.0129626</b> | <b>3739,4</b> | <b>4257,9</b> | <b>6,9150</b> | <b>.0102831</b> | <b>3710,3</b> | <b>4224,4</b> | <b>6,7882</b> | <b>.0085083</b> | <b>3681,0</b> | <b>4191,5</b> | <b>6,6805</b> |
| 1000       | .0143238        | 3954,6        | 4527,6        | 7,1356        | .0114113        | 3930,5        | 4501,1        | 7,0146        | .0094800        | 3906,4        | 4475,2        | 6,9126        |
| 1100       | .0156426        | 4167,4        | 4793,1        | 7,3364        | .0124966        | 4145,7        | 4770,6        | 7,2183        | .0104091        | 4124,1        | 4748,6        | 7,1194        |
| 1200       | .0169403        | 4380,1        | 5057,7        | 7,5224        | .0135606        | 4359,1        | 5037,2        | 7,4058        | .0113167        | 4338,2        | 5017,2        | 7,3082        |
| 1300       | .0182292        | 4594,3        | 5323,5        | 7,6969        | .0146159        | 4572,8        | 5303,6        | 7,5807        | .0122155        | 4551,4        | 5284,3        | 7,4837        |

Tabela A.1.4 — Água líquida comprimida

| T          | p = 5,00 MPa (263,99) |                |                |               | p = 10,00 MPa (311,06) |                |                |               | p = 15 MPa (342,24) |                |                |               |
|------------|-----------------------|----------------|----------------|---------------|------------------------|----------------|----------------|---------------|---------------------|----------------|----------------|---------------|
|            | v                     | u              | h              | s             | v                      | u              | h              | s             | v                   | u              | h              | s             |
| Sat.       | .0012859              | 1147,78        | 1154,21        | 2,9201        | .0014524               | 1393,00        | 1401,53        | 3,3595        | .0016581            | 1585,58        | 1610,45        | 3,6847        |
| 0          | .0009977              | 0,03           | 5,02           | 0,0001        | .0009952               | 0,10           | 10,05          | 0,0003        | .0009928            | 0,15           | 15,04          | 0,0004        |
| 20         | .0009995              | 83,64          | 88,64          | 0,2955        | .0009972               | 83,35          | 93,32          | 0,2945        | .0009950            | 83,05          | 97,97          | 0,2934        |
| 40         | .0010056              | 166,93         | 171,95         | 0,5705        | .0010034               | 166,33         | 176,36         | 0,5685        | .0010013            | 165,73         | 180,75         | 0,5665        |
| <b>60</b>  | <b>.0010149</b>       | <b>250,21</b>  | <b>255,28</b>  | <b>0,8284</b> | <b>.0010127</b>        | <b>249,34</b>  | <b>259,47</b>  | <b>0,8258</b> | <b>.0010105</b>     | <b>248,49</b>  | <b>263,65</b>  | <b>0,8231</b> |
| 80         | .0010268              | 333,69         | 338,83         | 1,0719        | .0010245               | 332,56         | 342,81         | 1,0687        | .0010222            | 331,46         | 346,79         | 1,0655        |
| 100        | .0010410              | 417,50         | 422,71         | 1,3030        | .0010385               | 416,09         | 426,48         | 1,2992        | .0010361            | 414,72         | 430,26         | 1,2954        |
| 120        | .0010576              | 501,79         | 507,07         | 1,5232        | .0010549               | 500,07         | 510,61         | 1,5188        | .0010522            | 498,39         | 514,17         | 1,5144        |
| 140        | .0010768              | 586,74         | 592,13         | 1,7342        | .0010737               | 584,67         | 595,40         | 1,7291        | .0010707            | 582,64         | 598,70         | 1,7241        |
| <b>160</b> | <b>.0010988</b>       | <b>672,61</b>  | <b>678,10</b>  | <b>1,9374</b> | <b>.0010953</b>        | <b>670,11</b>  | <b>681,07</b>  | <b>1,9316</b> | <b>.0010918</b>     | <b>667,69</b>  | <b>684,07</b>  | <b>1,9259</b> |
| 180        | .0011240              | 759,62         | 765,24         | 2,1341        | .0011199               | 756,63         | 767,83         | 2,1274        | .0011159            | 753,74         | 770,48         | 2,1209        |
| 200        | .0011530              | 848,08         | 853,85         | 2,3254        | .0011480               | 844,49         | 855,97         | 2,3178        | .0011433            | 841,04         | 858,18         | 2,3103        |
| 220        | .0011866              | 938,43         | 944,36         | 2,5128        | .0011805               | 934,07         | 945,88         | 2,5038        | .0011748            | 929,89         | 947,52         | 2,4952        |
| 240        | .0012264              | 1031,34        | 1037,47        | 2,6978        | .0012187               | 1025,94        | 1038,13        | 2,6872        | .0012114            | 1020,82        | 1038,99        | 2,6770        |
| <b>260</b> | <b>.0012748</b>       | <b>1127,92</b> | <b>1134,30</b> | <b>2,8829</b> | <b>.0012645</b>        | <b>1121,03</b> | <b>1133,68</b> | <b>2,8698</b> | <b>.0012550</b>     | <b>1114,59</b> | <b>1133,41</b> | <b>2,8575</b> |
| 280        | —                     | —              | —              | —             | .0013216               | 1220,90        | 1234,11        | 3,0547        | .0013084            | 1212,47        | 1232,09        | 3,0392        |
| 300        | —                     | —              | —              | —             | .0013972               | 1328,34        | 1342,31        | 3,2468        | .0013770            | 1316,58        | 1337,23        | 3,2259        |
| 320        | —                     | —              | —              | —             | —                      | —              | —              | —             | .0014724            | 1431,05        | 1453,13        | 3,4246        |
| 340        | —                     | —              | —              | —             | —                      | —              | —              | —             | .0016311            | 1567,42        | 1591,88        | 3,6545        |
| T          | p = 20 MPa (365,81)   |                |                |               | p = 30 MPa             |                |                |               | p = 50 MPa          |                |                |               |
|            | v                     | u              | h              | s             | v                      | u              | h              | s             | v                   | u              | h              | s             |
| Sat.       | .0020353              | 1785,47        | 1826,18        | 4,0137        | —                      | —              | —              | —             | —                   | —              | —              | —             |
| 0          | .0009904              | 0,20           | 20,00          | 0,0004        | .0009856               | 0,25           | 29,82          | 0,0001        | .0009766            | 0,20           | 49,03          | -0,0014       |
| 20         | .0009928              | 82,75          | 102,61         | 0,2922        | .0009886               | 82,16          | 111,82         | 0,2898        | .0009804            | 80,98          | 130,00         | 0,2847        |
| 40         | .0009992              | 165,15         | 185,14         | 0,5646        | .0009951               | 164,01         | 193,87         | 0,5606        | .0009872            | 161,84         | 211,20         | 0,5526        |
| 60         | .0010084              | 247,66         | 267,82         | 0,8205        | .0010042               | 246,03         | 276,16         | 0,8153        | .0009962            | 242,96         | 292,77         | 0,8051        |
| 80         | .0010199              | 330,38         | 350,78         | 1,0623        | .0010156               | 328,28         | 358,75         | 1,0561        | .0010073            | 324,32         | 374,68         | 1,0439        |

Tabela A.1.4 (Continuação) — Água líquida comprimida

| <i>T</i>   | <i>p</i> = 20 MPa (365,81) |                |                |               | <i>p</i> = 30 MPa |                |                |               | <i>p</i> = 50 MPa |                |                |               |
|------------|----------------------------|----------------|----------------|---------------|-------------------|----------------|----------------|---------------|-------------------|----------------|----------------|---------------|
|            | <i>v</i>                   | <i>u</i>       | <i>h</i>       | <i>s</i>      | <i>v</i>          | <i>u</i>       | <i>h</i>       | <i>s</i>      | <i>v</i>          | <i>u</i>       | <i>h</i>       | <i>s</i>      |
| 100        | ,0010337                   | 413,37         | 434,04         | 1,2917        | ,0010290          | 410,76         | 441,63         | 1,2844        | ,0010201          | 405,86         | 456,87         | 1,2703        |
| 120        | ,0010496                   | 496,75         | 517,74         | 1,5101        | ,0010445          | 493,58         | 524,91         | 1,5017        | ,0010348          | 487,63         | 539,37         | 1,4857        |
| 140        | ,0010678                   | 580,67         | 602,03         | 1,7192        | ,0010621          | 576,86         | 608,73         | 1,7097        | ,0010515          | 569,76         | 622,33         | 1,6915        |
| 160        | ,0010885                   | 665,34         | 687,11         | 1,9203        | ,0010821          | 660,81         | 693,27         | 1,9095        | ,0010703          | 652,39         | 705,91         | 1,8890        |
| <b>180</b> | <b>,0011120</b>            | <b>750,94</b>  | <b>773,18</b>  | <b>2,1146</b> | <b>,0011047</b>   | <b>745,57</b>  | <b>778,71</b>  | <b>2,1024</b> | <b>,0010912</b>   | <b>735,68</b>  | <b>790,24</b>  | <b>2,0793</b> |
| 200        | ,0011387                   | 837,70         | 860,47         | 2,3031        | ,0011302          | 831,34         | 865,24         | 2,2892        | ,0011146          | 819,73         | 875,46         | 2,2634        |
| 220        | ,0011693                   | 925,89         | 949,27         | 2,4869        | ,0011590          | 918,32         | 953,09         | 2,4710        | ,0011408          | 904,67         | 961,71         | 2,4419        |
| 240        | ,0012046                   | 1015,94        | 1040,04        | 2,6673        | ,0011920          | 1006,84        | 1042,60        | 2,6489        | ,0011702          | 990,69         | 1049,20        | 2,6158        |
| 260        | ,0012462                   | 1108,53        | 1133,45        | 2,8459        | ,0012303          | 1097,38        | 1134,29        | 2,8242        | ,0012034          | 1078,06        | 1138,23        | 2,7860        |
| <b>280</b> | <b>,0012965</b>            | <b>1204,69</b> | <b>1230,62</b> | <b>3,0248</b> | <b>,0012755</b>   | <b>1190,69</b> | <b>1228,96</b> | <b>2,9985</b> | <b>,0012415</b>   | <b>1167,19</b> | <b>1229,26</b> | <b>2,9536</b> |
| 300        | ,0013596                   | 1306,10        | 1333,29        | 3,2071        | ,0013304          | 1287,89        | 1327,80        | 3,1740        | ,0012860          | 1258,66        | 1322,95        | 3,1200        |
| 320        | ,0014437                   | 1415,66        | 1444,53        | 3,3978        | ,0013997          | 1390,64        | 1432,63        | 3,3538        | ,0013388          | 1353,23        | 1420,17        | 3,2867        |
| 340        | ,0015683                   | 1539,64        | 1571,01        | 3,6074        | ,0014919          | 1501,71        | 1546,47        | 3,5425        | ,0014032          | 1451,91        | 1522,07        | 3,4556        |
| 360        | ,0018226                   | 1702,78        | 1739,23        | 3,8770        | ,0016265          | 1626,57        | 1675,36        | 3,7492        | ,0014838          | 1555,97        | 1630,16        | 3,6290        |
| <b>380</b> | —                          | —              | —              | —             | <b>,0018691</b>   | <b>1781,35</b> | <b>1837,43</b> | <b>4,0010</b> | <b>,0015883</b>   | <b>1667,13</b> | <b>1746,54</b> | <b>3,8100</b> |

Tabela A.1.5 — Saturação sólido - vapor

| Temp.<br>°C<br><i>T</i> | Pressão<br>kPa<br><i>P</i> | Volume específico<br>m³/kg                   |                                       | Energia interna<br>kJ/kg               |                                |                                       | Entalpia<br>kJ/kg                      |                                |                                       | Entropia<br>kJ/kg K                    |                                |                                       |
|-------------------------|----------------------------|----------------------------------------------|---------------------------------------|----------------------------------------|--------------------------------|---------------------------------------|----------------------------------------|--------------------------------|---------------------------------------|----------------------------------------|--------------------------------|---------------------------------------|
|                         |                            |                                              |                                       |                                        |                                |                                       |                                        |                                |                                       |                                        |                                |                                       |
|                         |                            | Sólido<br>sat.<br><i>v<sub>s</sub></i> × 10³ | Vapor<br>sat.<br><i>v<sub>v</sub></i> | Sólido<br>sat.<br><i>u<sub>s</sub></i> | Subl.<br><i>u<sub>sv</sub></i> | Vapor<br>sat.<br><i>u<sub>v</sub></i> | Sólido<br>sat.<br><i>h<sub>s</sub></i> | Subl.<br><i>h<sub>sv</sub></i> | Vapor<br>sat.<br><i>h<sub>v</sub></i> | Sólido<br>sat.<br><i>s<sub>s</sub></i> | Subl.<br><i>s<sub>sv</sub></i> | Vapor<br>sat.<br><i>s<sub>v</sub></i> |
| 0,01                    | 0,6113                     | 1,0908                                       | 206,153                               | -333,40                                | 2708,7                         | 2375,3                                | -333,40                                | 2834,7                         | 2501,3                                | -1,2210                                | 10,3772                        | 9,1562                                |
| 0                       | 0,6108                     | 1,0908                                       | 206,315                               | -333,42                                | 2708,7                         | 2375,3                                | -333,42                                | 2834,8                         | 2501,3                                | -1,2211                                | 10,3776                        | 9,1565                                |
| -2                      | 0,5177                     | 1,0905                                       | 241,663                               | -337,61                                | 2710,2                         | 2372,5                                | -337,61                                | 2835,3                         | 2497,6                                | -1,2369                                | 10,4562                        | 9,2193                                |
| -4                      | 0,4376                     | 1,0901                                       | 283,799                               | -341,78                                | 2711,5                         | 2369,8                                | -341,78                                | 2835,7                         | 2494,0                                | -1,2526                                | 10,5358                        | 9,2832                                |
| <b>-6</b>               | <b>0,3689</b>              | <b>1,0898</b>                                | <b>334,139</b>                        | <b>-345,91</b>                         | <b>2712,9</b>                  | <b>2367,0</b>                         | <b>-345,91</b>                         | <b>2836,2</b>                  | <b>2490,3</b>                         | <b>-1,2683</b>                         | <b>10,6165</b>                 | <b>9,3482</b>                         |
| -8                      | 0,3102                     | 1,0894                                       | 394,414                               | -350,02                                | 2714,2                         | 2364,2                                | -350,02                                | 2836,6                         | 2486,6                                | -1,2839                                | 10,6982                        | 9,4143                                |
| -10                     | 0,2601                     | 1,0891                                       | 466,757                               | -354,09                                | 2715,5                         | 2361,4                                | -354,09                                | 2837,0                         | 2482,9                                | -1,2995                                | 10,7809                        | 9,4815                                |
| -12                     | 0,2176                     | 1,0888                                       | 553,803                               | -358,14                                | 2716,8                         | 2358,7                                | -358,14                                | 2837,3                         | 2479,2                                | -1,3150                                | 10,8648                        | 9,5498                                |
| -14                     | 0,1815                     | 1,0884                                       | 658,824                               | -362,16                                | 2718,0                         | 2355,9                                | -362,16                                | 2837,6                         | 2475,5                                | -1,3306                                | 10,9498                        | 9,6192                                |
| <b>-16</b>              | <b>0,1510</b>              | <b>1,0881</b>                                | <b>785,907</b>                        | <b>-366,14</b>                         | <b>2719,2</b>                  | <b>2353,1</b>                         | <b>-366,14</b>                         | <b>2837,9</b>                  | <b>2471,8</b>                         | <b>-1,3461</b>                         | <b>11,0359</b>                 | <b>9,6898</b>                         |
| -18                     | 0,1252                     | 1,0878                                       | 940,183                               | -370,10                                | 2720,4                         | 2350,3                                | -370,10                                | 2838,2                         | 2468,1                                | -1,3617                                | 11,1233                        | 9,7616                                |
| -20                     | 0,10355                    | 1,0874                                       | 1128,113                              | -374,03                                | 2721,6                         | 2347,5                                | -374,03                                | 2838,4                         | 2464,3                                | -1,3772                                | 11,2120                        | 9,8348                                |
| -22                     | 0,08535                    | 1,0871                                       | 1357,864                              | -377,93                                | 2722,7                         | 2344,7                                | -377,93                                | 2838,6                         | 2460,6                                | -1,3928                                | 11,3020                        | 9,9093                                |
| -24                     | 0,07012                    | 1,0868                                       | 1639,753                              | -381,80                                | 2723,7                         | 2342,0                                | -381,80                                | 2838,7                         | 2456,9                                | -1,4083                                | 11,3935                        | 9,9852                                |
| <b>-26</b>              | <b>0,05741</b>             | <b>1,0864</b>                                | <b>1986,776</b>                       | <b>-385,64</b>                         | <b>2724,8</b>                  | <b>2339,2</b>                         | <b>-385,64</b>                         | <b>2838,9</b>                  | <b>2453,2</b>                         | <b>-1,4239</b>                         | <b>11,4864</b>                 | <b>10,0625</b>                        |
| -28                     | 0,04684                    | 1,0861                                       | 2415,201                              | -389,45                                | 2725,8                         | 2336,4                                | -389,45                                | 2839,0                         | 2449,5                                | -1,4394                                | 11,5808                        | 10,1413                               |
| -30                     | 0,03810                    | 1,0858                                       | 2945,228                              | -393,23                                | 2726,8                         | 2333,6                                | -393,23                                | 2839,0                         | 2445,8                                | -1,4550                                | 11,6765                        | 10,2215                               |
| -32                     | 0,03090                    | 1,0854                                       | 3601,823                              | -396,98                                | 2727,8                         | 2330,8                                | -396,98                                | 2839,1                         | 2442,1                                | -1,4705                                | 11,7733                        | 10,3028                               |
| -34                     | 0,02499                    | 1,0851                                       | 4416,253                              | -400,71                                | 2728,7                         | 2328,0                                | -400,71                                | 2839,1                         | 2438,4                                | -1,4860                                | 11,8713                        | 10,3853                               |
| <b>-36</b>              | <b>0,02016</b>             | <b>1,0848</b>                                | <b>5430,116</b>                       | <b>-404,40</b>                         | <b>2729,6</b>                  | <b>2325,2</b>                         | <b>-404,40</b>                         | <b>2839,1</b>                  | <b>2434,7</b>                         | <b>-1,5014</b>                         | <b>11,9704</b>                 | <b>10,4690</b>                        |
| -38                     | 0,01618                    | 1,0844                                       | 6707,022                              | -408,06                                | 2730,5                         | 2322,4                                | -408,06                                | 2839,0                         | 2431,0                                | -1,5168                                | 12,0714                        | 10,5546                               |
| -40                     | 0,01286                    | 1,0841                                       | 8366,396                              | -411,70                                | 2731,3                         | 2319,6                                | -411,70                                | 2838,9                         | 2427,2                                | -1,5321                                | 12,1768                        | 10,6447                               |

Tabela A.2 — Propriedades termodinâmicas da amônia

Tabela A.2.1 — Amônia saturada

| Temp.<br>°C<br><i>T</i> | Pressão                 | Volume específico, m³/kg                |                                |                                       | Entalpia, kJ/kg                         |                                |                                       | Entropia, kJ/kg K                       |                                |                                       |
|-------------------------|-------------------------|-----------------------------------------|--------------------------------|---------------------------------------|-----------------------------------------|--------------------------------|---------------------------------------|-----------------------------------------|--------------------------------|---------------------------------------|
|                         | Abs.<br>kPa<br><i>p</i> | Líquido<br>sat.<br><i>v<sub>l</sub></i> | Evap.<br><i>v<sub>lv</sub></i> | Vapor<br>sat.<br><i>v<sub>v</sub></i> | Líquido<br>sat.<br><i>h<sub>l</sub></i> | Evap.<br><i>h<sub>lv</sub></i> | Vapor<br>sat.<br><i>h<sub>v</sub></i> | Líquido<br>sat.<br><i>s<sub>l</sub></i> | Evap.<br><i>s<sub>lv</sub></i> | Vapor<br>sat.<br><i>s<sub>v</sub></i> |
| -50                     | 40,86                   | 0,001424                                | 2,62524                        | 2,62667                               | -43,76                                  | 1416,34                        | 1372,57                               | -0,1916                                 | 6,3470                         | 6,1553                                |
| -48                     | 45,94                   | 0,001429                                | 2,35297                        | 2,35440                               | -35,04                                  | 1410,95                        | 1375,90                               | -0,1528                                 | 6,2666                         | 6,1139                                |
| -46                     | 51,52                   | 0,001434                                | 2,11359                        | 2,11503                               | -26,31                                  | 1405,50                        | 1379,19                               | -0,1142                                 | 6,1875                         | 6,0733                                |
| -44                     | 57,66                   | 0,001439                                | 1,90262                        | 1,90406                               | -17,56                                  | 1400,00                        | 1382,44                               | -0,0759                                 | 6,1095                         | 6,0336                                |
| -42                     | <b>64,38</b>            | <b>0,001444</b>                         | <b>1,71625</b>                 | <b>1,71769</b>                        | <b>-8,79</b>                            | <b>1394,44</b>                 | <b>1385,65</b>                        | <b>-0,0378</b>                          | <b>6,0326</b>                  | <b>5,9948</b>                         |
| -40                     | 71,72                   | 0,001450                                | 1,55124                        | 1,55269                               | 0                                       | 1388,82                        | 1388,82                               | 0                                       | 5,9568                         | 5,9568                                |
| -38                     | 79,74                   | 0,001455                                | 1,40482                        | 1,40627                               | 8,81                                    | 1383,13                        | 1391,94                               | 0,0376                                  | 5,8820                         | 5,9196                                |
| -36                     | 88,48                   | 0,001460                                | 1,27461                        | 1,27607                               | 17,64                                   | 1377,39                        | 1395,03                               | 0,0749                                  | 5,8082                         | 5,8831                                |
| -34                     | 97,98                   | 0,001465                                | 1,15857                        | 1,16004                               | 26,49                                   | 1371,58                        | 1398,07                               | 0,1120                                  | 5,7353                         | 5,8473                                |
| -32                     | <b>108,29</b>           | <b>0,001471</b>                         | <b>1,05496</b>                 | <b>1,05643</b>                        | <b>35,36</b>                            | <b>1365,70</b>                 | <b>1401,06</b>                        | <b>0,1489</b>                           | <b>5,6634</b>                  | <b>5,8123</b>                         |
| -30                     | 119,46                  | 0,001476                                | 0,96226                        | 0,96374                               | 44,26                                   | 1359,76                        | 1404,01                               | 0,1856                                  | 5,5924                         | 5,7780                                |
| -28                     | 131,54                  | 0,001482                                | 0,87916                        | 0,88064                               | 53,17                                   | 1353,74                        | 1406,92                               | 0,2220                                  | 5,5223                         | 5,7443                                |
| -26                     | 144,59                  | 0,001487                                | 0,80453                        | 0,80602                               | 62,11                                   | 1347,66                        | 1409,77                               | 0,2582                                  | 5,4530                         | 5,7113                                |
| -24                     | 158,65                  | 0,001493                                | 0,73738                        | 0,73887                               | 71,07                                   | 1341,51                        | 1412,58                               | 0,2942                                  | 5,3846                         | 5,6788                                |
| -22                     | <b>173,80</b>           | <b>0,001498</b>                         | <b>0,67685</b>                 | <b>0,67835</b>                        | <b>80,05</b>                            | <b>1335,29</b>                 | <b>1415,34</b>                        | <b>0,3301</b>                           | <b>5,3170</b>                  | <b>5,6470</b>                         |
| -20                     | 190,08                  | 0,001504                                | 0,62220                        | 0,62371                               | 89,05                                   | 1329,00                        | 1418,05                               | 0,3657                                  | 5,2501                         | 5,6158                                |
| -18                     | 207,56                  | 0,001510                                | 0,57277                        | 0,57428                               | 98,08                                   | 1322,64                        | 1420,71                               | 0,4011                                  | 5,1840                         | 5,5851                                |
| -16                     | 226,29                  | 0,001516                                | 0,52800                        | 0,52951                               | 107,12                                  | 1316,20                        | 1423,32                               | 0,4363                                  | 5,1187                         | 5,5550                                |
| -14                     | 246,35                  | 0,001522                                | 0,48737                        | 0,48889                               | 116,19                                  | 1309,68                        | 1425,88                               | 0,4713                                  | 5,0541                         | 5,5254                                |
| -12                     | <b>267,79</b>           | <b>0,001528</b>                         | <b>0,45045</b>                 | <b>0,45197</b>                        | <b>125,29</b>                           | <b>1303,09</b>                 | <b>1428,38</b>                        | <b>0,5061</b>                           | <b>4,9901</b>                  | <b>5,4963</b>                         |
| -10                     | 290,67                  | 0,001534                                | 0,41684                        | 0,41837                               | 134,41                                  | 1296,42                        | 1430,83                               | 0,5408                                  | 4,9269                         | 5,4676                                |
| -8                      | 315,08                  | 0,001540                                | 0,38621                        | 0,38775                               | 143,55                                  | 1289,67                        | 1433,22                               | 0,5753                                  | 4,8642                         | 5,4395                                |
| -6                      | 341,07                  | 0,001546                                | 0,35824                        | 0,35979                               | 152,72                                  | 1282,84                        | 1435,56                               | 0,6095                                  | 4,8023                         | 5,4118                                |
| -4                      | 368,72                  | 0,001553                                | 0,33268                        | 0,33423                               | 161,91                                  | 1275,93                        | 1437,84                               | 0,6437                                  | 4,7409                         | 5,3846                                |
| -2                      | <b>398,10</b>           | <b>0,001559</b>                         | <b>0,30928</b>                 | <b>0,31084</b>                        | <b>171,12</b>                           | <b>1268,94</b>                 | <b>1440,06</b>                        | <b>0,6776</b>                           | <b>4,6801</b>                  | <b>5,3577</b>                         |
| 0                       | 429,29                  | 0,001566                                | 0,28783                        | 0,28940                               | 180,36                                  | 1261,86                        | 1442,22                               | 0,7114                                  | 4,6199                         | 5,3313                                |
| 2                       | 462,34                  | 0,001573                                | 0,26815                        | 0,26972                               | 189,63                                  | 1254,69                        | 1444,32                               | 0,7450                                  | 4,5603                         | 5,3053                                |
| 4                       | 497,35                  | 0,001579                                | 0,25005                        | 0,25163                               | 198,93                                  | 1247,43                        | 1446,35                               | 0,7785                                  | 4,5012                         | 5,2796                                |
| 6                       | 534,39                  | 0,001586                                | 0,23341                        | 0,23499                               | 208,25                                  | 1240,08                        | 1448,32                               | 0,8118                                  | 4,4426                         | 5,2543                                |
| 8                       | <b>573,54</b>           | <b>0,001593</b>                         | <b>0,21807</b>                 | <b>0,21966</b>                        | <b>217,60</b>                           | <b>1232,63</b>                 | <b>1450,23</b>                        | <b>0,8449</b>                           | <b>4,3845</b>                  | <b>5,2294</b>                         |
| 10                      | 614,87                  | 0,001600                                | 0,20392                        | 0,20553                               | 226,97                                  | 1225,10                        | 1452,07                               | 0,8779                                  | 4,3269                         | 5,2048                                |
| 12                      | 658,48                  | 0,001608                                | 0,19086                        | 0,19247                               | 236,38                                  | 1217,46                        | 1453,84                               | 0,9108                                  | 4,2698                         | 5,1805                                |
| 14                      | 704,43                  | 0,001615                                | 0,17878                        | 0,18040                               | 245,81                                  | 1209,72                        | 1455,53                               | 0,9435                                  | 4,2131                         | 5,1565                                |
| 16                      | 752,81                  | 0,001623                                | 0,16761                        | 0,16923                               | 255,28                                  | 1201,88                        | 1457,16                               | 0,9760                                  | 4,1568                         | 5,1328                                |
| 18                      | <b>803,71</b>           | <b>0,001630</b>                         | <b>0,15725</b>                 | <b>0,15888</b>                        | <b>264,77</b>                           | <b>1193,94</b>                 | <b>1458,71</b>                        | <b>1,0085</b>                           | <b>4,1009</b>                  | <b>5,1094</b>                         |
| 20                      | 857,22                  | 0,001638                                | 0,14764                        | 0,14928                               | 274,30                                  | 1185,89                        | 1460,18                               | 1,0408                                  | 4,0455                         | 5,0863                                |
| 22                      | 913,41                  | 0,001646                                | 0,13872                        | 0,14037                               | 283,85                                  | 1177,73                        | 1461,58                               | 1,0730                                  | 3,9904                         | 5,0634                                |
| 24                      | 972,38                  | 0,001654                                | 0,13043                        | 0,13208                               | 293,44                                  | 1169,45                        | 1462,89                               | 1,1050                                  | 3,9357                         | 5,0407                                |
| 26                      | 1034,21                 | 0,001663                                | 0,12272                        | 0,12438                               | 303,07                                  | 1161,06                        | 1464,13                               | 1,1370                                  | 3,8813                         | 5,0182                                |
| 28                      | <b>1099,00</b>          | <b>0,001671</b>                         | <b>0,11553</b>                 | <b>0,11720</b>                        | <b>312,72</b>                           | <b>1152,55</b>                 | <b>1465,27</b>                        | <b>1,1688</b>                           | <b>3,8272</b>                  | <b>4,9960</b>                         |
| 30                      | 1166,83                 | 0,001680                                | 0,10883                        | 0,11051                               | 322,42                                  | 1143,92                        | 1466,33                               | 1,2005                                  | 3,7735                         | 4,9740                                |
| 32                      | 1237,80                 | 0,001688                                | 0,10258                        | 0,10427                               | 332,14                                  | 1135,16                        | 1467,30                               | 1,2321                                  | 3,7200                         | 4,9521                                |
| 34                      | 1312,00                 | 0,001697                                | 0,09675                        | 0,09845                               | 341,91                                  | 1126,27                        | 1468,17                               | 1,2635                                  | 3,6669                         | 4,9304                                |
| 36                      | 1389,52                 | 0,001707                                | 0,09129                        | 0,09300                               | 351,71                                  | 1117,25                        | 1468,95                               | 1,2949                                  | 3,6140                         | 4,9089                                |
| 38                      | <b>1470,46</b>          | <b>0,001716</b>                         | <b>0,08619</b>                 | <b>0,08790</b>                        | <b>361,55</b>                           | <b>1108,09</b>                 | <b>1469,64</b>                        | <b>1,3262</b>                           | <b>3,5613</b>                  | <b>4,8875</b>                         |
| 40                      | 1554,92                 | 0,001725                                | 0,08141                        | 0,08313                               | 371,43                                  | 1098,79                        | 1470,22                               | 1,3574                                  | 3,5088                         | 4,8662                                |
| 42                      | 1642,98                 | 0,001735                                | 0,07693                        | 0,07866                               | 381,35                                  | 1089,34                        | 1470,69                               | 1,3885                                  | 3,4566                         | 4,8451                                |
| 44                      | 1734,75                 | 0,001745                                | 0,07272                        | 0,07447                               | 391,31                                  | 1079,75                        | 1471,06                               | 1,4195                                  | 3,4045                         | 4,8240                                |
| 46                      | 1830,33                 | 0,001755                                | 0,06878                        | 0,07053                               | 401,32                                  | 1070,00                        | 1471,32                               | 1,4504                                  | 3,3526                         | 4,8030                                |
| 48                      | <b>1929,82</b>          | <b>0,001766</b>                         | <b>0,06507</b>                 | <b>0,06684</b>                        | <b>411,38</b>                           | <b>1060,09</b>                 | <b>1471,46</b>                        | <b>1,4813</b>                           | <b>3,3009</b>                  | <b>4,7822</b>                         |
| 50                      | 2033,32                 | 0,001777                                | 0,06159                        | 0,06336                               | 421,48                                  | 1050,01                        | 1471,49                               | 1,5121                                  | 3,2493                         | 4,7613                                |

Tabela A.2.2 — Amônia superaquecida

| Pressão abs.<br>kPa<br>(Temp. sat.)<br>°C |                       | Temperatura, °C |               |               |               |               |               |               |               |               |               |               |               |
|-------------------------------------------|-----------------------|-----------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|
|                                           |                       | -20             | -10           | 0             | 10            | 20            | 30            | 40            | 50            | 60            | 70            | 80            | 100           |
| 50                                        | v                     | 2,4463          | 2,5471        | 2,6474        | 2,7472        | 2,8466        | 2,9458        | 3,0447        | 3,1435        | 3,2421        | 3,3406        | 3,4390        | —             |
|                                           | h                     | 1434,6          | 1455,7        | 1476,9        | 1498,1        | 1519,3        | 1540,6        | 1562,0        | 1583,5        | 1605,1        | 1626,9        | 1648,8        | —             |
|                                           | (-46,53) <sub>s</sub> | 6,3187          | 6,4006        | 6,4795        | 6,5556        | 6,6293        | 6,7008        | 6,7703        | 6,8379        | 6,9038        | 6,9682        | 7,0312        | —             |
| 75                                        | v                     | <b>1,6222</b>   | <b>1,6905</b> | <b>1,7582</b> | <b>1,8255</b> | <b>1,8924</b> | <b>1,9591</b> | <b>2,0255</b> | <b>2,0917</b> | <b>2,1577</b> | <b>2,2237</b> | <b>2,2895</b> | —             |
|                                           | h                     | <b>1431,7</b>   | <b>1453,3</b> | <b>1474,8</b> | <b>1496,2</b> | <b>1517,7</b> | <b>1539,2</b> | <b>1560,7</b> | <b>1582,4</b> | <b>1604,1</b> | <b>1626,0</b> | <b>1648,0</b> | —             |
|                                           | (-39,16) <sub>s</sub> | <b>6,1120</b>   | <b>6,1954</b> | <b>6,2756</b> | <b>6,3527</b> | <b>6,4272</b> | <b>6,4993</b> | <b>6,5693</b> | <b>6,6373</b> | <b>6,7036</b> | <b>6,7683</b> | <b>6,8315</b> | —             |
| 100                                       | v                     | 1,2101          | 1,2621        | 1,3136        | 1,3647        | 1,4153        | 1,4657        | 1,5158        | 1,5658        | 1,6156        | 1,6652        | 1,7148        | 1,8137        |
|                                           | h                     | 1428,8          | 1450,8        | 1472,6        | 1494,4        | 1516,1        | 1537,7        | 1559,5        | 1581,2        | 1603,1        | 1625,1        | 1647,1        | 1691,7        |
|                                           | (-33,59) <sub>s</sub> | 5,9626          | 6,0477        | 6,1291        | 6,2073        | 6,2826        | 6,3553        | 6,4258        | 6,4943        | 6,5609        | 6,6258        | 6,6892        | 6,8120        |
| 125                                       | v                     | <b>0,9627</b>   | <b>1,0051</b> | <b>1,0468</b> | <b>1,0881</b> | <b>1,1290</b> | <b>1,1696</b> | <b>1,2100</b> | <b>1,2502</b> | <b>1,2903</b> | <b>1,3302</b> | <b>1,3700</b> | <b>1,4494</b> |
|                                           | h                     | <b>1425,9</b>   | <b>1448,3</b> | <b>1470,5</b> | <b>1492,5</b> | <b>1514,4</b> | <b>1536,3</b> | <b>1558,2</b> | <b>1580,1</b> | <b>1602,1</b> | <b>1624,1</b> | <b>1646,3</b> | <b>1691,0</b> |
|                                           | (-29,06) <sub>s</sub> | <b>5,8446</b>   | <b>5,9314</b> | <b>6,0141</b> | <b>6,0933</b> | <b>6,1694</b> | <b>6,2428</b> | <b>6,3138</b> | <b>6,3827</b> | <b>6,4496</b> | <b>6,5149</b> | <b>6,5785</b> | <b>6,7017</b> |
| 150                                       | v                     | 0,7977          | 0,8336        | 0,8689        | 0,9037        | 0,9381        | 0,9723        | 1,0062        | 1,0398        | 1,0734        | 1,1068        | 1,1401        | 1,2065        |
|                                           | h                     | 1422,9          | 1445,7        | 1468,3        | 1490,6        | 1512,8        | 1534,8        | 1556,9        | 1578,9        | 1601,0        | 1623,2        | 1645,4        | 1690,2        |
|                                           | (-25,21) <sub>s</sub> | 5,7465          | 5,8349        | 5,9189        | 5,9992        | 6,0761        | 6,1502        | 6,2217        | 6,2910        | 6,3583        | 6,4238        | 6,4877        | 6,6112        |
| 200                                       | v                     | —               | <b>0,6193</b> | <b>0,6465</b> | <b>0,6732</b> | <b>0,6995</b> | <b>0,7255</b> | <b>0,7513</b> | <b>0,7769</b> | <b>0,8023</b> | <b>0,8275</b> | <b>0,8527</b> | <b>0,9028</b> |
|                                           | h                     | —               | <b>1440,6</b> | <b>1463,8</b> | <b>1486,8</b> | <b>1509,4</b> | <b>1531,9</b> | <b>1554,3</b> | <b>1576,6</b> | <b>1598,9</b> | <b>1621,3</b> | <b>1643,7</b> | <b>1688,8</b> |
|                                           | (-18,85) <sub>s</sub> | —               | <b>5,6791</b> | <b>5,7659</b> | <b>5,8484</b> | <b>5,9270</b> | <b>6,0025</b> | <b>6,0751</b> | <b>6,1453</b> | <b>6,2133</b> | <b>6,2794</b> | <b>6,3437</b> | <b>6,4679</b> |
| 250                                       | v                     | —               | 0,4905        | 0,5129        | 0,5348        | 0,5563        | 0,5774        | 0,5983        | 0,6190        | 0,6396        | 0,6600        | 0,6803        | 0,7206        |
|                                           | h                     | —               | 1435,3        | 1459,3        | 1482,9        | 1506,0        | 1529,0        | 1551,7        | 1574,3        | 1596,8        | 1619,4        | 1641,9        | 1687,3        |
|                                           | (-13,65) <sub>s</sub> | —               | 5,5544        | 5,6441        | 5,7288        | 5,8093        | 5,8861        | 5,9599        | 6,0309        | 6,0997        | 6,1663        | 6,2312        | 6,3561        |
| 300                                       | v                     | —               | —             | <b>0,4238</b> | <b>0,4425</b> | <b>0,4608</b> | <b>0,4787</b> | <b>0,4964</b> | <b>0,5138</b> | <b>0,5311</b> | <b>0,5483</b> | <b>0,5653</b> | <b>0,5992</b> |
|                                           | h                     | —               | —             | <b>1454,7</b> | <b>1478,9</b> | <b>1502,6</b> | <b>1525,9</b> | <b>1549,0</b> | <b>1571,9</b> | <b>1594,7</b> | <b>1617,5</b> | <b>1640,2</b> | <b>1685,8</b> |
|                                           | (-9,22) <sub>s</sub>  | —               | —             | <b>5,5420</b> | <b>5,6290</b> | <b>5,7113</b> | <b>5,7896</b> | <b>5,8645</b> | <b>5,9365</b> | <b>6,0060</b> | <b>6,0732</b> | <b>6,1385</b> | <b>6,2642</b> |
| 350                                       | v                     | —               | —             | 0,3601        | 0,3765        | 0,3925        | 0,4081        | 0,4235        | 0,4386        | 0,4536        | 0,4685        | 0,4832        | 0,5124        |
|                                           | h                     | —               | —             | 1449,9        | 1474,9        | 1499,1        | 1522,9        | 1546,3        | 1569,5        | 1592,6        | 1615,5        | 1638,4        | 1684,3        |
|                                           | (-5,34) <sub>s</sub>  | —               | —             | 5,4532        | 5,5427        | 5,6270        | 5,7068        | 5,7828        | 5,8557        | 5,9259        | 5,9938        | 6,0596        | 6,1860        |
| 400                                       | v                     | —               | —             | <b>0,3123</b> | <b>0,3270</b> | <b>0,3413</b> | <b>0,3552</b> | <b>0,3688</b> | <b>0,3823</b> | <b>0,3955</b> | <b>0,4086</b> | <b>0,4216</b> | <b>0,4473</b> |
|                                           | h                     | —               | —             | <b>1445,1</b> | <b>1470,7</b> | <b>1495,6</b> | <b>1519,8</b> | <b>1543,6</b> | <b>1567,1</b> | <b>1590,4</b> | <b>1613,6</b> | <b>1636,7</b> | <b>1682,8</b> |
|                                           | (-1,87) <sub>s</sub>  | —               | —             | <b>5,3741</b> | <b>5,4663</b> | <b>5,5525</b> | <b>5,6338</b> | <b>5,7111</b> | <b>5,7850</b> | <b>5,8560</b> | <b>5,9244</b> | <b>5,9907</b> | <b>6,1179</b> |
| 450                                       | v                     | —               | —             | —             | 0,2885        | 0,3014        | 0,3140        | 0,3263        | 0,3384        | 0,3503        | 0,3620        | 0,3737        | 0,3967        |
|                                           | h                     | —               | —             | —             | 1466,5        | 1492,0        | 1516,7        | 1540,9        | 1564,7        | 1588,2        | 1611,6        | 1634,9        | 1681,3        |
|                                           | ( 1,27) <sub>s</sub>  | —               | —             | —             | 5,3972        | 5,4855        | 5,5685        | 5,6470        | 5,7219        | 5,7936        | 5,8627        | 5,9295        | 6,0575        |
|                                           |                       | 20              | 30            | 40            | 50            | 60            | 70            | 80            | 100           | 120           | 140           | 160           | 180           |
| 500                                       | v                     | 0,2695          | 0,2810        | 0,2923        | 0,3033        | 0,3141        | 0,3248        | 0,3353        | 0,3562        | 0,3768        | 0,3972        | —             | —             |
|                                           | h                     | 1488,3          | 1513,5        | 1538,1        | 1562,3        | 1586,1        | 1609,6        | 1633,1        | 1679,8        | 1726,6        | 1773,8        | —             | —             |
|                                           | ( 4,15) <sub>s</sub>  | 5,4244          | 5,5090        | 5,5889        | 5,6647        | 5,7373        | 5,8070        | 5,8744        | 6,0031        | 6,1253        | 6,2422        | —             | —             |
| 600                                       | v                     | <b>0,2215</b>   | <b>0,2315</b> | <b>0,2412</b> | <b>0,2506</b> | <b>0,2598</b> | <b>0,2689</b> | <b>0,2778</b> | <b>0,2955</b> | <b>0,3128</b> | <b>0,3300</b> | —             | —             |
|                                           | h                     | <b>1480,8</b>   | <b>1507,1</b> | <b>1532,5</b> | <b>1557,3</b> | <b>1581,6</b> | <b>1605,7</b> | <b>1629,5</b> | <b>1676,8</b> | <b>1724,0</b> | <b>1771,5</b> | —             | —             |
|                                           | ( 9,29) <sub>s</sub>  | <b>5,3156</b>   | <b>5,4037</b> | <b>5,4862</b> | <b>5,5641</b> | <b>5,6383</b> | <b>5,7094</b> | <b>5,7778</b> | <b>5,9081</b> | <b>6,0314</b> | <b>6,1491</b> | —             | —             |
| 700                                       | v                     | 0,1872          | 0,1961        | 0,2046        | 0,2129        | 0,2210        | 0,2289        | 0,2367        | 0,2521        | 0,2671        | 0,2819        | —             | —             |
|                                           | h                     | 1473,0          | 1500,4        | 1526,7        | 1552,2        | 1577,1        | 1601,6        | 1625,8        | 1673,7        | 1721,4        | 1769,2        | —             | —             |
|                                           | (13,81) <sub>s</sub>  | 5,2196          | 5,3115        | 5,3968        | 5,4770        | 5,5529        | 5,6254        | 5,6949        | 5,8268        | 5,9512        | 6,0698        | —             | —             |
| 800                                       | v                     | <b>0,1614</b>   | <b>0,1695</b> | <b>0,1772</b> | <b>0,1846</b> | <b>0,1919</b> | <b>0,1990</b> | <b>0,2059</b> | <b>0,2195</b> | <b>0,2328</b> | <b>0,2459</b> | <b>0,2589</b> | —             |
|                                           | h                     | <b>1464,9</b>   | <b>1493,5</b> | <b>1520,8</b> | <b>1547,0</b> | <b>1572,5</b> | <b>1597,5</b> | <b>1622,1</b> | <b>1670,6</b> | <b>1718,7</b> | <b>1766,9</b> | <b>1815,3</b> | —             |
|                                           | (17,86) <sub>s</sub>  | <b>5,1328</b>   | <b>5,2287</b> | <b>5,3171</b> | <b>5,3996</b> | <b>5,4774</b> | <b>5,5513</b> | <b>5,6219</b> | <b>5,7555</b> | <b>5,8811</b> | <b>6,0006</b> | <b>6,1150</b> | —             |
| 900                                       | v                     | —               | 0,1487        | 0,1558        | 0,1626        | 0,1692        | 0,1756        | 0,1819        | 0,1942        | 0,2061        | 0,2179        | 0,2295        | —             |
|                                           | h                     | —               | 1486,5        | 1514,7        | 1541,7        | 1567,9        | 1593,3        | 1618,4        | 1667,5        | 1716,1        | 1764,5        | 1813,2        | —             |
|                                           | (21,53) <sub>s</sub>  | —               | 5,1530        | 5,2447        | 5,3296        | 5,4093        | 5,4847        | 5,5565        | 5,6919        | 5,8187        | 5,9389        | 6,0541        | —             |
| 1000                                      | v                     | —               | <b>0,1321</b> | <b>0,1387</b> | <b>0,1450</b> | <b>0,1511</b> | <b>0,1570</b> | <b>0,1627</b> | <b>0,1739</b> | <b>0,1848</b> | <b>0,1955</b> | <b>0,2060</b> | <b>0,2164</b> |
|                                           | h                     | —               | <b>1479,1</b> | <b>1508,5</b> | <b>1536,3</b> | <b>1563,1</b> | <b>1589,1</b> | <b>1614,6</b> | <b>1664,3</b> | <b>1713,4</b> | <b>1762,2</b> | <b>1811,2</b> | <b>1860,5</b> |
|                                           | (24,91) <sub>s</sub>  | —               | <b>5,0826</b> | <b>5,1778</b> | <b>5,2654</b> | <b>5,3471</b> | <b>5,4240</b> | <b>5,4971</b> | <b>5,6342</b> | <b>5,7622</b> | <b>5,8834</b> | <b>5,9992</b> | <b>6,1105</b> |

Tabela A.2.2 (Continuação) — Amônia superaquecida

| Pressão abs.<br>kPa<br>(Temp. sat.)<br>°C |   | Temperatura, °C |        |        |        |        |        |        |        |        |        |     |     |
|-------------------------------------------|---|-----------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|-----|-----|
|                                           |   | 40              | 50     | 60     | 70     | 80     | 100    | 120    | 140    | 160    | 180    | 200 | 220 |
| 1200<br>(30,95)                           | v | 0,1129          | 0,1185 | 0,1238 | 0,1289 | 0,1339 | 0,1435 | 0,1527 | 0,1618 | 0,1707 | 0,1795 | —   | —   |
|                                           | h | 1495,4          | 1525,1 | 1553,3 | 1580,5 | 1606,8 | 1658,0 | 1708,0 | 1757,5 | 1807,1 | 1856,9 | —   | —   |
|                                           | s | 5,0564          | 5,1497 | 5,2357 | 5,3159 | 5,3916 | 5,5325 | 5,6631 | 5,7860 | 5,9031 | 6,0156 | —   | —   |
| 1400<br>(36,26)                           | v | 0,0943          | 0,0994 | 0,1042 | 0,1088 | 0,1132 | 0,1217 | 0,1299 | 0,1378 | 0,1455 | 0,1532 | —   | —   |
|                                           | h | 1481,6          | 1513,4 | 1543,1 | 1571,5 | 1598,8 | 1651,4 | 1702,5 | 1752,8 | 1802,9 | 1853,2 | —   | —   |
|                                           | s | 4,9463          | 5,0462 | 5,1370 | 5,2209 | 5,2994 | 5,4443 | 5,5775 | 5,7023 | 5,8208 | 5,9343 | —   | —   |
| 1600<br>(41,03)                           | v | —               | 0,0851 | 0,0895 | 0,0937 | 0,0977 | 0,1054 | 0,1127 | 0,1197 | 0,1266 | 0,1334 | —   | —   |
|                                           | h | —               | 1501,0 | 1532,5 | 1562,3 | 1590,7 | 1644,8 | 1696,9 | 1748,0 | 1798,7 | 1849,5 | —   | —   |
|                                           | s | —               | 4,9510 | 5,0472 | 5,1351 | 5,2167 | 5,3659 | 5,5018 | 5,6286 | 5,7485 | 5,8631 | —   | —   |
| 1800<br>(45,37)                           | v | —               | 0,0738 | 0,0780 | 0,0819 | 0,0857 | 0,0927 | 0,0993 | 0,1057 | 0,1119 | 0,1180 | —   | —   |
|                                           | h | —               | 1487,9 | 1521,4 | 1552,7 | 1582,2 | 1638,0 | 1691,2 | 1743,1 | 1794,5 | 1845,7 | —   | —   |
|                                           | s | —               | 4,8614 | 4,9637 | 5,0561 | 5,1410 | 5,2948 | 5,4337 | 5,5624 | 5,6838 | 5,7995 | —   | —   |
| 2000<br>(49,36)                           | v | —               | 0,0647 | 0,0687 | 0,0725 | 0,0760 | 0,0825 | 0,0886 | 0,0945 | 0,1002 | 0,1057 | —   | —   |
|                                           | h | —               | 1473,9 | 1509,8 | 1542,7 | 1573,5 | 1631,1 | 1685,5 | 1738,2 | 1790,2 | 1842,0 | —   | —   |
|                                           | s | —               | 4,7754 | 4,8848 | 4,9821 | 5,0707 | 5,2294 | 5,3714 | 5,5022 | 5,6251 | 5,7420 | —   | —   |

Tabela A.3 — Propriedades termodinâmicas do refrigerante-12 (Diclorodifluormetano)

Tabela A.3.1 — R-12 saturado

| Temp.<br>°C<br><i>T</i> | Pressão                 |                 | Volume específico, m³/kg     |                               |                              | Entalpia, kJ/kg              |                               |                              | Entropia, kJ/kg K            |                               |                              |
|-------------------------|-------------------------|-----------------|------------------------------|-------------------------------|------------------------------|------------------------------|-------------------------------|------------------------------|------------------------------|-------------------------------|------------------------------|
|                         | Abs.<br>MPa<br><i>p</i> |                 | Líquido                      |                               | Vapor                        | Líquido                      |                               | Vapor                        | Líquido                      |                               | Vapor                        |
|                         |                         |                 | sat.<br><i>v<sub>f</sub></i> | Evap.<br><i>v<sub>h</sub></i> | sat.<br><i>v<sub>g</sub></i> | sat.<br><i>h<sub>f</sub></i> | Evap.<br><i>h<sub>h</sub></i> | sat.<br><i>h<sub>g</sub></i> | sat.<br><i>s<sub>f</sub></i> | Evap.<br><i>s<sub>h</sub></i> | sat.<br><i>s<sub>g</sub></i> |
| -90                     | 0,00284                 | 0,000608        | 4,414937                     | 4,415545                      | —                            | -43,284                      | 189,748                       | 146,464                      | -0,20863                     | 1,03593                       | 0,82730                      |
| -85                     | 0,00424                 | 0,000612        | 3,036704                     | 3,037316                      | —                            | -39,005                      | 187,737                       | 148,731                      | -0,18558                     | 0,99771                       | 0,81213                      |
| -80                     | 0,00617                 | 0,000617        | 2,137728                     | 2,138345                      | —                            | -34,721                      | 185,740                       | 151,018                      | -0,16312                     | 0,96155                       | 0,79843                      |
| -75                     | 0,00879                 | 0,000622        | 1,537030                     | 1,537651                      | —                            | -30,430                      | 183,751                       | 153,321                      | -0,14119                     | 0,92725                       | 0,78606                      |
| -70                     | <b>0,01227</b>          | <b>0,000627</b> | <b>1,126654</b>              | <b>1,127280</b>               | —                            | <b>-26,128</b>               | <b>181,764</b>                | <b>155,636</b>               | <b>-0,11977</b>              | <b>0,89465</b>                | <b>0,77489</b>               |
| -65                     | 0,01680                 | 0,000632        | 0,840534                     | 0,841166                      | —                            | -21,814                      | 179,774                       | 157,960                      | -0,09880                     | 0,86361                       | 0,76480                      |
| -60                     | 0,02262                 | 0,000637        | 0,637274                     | 0,637911                      | —                            | -17,485                      | 177,775                       | 160,289                      | -0,07827                     | 0,83397                       | 0,75570                      |
| -55                     | 0,02998                 | 0,000642        | 0,490358                     | 0,491000                      | —                            | -13,141                      | 175,762                       | 162,621                      | -0,05815                     | 0,80563                       | 0,74748                      |
| -50                     | 0,03915                 | 0,000648        | 0,382457                     | 0,383105                      | —                            | -8,779                       | 173,730                       | 164,951                      | -0,03841                     | 0,77848                       | 0,74007                      |
| -45                     | <b>0,05044</b>          | <b>0,000654</b> | <b>0,302029</b>              | <b>0,302682</b>               | —                            | <b>-4,400</b>                | <b>171,676</b>                | <b>167,276</b>               | <b>-0,01903</b>              | <b>0,75241</b>                | <b>0,73338</b>               |
| -40                     | 0,06417                 | 0,000659        | 0,241251                     | 0,241910                      | 0                            | 0                            | 169,595                       | 169,595                      | 0                            | 0,72735                       | 0,72735                      |
| -35                     | 0,08071                 | 0,000666        | 0,194732                     | 0,195398                      | 4,420                        | 167,482                      | 171,903                       | 0,01871                      | 0,70322                      | 0,72193                       | 0,72193                      |
| -30                     | 0,10041                 | 0,000672        | 0,158703                     | 0,159375                      | 8,862                        | 165,335                      | 174,197                       | 0,03711                      | 0,67993                      | 0,71704                       | 0,71704                      |
| -25                     | 0,12368                 | 0,000679        | 0,130487                     | 0,131166                      | 13,327                       | 163,149                      | 176,476                       | 0,05522                      | 0,65742                      | 0,71264                       | 0,71264                      |
| -20                     | <b>0,15093</b>          | <b>0,000685</b> | <b>0,108162</b>              | <b>0,108847</b>               | <b>17,816</b>                | <b>160,920</b>               | <b>178,736</b>                | <b>0,07306</b>               | <b>0,63563</b>               | <b>0,70869</b>                | <b>0,70869</b>               |
| -15                     | 0,18260                 | 0,000693        | 0,090326                     | 0,091018                      | 22,331                       | 158,643                      | 180,974                       | 0,09063                      | 0,61450                      | 0,70513                       | 0,70513                      |
| -10                     | 0,21912                 | 0,000700        | 0,075946                     | 0,076646                      | 26,874                       | 156,314                      | 183,188                       | 0,10796                      | 0,59397                      | 0,70194                       | 0,70194                      |
| -5                      | 0,26096                 | 0,000708        | 0,064255                     | 0,064963                      | 31,446                       | 153,928                      | 185,375                       | 0,12506                      | 0,57400                      | 0,69907                       | 0,69907                      |
| 0                       | 0,30861                 | 0,000716        | 0,054673                     | 0,055389                      | 36,052                       | 151,479                      | 187,531                       | 0,14196                      | 0,55453                      | 0,69649                       | 0,69649                      |
| 5                       | <b>0,36255</b>          | <b>0,000724</b> | <b>0,046761</b>              | <b>0,047485</b>               | <b>40,694</b>                | <b>148,961</b>               | <b>189,654</b>                | <b>0,15865</b>               | <b>0,53551</b>               | <b>0,69416</b>                | <b>0,69416</b>               |
| 10                      | 0,42330                 | 0,000733        | 0,040180                     | 0,040914                      | 45,375                       | 146,365                      | 191,740                       | 0,17517                      | 0,51689                      | 0,69206                       | 0,69206                      |
| 15                      | 0,49137                 | 0,000743        | 0,034671                     | 0,035413                      | 50,100                       | 143,684                      | 193,784                       | 0,19154                      | 0,49862                      | 0,69015                       | 0,69015                      |
| 20                      | 0,56729                 | 0,000752        | 0,030028                     | 0,030780                      | 54,874                       | 140,909                      | 195,783                       | 0,20777                      | 0,48064                      | 0,68841                       | 0,68841                      |
| 25                      | 0,65162                 | 0,000763        | 0,026091                     | 0,026854                      | 59,702                       | 138,028                      | 197,730                       | 0,22388                      | 0,46292                      | 0,68680                       | 0,68680                      |
| 30                      | <b>0,74490</b>          | <b>0,000774</b> | <b>0,022734</b>              | <b>0,023508</b>               | <b>64,592</b>                | <b>135,028</b>               | <b>199,620</b>                | <b>0,23991</b>               | <b>0,44539</b>               | <b>0,68530</b>                | <b>0,68530</b>               |
| 35                      | 0,84772                 | 0,000786        | 0,019855                     | 0,020641                      | 69,551                       | 131,896                      | 201,446                       | 0,25587                      | 0,42800                      | 0,68387                       | 0,68387                      |
| 40                      | 0,96065                 | 0,000798        | 0,017373                     | 0,018171                      | 74,587                       | 128,613                      | 203,200                       | 0,27179                      | 0,41068                      | 0,68248                       | 0,68248                      |
| 45                      | 1,08432                 | 0,000811        | 0,015220                     | 0,016032                      | 79,712                       | 125,160                      | 204,872                       | 0,28771                      | 0,39338                      | 0,68109                       | 0,68109                      |
| 50                      | 1,21932                 | 0,000826        | 0,013344                     | 0,014170                      | 84,936                       | 121,514                      | 206,450                       | 0,30366                      | 0,37601                      | 0,67967                       | 0,67967                      |
| 55                      | 1,36630                 | 0,000841        | 0,011701                     | 0,012542                      | 90,274                       | 117,645                      | 207,920                       | 0,31967                      | 0,35849                      | 0,67817                       | 0,67817                      |

Tabela A.3.1 (Continuação) — R-12 saturado

| Temp.<br>°C<br><i>T</i> | Pressão<br>Abs.<br>MPa<br><i>p</i> | Volume específico, m³/kg     |                                |                              | Entalpia, kJ/kg              |                                |                              | Entropia, kJ/kg K            |                                |                              |
|-------------------------|------------------------------------|------------------------------|--------------------------------|------------------------------|------------------------------|--------------------------------|------------------------------|------------------------------|--------------------------------|------------------------------|
|                         |                                    | Líquido                      |                                | Vapor                        | Líquido                      |                                | Vapor                        | Líquido                      |                                | Vapor                        |
|                         |                                    | sat.<br><i>v<sub>l</sub></i> | Evap.<br><i>v<sub>lv</sub></i> | sat.<br><i>v<sub>v</sub></i> | sat.<br><i>h<sub>l</sub></i> | Evap.<br><i>h<sub>lv</sub></i> | sat.<br><i>h<sub>v</sub></i> | sat.<br><i>s<sub>l</sub></i> | Evap.<br><i>s<sub>lv</sub></i> | sat.<br><i>s<sub>v</sub></i> |
| 60                      | 1,52592                            | 0,000858                     | 0,010253                       | 0,011111                     | 95,743                       | 113,521                        | 209,264                      | 0,33580                      | 0,34073                        | 0,67653                      |
| 65                      | 1,69884                            | 0,000877                     | 0,008971                       | 0,009847                     | 101,362                      | 109,099                        | 210,460                      | 0,35209                      | 0,32262                        | 0,67471                      |
| 70                      | 1,88578                            | 0,000897                     | 0,007828                       | 0,008725                     | 107,155                      | 104,326                        | 211,481                      | 0,36861                      | 0,30401                        | 0,67262                      |
| 75                      | 2,08745                            | 0,000920                     | 0,006802                       | 0,007723                     | 113,153                      | 99,136                         | 212,288                      | 0,38543                      | 0,28474                        | 0,67017                      |
| 80                      | 2,30460                            | 0,000946                     | 0,005875                       | 0,006821                     | 119,394                      | 93,437                         | 212,832                      | 0,40265                      | 0,26457                        | 0,66722                      |
| 85                      | 2,53802                            | 0,000976                     | 0,005029                       | 0,006005                     | 125,932                      | 87,107                         | 213,039                      | 0,42040                      | 0,24320                        | 0,66361                      |
| 90                      | 2,78850                            | 0,001012                     | 0,004246                       | 0,005258                     | 132,841                      | 79,961                         | 212,802                      | 0,43887                      | 0,22018                        | 0,65905                      |
| 95                      | 3,05689                            | 0,001056                     | 0,003508                       | 0,004563                     | 140,235                      | 71,707                         | 211,942                      | 0,45833                      | 0,19477                        | 0,65310                      |
| 100                     | 3,34406                            | 0,001113                     | 0,002790                       | 0,003903                     | 148,314                      | 61,810                         | 210,124                      | 0,47928                      | 0,16564                        | 0,64492                      |
| 105                     | 3,65093                            | 0,001197                     | 0,002045                       | 0,003242                     | 157,521                      | 49,047                         | 206,568                      | 0,50285                      | 0,12970                        | 0,63254                      |
| 110                     | 3,97846                            | 0,001364                     | 0,001098                       | 0,002462                     | 169,550                      | 28,444                         | 197,995                      | 0,53334                      | 0,07423                        | 0,60758                      |
| 112                     | 4,11548                            | 0,001792                     | 0                              | 0,001792                     | 183,418                      | 0                              | 183,418                      | 0,56888                      | 0                              | 0,56888                      |

Tabela A.3.2 — Refrigerante-12 superaquecido

| Temp.<br>°C | <i>v</i>        | <i>h</i>       | <i>s</i>       | <i>v</i>        | <i>h</i>       | <i>s</i>       | <i>v</i>        | <i>h</i>       | <i>s</i>       |
|-------------|-----------------|----------------|----------------|-----------------|----------------|----------------|-----------------|----------------|----------------|
|             | m³/kg           | kJ/kg          | kJ/kg K        | m³/kg           | kJ/kg          | kJ/kg K        | m³/kg           | kJ/kg          | kJ/kg K        |
|             | 0,05 MPa        |                |                | 0,10 MPa        |                |                | 0,15 MPa        |                |                |
| -20         | 0,341859        | 181,170        | 0,79172        | 0,167702        | 179,987        | 0,74064        | —               | —              | —              |
| -10         | 0,356228        | 186,889        | 0,81388        | 0,175223        | 185,839        | 0,76331        | 0,114826        | 184,753        | 0,73240        |
| 0           | 0,370509        | 192,705        | 0,83557        | 0,182648        | 191,765        | 0,78541        | 0,119980        | 190,800        | 0,75495        |
| 10          | 0,384717        | 198,614        | 0,85681        | 0,189995        | 197,770        | 0,80700        | 0,125051        | 196,906        | 0,77690        |
| 20          | <b>0,398864</b> | <b>204,617</b> | <b>0,87764</b> | <b>0,197277</b> | <b>203,855</b> | <b>0,82812</b> | <b>0,130053</b> | <b>203,077</b> | <b>0,79832</b> |
| 30          | 0,412960        | 210,710        | 0,89808        | 0,204507        | 210,018        | 0,84879        | 0,135000        | 209,314        | 0,81924        |
| 40          | 0,427014        | 216,891        | 0,91814        | 0,211692        | 216,262        | 0,86905        | 0,139900        | 215,621        | 0,83971        |
| 50          | 0,441031        | 223,160        | 0,93784        | 0,218839        | 222,583        | 0,88892        | 0,144761        | 221,998        | 0,85975        |
| 60          | 0,455018        | 229,512        | 0,95720        | 0,225956        | 228,982        | 0,90842        | 0,149589        | 228,446        | 0,87940        |
| 70          | <b>0,468980</b> | <b>235,946</b> | <b>0,97623</b> | <b>0,233045</b> | <b>235,457</b> | <b>0,92757</b> | <b>0,154391</b> | <b>234,963</b> | <b>0,89867</b> |
| 80          | 0,482919        | 242,460        | 0,99494        | 0,240112        | 242,007        | 0,94638        | 0,159168        | 241,549        | 0,91759        |
| 90          | 0,496839        | 249,050        | 1,01334        | 0,247160        | 248,629        | 0,96487        | 0,163926        | 248,204        | 0,93617        |
|             | 0,20 MPa        |                |                | 0,25 MPa        |                |                | 0,30 MPa        |                |                |
| 0           | 0,088609        | 189,805        | 0,73249        | 0,069752        | 188,779        | 0,71437        | 0,057150        | 187,718        | 0,69894        |
| 10          | 0,092550        | 196,020        | 0,75484        | 0,073024        | 195,109        | 0,73713        | 0,059984        | 194,173        | 0,72215        |
| 20          | 0,096419        | 202,281        | 0,77657        | 0,076219        | 201,468        | 0,75920        | 0,062735        | 200,636        | 0,74458        |
| 30          | 0,100229        | 208,597        | 0,79775        | 0,079351        | 207,866        | 0,78066        | 0,065419        | 207,119        | 0,76633        |
| 40          | <b>0,103990</b> | <b>214,971</b> | <b>0,81843</b> | <b>0,082432</b> | <b>214,309</b> | <b>0,80157</b> | <b>0,068049</b> | <b>213,635</b> | <b>0,78747</b> |
| 50          | 0,107710        | 221,405        | 0,83866        | 0,085470        | 220,803        | 0,82198        | 0,070636        | 220,191        | 0,80808        |
| 60          | 0,111397        | 227,902        | 0,85846        | 0,088474        | 227,351        | 0,84193        | 0,073186        | 226,793        | 0,82820        |
| 70          | 0,115056        | 234,462        | 0,87786        | 0,091449        | 233,956        | 0,86147        | 0,075706        | 233,444        | 0,84787        |
| 80          | 0,118691        | 241,087        | 0,89689        | 0,094399        | 240,620        | 0,88061        | 0,078200        | 240,147        | 0,86712        |
| 90          | <b>0,122305</b> | <b>247,775</b> | <b>0,91556</b> | <b>0,097328</b> | <b>247,341</b> | <b>0,89937</b> | <b>0,080673</b> | <b>246,904</b> | <b>0,88599</b> |
| 100         | 0,125902        | 254,525        | 0,93390        | 0,100239        | 254,122        | 0,91779        | 0,083127        | 253,716        | 0,90449        |
| 110         | 0,129484        | 261,338        | 0,95191        | 0,103135        | 260,962        | 0,93588        | 0,085566        | 260,582        | 0,92265        |
|             | 0,40 MPa        |                |                | 0,50 MPa        |                |                | 0,60 MPa        |                |                |
| 20          | 0,045837        | 198,906        | 0,72043        | 0,035646        | 197,077        | 0,70043        | —               | —              | —              |
| 30          | 0,047971        | 205,577        | 0,74281        | 0,037464        | 203,963        | 0,72352        | 0,030422        | 202,263        | 0,70679        |
| 40          | 0,050046        | 212,250        | 0,76447        | 0,039215        | 210,810        | 0,74574        | 0,031966        | 209,307        | 0,72965        |
| 50          | 0,052072        | 218,939        | 0,78549        | 0,040912        | 217,643        | 0,76722        | 0,033450        | 216,300        | 0,75163        |
| 60          | <b>0,054059</b> | <b>225,653</b> | <b>0,80595</b> | <b>0,042566</b> | <b>224,479</b> | <b>0,78806</b> | <b>0,034887</b> | <b>223,268</b> | <b>0,77287</b> |
| 70          | 0,056014        | 232,401        | 0,82591        | 0,044185        | 231,330        | 0,80832        | 0,036286        | 230,231        | 0,79346        |
| 80          | 0,057941        | 239,188        | 0,84540        | 0,045775        | 238,206        | 0,82807        | 0,037653        | 237,201        | 0,81348        |
| 90          | 0,059846        | 246,017        | 0,86447        | 0,047341        | 245,112        | 0,84735        | 0,038996        | 244,188        | 0,83299        |
| 100         | 0,061731        | 252,892        | 0,88315        | 0,048886        | 252,054        | 0,86621        | 0,040316        | 251,200        | 0,85204        |

Tabela A.3.2 (Continuação) — Refrigerante-12 superaquecido

| Temp.<br>°C | $v$<br>m³/kg | $h$<br>kJ/kg | $s$<br>kJ/kg K | $v$<br>m³/kg | $h$<br>kJ/kg | $s$<br>kJ/kg K | $v$<br>m³/kg | $h$<br>kJ/kg | $s$<br>kJ/kg K |
|-------------|--------------|--------------|----------------|--------------|--------------|----------------|--------------|--------------|----------------|
| 0,40 MPa    |              |              |                | 0,50 MPa     |              |                | 0,60 MPa     |              |                |
| 110         | 0.063601     | 259.815      | 0.90145        | 0.050415     | 259.035      | 0.88467        | 0.041619     | 258.242      | 0.87066        |
| 120         | 0.065456     | 266.786      | 0.91941        | 0.051929     | 266.057      | 0.90276        | 0.042907     | 265.318      | 0.88889        |
| 130         | 0.067299     | 273.806      | 0.93704        | 0.053430     | 273.123      | 0.92050        | 0.044181     | 272.431      | 0.90675        |
| 0,70 MPa    |              |              |                | 0,80 MPa     |              |                | 0,90 MPa     |              |                |
| 40          | 0.026761     | 207.732      | 0.71529        | 0.022830     | 206.074      | 0.70210        | 0.019744     | 204.320      | 0.68972        |
| 50          | 0.028100     | 214.903      | 0.73783        | 0.024068     | 213.446      | 0.72527        | 0.020912     | 211.921      | 0.71361        |
| 60          | 0.029387     | 222.017      | 0.75951        | 0.025247     | 220.720      | 0.74744        | 0.022012     | 219.373      | 0.73633        |
| 70          | 0.030632     | 229.099      | 0.78045        | 0.026380     | 227.934      | 0.76878        | 0.023062     | 226.730      | 0.75808        |
| 80          | 0.031843     | 236.171      | 0.80076        | 0.027477     | 235.114      | 0.78940        | 0.024073     | 234.028      | 0.77905        |
| 90          | 0.033028     | 243.244      | 0.82051        | 0.028545     | 242.279      | 0.80941        | 0.025051     | 241.290      | 0.79932        |
| 100         | 0.034189     | 250.330      | 0.83976        | 0.029588     | 249.443      | 0.82887        | 0.026005     | 248.537      | 0.81901        |
| 110         | 0.035332     | 257.436      | 0.85855        | 0.030612     | 256.616      | 0.84784        | 0.026937     | 255.781      | 0.83817        |
| 120         | 0.036459     | 264.568      | 0.87693        | 0.031619     | 263.806      | 0.86636        | 0.027852     | 263.032      | 0.85685        |
| 130         | 0.037572     | 271.730      | 0.89492        | 0.032612     | 271.019      | 0.88448        | 0.028751     | 270.298      | 0.87510        |
| 140         | 0.038673     | 278.925      | 0.91254        | 0.033592     | 278.259      | 0.90221        | 0.029639     | 277.585      | 0.89295        |
| 150         | 0.039765     | 286.155      | 0.92984        | 0.034563     | 285.529      | 0.91960        | 0.030515     | 284.896      | 0.91043        |
| 1,00 MPa    |              |              |                | 1,20 MPa     |              |                | 1,40 MPa     |              |                |
| 50          | 0.018366     | 210.317      | 0.70259        | 0.014483     | 206.813      | 0.68165        | —            | —            | —              |
| 60          | 0.019410     | 217.970      | 0.72591        | 0.015463     | 214.964      | 0.70649        | 0.012579     | 211.613      | 0.68806        |
| 70          | 0.020397     | 225.485      | 0.74814        | 0.016368     | 222.851      | 0.72982        | 0.013448     | 219.984      | 0.71281        |
| 80          | 0.021341     | 232.910      | 0.76946        | 0.017221     | 230.568      | 0.75198        | 0.014247     | 228.059      | 0.73601        |
| 90          | 0.022251     | 240.278      | 0.79004        | 0.018032     | 238.171      | 0.77321        | 0.014997     | 235.940      | 0.75802        |
| 100         | 0.023133     | 247.612      | 0.80996        | 0.018812     | 245.699      | 0.79366        | 0.015710     | 243.692      | 0.77907        |
| 110         | 0.023993     | 254.931      | 0.82931        | 0.019567     | 253.180      | 0.81344        | 0.016393     | 251.355      | 0.79934        |
| 120         | 0.024835     | 262.246      | 0.84816        | 0.020301     | 260.632      | 0.83265        | 0.017053     | 258.961      | 0.81893        |
| 130         | 0.025661     | 269.567      | 0.86655        | 0.021018     | 268.072      | 0.85133        | 0.017695     | 266.530      | 0.83795        |
| 140         | 0.026474     | 276.902      | 0.88452        | 0.021721     | 275.509      | 0.86955        | 0.018321     | 274.078      | 0.85644        |
| 150         | 0.027275     | 284.255      | 0.90211        | 0.022412     | 282.952      | 0.88735        | 0.018934     | 281.618      | 0.87447        |
| 160         | 0.028068     | 291.632      | 0.91933        | 0.023093     | 290.408      | 0.90477        | 0.019535     | 289.158      | 0.89208        |
| 1,60 MPa    |              |              |                | 1,80 MPa     |              |                | 2,00 MPa     |              |                |
| 70          | 0.011208     | 216.810      | 0.69641        | 0.009406     | 213.208      | 0.67992        | —            | —            | —              |
| 80          | 0.011984     | 225.344      | 0.72092        | 0.010187     | 222.363      | 0.70622        | 0.008704     | 219.024      | 0.69143        |
| 90          | 0.012698     | 233.563      | 0.74387        | 0.010884     | 231.007      | 0.73036        | 0.009406     | 228.226      | 0.71713        |
| 100         | 0.013366     | 241.575      | 0.76564        | 0.011525     | 239.332      | 0.75297        | 0.010035     | 236.936      | 0.74079        |
| 110         | 0.014000     | 249.448      | 0.78646        | 0.012126     | 247.446      | 0.77443        | 0.010615     | 245.336      | 0.76300        |
| 120         | 0.014608     | 257.225      | 0.80649        | 0.012697     | 255.417      | 0.79497        | 0.011159     | 253.528      | 0.78411        |
| 130         | 0.015195     | 264.937      | 0.82586        | 0.013244     | 263.288      | 0.81474        | 0.011676     | 261.577      | 0.80433        |
| 140         | 0.015765     | 272.606      | 0.84465        | 0.013772     | 271.090      | 0.83385        | 0.012172     | 269.526      | 0.82380        |
| 150         | 0.016320     | 280.250      | 0.86293        | 0.014284     | 278.847      | 0.85240        | 0.012651     | 277.405      | 0.84265        |
| 160         | 0.016864     | 287.880      | 0.88076        | 0.014784     | 286.574      | 0.87045        | 0.013116     | 285.237      | 0.86094        |
| 170         | 0.017398     | 295.506      | 0.89816        | 0.015272     | 294.284      | 0.88805        | 0.013570     | 293.037      | 0.87874        |
| 180         | 0.017923     | 303.136      | 0.91519        | 0.015752     | 301.988      | 0.90524        | 0.014013     | 300.819      | 0.89611        |
| 2,50 MPa    |              |              |                | 3,00 MPa     |              |                | 3,50 MPa     |              |                |
| 90          | 0.006595     | 219.736      | 0.68284        | —            | —            | —              | —            | —            | —              |
| 100         | 0.007264     | 230.029      | 0.71081        | 0.005231     | 220.723      | 0.67755        | —            | —            | —              |
| 110         | 0.007837     | 239.453      | 0.73573        | 0.005886     | 232.256      | 0.70806        | 0.004324     | 222.360      | 0.67559        |
| 120         | 0.008351     | 248.379      | 0.75873        | 0.006419     | 242.398      | 0.73420        | 0.004959     | 235.086      | 0.70840        |
| 130         | 0.008827     | 256.986      | 0.78035        | 0.006887     | 251.825      | 0.75788        | 0.005456     | 245.865      | 0.73548        |
| 140         | 0.009273     | 265.377      | 0.80091        | 0.007313     | 260.818      | 0.77991        | 0.005884     | 255.728      | 0.75965        |
| 150         | 0.009697     | 273.616      | 0.82062        | 0.007709     | 269.521      | 0.80072        | 0.006270     | 265.053      | 0.78195        |
| 160         | 0.010104     | 281.748      | 0.83961        | 0.008083     | 278.024      | 0.82059        | 0.006626     | 274.027      | 0.80291        |
| 170         | 0.010497     | 289.802      | 0.85799        | 0.008439     | 286.384      | 0.83967        | 0.006961     | 282.759      | 0.82284        |
| 180         | 0.010879     | 297.802      | 0.87584        | 0.008782     | 294.640      | 0.85809        | 0.007279     | 291.319      | 0.84194        |
| 190         | 0.011250     | 305.764      | 0.89322        | 0.009114     | 302.820      | 0.87594        | 0.007584     | 299.752      | 0.86035        |
| 200         | 0.011614     | 313.701      | 0.91018        | 0.009436     | 310.946      | 0.89330        | 0.007878     | 308.092      | 0.87816        |

Tabela A.3.2 (Continuação) — Refrigerante-12 superaquecido

| Temp.<br>°C | $v$<br>m³/kg | $h$<br>kJ/kg | $s$<br>kJ/kg K | $v$<br>m³/kg | $h$<br>kJ/kg | $s$<br>kJ/kg K | $v$<br>m³/kg | $h$<br>kJ/kg | $s$<br>kJ/kg K |
|-------------|--------------|--------------|----------------|--------------|--------------|----------------|--------------|--------------|----------------|
| 4,00 MPa    |              |              |                | 5,00 MPa     |              |                |              |              |                |
| 120         | 0,003736     | 225,180      | 0,67769        | 0,001369     | 176,303      | 0,54710        | —            | —            | —              |
| 130         | 0,004325     | 238,691      | 0,71164        | 0,002501     | 216,458      | 0,64811        | —            | —            | —              |
| 140         | 0,004781     | 249,930      | 0,73918        | 0,003139     | 235,004      | 0,69359        | —            | —            | —              |
| 150         | 0,005172     | 260,124      | 0,76357        | 0,003585     | 248,416      | 0,72568        | —            | —            | —              |
| 160         | 0,005522     | 269,710      | 0,78596        | 0,003950     | 259,910      | 0,75253        | —            | —            | —              |
| 170         | 0,005845     | 278,903      | 0,80694        | 0,004268     | 270,400      | 0,77648        | —            | —            | —              |
| 180         | 0,006147     | 287,825      | 0,82685        | 0,004555     | 280,276      | 0,79851        | —            | —            | —              |
| 190         | 0,006434     | 296,552      | 0,84590        | 0,004821     | 289,740      | 0,81917        | —            | —            | —              |
| 200         | 0,006708     | 305,136      | 0,86424        | 0,005071     | 298,916      | 0,83877        | —            | —            | —              |
| 210         | 0,006972     | 313,614      | 0,88197        | 0,005308     | 307,882      | 0,85753        | —            | —            | —              |
| 220         | 0,007228     | 322,013      | 0,89917        | 0,005535     | 316,690      | 0,87557        | —            | —            | —              |
| 230         | 0,007477     | 330,352      | 0,91592        | 0,005753     | 325,380      | 0,89301        | —            | —            | —              |

Tabela A.4 — Propriedades termodinâmicas do refrigerante-22 (Clorodifluormetano)

Tabela A.4.1 — R-22 saturado

| Temp.<br>°C<br>$T$ | Pressão       | Volume específico, m³/kg |                 |                 | Entalpia, kJ/kg |                |                | Entropia, kJ/kg K |               |               |
|--------------------|---------------|--------------------------|-----------------|-----------------|-----------------|----------------|----------------|-------------------|---------------|---------------|
|                    | Abs.          | Líquido                  | Evap.           | Vapor           | Líquido         | Evap.          | Vapor          | Líquido           | Evap.         | Vapor         |
|                    | MPa<br>$p$    | sat.<br>$v_f$            | $v_{fg}$        | sat.<br>$v_g$   | sat.<br>$h_f$   | $h_{fg}$       | sat.<br>$h_g$  | sat.<br>$s_f$     | $s_{fg}$      | sat.<br>$s_g$ |
| -70                | 0,0205        | 0,000670                 | 0,940268        | 0,940938        | -30,607         | 249,425        | 218,818        | -0,1401           | 1,2277        | 1,0876        |
| -65                | 0,0280        | 0,000676                 | 0,704796        | 0,705472        | -25,658         | 246,925        | 221,267        | -0,1161           | 1,1862        | 1,0701        |
| -60                | 0,0375        | 0,000682                 | 0,536470        | 0,537152        | -20,652         | 244,354        | 223,702        | -0,0924           | 1,1463        | 1,0540        |
| -55                | 0,0495        | 0,000689                 | 0,414138        | 0,414827        | -15,585         | 241,703        | 226,117        | -0,0689           | 1,1079        | 1,0390        |
| -50                | <b>0,0644</b> | <b>0,000695</b>          | <b>0,323862</b> | <b>0,324557</b> | <b>-10,456</b>  | <b>238,965</b> | <b>228,509</b> | <b>-0,0457</b>    | <b>1,0708</b> | <b>1,0251</b> |
| -45                | 0,0827        | 0,000702                 | 0,256288        | 0,256990        | -5,262          | 236,132        | 230,870        | -0,0227           | 1,0349        | 1,0122        |
| -40                | 0,1049        | 0,000709                 | 0,205036        | 0,205745        | 0               | 233,198        | 233,197        | 0                 | 1,0002        | 1,0002        |
| -35                | 0,1317        | 0,000717                 | 0,165683        | 0,166400        | 5,328           | 230,156        | 235,484        | 0,0225            | 0,9664        | 0,9889        |
| -30                | 0,1635        | 0,000725                 | 0,135120        | 0,135844        | 10,725          | 227,001        | 237,726        | 0,0449            | 0,9335        | 0,9784        |
| -25                | <b>0,2010</b> | <b>0,000733</b>          | <b>0,111126</b> | <b>0,111859</b> | <b>16,191</b>   | <b>223,727</b> | <b>239,918</b> | <b>0,0670</b>     | <b>0,9015</b> | <b>0,9685</b> |
| -20                | 0,2448        | 0,000741                 | 0,092102        | 0,092843        | 21,728          | 220,327        | 242,055        | 0,0890            | 0,8703        | 0,9593        |
| -15                | 0,2957        | 0,000750                 | 0,076876        | 0,077625        | 27,334          | 216,798        | 244,132        | 0,1107            | 0,8398        | 0,9505        |
| -10                | 0,3543        | 0,000759                 | 0,064581        | 0,065340        | 33,012          | 213,132        | 246,144        | 0,1324            | 0,8099        | 0,9422        |
| -5                 | 0,4213        | 0,000768                 | 0,054571        | 0,055339        | 38,762          | 209,323        | 248,085        | 0,1538            | 0,7806        | 0,9344        |
| <b>0</b>           | <b>0,4976</b> | <b>0,000778</b>          | <b>0,046357</b> | <b>0,047135</b> | <b>44,586</b>   | <b>205,364</b> | <b>249,949</b> | <b>0,1751</b>     | <b>0,7518</b> | <b>0,9269</b> |
| 5                  | 0,5838        | 0,000789                 | 0,039567        | 0,040356        | 50,485          | 201,246        | 251,731        | 0,1963            | 0,7235        | 0,9197        |
| 10                 | 0,6807        | 0,000800                 | 0,033914        | 0,034714        | 56,463          | 196,960        | 253,423        | 0,2173            | 0,6956        | 0,9129        |
| 15                 | 0,7891        | 0,000812                 | 0,029176        | 0,029987        | 62,523          | 192,495        | 255,018        | 0,2382            | 0,6680        | 0,9062        |
| 20                 | 0,9099        | 0,000824                 | 0,025179        | 0,026003        | 68,670          | 187,836        | 256,506        | 0,2590            | 0,6407        | 0,8997        |
| <b>25</b>          | <b>1,0439</b> | <b>0,000838</b>          | <b>0,021787</b> | <b>0,022624</b> | <b>74,910</b>   | <b>182,968</b> | <b>257,877</b> | <b>0,2797</b>     | <b>0,6137</b> | <b>0,8934</b> |
| 30                 | 1,1919        | 0,000852                 | 0,018890        | 0,019742        | 81,250          | 177,869        | 259,119        | 0,3004            | 0,5867        | 0,8871        |
| 35                 | 1,3548        | 0,000867                 | 0,016401        | 0,017269        | 87,700          | 172,516        | 260,216        | 0,3210            | 0,5598        | 0,8809        |
| 40                 | 1,5335        | 0,000884                 | 0,014251        | 0,015135        | 94,272          | 166,877        | 261,149        | 0,3417            | 0,5329        | 0,8746        |
| 45                 | 1,7290        | 0,000902                 | 0,012382        | 0,013284        | 100,982         | 160,914        | 261,896        | 0,3624            | 0,5058        | 0,8682        |
| <b>50</b>          | <b>1,9423</b> | <b>0,000922</b>          | <b>0,010747</b> | <b>0,011669</b> | <b>107,851</b>  | <b>154,576</b> | <b>262,428</b> | <b>0,3832</b>     | <b>0,4783</b> | <b>0,8615</b> |
| 55                 | 2,1744        | 0,000944                 | 0,009308        | 0,010252        | 114,905         | 147,800        | 262,705        | 0,4042            | 0,4504        | 0,8546        |
| 60                 | 2,4266        | 0,000969                 | 0,008032        | 0,009001        | 122,180         | 140,497        | 262,678        | 0,4255            | 0,4217        | 0,8472        |
| 65                 | 2,6999        | 0,000997                 | 0,006890        | 0,007887        | 129,729         | 132,547        | 262,276        | 0,4472            | 0,3920        | 0,8391        |
| 70                 | 2,9959        | 0,001030                 | 0,005859        | 0,006889        | 137,625         | 123,772        | 261,397        | 0,4695            | 0,3607        | 0,8302        |
| <b>75</b>          | <b>3,3161</b> | <b>0,001069</b>          | <b>0,004914</b> | <b>0,005983</b> | <b>145,986</b>  | <b>113,902</b> | <b>259,888</b> | <b>0,4927</b>     | <b>0,3272</b> | <b>0,8198</b> |
| 80                 | 3,6623        | 0,001118                 | 0,004031        | 0,005149        | 155,011         | 102,475        | 257,486        | 0,5173            | 0,2902        | 0,8075        |
| 85                 | 4,0368        | 0,001183                 | 0,003175        | 0,004358        | 165,092         | 88,598         | 253,690        | 0,5445            | 0,2474        | 0,7918        |
| 90                 | 4,4425        | 0,001282                 | 0,002282        | 0,003564        | 177,204         | 70,037         | 247,241        | 0,5767            | 0,1929        | 0,7695        |
| 95                 | 4,8835        | 0,001521                 | 0,001030        | 0,002551        | 196,359         | 34,925         | 231,284        | 0,6273            | 0,0949        | 0,7222        |
| <b>96,006</b>      | <b>4,9773</b> | <b>0,001906</b>          | <b>0</b>        | <b>0,001906</b> | <b>212,546</b>  | <b>0</b>       | <b>212,546</b> | <b>0,6708</b>     | <b>0</b>      | <b>0,6708</b> |



Tabela A.4.2 — Refrigerante-22 superaquecido

| Temp.<br>°C | $v$<br>m <sup>3</sup> /kg | $h$<br>kJ/kg   | $s$<br>kJ/kg K | $v$<br>m <sup>3</sup> /kg | $h$<br>kJ/kg   | $s$<br>kJ/kg K | $v$<br>m <sup>3</sup> /kg | $h$<br>kJ/kg   | $s$<br>kJ/kg K |
|-------------|---------------------------|----------------|----------------|---------------------------|----------------|----------------|---------------------------|----------------|----------------|
| 0,05 MPa    |                           |                | 0,10 MPa       |                           |                | 0,15 MPa       |                           |                |                |
| -40         | 0,440633                  | 234,724        | 1,07616        | 0,216331                  | 233,337        | 1,00523        | —                         | —              | —              |
| -30         | 0,460641                  | 240,602        | 1,10084        | 0,226754                  | 239,359        | 1,03052        | 0,148723                  | 238,078        | 0,98773        |
| -20         | 0,480543                  | 246,586        | 1,12495        | 0,237064                  | 245,466        | 1,05513        | 0,155851                  | 244,319        | 1,01288        |
| -10         | 0,500357                  | 252,676        | 1,14855        | 0,247279                  | 251,665        | 1,07914        | 0,162879                  | 250,631        | 1,03733        |
| 0           | <b>0,520095</b>           | <b>258,874</b> | <b>1,17166</b> | <b>0,257415</b>           | <b>257,956</b> | <b>1,10261</b> | <b>0,169823</b>           | <b>257,022</b> | <b>1,06116</b> |
| 10          | 0,539771                  | 265,180        | 1,19433        | 0,267485                  | 264,345        | 1,12558        | 0,176699                  | 263,496        | 1,08444        |
| 20          | 0,559393                  | 271,594        | 1,21659        | 0,277500                  | 270,831        | 1,14809        | 0,183516                  | 270,057        | 1,10721        |
| 30          | 0,578970                  | 278,115        | 1,23846        | 0,287467                  | 277,416        | 1,17017        | 0,190284                  | 276,709        | 1,12952        |
| 40          | 0,598507                  | 284,743        | 1,25998        | 0,297394                  | 284,101        | 1,19187        | 0,197011                  | 283,452        | 1,15140        |
| 50          | <b>0,618011</b>           | <b>291,478</b> | <b>1,28114</b> | <b>0,307287</b>           | <b>290,887</b> | <b>1,21320</b> | <b>0,203702</b>           | <b>290,289</b> | <b>1,17289</b> |
| 60          | 0,637485                  | 298,319        | 1,30199        | 0,317149                  | 297,772        | 1,23418        | 0,210362                  | 297,220        | 1,19402        |
| 70          | 0,656935                  | 305,265        | 1,32253        | 0,326986                  | 304,757        | 1,25484        | 0,216997                  | 304,246        | 1,21479        |
| 80          | 0,676362                  | 312,314        | 1,34278        | 0,336801                  | 311,842        | 1,27519        | 0,223608                  | 311,368        | 1,23525        |
| 90          | 0,695771                  | 319,465        | 1,36275        | 0,346596                  | 319,026        | 1,29524        | 0,230200                  | 318,584        | 1,25540        |
| 0,20 MPa    |                           |                | 0,25 MPa       |                           |                | 0,30 MPa       |                           |                |                |
| -20         | 0,115203                  | 243,140        | 0,98184        | —                         | —              | —              | —                         | —              | —              |
| -10         | 0,120647                  | 249,574        | 1,00676        | 0,095280                  | 248,492        | 0,98231        | 0,078344                  | 247,382        | 0,96170        |
| 0           | 0,126003                  | 256,069        | 1,03098        | 0,099689                  | 255,097        | 1,00695        | 0,082128                  | 254,104        | 0,98677        |
| 10          | 0,131286                  | 262,633        | 1,05458        | 0,104022                  | 261,755        | 1,03089        | 0,085832                  | 260,861        | 1,01106        |
| 20          | <b>0,136509</b>           | <b>269,273</b> | <b>1,07763</b> | <b>0,108292</b>           | <b>268,476</b> | <b>1,05421</b> | <b>0,089469</b>           | <b>267,667</b> | <b>1,03468</b> |
| 30          | 0,141681                  | 275,992        | 1,10016        | 0,112508                  | 275,267        | 1,07699        | 0,093051                  | 274,531        | 1,05771        |
| 40          | 0,146809                  | 282,796        | 1,12224        | 0,116681                  | 282,132        | 1,09927        | 0,096588                  | 281,460        | 1,08019        |
| 50          | 0,151902                  | 289,686        | 1,14390        | 0,120815                  | 289,076        | 1,12109        | 0,100085                  | 288,460        | 1,10220        |
| 60          | 0,156963                  | 296,664        | 1,16516        | 0,124918                  | 296,102        | 1,14250        | 0,103550                  | 295,535        | 1,12376        |
| 70          | <b>0,161991</b>           | <b>303,731</b> | <b>1,18607</b> | <b>0,128993</b>           | <b>303,212</b> | <b>1,16353</b> | <b>0,106986</b>           | <b>302,689</b> | <b>1,14491</b> |
| 80          | 0,167008                  | 310,890        | 1,20663        | 0,133044                  | 310,409        | 1,18420        | 0,110399                  | 309,924        | 1,16569        |
| 90          | 0,171999                  | 318,139        | 1,22687        | 0,137075                  | 317,692        | 1,20454        | 0,113790                  | 317,241        | 1,18612        |
| 100         | 0,176972                  | 325,480        | 1,24681        | 0,141089                  | 325,063        | 1,22456        | 0,117164                  | 324,643        | 1,20623        |
| 110         | 0,181931                  | 332,912        | 1,26646        | 0,145086                  | 332,522        | 1,24428        | 0,120522                  | 332,129        | 1,22603        |
| 0,40 MPa    |                           |                | 0,50 MPa       |                           |                | 0,60 MPa       |                           |                |                |
| 0           | 0,060131                  | 252,051        | 0,95359        | —                         | —              | —              | —                         | —              | —              |
| 10          | 0,063060                  | 259,023        | 0,97866        | 0,049355                  | 257,108        | 0,95223        | 0,040180                  | 255,109        | 0,92945        |
| 20          | 0,065915                  | 266,010        | 1,00291        | 0,051751                  | 264,295        | 0,97717        | 0,042280                  | 262,517        | 0,95517        |
| 30          | 0,068710                  | 273,029        | 1,02646        | 0,054081                  | 271,483        | 1,00128        | 0,044307                  | 269,888        | 0,97989        |
| 40          | <b>0,071455</b>           | <b>280,092</b> | <b>1,04938</b> | <b>0,056358</b>           | <b>278,690</b> | <b>1,02467</b> | <b>0,046276</b>           | <b>277,250</b> | <b>1,00378</b> |
| 50          | 0,074160                  | 287,209        | 1,07175        | 0,058590                  | 285,930        | 1,04743        | 0,048198                  | 284,622        | 1,02695        |
| 60          | 0,076830                  | 294,386        | 1,09362        | 0,060786                  | 293,215        | 1,06963        | 0,050081                  | 292,020        | 1,04950        |
| 70          | 0,079470                  | 301,630        | 1,11504        | 0,062951                  | 300,552        | 1,09133        | 0,051931                  | 299,456        | 1,07149        |
| 80          | 0,082085                  | 308,944        | 1,13605        | 0,065090                  | 307,949        | 1,11257        | 0,053754                  | 306,938        | 1,09298        |
| 90          | <b>0,084679</b>           | <b>316,332</b> | <b>1,15668</b> | <b>0,067206</b>           | <b>315,410</b> | <b>1,13340</b> | <b>0,055553</b>           | <b>314,475</b> | <b>1,11403</b> |
| 100         | 0,087254                  | 323,796        | 1,17695        | 0,069303                  | 322,939        | 1,15386        | 0,057332                  | 322,071        | 1,13466        |
| 110         | 0,089813                  | 331,339        | 1,19690        | 0,071384                  | 330,539        | 1,17395        | 0,059094                  | 329,731        | 1,15492        |
| 120         | 0,092358                  | 338,961        | 1,21654        | 0,073450                  | 338,213        | 1,19373        | 0,060842                  | 337,458        | 1,17482        |
| 130         | 0,094890                  | 346,664        | 1,23588        | 0,075503                  | 345,963        | 1,21319        | 0,062576                  | 345,255        | 1,19441        |
| 0,70 MPa    |                           |                | 0,80 MPa       |                           |                | 0,90 MPa       |                           |                |                |
| 20          | 0,035487                  | 260,667        | 0,93565        | 0,030366                  | 258,737        | 0,91787        | 0,026355                  | 256,713        | 0,90132        |
| 30          | 0,037305                  | 268,240        | 0,96105        | 0,032034                  | 266,533        | 0,94402        | 0,027915                  | 264,760        | 0,92831        |
| 40          | 0,039059                  | 275,769        | 0,98549        | 0,033632                  | 274,243        | 0,96905        | 0,029397                  | 272,670        | 0,95398        |
| 50          | 0,040763                  | 283,282        | 1,00910        | 0,035175                  | 281,907        | 0,99314        | 0,030819                  | 280,497        | 0,97859        |
| 60          | <b>0,042424</b>           | <b>290,800</b> | <b>1,03201</b> | <b>0,036674</b>           | <b>289,553</b> | <b>1,01644</b> | <b>0,032193</b>           | <b>288,278</b> | <b>1,00230</b> |
| 70          | 0,044052                  | 298,339        | 1,05431        | 0,038136                  | 297,202        | 1,03906        | 0,033528                  | 296,042        | 1,02526        |
| 80          | 0,045650                  | 305,912        | 1,07606        | 0,039568                  | 304,868        | 1,06108        | 0,034832                  | 303,807        | 1,04757        |
| 90          | 0,047224                  | 313,527        | 1,09732        | 0,040974                  | 312,565        | 1,08257        | 0,036108                  | 311,590        | 1,06930        |
| 100         | 0,048778                  | 321,192        | 1,11815        | 0,042359                  | 320,303        | 1,10359        | 0,037363                  | 319,401        | 1,09052        |

**Tabela A.4.2 (Continuação) — Refrigerante-22 superaquecido**

| Temp.<br>°C | $v$<br>m³/kg | $h$<br>kJ/kg | $s$<br>kJ/kg K | $v$<br>m³/kg | $h$<br>kJ/kg | $s$<br>kJ/kg K | $v$<br>m³/kg | $h$<br>kJ/kg | $s$<br>kJ/kg K |
|-------------|--------------|--------------|----------------|--------------|--------------|----------------|--------------|--------------|----------------|
| 0,70 MPa    |              |              | 0,80 MPa       |              |              | 0,90 MPa       |              |              |                |
| 110         | 0,050313     | 328,914      | 1,13856        | 0,043725     | 328,087      | 1,12417        | 0,038598     | 327,251      | 1,11128        |
| 120         | 0,051834     | 336,696      | 1,15861        | 0,045076     | 335,925      | 1,14437        | 0,039817     | 335,147      | 1,13162        |
| 130         | 0,053341     | 344,541      | 1,17832        | 0,046413     | 343,821      | 1,16420        | 0,041022     | 343,094      | 1,15158        |
| 140         | 0,054836     | 352,454      | 1,19770        | 0,047738     | 351,778      | 1,18369        | 0,042215     | 351,097      | 1,17119        |
| 150         | 0,056321     | 360,435      | 1,21679        | 0,049052     | 359,799      | 1,20288        | 0,043398     | 359,159      | 1,19047        |
| 1,00 MPa    |              |              | 1,20 MPa       |              |              | 1,40 MPa       |              |              |                |
| 30          | 0,024600     | 262,912      | 0,91358        | —            | —            | —              | —            | —            | —              |
| 40          | 0,025995     | 271,042      | 0,93996        | 0,020851     | 267,602      | 0,91411        | 0,017120     | 263,861      | 0,89010        |
| 50          | 0,027323     | 279,046      | 0,96512        | 0,022051     | 276,011      | 0,94055        | 0,018247     | 272,766      | 0,91809        |
| 60          | 0,028601     | 286,973      | 0,98928        | 0,023191     | 284,263      | 0,96570        | 0,019299     | 281,401      | 0,94441        |
| 70          | 0,029836     | 294,859      | 1,01260        | 0,024282     | 292,415      | 0,98981        | 0,020295     | 289,858      | 0,96942        |
| 80          | 0,031038     | 302,727      | 1,03520        | 0,025336     | 300,508      | 1,01305        | 0,021248     | 298,202      | 0,99339        |
| 90          | 0,032213     | 310,599      | 1,05718        | 0,026359     | 308,570      | 1,03556        | 0,022167     | 306,473      | 1,01649        |
| 100         | 0,033364     | 318,488      | 1,07861        | 0,027357     | 316,623      | 1,05744        | 0,023058     | 314,703      | 1,03884        |
| 110         | 0,034495     | 326,405      | 1,09955        | 0,028334     | 324,682      | 1,07875        | 0,023926     | 322,916      | 1,06056        |
| 120         | 0,035609     | 334,360      | 1,12004        | 0,029292     | 332,762      | 1,09957        | 0,024775     | 331,128      | 1,08172        |
| 130         | 0,036709     | 342,360      | 1,14014        | 0,030236     | 340,871      | 1,11994        | 0,025608     | 339,354      | 1,10238        |
| 140         | 0,037797     | 350,410      | 1,15986        | 0,031166     | 349,019      | 1,13990        | 0,026426     | 347,603      | 1,12259        |
| 150         | 0,038873     | 358,514      | 1,17924        | 0,032084     | 357,210      | 1,15949        | 0,027233     | 355,885      | 1,14240        |
| 160         | 0,039940     | 366,677      | 1,19831        | 0,032993     | 365,450      | 1,17873        | 0,028029     | 364,206      | 1,16183        |
| 1,60 MPa    |              |              | 1,80 MPa       |              |              | 2,00 MPa       |              |              |                |
| 50          | 0,015351     | 269,262      | 0,89689        | 0,013052     | 265,423      | 0,87625        | —            | —            | —              |
| 60          | 0,016351     | 278,358      | 0,92461        | 0,014028     | 275,097      | 0,90573        | 0,012135     | 271,563      | 0,88729        |
| 70          | 0,017284     | 287,171      | 0,95068        | 0,014921     | 284,331      | 0,93304        | 0,013008     | 281,310      | 0,91612        |
| 80          | 0,018167     | 295,797      | 0,97546        | 0,015755     | 293,282      | 0,95876        | 0,013811     | 290,640      | 0,94292        |
| 90          | 0,019011     | 304,301      | 0,99920        | 0,016546     | 302,046      | 0,98323        | 0,014563     | 299,697      | 0,96821        |
| 100         | 0,019825     | 312,725      | 1,02209        | 0,017303     | 310,683      | 1,00669        | 0,015277     | 308,571      | 0,99232        |
| 110         | 0,020614     | 321,103      | 1,04424        | 0,018032     | 319,239      | 1,02932        | 0,015960     | 317,322      | 1,01546        |
| 120         | 0,021382     | 329,457      | 1,06576        | 0,018738     | 327,745      | 1,05123        | 0,016619     | 325,991      | 1,03780        |
| 130         | 0,022133     | 337,805      | 1,08673        | 0,019427     | 336,224      | 1,07253        | 0,017258     | 334,610      | 1,05944        |
| 140         | 0,022869     | 346,162      | 1,10721        | 0,020099     | 344,695      | 1,09329        | 0,017881     | 343,201      | 1,08049        |
| 150         | 0,023592     | 354,540      | 1,12724        | 0,020759     | 353,172      | 1,11356        | 0,018490     | 351,783      | 1,10102        |
| 160         | 0,024305     | 362,945      | 1,14688        | 0,021407     | 361,666      | 1,13340        | 0,019087     | 360,369      | 1,12107        |
| 170         | 0,025008     | 371,386      | 1,16614        | 0,022045     | 370,186      | 1,15284        | 0,019673     | 368,970      | 1,14070        |
| 180         | 0,025703     | 379,869      | 1,18507        | 0,022675     | 378,738      | 1,17193        | 0,020251     | 377,595      | 1,15995        |
| 2,50 MPa    |              |              | 3,00 MPa       |              |              | 3,50 MPa       |              |              |                |
| 70          | 0,009459     | 272,677      | 0,87476        | —            | —            | —              | —            | —            | —              |
| 80          | 0,010243     | 283,332      | 0,90537        | 0,007747     | 274,530      | 0,86780        | 0,005765     | 262,739      | 0,82489        |
| 90          | 0,010948     | 293,338      | 0,93332        | 0,008465     | 286,042      | 0,89995        | 0,006597     | 277,268      | 0,86548        |
| 100         | 0,011598     | 302,935      | 0,95939        | 0,009098     | 296,663      | 0,92881        | 0,007257     | 289,504      | 0,89872        |
| 110         | 0,012208     | 312,261      | 0,98405        | 0,009674     | 306,744      | 0,95547        | 0,007829     | 300,640      | 0,92818        |
| 120         | 0,012788     | 321,400      | 1,00760        | 0,010211     | 316,470      | 0,98053        | 0,008346     | 311,129      | 0,95520        |
| 130         | 0,013343     | 330,412      | 1,03023        | 0,010717     | 325,955      | 1,00435        | 0,008825     | 321,196      | 0,98049        |
| 140         | 0,013880     | 339,336      | 1,05210        | 0,011200     | 335,270      | 1,02718        | 0,009276     | 330,976      | 1,00445        |
| 150         | 0,014400     | 348,205      | 1,07331        | 0,011665     | 344,467      | 1,04918        | 0,009704     | 340,554      | 1,02736        |
| 160         | 0,014907     | 357,040      | 1,09395        | 0,012114     | 353,584      | 1,07047        | 0,010114     | 349,989      | 1,04940        |
| 170         | 0,015402     | 365,860      | 1,11408        | 0,012550     | 362,647      | 1,09116        | 0,010510     | 359,324      | 1,07071        |
| 180         | 0,015887     | 374,679      | 1,13376        | 0,012976     | 371,679      | 1,11131        | 0,010894     | 368,590      | 1,09138        |
| 190         | 0,016364     | 383,508      | 1,15303        | 0,013392     | 380,695      | 1,13099        | 0,011268     | 377,810      | 1,11151        |
| 200         | 0,016834     | 392,354      | 1,17192        | 0,013801     | 389,708      | 1,15024        | 0,011634     | 387,004      | 1,13115        |
| 4,00 MPa    |              |              | 5,00 MPa       |              |              | 6,00 MPa       |              |              |                |
| 90          | 0,005037     | 265,629      | 0,82544        | —            | —            | —              | —            | —            | —              |
| 100         | 0,005804     | 280,997      | 0,86721        | 0,003334     | 253,042      | 0,78005        | —            | —            | —              |
| 110         | 0,006405     | 293,748      | 0,90094        | 0,004255     | 275,919      | 0,84064        | 0,002432     | 243,278      | 0,74674        |
| 120         | 0,006924     | 305,273      | 0,93064        | 0,004851     | 291,362      | 0,88045        | 0,003333     | 272,385      | 0,82185        |
| 130         | 0,007391     | 316,080      | 0,95778        | 0,005335     | 304,469      | 0,91337        | 0,003899     | 290,253      | 0,86675        |

Tabela A.4.2 (Continuação) — Refrigerante-22 superaquecido

| Temp.<br>°C | $v$<br>m³/kg | $h$<br>kJ/kg | $s$<br>kJ/kg K | $v$<br>m³/kg | $h$<br>kJ/kg | $s$<br>kJ/kg K | $v$<br>m³/kg | $h$<br>kJ/kg | $s$<br>kJ/kg K |
|-------------|--------------|--------------|----------------|--------------|--------------|----------------|--------------|--------------|----------------|
| 4,00 MPa    |              |              |                | 5,00 MPa     |              |                | 6,00 MPa     |              |                |
| 140         | 0,007822     | 326,422      | 0,98312        | 0,005757     | 316,379      | 0,94256        | 0,004345     | 304,757      | 0,90230        |
| 150         | 0,008226     | 336,446      | 1,00710        | 0,006139     | 327,563      | 0,96931        | 0,004728     | 317,633      | 0,93310        |
| 160         | 0,008610     | 346,246      | 1,02999        | 0,006493     | 338,266      | 0,99431        | 0,005071     | 329,553      | 0,96094        |
| 170         | 0,008978     | 355,885      | 1,05199        | 0,006826     | 348,633      | 1,01797        | 0,005386     | 340,849      | 0,98673        |
| 180         | 0,009332     | 365,409      | 1,07324        | 0,007142     | 358,760      | 1,04057        | 0,005680     | 351,715      | 1,01098        |
| 190         | 0,009675     | 374,853      | 1,09386        | 0,007444     | 368,713      | 1,06230        | 0,005958     | 362,271      | 1,03402        |
| 200         | 0,010009     | 384,240      | 1,11391        | 0,007735     | 378,537      | 1,08328        | 0,006222     | 372,602      | 1,05609        |
| 210         | 0,010335     | 393,593      | 1,13347        | 0,008018     | 388,268      | 1,10363        | 0,006477     | 382,764      | 1,07734        |
| 220         | 0,010654     | 402,925      | 1,15259        | 0,008292     | 397,932      | 1,12343        | 0,006722     | 392,801      | 1,09790        |

Tabela A.5 — Propriedades termodinâmicas do refrigerante-134a (1,1,1,2 - Tetrafluormetano)

Tabela A.5.1 — R-134a saturado

| Temp.<br>°C<br>$T$ | Pressão            | Volume específico, m³/kg |                   |                        | Entalpia, kJ/kg          |                   |                        | Entropia, kJ/kg K        |                   |                        |
|--------------------|--------------------|--------------------------|-------------------|------------------------|--------------------------|-------------------|------------------------|--------------------------|-------------------|------------------------|
|                    | Abs.<br>MPa<br>$p$ | Líquido<br>sat.<br>$v_f$ | Evap.<br>$v_{fg}$ | Vapor<br>sat.<br>$v_g$ | Líquido<br>sat.<br>$h_f$ | Evap.<br>$h_{fg}$ | Vapor<br>sat.<br>$h_g$ | Líquido<br>sat.<br>$s_f$ | Evap.<br>$s_{fg}$ | Vapor<br>sat.<br>$s_g$ |
|                    |                    |                          |                   |                        |                          |                   |                        |                          |                   |                        |
| -33                | 0,0737             | 0,000718                 | 0,25574           | 0,25646                | 157,417                  | 220,491           | 377,908                | 0,8346                   | 0,9181            | 1,7528                 |
| -30                | 0,0851             | 0,000722                 | 0,22330           | 0,22402                | 161,118                  | 218,683           | 379,802                | 0,8499                   | 0,8994            | 1,7493                 |
| -26,25             | 0,1013             | 0,000728                 | 0,18947           | 0,19020                | 165,802                  | 216,360           | 382,162                | 0,8690                   | 0,8763            | 1,7453                 |
| -25                | 0,1073             | 0,000730                 | 0,17956           | 0,18029                | 167,381                  | 215,569           | 382,950                | 0,8754                   | 0,8687            | 1,7441                 |
| -20                | <b>0,1337</b>      | <b>0,000738</b>          | <b>0,14575</b>    | <b>0,14649</b>         | <b>173,744</b>           | <b>212,340</b>    | <b>386,083</b>         | <b>0,9007</b>            | <b>0,8388</b>     | <b>1,7395</b>          |
| -15                | 0,1650             | 0,000746                 | 0,11932           | 0,12007                | 180,193                  | 209,004           | 389,197                | 0,9258                   | 0,8096            | 1,7354                 |
| -10                | 0,2017             | 0,000755                 | 0,098454          | 0,099209               | 186,721                  | 205,564           | 392,285                | 0,9507                   | 0,7812            | 1,7319                 |
| -5                 | 0,2445             | 0,000764                 | 0,081812          | 0,082576               | 193,324                  | 202,016           | 395,340                | 0,9755                   | 0,7534            | 1,7288                 |
| 0                  | 0,2940             | 0,000773                 | 0,068420          | 0,069193               | 200,000                  | 198,356           | 398,356                | 1,0000                   | 0,7262            | 1,7262                 |
| 5                  | <b>0,3509</b>      | <b>0,000783</b>          | <b>0,057551</b>   | <b>0,058334</b>        | <b>206,751</b>           | <b>194,572</b>    | <b>401,323</b>         | <b>1,0243</b>            | <b>0,6995</b>     | <b>1,7239</b>          |
| 10                 | 0,4158             | 0,000794                 | 0,048658          | 0,049451               | 213,580                  | 190,652           | 404,233                | 1,0485                   | 0,6733            | 1,7218                 |
| 15                 | 0,4895             | 0,000805                 | 0,041326          | 0,042131               | 220,492                  | 186,582           | 407,075                | 1,0725                   | 0,6475            | 1,7200                 |
| 20                 | 0,5728             | 0,000817                 | 0,035238          | 0,036055               | 227,493                  | 182,345           | 409,838                | 1,0963                   | 0,6220            | 1,7183                 |
| 25                 | 0,6663             | 0,000829                 | 0,030148          | 0,030977               | 234,590                  | 177,920           | 412,509                | 1,1201                   | 0,5967            | 1,7168                 |
| <b>30</b>          | <b>0,7710</b>      | <b>0,000843</b>          | <b>0,025865</b>   | <b>0,026707</b>        | <b>241,790</b>           | <b>173,285</b>    | <b>415,075</b>         | <b>1,1437</b>            | <b>0,5716</b>     | <b>1,7153</b>          |
| 35                 | 0,8876             | 0,000857                 | 0,022237          | 0,023094               | 249,103                  | 168,415           | 417,518                | 1,1673                   | 0,5465            | 1,7139                 |
| 40                 | 1,0171             | 0,000873                 | 0,019147          | 0,020020               | 256,539                  | 163,282           | 419,821                | 1,1909                   | 0,5214            | 1,7123                 |
| 45                 | 1,1602             | 0,000890                 | 0,016499          | 0,017389               | 264,110                  | 157,852           | 421,962                | 1,2145                   | 0,4962            | 1,7106                 |
| 50                 | 1,3180             | 0,000908                 | 0,014217          | 0,015124               | 271,830                  | 152,085           | 423,915                | 1,2381                   | 0,4706            | 1,7088                 |
| <b>55</b>          | <b>1,4915</b>      | <b>0,000928</b>          | <b>0,012237</b>   | <b>0,013166</b>        | <b>279,718</b>           | <b>145,933</b>    | <b>425,650</b>         | <b>1,2619</b>            | <b>0,4447</b>     | <b>1,7066</b>          |
| 60                 | 1,6818             | 0,000951                 | 0,010511          | 0,011462               | 287,794                  | 139,336           | 427,130                | 1,2857                   | 0,4182            | 1,7040                 |
| 65                 | 1,8898             | 0,000976                 | 0,008995          | 0,009970               | 296,088                  | 132,216           | 428,305                | 1,3099                   | 0,3910            | 1,7009                 |
| 70                 | 2,1169             | 0,001005                 | 0,007653          | 0,008657               | 304,642                  | 124,468           | 429,110                | 1,3343                   | 0,3627            | 1,6970                 |
| 75                 | 2,3644             | 0,001038                 | 0,006453          | 0,007491               | 313,513                  | 115,939           | 429,451                | 1,3592                   | 0,3330            | 1,6923                 |
| <b>80</b>          | <b>2,6337</b>      | <b>0,001078</b>          | <b>0,005368</b>   | <b>0,006446</b>        | <b>322,794</b>           | <b>106,395</b>    | <b>429,189</b>         | <b>1,3849</b>            | <b>0,3013</b>     | <b>1,6862</b>          |
| 85                 | 2,9265             | 0,001128                 | 0,004367          | 0,005495               | 332,644                  | 95,440            | 428,084                | 1,4117                   | 0,2665            | 1,6782                 |
| 90                 | 3,2448             | 0,001195                 | 0,003412          | 0,004606               | 343,380                  | 82,295            | 425,676                | 1,4404                   | 0,2266            | 1,6670                 |
| 95                 | 3,5914             | 0,001297                 | 0,002432          | 0,003729               | 355,834                  | 64,984            | 420,818                | 1,4733                   | 0,1765            | 1,6498                 |
| 101,15             | 4,0640             | 0,001969                 | 0                 | 0,001969               | 390,977                  | 0                 | 390,977                | 1,5658                   | 0                 | 1,5658                 |

Tabela A.5.2 — Refrigerante-134a superaquecido

| Temp.<br>°C | $v$<br>m <sup>3</sup> /kg | $h$<br>kJ/kg | $s$<br>kJ/kg K | $v$<br>m <sup>3</sup> /kg | $h$<br>kJ/kg | $s$<br>kJ/kg K | $v$<br>m <sup>3</sup> /kg | $h$<br>kJ/kg | $s$<br>kJ/kg K |
|-------------|---------------------------|--------------|----------------|---------------------------|--------------|----------------|---------------------------|--------------|----------------|
| 0,10 MPa    |                           |              |                | 0,15 MPa                  |              |                | 0,20 MPa                  |              |                |
| -25         | 0,19400                   | 383,212      | 1,75058        | —                         | —            | —              | —                         | —            | —              |
| -20         | 0,19860                   | 387,215      | 1,76655        | —                         | —            | —              | —                         | —            | —              |
| -10         | 0,20765                   | 395,270      | 1,79775        | 0,13603                   | 393,839      | 1,76058        | 0,10013                   | 392,338      | 1,73276        |
| 0           | 0,21652                   | 403,413      | 1,82813        | 0,14222                   | 402,187      | 1,79171        | 0,10501                   | 400,911      | 1,76474        |
| 10          | 0,22527                   | 411,668      | 1,85780        | 0,14828                   | 410,602      | 1,82197        | 0,10974                   | 409,500      | 1,79562        |
| 20          | 0,23393                   | 420,048      | 1,88689        | 0,15424                   | 419,111      | 1,85150        | 0,11436                   | 418,145      | 1,82563        |
| 30          | 0,24250                   | 428,564      | 1,91545        | 0,16011                   | 427,730      | 1,88041        | 0,11889                   | 426,875      | 1,85491        |
| 40          | 0,25102                   | 437,223      | 1,94355        | 0,16592                   | 436,473      | 1,90879        | 0,12335                   | 435,708      | 1,88357        |
| 50          | 0,25948                   | 446,029      | 1,97123        | 0,17168                   | 445,350      | 1,93669        | 0,12776                   | 444,658      | 1,91171        |
| 60          | 0,26791                   | 454,986      | 1,99853        | 0,17740                   | 454,366      | 1,96416        | 0,13213                   | 453,735      | 1,93937        |
| 70          | 0,27631                   | 464,096      | 2,02547        | 0,18308                   | 463,525      | 1,99125        | 0,13646                   | 462,946      | 1,96661        |
| 80          | 0,28468                   | 473,359      | 2,05208        | 0,18874                   | 472,831      | 2,01798        | 0,14076                   | 472,296      | 1,99346        |
| 90          | 0,29303                   | 482,777      | 2,07837        | 0,19437                   | 482,285      | 2,04438        | 0,14504                   | 481,788      | 2,01997        |
| 100         | 0,30136                   | 492,349      | 2,10437        | 0,19999                   | 491,888      | 2,07046        | 0,14930                   | 491,424      | 2,04614        |
| 0,25 MPa    |                           |              |                | 0,30 MPa                  |              |                | 0,40 MPa                  |              |                |
| 0           | 0,082637                  | 399,579      | 1,74284        | —                         | —            | —              | —                         | —            | —              |
| 10          | 0,086584                  | 408,357      | 1,77440        | 0,071110                  | 407,171      | 1,75637        | 0,051681                  | 404,651      | 1,72611        |
| 20          | 0,090408                  | 417,151      | 1,80492        | 0,074415                  | 416,124      | 1,78744        | 0,054362                  | 413,965      | 1,75844        |
| 30          | 0,094139                  | 425,997      | 1,83460        | 0,077620                  | 425,096      | 1,81754        | 0,056926                  | 423,216      | 1,78947        |
| 40          | 0,097798                  | 434,925      | 1,86357        | 0,080748                  | 434,124      | 1,84684        | 0,059402                  | 432,465      | 1,81949        |
| 50          | 0,101401                  | 443,953      | 1,89195        | 0,083816                  | 443,234      | 1,87547        | 0,061812                  | 441,751      | 1,84868        |
| 60          | 0,104958                  | 453,094      | 1,91980        | 0,086838                  | 452,442      | 1,90354        | 0,064169                  | 451,104      | 1,87718        |
| 70          | 0,108480                  | 462,359      | 1,94720        | 0,089821                  | 461,763      | 1,93110        | 0,066484                  | 460,545      | 1,90510        |
| 80          | 0,111972                  | 471,754      | 1,97419        | 0,092774                  | 471,206      | 1,95823        | 0,068767                  | 470,088      | 1,93252        |
| 90          | 0,115440                  | 481,285      | 2,00080        | 0,095702                  | 480,777      | 1,98495        | 0,071022                  | 479,745      | 1,95948        |
| 100         | 0,118888                  | 490,955      | 2,02707        | 0,098609                  | 490,482      | 2,01131        | 0,073254                  | 489,523      | 1,98604        |
| 110         | 0,122318                  | 500,766      | 2,05302        | 0,101498                  | 500,324      | 2,03734        | 0,075468                  | 499,428      | 2,01223        |
| 120         | 0,125734                  | 510,720      | 2,07866        | 0,104371                  | 510,304      | 2,06305        | 0,077665                  | 509,464      | 2,03809        |
| 0,50 MPa    |                           |              |                | 0,60 MPa                  |              |                | 0,70 MPa                  |              |                |
| 20          | 0,042256                  | 411,645      | 1,73420        | —                         | —            | —              | —                         | —            | —              |
| 30          | 0,044457                  | 421,221      | 1,76632        | 0,036094                  | 419,093      | 1,74610        | 0,030069                  | 416,809      | 1,72770        |
| 40          | 0,046557                  | 430,720      | 1,79715        | 0,037958                  | 428,881      | 1,77786        | 0,031781                  | 426,933      | 1,76056        |
| 50          | 0,048581                  | 440,205      | 1,82696        | 0,039735                  | 438,589      | 1,80838        | 0,033392                  | 436,895      | 1,79187        |
| 60          | 0,050547                  | 449,718      | 1,85596        | 0,041447                  | 448,279      | 1,83791        | 0,034929                  | 446,782      | 1,82201        |
| 70          | 0,052467                  | 459,290      | 1,88426        | 0,043108                  | 457,994      | 1,86664        | 0,036410                  | 456,655      | 1,85121        |
| 80          | 0,054351                  | 468,942      | 1,91199        | 0,044730                  | 467,764      | 1,89471        | 0,037848                  | 466,554      | 1,87964        |
| 90          | 0,056205                  | 478,690      | 1,93921        | 0,046319                  | 477,611      | 1,92220        | 0,039251                  | 476,507      | 1,90743        |
| 100         | 0,058035                  | 488,546      | 1,96598        | 0,047883                  | 487,550      | 1,94920        | 0,040627                  | 486,535      | 1,93467        |
| 110         | 0,059845                  | 498,518      | 1,99235        | 0,049426                  | 497,594      | 1,97576        | 0,041980                  | 496,654      | 1,96143        |
| 120         | 0,061639                  | 508,613      | 2,01836        | 0,050951                  | 507,750      | 2,00193        | 0,043314                  | 506,875      | 1,98777        |
| 130         | 0,063418                  | 518,835      | 2,04403        | 0,052461                  | 518,026      | 2,02774        | 0,044633                  | 517,207      | 2,01372        |
| 140         | 0,065184                  | 529,187      | 2,06940        | 0,053958                  | 528,425      | 2,05322        | 0,045938                  | 527,656      | 2,03932        |
| 0,80 MPa    |                           |              |                | 0,90 MPa                  |              |                | 1,00 MPa                  |              |                |
| 40          | 0,027113                  | 424,860      | 1,74457        | 0,023446                  | 422,642      | 1,72943        | 0,020473                  | 420,249      | 1,71479        |
| 50          | 0,028611                  | 435,114      | 1,77680        | 0,024868                  | 433,235      | 1,76273        | 0,021849                  | 431,243      | 1,74936        |
| 60          | 0,030024                  | 445,223      | 1,80761        | 0,026192                  | 443,595      | 1,79431        | 0,023110                  | 441,890      | 1,78181        |
| 70          | 0,031375                  | 455,270      | 1,83732        | 0,027447                  | 453,835      | 1,82459        | 0,024293                  | 452,345      | 1,81273        |
| 80          | 0,032678                  | 465,308      | 1,86616        | 0,028649                  | 464,025      | 1,85387        | 0,025417                  | 462,703      | 1,84248        |
| 90          | 0,033944                  | 475,375      | 1,89427        | 0,029810                  | 474,216      | 1,88232        | 0,026497                  | 473,027      | 1,87131        |
| 100         | 0,035180                  | 485,499      | 1,92177        | 0,030940                  | 484,441      | 1,91010        | 0,027543                  | 483,361      | 1,89938        |
| 110         | 0,036392                  | 495,698      | 1,94874        | 0,032043                  | 494,726      | 1,93730        | 0,028561                  | 493,736      | 1,92682        |
| 120         | 0,037584                  | 505,988      | 1,97525        | 0,033126                  | 505,088      | 1,96399        | 0,029556                  | 504,175      | 1,95371        |
| 130         | 0,038760                  | 516,379      | 2,00135        | 0,034190                  | 515,542      | 1,99025        | 0,030533                  | 514,694      | 1,98013        |
| 140         | 0,039921                  | 526,880      | 2,02708        | 0,035241                  | 526,096      | 2,01611        | 0,031495                  | 525,305      | 2,00613        |
| 150         | 0,041071                  | 537,496      | 2,05247        | 0,036278                  | 536,760      | 2,04161        | 0,032444                  | 536,017      | 2,03175        |

Tabela A.5.2 (Continuação) — Refrigerante-134a superaquecido

| Temp.<br>°C | $v$<br>m <sup>3</sup> /kg | $h$<br>kJ/kg   | $s$<br>kJ/kg K | $v$<br>m <sup>3</sup> /kg | $h$<br>kJ/kg   | $s$<br>kJ/kg K | $v$<br>m <sup>3</sup> /kg | $h$<br>kJ/kg   | $s$<br>kJ/kg K |
|-------------|---------------------------|----------------|----------------|---------------------------|----------------|----------------|---------------------------|----------------|----------------|
| 1,20 MPa    |                           |                | 1,40 MPa       |                           |                | 1,60 MPa       |                           |                |                |
| 50          | 0.017243                  | 426.845        | 1.72373        | —                         | —              | —              | —                         | —              | —              |
| 60          | 0.018439                  | 438.210        | 1.75837        | 0.015032                  | 434.079        | 1.73597        | 0.012392                  | 429.322        | 1.71349        |
| 70          | 0.019530                  | 449.179        | 1.79081        | 0.016083                  | 445.720        | 1.77040        | 0.013449                  | 441.888        | 1.75066        |
| 80          | 0.020548                  | 459.925        | 1.82168        | 0.017040                  | 456.944        | 1.80265        | 0.014378                  | 453.722        | 1.78466        |
| <b>90</b>   | <b>0.021512</b>           | <b>470,551</b> | <b>1,85135</b> | <b>0.017931</b>           | <b>467,931</b> | <b>1,83333</b> | <b>0.015225</b>           | <b>465,145</b> | <b>1,81656</b> |
| 100         | 0.022436                  | 481.128        | 1.88009        | 0.018775                  | 478.790        | 1.86282        | 0.016015                  | 476.333        | 1.84695        |
| 110         | 0.023329                  | 491.702        | 1.90805        | 0.019583                  | 489.589        | 1.89139        | 0.016763                  | 487.390        | 1.87619        |
| 120         | 0.024197                  | 502.307        | 1.93537        | 0.020362                  | 500.379        | 1.91918        | 0.017479                  | 498.387        | 1.90452        |
| 130         | 0.025044                  | 512.965        | 1.96214        | 0.021118                  | 511.192        | 1.94634        | 0.018169                  | 509.371        | 1.93211        |
| <b>140</b>  | <b>0.025874</b>           | <b>523,697</b> | <b>1,98844</b> | <b>0.021856</b>           | <b>522,054</b> | <b>1,97296</b> | <b>0.018840</b>           | <b>520,376</b> | <b>1,95908</b> |
| 150         | 0.026691                  | 534.514        | 2.01431        | 0.022579                  | 532.984        | 1.99910        | 0.019493                  | 531.427        | 1.98551        |
| 160         | 0.027495                  | 545.426        | 2.03980        | 0.023289                  | 543.994        | 2.02481        | 0.020133                  | 542.542        | 2.01147        |
| 170         | 0.028289                  | 556.443        | 2.06494        | 0.023988                  | 555.097        | 2.05015        | 0.020761                  | 553.735        | 2.03702        |
| 1,80 MPa    |                           |                | 2,00 MPa       |                           |                | 2,50 MPa       |                           |                |                |
| 70          | 0.011341                  | 437.562        | 1.73085        | 0.009581                  | 432.531        | 1.71011        | —                         | —              | —              |
| 80          | 0.012273                  | 450.202        | 1.76717        | 0.010550                  | 446.304        | 1.74968        | 0.007221                  | 433.797        | 1.70180        |
| 90          | 0.013099                  | 462.164        | 1.80057        | 0.011374                  | 458.951        | 1.78500        | 0.008157                  | 449.499        | 1.74567        |
| 100         | 0.013854                  | 473.741        | 1.83202        | 0.012111                  | 470.996        | 1.81772        | 0.008907                  | 463.279        | 1.78311        |
| <b>110</b>  | <b>0.014560</b>           | <b>485,095</b> | <b>1.86205</b> | <b>0.012789</b>           | <b>482,693</b> | <b>1,84866</b> | <b>0.009558</b>           | <b>476,129</b> | <b>1,81709</b> |
| 120         | 0.015230                  | 496.325        | 1.89098        | 0.013424                  | 494.187        | 1.87827        | 0.010148                  | 488.457        | 1.84886        |
| 130         | 0.015871                  | 507.498        | 1.91905        | 0.014028                  | 505.569        | 1.90686        | 0.010694                  | 500.474        | 1.87904        |
| 140         | 0.016490                  | 518.659        | 1.94639        | 0.014608                  | 516.900        | 1.93463        | 0.011208                  | 512.307        | 1.90804        |
| 150         | 0.017091                  | 529.841        | 1.97314        | 0.015168                  | 528.224        | 1.96171        | 0.011698                  | 524.037        | 1.93609        |
| <b>160</b>  | <b>0.017677</b>           | <b>541,068</b> | <b>1,99936</b> | <b>0.015712</b>           | <b>539,571</b> | <b>1,98821</b> | <b>0.012169</b>           | <b>535,722</b> | <b>1,96338</b> |
| 170         | 0.018251                  | 552.357        | 2.02513        | 0.016242                  | 550.963        | 2.01421        | 0.012624                  | 547.399        | 1.99004        |
| 180         | 0.018814                  | 563.724        | 2.05049        | 0.016762                  | 562.418        | 2.03977        | 0.013066                  | 559.098        | 2.01614        |
| 190         | 0.019369                  | 575.177        | 2.07549        | 0.017272                  | 573.950        | 2.06494        | 0.013498                  | 570.841        | 2.04177        |
| 3,00 MPa    |                           |                | 3,50 MPa       |                           |                | 4,00 MPa       |                           |                |                |
| 90          | 0.005755                  | 436.193        | 1.69950        | —                         | —              | —              | —                         | —              | —              |
| 100         | 0.006653                  | 453.731        | 1.74717        | 0.004839                  | 440.433        | 1.70386        | —                         | —              | —              |
| 110         | 0.007339                  | 468.500        | 1.78623        | 0.005667                  | 459.211        | 1.75355        | 0.004277                  | 446.844        | 1.71480        |
| 120         | 0.007924                  | 482.043        | 1.82113        | 0.006289                  | 474.697        | 1.79346        | 0.005005                  | 465.987        | 1.76415        |
| <b>130</b>  | <b>0.008446</b>           | <b>494,915</b> | <b>1,85347</b> | <b>0.006813</b>           | <b>488,771</b> | <b>1,82881</b> | <b>0.005559</b>           | <b>481,865</b> | <b>1,80404</b> |
| 140         | 0.008926                  | 507.388        | 1.88403        | 0.007279                  | 502.079        | 1.86142        | 0.006027                  | 496.295        | 1.83940        |
| 150         | 0.009375                  | 519.618        | 1.91328        | 0.007706                  | 514.928        | 1.89216        | 0.006444                  | 509.925        | 1.87200        |
| 160         | 0.009801                  | 531.704        | 1.94151        | 0.008103                  | 527.496        | 1.92151        | 0.006825                  | 523.072        | 1.90271        |
| 170         | 0.010208                  | 543.713        | 1.96892        | 0.008480                  | 539.890        | 1.94980        | 0.007181                  | 535.917        | 1.93203        |
| <b>180</b>  | <b>0.010601</b>           | <b>555,690</b> | <b>1,99565</b> | <b>0.008839</b>           | <b>552,185</b> | <b>1,97724</b> | <b>0.007517</b>           | <b>548,573</b> | <b>1,96028</b> |
| 190         | 0.010982                  | 567.670        | 2.02180        | 0.009185                  | 564.430        | 2.00397        | 0.007837                  | 561.117        | 1.98766        |
| 200         | 0.011353                  | 579.678        | 2.04745        | 0.009519                  | 576.665        | 2.03010        | 0.008145                  | 573.601        | 2.01432        |

Tabela A.6 — Propriedades termodinâmicas do nitrogênio

Tabela A.6.1 — Nitrogênio saturado

| Temp.<br>K<br>$T$ | Pressão            | Volume específico, m <sup>3</sup> /kg |                 |                        | Entalpia, kJ/kg          |                |                        | Entropia, kJ/kg K        |                |                        |
|-------------------|--------------------|---------------------------------------|-----------------|------------------------|--------------------------|----------------|------------------------|--------------------------|----------------|------------------------|
|                   | Abs.<br>MPa<br>$p$ | Líquido<br>sat.<br>$v_f$              | Evap.<br>$v_g$  | Vapor<br>sat.<br>$v_g$ | Líquido<br>sat.<br>$h_f$ | Evap.<br>$h_g$ | Vapor<br>sat.<br>$h_g$ | Líquido<br>sat.<br>$s_f$ | Evap.<br>$s_g$ | Vapor<br>sat.<br>$s_g$ |
| 63,148            | 0,01252            | 0,001150                              | 1,480099        | 1,481249               | -150,911                 | 215,392        | 64,482                 | 2,4234                   | 3,4108         | 5,8342                 |
| 65                | 0,01741            | 0,001160                              | 1,092665        | 1,093825               | -147,172                 | 213,384        | 66,212                 | 2,4816                   | 3,2829         | 5,7646                 |
| <b>70</b>         | <b>0,03858</b>     | <b>0,001191</b>                       | <b>0,525015</b> | <b>0,526206</b>        | <b>-137,088</b>          | <b>207,788</b> | <b>70,700</b>          | <b>2,6307</b>            | <b>2,9683</b>  | <b>5,5991</b>          |
| 75                | 0,07610            | 0,001223                              | 0,280499        | 0,281722               | -126,949                 | 201,816        | 74,867                 | 2,7700                   | 2,6909         | 5,4609                 |
| 77,348            | 0,101325           | 0,001240                              | 0,215145        | 0,216385               | -122,150                 | 198,839        | 76,689                 | 2,8326                   | 2,5707         | 5,4033                 |

Tabela A.6.1 (Continuação) — Nitrogênio saturado

| Temp.<br>K<br>$T$ | Pressão<br>Abs.<br>MPa<br>$p$ | Volume específico, m <sup>3</sup> /kg |                   |                        | Entalpia, kJ/kg          |                   |                        | Entropia, kJ/kg K        |                   |                        |
|-------------------|-------------------------------|---------------------------------------|-------------------|------------------------|--------------------------|-------------------|------------------------|--------------------------|-------------------|------------------------|
|                   |                               | Líquido<br>sat.<br>$v_f$              | Evap.<br>$v_{fg}$ | Vapor<br>sat.<br>$v_g$ | Líquido<br>sat.<br>$h_f$ | Evap.<br>$h_{fg}$ | Vapor<br>sat.<br>$h_g$ | Líquido<br>sat.<br>$s_f$ | Evap.<br>$s_{fg}$ | Vapor<br>sat.<br>$s_g$ |
|                   |                               |                                       |                   |                        |                          |                   |                        |                          |                   |                        |
| 80                | 0,13699                       | 0,001259                              | 0,162485          | 0,163744               | -116,689                 | 195,319           | 78,630                 | 2,9014                   | 2,4415            | 5,3429                 |
| 85                | 0,22903                       | 0,001299                              | 0,100204          | 0,101503               | -106,252                 | 188,149           | 81,898                 | 3,0266                   | 2,2136            | 5,2401                 |
| 90                | 0,36066                       | 0,001343                              | 0,064803          | 0,066146               | -95,577                  | 180,137           | 84,560                 | 3,1466                   | 2,0016            | 5,1482                 |
| 95                | 0,54082                       | 0,001393                              | 0,043398          | 0,044792               | -84,593                  | 171,075           | 86,482                 | 3,2627                   | 1,8009            | 5,0636                 |
| 100               | <b>0,77881</b>                | <b>0,001452</b>                       | <b>0,029764</b>   | <b>0,031216</b>        | <b>-73,199</b>           | <b>160,691</b>    | <b>87,493</b>          | <b>3,3761</b>            | <b>1,6070</b>     | <b>4,9831</b>          |
| 105               | 1,08423                       | 0,001522                              | 0,020673          | 0,022195               | -61,238                  | 148,597           | 87,359                 | 3,4883                   | 1,4153            | 4,9036                 |
| 110               | 1,46717                       | 0,001610                              | 0,014342          | 0,015952               | -48,446                  | 134,165           | 85,719                 | 3,6017                   | 1,2197            | 4,8215                 |
| 115               | 1,93875                       | 0,001729                              | 0,009717          | 0,011445               | -34,308                  | 116,212           | 81,904                 | 3,7204                   | 1,0106            | 4,7310                 |
| 120               | 2,51248                       | 0,001915                              | 0,006083          | 0,007998               | -17,605                  | 91,930            | 74,324                 | 3,8536                   | 0,7661            | 4,6197                 |
| 125               | <b>3,20886</b>                | <b>0,002353</b>                       | <b>0,002530</b>   | <b>0,004883</b>        | <b>6,677</b>             | <b>48,762</b>     | <b>55,438</b>          | <b>4,0395</b>            | <b>0,3901</b>     | <b>4,4296</b>          |
| 126,193           | 3,39780                       | 0,003194                              | 0                 | 0,003194               | 29,791                   | 0                 | 29,791                 | 4,2193                   | 0                 | 4,2193                 |

Tabela A.6.2 — Nitrogênio superaquecido (as unidades são as mesmas da Tabela anterior)

| Pressão<br>abs.<br>MPa | Temperatura, K |                 |                 |                 |                 |                 |                 |                 |                 |                 |
|------------------------|----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                        | 100            | 125             | 150             | 175             | 200             | 225             | 250             | 275             | 300             |                 |
| 0,1                    | v              | 0,291030        | 0,367236        | 0,442612        | 0,517577        | 0,592311        | 0,666904        | 0,741404        | 0,815839        | 0,890229        |
|                        | h              | 101,938         | 128,423         | 154,695         | 180,860         | 206,967         | 233,039         | 259,090         | 285,128         | 311,160         |
|                        | s              | 5,6944          | 5,9308          | 6,1225          | 6,2838          | 6,4232          | 6,5461          | 6,6559          | 6,7551          | 6,8457          |
| 0,2                    | v              | <b>0,142521</b> | <b>0,181711</b> | <b>0,220007</b> | <b>0,257878</b> | <b>0,295515</b> | <b>0,333008</b> | <b>0,370408</b> | <b>0,407743</b> | <b>0,445033</b> |
|                        | h              | <b>100,238</b>  | <b>127,294</b>  | <b>153,876</b>  | <b>180,236</b>  | <b>206,476</b>  | <b>232,644</b>  | <b>258,766</b>  | <b>284,861</b>  | <b>310,938</b>  |
|                        | s              | <b>5,4775</b>   | <b>5,7191</b>   | <b>5,9130</b>   | <b>6,0755</b>   | <b>6,2157</b>   | <b>6,3390</b>   | <b>6,4491</b>   | <b>6,5486</b>   | <b>6,6393</b>   |
| 0,5                    | v              | 0,053062        | 0,070328        | 0,086429        | 0,102059        | 0,117442        | 0,132677        | 0,147817        | 0,162892        | 0,177921        |
|                        | h              | 94,460          | 123,776         | 151,376         | 178,349         | 204,998         | 231,458         | 257,799         | 284,063         | 310,276         |
|                        | s              | 5,1660          | 5,4282          | 5,6296          | 5,7959          | 5,9383          | 6,0629          | 6,1740          | 6,2741          | 6,3653          |
| 1,0                    | v              | —               | <b>0,033064</b> | <b>0,041876</b> | <b>0,050120</b> | <b>0,058093</b> | <b>0,065911</b> | <b>0,073631</b> | <b>0,081285</b> | <b>0,088893</b> |
|                        | h              | —               | <b>117,397</b>  | <b>147,062</b>  | <b>175,156</b>  | <b>202,522</b>  | <b>229,482</b>  | <b>256,194</b>  | <b>282,743</b>  | <b>309,182</b>  |
|                        | s              | —               | <b>5,1872</b>   | <b>5,4039</b>   | <b>5,5772</b>   | <b>5,723</b>    | <b>5,8504</b>   | <b>5,9630</b>   | <b>6,0642</b>   | <b>6,1562</b>   |
| 2,0                    | v              | —               | 0,014030        | 0,019541        | 0,024153        | 0,028436        | 0,032548        | 0,036558        | 0,040500        | 0,044395        |
|                        | h              | —               | 101,541         | 137,779         | 168,584         | 197,528         | 225,543         | 253,014         | 280,140         | 307,034         |
|                        | s              | —               | 4,8887          | 5,1541          | 5,3443          | 5,4989          | 5,6310          | 5,7467          | 5,8502          | 5,9438          |
| 4,0                    | v              | —               | —               | <b>0,008231</b> | <b>0,011185</b> | <b>0,013650</b> | <b>0,015912</b> | <b>0,018063</b> | <b>0,020145</b> | <b>0,022179</b> |
|                        | h              | —               | —               | <b>115,595</b>  | <b>154,672</b>  | <b>187,417</b>  | <b>217,740</b>  | <b>246,800</b>  | <b>275,098</b>  | <b>302,898</b>  |
|                        | s              | —               | —               | <b>4,8379</b>   | <b>5,0797</b>   | <b>5,2548</b>   | <b>5,3978</b>   | <b>5,5203</b>   | <b>5,6282</b>   | <b>5,7250</b>   |
| 6,0                    | v              | 0,004421        | 0,006909        | 0,008771        | 0,010412        | 0,011937        | 0,013393        | 0,014803        | 0,017532        | 0,020187        |
|                        | h              | 87,298          | 139,945         | 177,293         | 210,125         | 240,822         | 270,294         | 298,988         | 354,951         | 409,83          |
|                        | s              | 4,5685          | 4,8956          | 5,0955          | 5,2503          | 5,3797          | 5,4921          | 5,5920          | 5,7646          | 5,9112          |
| 8,0                    | v              | <b>0,002914</b> | <b>0,004861</b> | <b>0,006387</b> | <b>0,007701</b> | <b>0,008905</b> | <b>0,010042</b> | <b>0,011135</b> | <b>0,013236</b> | <b>0,015264</b> |
|                        | h              | <b>61,924</b>   | <b>125,326</b>  | <b>167,469</b>  | <b>202,833</b>  | <b>235,145</b>  | <b>265,761</b>  | <b>295,318</b>  | <b>352,511</b>  | <b>408,237</b>  |
|                        | s              | <b>4,3522</b>   | <b>4,7460</b>   | <b>4,9717</b>   | <b>5,1385</b>   | <b>5,2748</b>   | <b>5,3916</b>   | <b>5,4945</b>   | <b>5,6709</b>   | <b>5,8197</b>   |
| 10,0                   | v              | 0,002388        | 0,003752        | 0,005014        | 0,006112        | 0,007113        | 0,008053        | 0,008952        | 0,01067         | 0,01232         |
|                        | h              | 48,659          | 112,363         | 158,353         | 196,022         | 229,841         | 261,532         | 291,902         | 350,260         | 406,790         |
|                        | s              | 4,2290          | 4,6233          | 4,8697          | 5,0474          | 5,1901          | 5,3109          | 5,4167          | 5,5967          | 5,7477          |
| 15,0                   | v              | <b>0,001955</b> | <b>0,002598</b> | <b>0,003365</b> | <b>0,004109</b> | <b>0,004804</b> | <b>0,005461</b> | <b>0,006088</b> | <b>0,007280</b> | <b>0,008416</b> |
|                        | h              | <b>36,805</b>   | <b>91,928</b>   | <b>140,599</b>  | <b>181,908</b>  | <b>218,586</b>  | <b>252,470</b>  | <b>284,565</b>  | <b>345,466</b>  | <b>403,791</b>  |
|                        | s              | <b>4,0790</b>   | <b>4,4191</b>   | <b>4,6796</b>   | <b>4,8745</b>   | <b>5,0292</b>   | <b>5,1585</b>   | <b>5,2702</b>   | <b>5,4581</b>   | <b>5,6139</b>   |
| 20,0                   | v              | 0,001782        | 0,002187        | 0,002687        | 0,003213        | 0,003729        | 0,004226        | 0,004704        | 0,005617        | 0,006487        |
|                        | h              | 33,644          | 83,317          | 130,168         | 172,324         | 210,434         | 245,699         | 279,007         | 341,856         | 401,649         |
|                        | s              | 3,9960          | 4,3024          | 4,5529          | 4,7517          | 4,9124          | 5,0469          | 5,1629          | 5,3568          | 5,5166          |

Tabela A.7 — Propriedades termodinâmicas do metano

Tabela A.7.1 — Metano saturado

| Temp.<br>K<br><i>T</i> | Pressão                 |                | Volume específico, m³/kg     |                                |                              | Entalpia, kJ/kg              |                                |                              | Entropia, kJ/kg K            |                                |                              |
|------------------------|-------------------------|----------------|------------------------------|--------------------------------|------------------------------|------------------------------|--------------------------------|------------------------------|------------------------------|--------------------------------|------------------------------|
|                        | Abs.<br>MPa<br><i>p</i> |                | Líquido                      |                                | Vapor                        | Líquido                      |                                | Vapor                        | Líquido                      |                                | Vapor                        |
|                        |                         |                | sat.<br><i>v<sub>l</sub></i> | Evap.<br><i>v<sub>lv</sub></i> | sat.<br><i>v<sub>v</sub></i> | sat.<br><i>h<sub>l</sub></i> | Evap.<br><i>h<sub>lv</sub></i> | sat.<br><i>h<sub>v</sub></i> | sat.<br><i>s<sub>l</sub></i> | Evap.<br><i>s<sub>lv</sub></i> | sat.<br><i>s<sub>v</sub></i> |
| 90,685                 | 0,01169                 | 0,00221        | 3,97955                      | 3,98176                        | −358,1                       | 543,1                        | 185,1                          | 4,226                        | 5,989                        | 10,216                         |                              |
| 95                     | 0,01983                 | 0,00224        | 2,44824                      | 2,45048                        | −343,7                       | 537,2                        | 193,4                          | 4,381                        | 5,654                        | 10,035                         |                              |
| 100                    | 0,03441                 | 0,00228        | 1,47657                      | 1,47885                        | −326,8                       | 529,8                        | 202,9                          | 4,554                        | 5,298                        | 9,851                          |                              |
| 105                    | 0,05643                 | 0,00231        | 0,93791                      | 0,94022                        | −309,7                       | 521,8                        | 212,2                          | 4,721                        | 4,970                        | 9,691                          |                              |
| 110                    | <b>0,08820</b>          | <b>0,00235</b> | <b>0,62219</b>               | <b>0,62454</b>                 | <b>−292,3</b>                | <b>513,3</b>                 | <b>221,0</b>                   | <b>4,882</b>                 | <b>4,666</b>                 | <b>9,548</b>                   |                              |
| 115                    | 0,13232                 | 0,00239        | 0,42808                      | 0,43048                        | −274,7                       | 504,1                        | 229,4                          | 5,037                        | 4,384                        | 9,421                          |                              |
| 120                    | 0,19158                 | 0,00244        | 0,30371                      | 0,30615                        | −257,0                       | 494,2                        | 237,2                          | 5,187                        | 4,118                        | 9,305                          |                              |
| 125                    | 0,26896                 | 0,00249        | 0,22110                      | 0,22359                        | −239,0                       | 483,4                        | 244,5                          | 5,332                        | 3,868                        | 9,200                          |                              |
| 130                    | 0,36760                 | 0,00254        | 0,16448                      | 0,16702                        | −220,7                       | 471,7                        | 251,0                          | 5,473                        | 3,629                        | 9,102                          |                              |
| 135                    | <b>0,49072</b>          | <b>0,00259</b> | <b>0,12457</b>               | <b>0,12717</b>                 | <b>−202,1</b>                | <b>458,9</b>                 | <b>256,8</b>                   | <b>5,611</b>                 | <b>3,399</b>                 | <b>9,011</b>                   |                              |
| 140                    | 0,64165                 | 0,00265        | 0,09574                      | 0,09839                        | −183,2                       | 444,8                        | 261,7                          | 5,746                        | 3,177                        | 8,924                          |                              |
| 145                    | 0,82379                 | 0,00272        | 0,07444                      | 0,07716                        | −163,7                       | 429,4                        | 265,7                          | 5,879                        | 2,961                        | 8,841                          |                              |
| 150                    | 1,04065                 | 0,00279        | 0,05838                      | 0,06117                        | −143,7                       | 412,3                        | 268,5                          | 6,011                        | 2,748                        | 8,759                          |                              |
| 155                    | 1,29580                 | 0,00288        | 0,04604                      | 0,04892                        | −123,1                       | 393,3                        | 270,2                          | 6,141                        | 2,537                        | 8,679                          |                              |
| 160                    | <b>1,59296</b>          | <b>0,00297</b> | <b>0,03638</b>               | <b>0,03935</b>                 | <b>−101,6</b>                | <b>372,0</b>                 | <b>270,3</b>                   | <b>6,272</b>                 | <b>2,325</b>                 | <b>8,597</b>                   |                              |
| 165                    | 1,93607                 | 0,00309        | 0,02868                      | 0,03176                        | −79,1                        | 347,8                        | 268,7                          | 6,405                        | 2,108                        | 8,512                          |                              |
| 170                    | 2,32936                 | 0,00322        | 0,02241                      | 0,02563                        | −55,2                        | 320,0                        | 264,8                          | 6,540                        | 1,882                        | 8,422                          |                              |
| 175                    | 2,77762                 | 0,00339        | 0,01718                      | 0,02058                        | −29,3                        | 287,2                        | 257,9                          | 6,681                        | 1,641                        | 8,322                          |                              |
| 180                    | 3,28655                 | 0,00362        | 0,01266                      | 0,01628                        | −0,5                         | 246,8                        | 246,2                          | 6,833                        | 1,371                        | 8,204                          |                              |
| 185                    | <b>3,86361</b>          | <b>0,00398</b> | <b>0,00845</b>               | <b>0,01243</b>                 | <b>33,8</b>                  | <b>192,1</b>                 | <b>225,9</b>                   | <b>7,009</b>                 | <b>1,038</b>                 | <b>8,048</b>                   |                              |
| 190                    | 4,52082                 | 0,00499        | 0,00298                      | 0,00796                        | 92,2                         | 79,8                         | 172,0                          | 7,305                        | 0,420                        | 7,725                          |                              |
| 190,551                | 4,59920                 | 0,00615        | 0                            | 0,00615                        | 129,7                        | 0                            | 129,7                          | 7,500                        | 0                            | 7,500                          |                              |

Tabela A.7.2 — Metano superaquecido (as unidades são as mesmas da Tabela anterior)

| Pressão<br>abs.<br>MPa | Temperatura, K   |         |         |         |         |         |         |         |         |         |
|------------------------|------------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
|                        | 150              | 175     | 200     | 225     | 250     | 275     | 300     | 350     | 400     | 450     |
| 0,05                   | <i>v</i> 1,5433  | 1,8054  | 2,0665  | 2,3270  | 2,5872  | 2,8472  | 3,1069  | 3,6262  | 4,1451  | —       |
|                        | <i>h</i> 308,5   | 360,8   | 413,2   | 465,8   | 518,9   | 572,9   | 628,1   | 742,9   | 865,4   | —       |
|                        | <i>s</i> 10,5170 | 10,8399 | 11,1196 | 11,3674 | 11,5914 | 11,7972 | 11,9891 | 12,3429 | 12,6697 | —       |
| 0,10                   | <i>v</i> 0,7659  | 0,8984  | 1,0299  | 1,1609  | 1,2915  | 1,4219  | 1,5521  | 1,8123  | 2,0721  | —       |
|                        | <i>h</i> 306,8   | 359,6   | 412,2   | 465,0   | 518,3   | 572,4   | 627,6   | 742,6   | 865,1   | —       |
|                        | <i>s</i> 10,1504 | 10,4759 | 10,7570 | 11,0058 | 11,2303 | 11,4365 | 11,6286 | 11,9829 | 12,3099 | —       |
| 0,50                   | <i>v</i> 0,1433  | 0,1726  | 0,2006  | 0,2280  | 0,2550  | 0,2817  | 0,3083  | 0,3611  | 0,4137  | —       |
|                        | <i>h</i> 292,3   | 349,1   | 404,1   | 458,5   | 512,9   | 567,8   | 623,7   | 739,6   | 862,8   | —       |
|                        | <i>s</i> 9,2515  | 9,6021  | 9,8959  | 10,1520 | 10,3812 | 10,5906 | 10,7850 | 11,1422 | 11,4710 | —       |
| 1,00                   | <i>v</i> 0,0643  | 0,0815  | 0,0968  | 0,1113  | 0,1254  | 0,1392  | 0,1528  | 0,1798  | 0,2064  | —       |
|                        | <i>h</i> 270,6   | 334,9   | 393,5   | 450,1   | 506,0   | 562,0   | 618,8   | 735,9   | 860,0   | —       |
|                        | <i>s</i> 8,7902  | 9,1871  | 9,5006  | 9,7672  | 10,0028 | 10,2164 | 10,4138 | 10,7748 | 11,1059 | —       |
| 1,50                   | <i>v</i> —       | 0,0508  | 0,0621  | 0,0724  | 0,0822  | 0,0917  | 0,1010  | 0,1193  | 0,1373  | —       |
|                        | <i>h</i> —       | 318,8   | 382,3   | 441,4   | 499,0   | 556,2   | 613,8   | 732,3   | 857,2   | —       |
|                        | <i>s</i> —       | 8,9121  | 9,2514  | 9,5303  | 9,7730  | 9,9911  | 10,1916 | 10,5565 | 10,8899 | —       |
| 2,00                   | <i>v</i> —       | 0,0350  | 0,0446  | 0,0529  | 0,0606  | 0,0680  | 0,0751  | 0,0891  | 0,1027  | —       |
|                        | <i>h</i> —       | 300,0   | 370,2   | 432,4   | 491,8   | 550,3   | 608,9   | 728,6   | 854,3   | —       |
|                        | <i>s</i> —       | 8,6839  | 9,0596  | 9,3532  | 9,6036  | 9,8266  | 10,0303 | 10,3992 | 10,7349 | —       |
| 3,00                   | <i>v</i> —       | —       | 0,0269  | 0,0333  | 0,0390  | 0,0442  | 0,0492  | 0,0589  | 0,0682  | 0,0774  |
|                        | <i>h</i> —       | —       | 342,7   | 413,3   | 477,1   | 538,3   | 598,8   | 721,2   | 848,8   | 983,5   |
|                        | <i>s</i> —       | —       | 8,7492  | 9,0823  | 9,3512  | 9,5848  | 9,7954  | 10,1726 | 10,5130 | 10,8303 |
| 4,00                   | <i>v</i> —       | —       | 0,0176  | 0,0235  | 0,0281  | 0,0324  | 0,0363  | 0,0438  | 0,0510  | 0,0580  |
|                        | <i>h</i> —       | —       | 308,2   | 392,4   | 461,6   | 526,1   | 588,7   | 713,9   | 843,2   | 979,2   |
|                        | <i>s</i> —       | —       | 8,4675  | 8,8653  | 9,1574  | 9,4031  | 9,6212  | 10,0071 | 10,3523 | 10,6725 |

Tabela A.7.2 (Continuação) — Metano superaquecido

| Pressão abs. |          | Temperatura, K |     |        |        |        |        |        |        |         |         |
|--------------|----------|----------------|-----|--------|--------|--------|--------|--------|--------|---------|---------|
| MPa          |          | 150            | 175 | 200    | 225    | 250    | 275    | 300    | 350    | 400     | 450     |
| 5,00         | <i>v</i> | —              | —   | 0,0114 | 0,0175 | 0,0216 | 0,0252 | 0,0286 | 0,0348 | 0,0406  | 0,0463  |
|              | <i>h</i> | —              | —   | 258,3  | 369,3  | 445,6  | 513,6  | 578,6  | 706,7  | 837,8   | 975,0   |
|              | <i>s</i> | —              | —   | 8,1459 | 8,6728 | 8,9945 | 9,2540 | 9,4802 | 9,8751 | 10,2251 | 10,5483 |
| 6,00         | <i>v</i> | —              | —   | 0,0061 | 0,0135 | 0,0173 | 0,0205 | 0,0234 | 0,0288 | 0,0338  | 0,0386  |
|              | <i>h</i> | —              | —   | 160,3  | 343,7  | 428,8  | 500,9  | 568,4  | 699,5  | 832,4   | 970,9   |
|              | <i>s</i> | —              | —   | 7,6125 | 8,4907 | 8,8502 | 9,1253 | 9,3601 | 9,7643 | 10,1192 | 10,4453 |
| 8,00         | <i>v</i> | —              | —   | 0,0041 | 0,0085 | 0,0120 | 0,0147 | 0,0171 | 0,0213 | 0,0252  | 0,0289  |
|              | <i>h</i> | —              | —   | 88,5   | 285,0  | 393,9  | 475,4  | 548,1  | 685,4  | 822,0   | 962,9   |
|              | <i>s</i> | —              | —   | 7,2069 | 8,1344 | 8,5954 | 8,9064 | 9,1598 | 9,5831 | 9,9477  | 10,2796 |
| 10,00        | <i>v</i> | —              | —   | 0,0038 | 0,0059 | 0,0089 | 0,0113 | 0,0133 | 0,0169 | 0,0201  | 0,0231  |
|              | <i>h</i> | —              | —   | 72,2   | 229,3  | 358,6  | 450,1  | 528,4  | 671,8  | 811,9   | 955,3   |
|              | <i>s</i> | —              | —   | 7,0862 | 7,8245 | 8,3716 | 8,7210 | 8,9936 | 9,4362 | 9,8104  | 10,1480 |

Tabela A.8 — Constantes críticas

| Substância                                     | Fórmula                               | Peso molecular | Temp. K      | Pressão MPa  | Volume m <sup>3</sup> /kmol | Fator Acentrico |
|------------------------------------------------|---------------------------------------|----------------|--------------|--------------|-----------------------------|-----------------|
| Amônia                                         | NH <sub>3</sub>                       | 17,031         | 405,5        | 11,35        | 0,0725                      | 0,250           |
| Argônio                                        | Ar                                    | 39,948         | 150,8        | 4,87         | 0,0749                      | 0,001           |
| Bromo                                          | Br <sub>2</sub>                       | 159,808        | 588          | 10,30        | 0,1272                      | 0,108           |
| Dióxido de carbono                             | CO <sub>2</sub>                       | 44,01          | 304,1        | 7,38         | 0,0939                      | 0,239           |
| <b>Monóxido de carbono</b>                     | <b>CO</b>                             | <b>28,01</b>   | <b>132,9</b> | <b>3,50</b>  | <b>0,0932</b>               | <b>0,066</b>    |
| Cloro                                          | Cl <sub>2</sub>                       | 70,906         | 416,9        | 7,98         | 0,1238                      | 0,090           |
| Deutério (normal)                              | D <sub>2</sub>                        | 4,032          | 38,4         | 1,66         | —                           | -0,160          |
| Flúor                                          | F <sub>2</sub>                        | 37,997         | 144,3        | 5,22         | 0,0663                      | 0,054           |
| Hélio                                          | He                                    | 4,003          | 5,19         | 0,227        | 0,0574                      | -0,365          |
| <b>Hélio<sup>3</sup></b>                       | <b>He</b>                             | <b>3,017</b>   | <b>3,31</b>  | <b>0,114</b> | <b>0,0729</b>               | <b>-0,473</b>   |
| Hidrogênio (normal)                            | H <sub>2</sub>                        | 2,016          | 33,2         | 1,30         | 0,0651                      | -0,218          |
| Criptônio                                      | Kr                                    | 83,80          | 209,4        | 5,50         | 0,0912                      | 0,005           |
| Neônio                                         | Ne                                    | 20,183         | 44,4         | 2,76         | 0,0416                      | -0,029          |
| Óxido nítrico                                  | NO                                    | 30,006         | 180          | 6,48         | 0,0577                      | 0,588           |
| <b>Nitrogênio</b>                              | <b>N<sub>2</sub></b>                  | <b>28,013</b>  | <b>126,2</b> | <b>3,39</b>  | <b>0,0898</b>               | <b>0,039</b>    |
| Dióxido de nitrogênio                          | NO <sub>2</sub>                       | 46,006         | 431          | 10,1         | 0,1678                      | 0,834           |
| Óxido nítrico                                  | N <sub>2</sub> O                      | 44,013         | 309,6        | 7,24         | 0,0974                      | 0,165           |
| Oxigênio                                       | O <sub>2</sub>                        | 31,999         | 154,6        | 5,04         | 0,0734                      | 0,025           |
| Dióxido de enxofre                             | SO <sub>2</sub>                       | 64,063         | 430,8        | 7,88         | 0,1222                      | 0,256           |
| <b>Água</b>                                    | <b>H<sub>2</sub>O</b>                 | <b>18,015</b>  | <b>647,3</b> | <b>22,12</b> | <b>0,0571</b>               | <b>0,344</b>    |
| Xenônio                                        | Xe                                    | 131,30         | 289,7        | 5,84         | 0,1184                      | 0,008           |
| Acetileno                                      | C <sub>2</sub> H <sub>2</sub>         | 26,038         | 308,3        | 6,14         | 0,1127                      | 0,190           |
| Benzeno                                        | C <sub>6</sub> H <sub>6</sub>         | 78,114         | 562,2        | 4,89         | 0,2590                      | 0,212           |
| <i>n</i> -Butano                               | C <sub>4</sub> H <sub>10</sub>        | 58,124         | 425,2        | 3,80         | 0,2550                      | 0,199           |
| <b>Tetracloreto de carbono</b>                 | <b>CCL<sub>4</sub></b>                | <b>153,823</b> | <b>556,4</b> | <b>4,56</b>  | <b>0,2759</b>               | <b>0,193</b>    |
| Difluorcloroetano <sup>a</sup> (142 <i>b</i> ) | CH <sub>3</sub> CCLF <sub>2</sub>     | 100,495        | 410,3        | 4,25         | 0,2310                      | 0,250           |
| Difluorclorometano (22)                        | CHCLF <sub>2</sub>                    | 86,469         | 369,3        | 4,97         | 0,1656                      | 0,221           |
| Clorofórmio                                    | CHCL <sub>3</sub>                     | 119,378        | 536,4        | 5,37         | 0,2389                      | 0,218           |
| Diclorodifluorometano (12)                     | CCL <sub>2</sub> F <sub>2</sub>       | 120,914        | 385,0        | 4,14         | 0,2167                      | 0,204           |
| <b>Diclorofluoretano<sup>a</sup> (141)</b>     | <b>CH<sub>3</sub>CCL<sub>2</sub>F</b> | <b>116,95</b>  | <b>481,5</b> | <b>4,54</b>  | <b>0,2520</b>               | <b>0,215</b>    |
| Diclorofluorometano (21)                       | CHCL <sub>2</sub> F                   | 102,923        | 451,6        | 5,18         | 0,1964                      | 0,210           |
| Diclorotrifluoretano <sup>a</sup> (123)        | CHCL <sub>2</sub> CF <sub>3</sub>     | 152,93         | 456,9        | 3,67         | 0,2781                      | 0,282           |
| Difluoretano <sup>a</sup> (152 <i>a</i> )      | CHF <sub>2</sub> CH <sub>3</sub>      | 66,05          | 386,4        | 4,52         | 0,1795                      | 0,275           |
| Etano                                          | C <sub>2</sub> H <sub>6</sub>         | 30,070         | 305,4        | 4,88         | 0,1483                      | 0,099           |



Tabela A.8 (Continuação) — Constantes críticas

| Substância                           | Fórmula                           | Peso molecular | Temp. K      | Pressão MPa | Volume m <sup>3</sup> /kmol | Fator Acentrico |
|--------------------------------------|-----------------------------------|----------------|--------------|-------------|-----------------------------|-----------------|
| Álcool etílico                       | C <sub>2</sub> H <sub>5</sub> OH  | 46,069         | 513,9        | 6,14        | 0,1671                      | 0,644           |
| Etileno                              | C <sub>2</sub> H <sub>4</sub>     | 28,054         | 282,4        | 5,04        | 0,1304                      | 0,089           |
| n-Heptano                            | C <sub>7</sub> H <sub>16</sub>    | 100,205        | 540,3        | 2,74        | 0,4320                      | 0,349           |
| n-Hexano                             | C <sub>6</sub> H <sub>14</sub>    | 86,178         | 507,5        | 3,01        | 0,3700                      | 0,299           |
| <b>Metano</b>                        | <b>CH<sub>4</sub></b>             | <b>16,043</b>  | <b>190,4</b> | <b>4,60</b> | <b>0,0992</b>               | <b>0,011</b>    |
| Álcool metílico                      | CH <sub>3</sub> OH                | 32,042         | 512,6        | 8,09        | 0,1180                      | 0,556           |
| Cloreto metílico                     | CH <sub>3</sub> CL                | 50,488         | 416,3        | 6,70        | 0,1389                      | 0,153           |
| n-Octano                             | C <sub>8</sub> H <sub>18</sub>    | 114,232        | 568,8        | 2,49        | 0,4920                      | 0,398           |
| n-Pentano                            | C <sub>5</sub> H <sub>12</sub>    | 72,151         | 469,7        | 3,37        | 0,3040                      | 0,251           |
| <b>Propano</b>                       | <b>C<sub>3</sub>H<sub>8</sub></b> | <b>44,094</b>  | <b>369,8</b> | <b>4,25</b> | <b>0,2030</b>               | <b>0,153</b>    |
| Propeno                              | C <sub>3</sub> H <sub>6</sub>     | 42,081         | 364,9        | 4,60        | 0,1810                      | 0,144           |
| Propino                              | C <sub>3</sub> H <sub>4</sub>     | 40,065         | 402,4        | 5,63        | 0,1640                      | 0,215           |
| Tetrafluormetano <sup>a</sup> (134a) | CF <sub>3</sub> CH <sub>2</sub> F | 102,03         | 374,2        | 4,06        | 0,1980                      | 0,327           |

Fonte: R. C. Reid, J. M. Prausnitz e B. E. Poling, *The Properties of Gases and Liquids*, 4ª edição, McGraw-Hill Book Company, New York, 1987.

<sup>a</sup> Dados de M. O. McLinden, NIST Thermophysics Division, 1989.

Tabela A.9 — Propriedades de vários sólidos e líquidos

| Sólido              | $c_p$ , kJ/kg K | $\rho$ , kg/m <sup>3</sup> | Líquido          | $c_p$ , kJ/kg K | $\rho$ , kg/m <sup>3</sup> |
|---------------------|-----------------|----------------------------|------------------|-----------------|----------------------------|
| Aluminio            | 0,9             | 2700                       | Amônia           | 4,8             | 602                        |
| Concreto            | 0,65            | 2300                       | Benzeno          | 1,72            | 879                        |
| Cobre               | 0,386           | 8900                       | Butano           | 2,469           | 556                        |
| Vidro               | 0,8             | 2300                       | Etanol           | 2,456           | 783                        |
| <b>Granito</b>      | <b>1,017</b>    | <b>2700</b>                | <b>Glicerina</b> | <b>2,40</b>     | <b>1200</b>                |
| Grafite             | 0,711           | 2500                       | Iso-octano       | 2,1             | 692                        |
| Ferro               | 0,450           | 7840                       | Mercúrio         | 0,139           | 13560                      |
| Chumbo              | 0,128           | 11310                      | Metanol          | 2,55            | 787                        |
| Borracha (macia)    | 1,84            | 1100                       | Óleo (leve)      | 1,8             | 910                        |
| <b>Areia (seca)</b> | <b>0,8</b>      | <b>1450-1750</b>           | <b>Propano</b>   | <b>2,54</b>     | <b>510</b>                 |
| Prata               | 0,235           | 10470                      | R-12             | 0,971           | 1310                       |
| Aço (AISI302)       | 0,48            | 8050                       | R-134a           | 1,43            | 1206                       |
| Estanho             | 0,217           | 5730                       | Água             | 4,184           | 997                        |
| Madeira (maioria)   | 1,76            | 350-700                    |                  |                 |                            |

Tabela A.10 — Propriedades de vários gases perfeitos a 300K

| Gás                 | Fórmula química                    | Peso molecular | $R$ kJ/kg K    | $c_{v0}$ kJ/kg K | $c_{p0}$ kJ/kg K | $k$          |
|---------------------|------------------------------------|----------------|----------------|------------------|------------------|--------------|
| Acetileno           | C <sub>2</sub> H <sub>2</sub>      | 26,038         | 0,3193         | 1,6986           | 1,3793           | 1,231        |
| Ar                  |                                    | 28,97          | 0,2870         | 1,0035           | 0,7165           | 1,400        |
| Amônia              | NH <sub>3</sub>                    | 17,031         | 0,48819        | 2,1300           | 1,6418           | 1,297        |
| Argonio             | Ar                                 | 39,948         | 0,20813        | 0,5203           | 0,3122           | 1,667        |
| <b>Butano</b>       | <b>C<sub>4</sub>H<sub>10</sub></b> | <b>58,124</b>  | <b>0,14304</b> | <b>1,7164</b>    | <b>1,5734</b>    | <b>1,091</b> |
| Dióxido de Carbono  | CO <sub>2</sub>                    | 44,01          | 0,18892        | 0,8418           | 0,6529           | 1,289        |
| Monóxido de Carbono | CO                                 | 28,01          | 0,29683        | 1,0413           | 0,7445           | 1,400        |

Tabela A.10 (Continuação) — Propriedades de vários gases perfeitos a 300K

| Gás                 | Fórmula química                  | Peso molecular | R<br>kJ/kg K | $c_{p0}$<br>kJ/kg K | $c_{v0}$<br>kJ/kg K | k     |
|---------------------|----------------------------------|----------------|--------------|---------------------|---------------------|-------|
| Etano               | C <sub>2</sub> H <sub>6</sub>    | 30,07          | 0,27650      | 1,7662              | 1,4897              | 1,186 |
| Etanol              | C <sub>2</sub> H <sub>5</sub> OH | 46,069         | 0,18048      | 1,427               | 1,246               | 1,145 |
| Etileno             | C <sub>2</sub> H <sub>4</sub>    | 28,054         | 0,29637      | 1,5482              | 1,2518              | 1,237 |
| Hélio               | He                               | 4,003          | 2,07703      | 5,1926              | 3,1156              | 1,667 |
| Hidrogênio          | H <sub>2</sub>                   | 2,016          | 4,12418      | 14,2091             | 10,0849             | 1,409 |
| Metano              | CH <sub>4</sub>                  | 16,04          | 0,51835      | 2,2537              | 1,7354              | 1,299 |
| Metanol             | CH <sub>3</sub> OH               | 32,042         | 0,25948      | 1,4050              | 1,1455              | 1,227 |
| Neônio              | Ne                               | 20,183         | 0,41195      | 1,0299              | 0,6179              | 1,667 |
| Nitrogênio          | N <sub>2</sub>                   | 28,013         | 0,29680      | 1,0416              | 0,7448              | 1,400 |
| Óxido nitroso       | N <sub>2</sub> O                 | 44,013         | 0,18891      | 0,8793              | 0,6904              | 1,274 |
| n-Octano            | C <sub>8</sub> H <sub>18</sub>   | 114,23         | 0,07279      | 1,7113              | 1,6385              | 1,044 |
| Oxigênio            | O <sub>2</sub>                   | 31,999         | 0,25983      | 0,9216              | 0,6618              | 1,393 |
| Propano             | C <sub>3</sub> H <sub>8</sub>    | 44,097         | 0,18855      | 1,6794              | 1,4909              | 1,126 |
| Vapor d'água        | H <sub>2</sub> O                 | 18,015         | 0,46152      | 1,8723              | 1,4108              | 1,327 |
| Dióxido de enxofre  | SO <sub>2</sub>                  | 64,059         | 0,12979      | 0,6236              | 0,4938              | 1,263 |
| Trióxido de enxofre | SO <sub>3</sub>                  | 80,058         | 0,10386      | 0,6346              | 0,5307              | 1,196 |

Tabela A.11 — Calores específicos a pressão constante de vários gases perfeitos a 300K

| $\bar{c}_{p0} = \text{kJ/kmol K}$ |                                                                                                | $\theta = T \text{ (Kelvin)}/100$ |             |
|-----------------------------------|------------------------------------------------------------------------------------------------|-----------------------------------|-------------|
| Gás                               |                                                                                                | Intervalo K                       | Erro Máx. % |
| N <sub>2</sub>                    | $\bar{c}_{p0} = 39,060 - 512,79 \theta^{-1.5} + 1072,7 \theta^{-2} - 820,40 \theta^{-3}$       | 300–3500                          | 0,43        |
| O <sub>2</sub>                    | $\bar{c}_{p0} = 37,432 + 0,020102 \theta^{1.5} - 178,576 \theta^{-1.5} + 236,88 \theta^{-2}$   | 300–3500                          | 0,30        |
| H <sub>2</sub>                    | $\bar{c}_{p0} = 56,505 - 702,74 \theta^{-0.75} + 1165,0 \theta^{-1} - 560,70 \theta^{-1.5}$    | 300–3500                          | 0,60        |
| CO                                | $\bar{c}_{p0} = 69,145 - 0,70463 \theta^{0.75} - 200,77 \theta^{-0.5} + 176,76 \theta^{-0.75}$ | 300–3500                          | 0,42        |
| OH                                | $\bar{c}_{p0} = 81,546 - 59,350 \theta^{0.25} + 17,329 \theta^{0.75} - 4,2660 \theta$          | 300–3500                          | 0,43        |
| NO                                | $\bar{c}_{p0} = 59,283 - 1,7096 \theta^{0.5} - 70,613 \theta^{-0.5} + 74,889 \theta^{-1.5}$    | 300–3500                          | 0,34        |
| H <sub>2</sub> O                  | $\bar{c}_{p0} = 143,05 - 183,54 \theta^{0.25} + 82,751 \theta^{0.5} - 3,6989 \theta$           | 300–3500                          | 0,43        |
| CO <sub>2</sub>                   | $\bar{c}_{p0} = -3,7357 + 30,529 \theta^{0.5} - 4,1034 \theta + 0,024198 \theta^2$             | 300–3500                          | 0,19        |
| NO <sub>2</sub>                   | $\bar{c}_{p0} = 46,045 + 216,10 \theta^{-0.5} - 363,66 \theta^{-0.75} + 232,550 \theta^{-2}$   | 300–3500                          | 0,26        |
| CH <sub>4</sub>                   | $\bar{c}_{p0} = -672,87 + 439,74 \theta^{0.25} - 24,875 \theta^{0.75} + 323,88 \theta^{-0.5}$  | 300–2000                          | 0,15        |
| C <sub>2</sub> H <sub>4</sub>     | $\bar{c}_{p0} = -95,395 + 123,15 \theta^{0.5} - 35,641 \theta^{0.75} + 182,77 \theta^{-3}$     | 300–2000                          | 0,07        |
| C <sub>2</sub> H <sub>6</sub>     | $\bar{c}_{p0} = 6,895 + 17,26 \theta - 0,6402 \theta^2 + 0,00728 \theta^3$                     | 300–1500                          | 0,83        |
| C <sub>3</sub> H <sub>8</sub>     | $\bar{c}_{p0} = -4,042 + 30,46 \theta - 1,571 \theta^2 + 0,03171 \theta^3$                     | 300–1500                          | 0,40        |
| C <sub>4</sub> H <sub>10</sub>    | $\bar{c}_{p0} = 3,954 + 37,12 \theta - 1,833 \theta^2 + 0,03498 \theta^3$                      | 300–1500                          | 0,54        |

Fonte: De T. C. Scott e R. E. Sonntag. University of Michigan, não publicado (1971), exceto C<sub>2</sub>H<sub>6</sub>, C<sub>3</sub>H<sub>8</sub>, C<sub>4</sub>H<sub>10</sub>, de K. A. Kobe, Petroleum Refiner, 28, No. 2, 113 (1949)

**Tabela A.12** — Propriedades termodinâmicas do ar (gás perfeito e a pressão de referência para a entropia é 0,1 MPa)

| $T$<br>K    | $u$<br>kJ/kg   | $h$<br>kJ/kg    | $s^0$<br>kJ/kgK | $p_r$           | $v_r$          |
|-------------|----------------|-----------------|-----------------|-----------------|----------------|
| 200         | 142,768        | 200,174         | 6,46260         | 0,27027         | 493,466        |
| 220         | 157,071        | 220,218         | 6,55812         | 0,37700         | 389,150        |
| 240         | 171,379        | 240,267         | 6,64535         | 0,51088         | 313,274        |
| 260         | 185,695        | 260,323         | 6,72562         | 0,67573         | 256,584        |
| <b>280</b>  | <b>200,022</b> | <b>280,390</b>  | <b>6,79998</b>  | <b>0,87556</b>  | <b>213,257</b> |
| 290         | 207,191        | 290,430         | 6,83521         | 0,98990         | 195,361        |
| 298,15      | 213,036        | 298,615         | 6,86305         | 1,09071         | 182,288        |
| 300         | 214,364        | 300,473         | 6,86926         | 1,11458         | 179,491        |
| 320         | 228,726        | 320,576         | 6,93413         | 1,39722         | 152,728        |
| <b>340</b>  | <b>243,113</b> | <b>340,704</b>  | <b>6,99515</b>  | <b>1,72814</b>  | <b>131,200</b> |
| 360         | 257,532        | 360,863         | 7,05276         | 2,11226         | 113,654        |
| 380         | 271,988        | 381,060         | 7,10735         | 2,55479         | 99,1882        |
| 400         | 286,487        | 401,299         | 7,15926         | 3,06119         | 87,1367        |
| 420         | 301,035        | 421,589         | 7,20875         | 3,63727         | 77,0025        |
| <b>440</b>  | <b>315,640</b> | <b>441,934</b>  | <b>7,25607</b>  | <b>4,28916</b>  | <b>68,4088</b> |
| 460         | 330,306        | 462,340         | 7,30142         | 5,02333         | 61,0658        |
| 480         | 345,039        | 482,814         | 7,34499         | 5,84663         | 54,7479        |
| 500         | 359,844        | 503,360         | 7,38692         | 6,76629         | 49,2777        |
| 520         | 374,726        | 523,982         | 7,42736         | 7,78997         | 44,5143        |
| <b>540</b>  | <b>389,689</b> | <b>544,686</b>  | <b>7,46642</b>  | <b>8,92569</b>  | <b>40,3444</b> |
| 560         | 404,736        | 565,474         | 7,50422         | 10,18197        | 36,6765        |
| 580         | 419,871        | 586,350         | 7,54084         | 11,56771        | 33,4358        |
| 600         | 435,097        | 607,316         | 7,57638         | 13,09232        | 30,5609        |
| 620         | 450,415        | 628,375         | 7,61090         | 14,76564        | 28,0008        |
| <b>640</b>  | <b>465,828</b> | <b>649,528</b>  | <b>7,64448</b>  | <b>16,59801</b> | <b>25,7132</b> |
| 660         | 481,335        | 670,776         | 7,67717         | 18,60025        | 23,6623        |
| 680         | 496,939        | 692,120         | 7,70903         | 20,78367        | 21,8182        |
| 700         | 512,639        | 713,561         | 7,74010         | 23,16010        | 20,1553        |
| 720         | 528,435        | 735,098         | 7,77044         | 25,74188        | 18,6519        |
| <b>740</b>  | <b>544,328</b> | <b>756,731</b>  | <b>7,80008</b>  | <b>28,54188</b> | <b>17,2894</b> |
| 760         | 560,316        | 778,460         | 7,82905         | 31,57347        | 16,0518        |
| 780         | 576,400        | 800,284         | 7,85740         | 34,85061        | 14,9250        |
| 800         | 592,577        | 822,202         | 7,88514         | 38,38777        | 13,8972        |
| 850         | 633,422        | 877,397         | 7,95207         | 48,46828        | 11,6948        |
| <b>900</b>  | <b>674,824</b> | <b>933,152</b>  | <b>8,01581</b>  | <b>60,51977</b> | <b>9,91692</b> |
| 950         | 716,756        | 989,436         | 8,07667         | 74,81519        | 8,46770        |
| 1000        | 759,189        | 1046,221        | 8,13493         | 91,65077        | 7,27604        |
| 1050        | 802,095        | 1103,478        | 8,19081         | 111,3467        | 6,28845        |
| 1100        | 845,445        | 1161,180        | 8,24449         | 134,2478        | 5,46408        |
| <b>1150</b> | <b>881,211</b> | <b>1219,298</b> | <b>8,29616</b>  | <b>160,7245</b> | <b>4,77141</b> |

Tabela A,12 (Continuação) — Propriedades termodinâmicas do ar (gás perfeito e a pressão de referência para a entropia é 0,1 MPa)

| $T$<br>K    | $u$<br>kJ/kg    | $h$<br>kJ/kg    | $s^0$<br>kJ/kgK | $p_r$           | $v_r$          |
|-------------|-----------------|-----------------|-----------------|-----------------|----------------|
| 1100        | 845,445         | 1161,180        | 8,24449         | 134,2478        | 5,46408        |
| 1120        | 862,903         | 1184,379        | 8,26539         | 144,3878        | 5,17272        |
| 1140        | 880,426         | 1207,642        | 8,28598         | 155,1245        | 4,90068        |
| 1160        | 898,012         | 1230,969        | 8,30626         | 166,4834        | 4,64642        |
| <b>1180</b> | <b>915,660</b>  | <b>1254,357</b> | <b>8,32625</b>  | <b>178,4908</b> | <b>4,40857</b> |
| 1200        | 933,367         | 1277,805        | 8,34596         | 191,1736        | 4,18586        |
| 1250        | 977,888         | 1336,677        | 8,39402         | 226,0192        | 3,68804        |
| 1300        | 1022,751        | 1395,892        | 8,44046         | 265,7145        | 3,26257        |
| 1350        | 1067,936        | 1455,429        | 8,48539         | 310,7426        | 2,89711        |
| <b>1400</b> | <b>1113,426</b> | <b>1515,270</b> | <b>8,52891</b>  | <b>361,6192</b> | <b>2,58171</b> |
| 1450        | 1159,202        | 1575,398        | 8,57111         | 418,8942        | 2,30831        |
| 1500        | 1205,253        | 1635,800        | 8,61208         | 483,1554        | 2,07031        |
| 1550        | 1251,547        | 1696,446        | 8,65185         | 554,9577        | 1,86253        |
| 1600        | 1298,079        | 1757,329        | 8,69051         | 634,9670        | 1,68035        |
| <b>1650</b> | <b>1344,834</b> | <b>1818,436</b> | <b>8,72811</b>  | <b>723,8560</b> | <b>1,52007</b> |
| 1700        | 1391,801        | 1879,755        | 8,76472         | 822,3320        | 1,37858        |
| 1750        | 1438,970        | 1941,275        | 8,80039         | 931,1376        | 1,25330        |
| 1800        | 1486,331        | 2002,987        | 8,83516         | 1051,051        | 1,14204        |
| 1850        | 1533,873        | 2064,882        | 8,86908         | 1182,888        | 1,04294        |
| <b>1900</b> | <b>1581,591</b> | <b>2126,951</b> | <b>8,90219</b>  | <b>1327,498</b> | <b>0,95445</b> |
| 1950        | 1629,474        | 2189,186        | 8,93452         | 1485,772        | 0,87521        |
| 2000        | 1677,518        | 2251,581        | 8,96611         | 1658,635        | 0,80410        |
| 2050        | 1725,714        | 2314,128        | 8,99699         | 1847,077        | 0,74012        |
| 2100        | 1774,057        | 2376,823        | 9,02721         | 2052,109        | 0,68242        |
| <b>2150</b> | <b>1822,541</b> | <b>2439,659</b> | <b>9,05678</b>  | <b>2274,789</b> | <b>0,63027</b> |
| 2200        | 1871,161        | 2502,630        | 9,08573         | 2516,217        | 0,58305        |
| 2250        | 1919,912        | 2565,733        | 9,11409         | 2777,537        | 0,54020        |
| 2300        | 1968,790        | 2628,962        | 9,14189         | 3059,939        | 0,50124        |
| 2350        | 2017,789        | 2692,313        | 9,16913         | 3364,658        | 0,46576        |
| <b>2400</b> | <b>2066,907</b> | <b>2755,782</b> | <b>9,19586</b>  | <b>3692,974</b> | <b>0,43338</b> |
| 2450        | 2116,138        | 2819,366        | 9,22208         | 4046,215        | 0,40378        |
| 2500        | 2165,480        | 2883,059        | 9,24781         | 4425,759        | 0,37669        |
| 2550        | 2214,929        | 2946,859        | 9,27308         | 4833,031        | 0,35185        |
| 2600        | 2264,481        | 3010,763        | 9,29790         | 5269,505        | 0,32903        |
| <b>2650</b> | <b>2314,133</b> | <b>3074,767</b> | <b>9,32228</b>  | <b>5736,707</b> | <b>0,30805</b> |
| 2700        | 2363,883        | 3138,868        | 9,34625         | 6236,215        | 0,28872        |
| 2750        | 2413,727        | 3203,064        | 9,36980         | 6769,657        | 0,27089        |
| 2800        | 2463,663        | 3267,351        | 9,39297         | 7338,715        | 0,25443        |
| 2850        | 2513,687        | 3331,726        | 9,41576         | 7945,124        | 0,23921        |
| <b>2900</b> | <b>2563,797</b> | <b>3396,188</b> | <b>9,43818</b>  | <b>8590,676</b> | <b>0,22511</b> |
| 2950        | 2613,990        | 3460,733        | 9,46025         | 9277,216        | 0,21205        |
| 3000        | 2664,265        | 3525,359        | 9,48198         | 10006,645       | 0,19992        |

**Tabela A.13** — Propriedades de várias substâncias (gases perfeitos e entropia relativa a 0,1 MPa)

| Nitrogênio, diatômico (N <sub>2</sub> )   |                                            |                         | Nitrogênio, monoatômico (N)                    |                         |
|-------------------------------------------|--------------------------------------------|-------------------------|------------------------------------------------|-------------------------|
| $\bar{h}_{f,298}^0 = 0 \text{ kJ / kmol}$ |                                            |                         | $\bar{h}_{f,298}^0 = 472680 \text{ kJ / kmol}$ |                         |
| $M = 28,013$                              |                                            |                         | $M = 14,007$                                   |                         |
| $T$<br>K                                  | $(\bar{h} - \bar{h}_{f,298}^0)$<br>kJ/kmol | $\bar{s}^0$<br>kJ/kmolK | $(\bar{h} - \bar{h}_{f,298}^0)$<br>kJ/kmol     | $\bar{s}^0$<br>kJ/kmolK |
| 0                                         | -8670                                      | 0                       | -6197                                          | 0                       |
| 100                                       | -5768                                      | 159,812                 | -4119                                          | 130,593                 |
| 200                                       | -2857                                      | 179,985                 | -2040                                          | 145,001                 |
| 298                                       | 0                                          | 191,609                 | 0                                              | 153,300                 |
| <b>300</b>                                | <b>54</b>                                  | <b>191,789</b>          | <b>38</b>                                      | <b>153,429</b>          |
| 400                                       | 2971                                       | 200,181                 | 2117                                           | 159,409                 |
| 500                                       | 5911                                       | 206,740                 | 4196                                           | 164,047                 |
| 600                                       | 8894                                       | 212,177                 | 6274                                           | 167,837                 |
| 700                                       | 11937                                      | 216,865                 | 8353                                           | 171,041                 |
| <b>800</b>                                | <b>15046</b>                               | <b>221,016</b>          | <b>10431</b>                                   | <b>173,816</b>          |
| 900                                       | 18223                                      | 224,757                 | 12510                                          | 176,265                 |
| 1000                                      | 21463                                      | 228,171                 | 14589                                          | 178,455                 |
| 1100                                      | 24760                                      | 231,314                 | 16667                                          | 180,436                 |
| 1200                                      | 28109                                      | 234,227                 | 18746                                          | 182,244                 |
| <b>1300</b>                               | <b>31503</b>                               | <b>236,943</b>          | <b>20825</b>                                   | <b>183,908</b>          |
| 1400                                      | 34936                                      | 239,487                 | 22903                                          | 185,448                 |
| 1500                                      | 38405                                      | 241,881                 | 24982                                          | 186,883                 |
| 1600                                      | 41904                                      | 244,139                 | 27060                                          | 188,224                 |
| 1700                                      | 45430                                      | 246,276                 | 29139                                          | 189,484                 |
| <b>1800</b>                               | <b>48979</b>                               | <b>248,304</b>          | <b>31218</b>                                   | <b>190,672</b>          |
| 1900                                      | 52549                                      | 250,234                 | 33296                                          | 191,796                 |
| 2000                                      | 56137                                      | 252,075                 | 35375                                          | 192,863                 |
| 2200                                      | 63362                                      | 255,518                 | 39534                                          | 194,845                 |
| 2400                                      | 70640                                      | 258,684                 | 43695                                          | 196,655                 |
| <b>2600</b>                               | <b>77963</b>                               | <b>261,615</b>          | <b>47860</b>                                   | <b>198,322</b>          |
| 2800                                      | 85323                                      | 264,342                 | 52033                                          | 199,868                 |
| 3000                                      | 92715                                      | 266,892                 | 56218                                          | 201,311                 |
| 3200                                      | 100134                                     | 269,286                 | 60420                                          | 202,667                 |
| 3400                                      | 107577                                     | 271,542                 | 64646                                          | 203,948                 |
| <b>3600</b>                               | <b>115042</b>                              | <b>273,675</b>          | <b>68902</b>                                   | <b>205,164</b>          |
| 3800                                      | 122526                                     | 275,698                 | 73194                                          | 206,325                 |
| 4000                                      | 130027                                     | 277,622                 | 77532                                          | 207,437                 |
| 4400                                      | 145078                                     | 281,209                 | 86367                                          | 209,542                 |
| 4800                                      | 160188                                     | 284,495                 | 95457                                          | 211,519                 |
| <b>5200</b>                               | <b>175352</b>                              | <b>287,530</b>          | <b>104843</b>                                  | <b>213,397</b>          |
| 5600                                      | 190572                                     | 290,349                 | 114550                                         | 215,195                 |
| 6000                                      | 205848                                     | 292,984                 | 124590                                         | 216,926                 |

Tabela A.13 (Continuação) — Propriedades de várias substâncias (gases perfeitos e entropia relativa a 0,1 MPa)

| Oxigênio, diatômico (O <sub>2</sub> )     |                                            |                         | Oxigênio, monoatômico (O)                      |                         |
|-------------------------------------------|--------------------------------------------|-------------------------|------------------------------------------------|-------------------------|
| $\bar{h}_{f,298}^0 = 0 \text{ kJ / kmol}$ |                                            |                         | $\bar{h}_{f,298}^0 = 249170 \text{ kJ / kmol}$ |                         |
| $M = 31,999$                              |                                            |                         | $M = 16,00$                                    |                         |
| $T$<br>K                                  | $(\bar{h} - \bar{h}_{f,298}^0)$<br>kJ/kmol | $\bar{s}^0$<br>kJ/kmolK | $(\bar{h} - \bar{h}_{f,298}^0)$<br>kJ/kmol     | $\bar{s}^0$<br>kJ/kmolK |
| 0                                         | -8683                                      | 0                       | -6725                                          | 0                       |
| 100                                       | -5777                                      | 173,308                 | -4518                                          | 135,947                 |
| 200                                       | -2868                                      | 193,483                 | -2186                                          | 152,153                 |
| 298                                       | 0                                          | 205,148                 | 0                                              | 161,059                 |
| <b>300</b>                                | <b>54</b>                                  | <b>205,329</b>          | <b>41</b>                                      | <b>161,194</b>          |
| 400                                       | 3027                                       | 213,873                 | 2207                                           | 167,431                 |
| 500                                       | 6086                                       | 220,693                 | 4343                                           | 172,198                 |
| 600                                       | 9245                                       | 226,450                 | 6462                                           | 176,060                 |
| 700                                       | 12499                                      | 231,465                 | 8570                                           | 179,310                 |
| <b>800</b>                                | <b>15836</b>                               | <b>235,920</b>          | <b>10671</b>                                   | <b>182,116</b>          |
| 900                                       | 19241                                      | 239,931                 | 12767                                          | 184,585                 |
| 1000                                      | 22703                                      | 243,579                 | 14860                                          | 186,790                 |
| 1100                                      | 26212                                      | 246,923                 | 16950                                          | 188,783                 |
| 1200                                      | 29761                                      | 250,011                 | 19039                                          | 190,600                 |
| <b>1300</b>                               | <b>33345</b>                               | <b>252,878</b>          | <b>21126</b>                                   | <b>192,270</b>          |
| 1400                                      | 36958                                      | 255,556                 | 23212                                          | 193,816                 |
| 1500                                      | 40600                                      | 258,068                 | 25296                                          | 195,254                 |
| 1600                                      | 44267                                      | 260,434                 | 27381                                          | 196,599                 |
| 1700                                      | 47959                                      | 262,673                 | 29464                                          | 197,862                 |
| <b>1800</b>                               | <b>51674</b>                               | <b>264,797</b>          | <b>31547</b>                                   | <b>199,053</b>          |
| 1900                                      | 55414                                      | 266,819                 | 33630                                          | 200,179                 |
| 2000                                      | 59176                                      | 268,748                 | 35713                                          | 201,247                 |
| 2200                                      | 66770                                      | 272,366                 | 39878                                          | 203,232                 |
| 2400                                      | 74453                                      | 275,708                 | 44045                                          | 205,045                 |
| <b>2600</b>                               | <b>82225</b>                               | <b>278,818</b>          | <b>48216</b>                                   | <b>206,714</b>          |
| 2800                                      | 90080                                      | 281,729                 | 52391                                          | 208,262                 |
| 3000                                      | 98013                                      | 284,466                 | 56574                                          | 209,705                 |
| 3200                                      | 106022                                     | 287,050                 | 60767                                          | 211,058                 |
| 3400                                      | 114101                                     | 289,499                 | 64971                                          | 212,332                 |
| <b>3600</b>                               | <b>122245</b>                              | <b>291,826</b>          | <b>69190</b>                                   | <b>213,538</b>          |
| 3800                                      | 130447                                     | 294,043                 | 73424                                          | 214,682                 |
| 4000                                      | 138705                                     | 296,161                 | 77675                                          | 215,773                 |
| 4400                                      | 155374                                     | 300,133                 | 86234                                          | 217,812                 |
| 4800                                      | 172240                                     | 303,801                 | 94873                                          | 219,691                 |
| <b>5200</b>                               | <b>189312</b>                              | <b>307,217</b>          | <b>103592</b>                                  | <b>221,435</b>          |
| 5600                                      | 206618                                     | 310,423                 | 112391                                         | 223,066                 |
| 6000                                      | 224210                                     | 313,457                 | 121264                                         | 224,597                 |

**Tabela A.13 (Continuação)** — Propriedades de várias substâncias (gases perfeitos e entropia relativa a 0,1 MPa)

| Dióxido de carbono (CO <sub>2</sub> )           |                                            |                         | Monóxido de carbono (CO)                        |                         |
|-------------------------------------------------|--------------------------------------------|-------------------------|-------------------------------------------------|-------------------------|
| $\bar{h}_{f,298}^0 = -393522 \text{ kJ / kmol}$ |                                            |                         | $\bar{h}_{f,298}^0 = -110527 \text{ kJ / kmol}$ |                         |
| $M = 44,01$                                     |                                            |                         | $M = 28,01$                                     |                         |
| $T$<br>K                                        | $(\bar{h} - \bar{h}_{f,298}^0)$<br>kJ/kmol | $\bar{s}^0$<br>kJ/kmolK | $(\bar{h} - \bar{h}_{f,298}^0)$<br>kJ/kmol      | $\bar{s}^0$<br>kJ/kmolK |
| 0                                               | -9364                                      | 0                       | -8671                                           | 0                       |
| 100                                             | -6457                                      | 179,010                 | -5772                                           | 165,852                 |
| 200                                             | -3413                                      | 199,976                 | -2860                                           | 186,024                 |
| 298                                             | 0                                          | 213,794                 | 0                                               | 197,651                 |
| <b>300</b>                                      | <b>69</b>                                  | <b>214,024</b>          | <b>54</b>                                       | <b>197,831</b>          |
| 400                                             | 4003                                       | 225,314                 | 2977                                            | 206,240                 |
| 500                                             | 8305                                       | 234,902                 | 5932                                            | 212,833                 |
| 600                                             | 12906                                      | 243,284                 | 8942                                            | 218,321                 |
| 700                                             | 17754                                      | 250,752                 | 12021                                           | 223,067                 |
| <b>800</b>                                      | <b>22806</b>                               | <b>257,496</b>          | <b>15174</b>                                    | <b>227,277</b>          |
| 900                                             | 28030                                      | 263,646                 | 18397                                           | 231,074                 |
| 1000                                            | 33397                                      | 269,299                 | 21686                                           | 234,538                 |
| 1100                                            | 38885                                      | 274,528                 | 25031                                           | 237,726                 |
| 1200                                            | 44473                                      | 279,390                 | 28427                                           | 240,679                 |
| <b>1300</b>                                     | <b>50148</b>                               | <b>283,931</b>          | <b>31867</b>                                    | <b>243,431</b>          |
| 1400                                            | 55895                                      | 288,190                 | 35343                                           | 246,006                 |
| 1500                                            | 61705                                      | 292,199                 | 38852                                           | 248,426                 |
| 1600                                            | 67569                                      | 295,984                 | 42388                                           | 250,707                 |
| 1700                                            | 73480                                      | 299,567                 | 45948                                           | 252,866                 |
| <b>1800</b>                                     | <b>79432</b>                               | <b>302,969</b>          | <b>49529</b>                                    | <b>254,913</b>          |
| 1900                                            | 85420                                      | 306,207                 | 53128                                           | 256,860                 |
| 2000                                            | 91439                                      | 309,294                 | 56743                                           | 258,716                 |
| 2200                                            | 103562                                     | 315,070                 | 64012                                           | 262,182                 |
| 2400                                            | 115779                                     | 320,384                 | 71326                                           | 265,361                 |
| <b>2600</b>                                     | <b>128074</b>                              | <b>325,307</b>          | <b>78679</b>                                    | <b>268,302</b>          |
| 2800                                            | 140435                                     | 329,887                 | 86070                                           | 271,044                 |
| 3000                                            | 152853                                     | 334,170                 | 93504                                           | 273,607                 |
| 3200                                            | 165321                                     | 338,194                 | 100962                                          | 276,012                 |
| 3400                                            | 177836                                     | 341,988                 | 108440                                          | 278,279                 |
| <b>3600</b>                                     | <b>190394</b>                              | <b>345,576</b>          | <b>115938</b>                                   | <b>280,422</b>          |
| 3800                                            | 202990                                     | 348,981                 | 123454                                          | 282,454                 |
| 4000                                            | 215624                                     | 352,221                 | 130989                                          | 284,387                 |
| 4400                                            | 240992                                     | 358,266                 | 146108                                          | 287,989                 |
| 4800                                            | 266488                                     | 363,812                 | 161285                                          | 291,290                 |
| <b>5200</b>                                     | <b>292112</b>                              | <b>368,939</b>          | <b>176510</b>                                   | <b>294,337</b>          |
| 5600                                            | 317870                                     | 373,711                 | 191782                                          | 297,167                 |
| 6000                                            | 343782                                     | 378,180                 | 207105                                          | 299,809                 |

**Tabela A.13 (Continuação)** — Propriedades de várias substâncias (gases perfeitos e entropia relativa a 0,1 MPa)

| <p>Água (H<sub>2</sub>O)</p> $\bar{h}_{f,298}^0 = -241826 \text{ kJ / kmol}$<br>$M = 18,015$ |                                 |                | <p>Hidroxila (OH)</p> $\bar{h}_{f,298}^0 = 38987 \text{ kJ / kmol}$<br>$M = 17,007$ |                |
|----------------------------------------------------------------------------------------------|---------------------------------|----------------|-------------------------------------------------------------------------------------|----------------|
| <i>T</i>                                                                                     | $(\bar{h} - \bar{h}_{f,298}^0)$ | $\bar{s}^0$    | $(\bar{h} - \bar{h}_{f,298}^0)$                                                     | $\bar{s}^0$    |
| K                                                                                            | kJ/kmol                         | kJ/kmolK       | kJ/kmol                                                                             | kJ/kmolK       |
| 0                                                                                            | -9904                           | 0              | -9172                                                                               | 0              |
| 100                                                                                          | -6617                           | 152,386        | -6140                                                                               | 149,591        |
| 200                                                                                          | -3282                           | 175,488        | -2975                                                                               | 171,592        |
| 298                                                                                          | 0                               | 188,835        | 0                                                                                   | 183,709        |
| <b>300</b>                                                                                   | <b>62</b>                       | <b>189,043</b> | <b>55</b>                                                                           | <b>183,894</b> |
| 400                                                                                          | 3450                            | 198,787        | 3034                                                                                | 192,466        |
| 500                                                                                          | 6922                            | 206,532        | 5991                                                                                | 199,066        |
| 600                                                                                          | 10499                           | 213,051        | 8943                                                                                | 204,448        |
| 700                                                                                          | 14190                           | 218,739        | 11902                                                                               | 209,008        |
| <b>800</b>                                                                                   | <b>18002</b>                    | <b>223,826</b> | <b>14881</b>                                                                        | <b>212,984</b> |
| 900                                                                                          | 21937                           | 228,460        | 17889                                                                               | 216,526        |
| 1000                                                                                         | 26000                           | 232,739        | 20935                                                                               | 219,735        |
| 1100                                                                                         | 30190                           | 236,732        | 24024                                                                               | 222,680        |
| 1200                                                                                         | 34506                           | 240,485        | 27159                                                                               | 225,408        |
| <b>1300</b>                                                                                  | <b>38941</b>                    | <b>244,035</b> | <b>30340</b>                                                                        | <b>227,955</b> |
| 1400                                                                                         | 43491                           | 247,406        | 33567                                                                               | 230,347        |
| 1500                                                                                         | 48149                           | 250,620        | 36838                                                                               | 232,604        |
| 1600                                                                                         | 52907                           | 253,690        | 40151                                                                               | 234,741        |
| 1700                                                                                         | 57757                           | 256,631        | 43502                                                                               | 236,772        |
| <b>1800</b>                                                                                  | <b>62693</b>                    | <b>259,452</b> | <b>46890</b>                                                                        | <b>238,707</b> |
| 1900                                                                                         | 67706                           | 262,162        | 50311                                                                               | 240,556        |
| 2000                                                                                         | 72788                           | 264,769        | 53763                                                                               | 242,328        |
| 2200                                                                                         | 83153                           | 269,706        | 60751                                                                               | 245,659        |
| 2400                                                                                         | 93741                           | 274,312        | 67840                                                                               | 248,743        |
| <b>2600</b>                                                                                  | <b>104520</b>                   | <b>278,625</b> | <b>75018</b>                                                                        | <b>251,614</b> |
| 2800                                                                                         | 115463                          | 282,680        | 82268                                                                               | 254,301        |
| 3000                                                                                         | 126548                          | 286,504        | 89585                                                                               | 256,825        |
| 3200                                                                                         | 137756                          | 290,120        | 96960                                                                               | 259,205        |
| 3400                                                                                         | 149073                          | 293,550        | 104388                                                                              | 261,456        |
| <b>3600</b>                                                                                  | <b>160484</b>                   | <b>296,812</b> | <b>111864</b>                                                                       | <b>263,592</b> |
| 3800                                                                                         | 171981                          | 299,919        | 119382                                                                              | 265,625        |
| 4000                                                                                         | 183552                          | 302,887        | 126940                                                                              | 267,563        |
| 4400                                                                                         | 206892                          | 308,448        | 142165                                                                              | 271,191        |
| 4800                                                                                         | 230456                          | 313,573        | 157522                                                                              | 274,531        |
| <b>5200</b>                                                                                  | <b>254216</b>                   | <b>318,328</b> | <b>173002</b>                                                                       | <b>277,629</b> |
| 5600                                                                                         | 278161                          | 322,764        | 188598                                                                              | 280,518        |
| 6000                                                                                         | 302295                          | 326,926        | 204309                                                                              | 283,227        |



**Tabela A.13 (Continuação) —** Propriedades de várias substâncias (gases perfeitos e entropia relativa a 0,1 MPa)

| Hidrogênio (H <sub>2</sub> )                             |                                            |                         | Hidrogênio monoatômico (H)                                    |                         |
|----------------------------------------------------------|--------------------------------------------|-------------------------|---------------------------------------------------------------|-------------------------|
| $\bar{h}_{f,298}^0 = 0 \text{ kJ / kmol}$<br>$M = 2,016$ |                                            |                         | $\bar{h}_{f,298}^0 = 217999 \text{ kJ / kmol}$<br>$M = 1,008$ |                         |
| $T$<br>K                                                 | $(\bar{h} - \bar{h}_{f,298}^0)$<br>kJ/kmol | $\bar{s}^0$<br>kJ/kmolK | $(\bar{h} - \bar{h}_{f,298}^0)$<br>kJ/kmol                    | $\bar{s}^0$<br>kJ/kmolK |
| 0                                                        | -8467                                      | 0                       | -6197                                                         | 0                       |
| 100                                                      | -5467                                      | 100,727                 | -4119                                                         | 92,009                  |
| 200                                                      | -2774                                      | 119,410                 | -2040                                                         | 106,417                 |
| 298                                                      | 0                                          | 130,678                 | 0                                                             | 114,716                 |
| <b>300</b>                                               | <b>53</b>                                  | <b>130,856</b>          | <b>38</b>                                                     | <b>114,845</b>          |
| 400                                                      | 2961                                       | 139,219                 | 2117                                                          | 120,825                 |
| 500                                                      | 5883                                       | 145,738                 | 4196                                                          | 125,463                 |
| 600                                                      | 8799                                       | 151,078                 | 6274                                                          | 129,253                 |
| 700                                                      | 11730                                      | 155,609                 | 8353                                                          | 132,457                 |
| <b>800</b>                                               | <b>14681</b>                               | <b>159,554</b>          | <b>10431</b>                                                  | <b>135,233</b>          |
| 900                                                      | 17657                                      | 163,060                 | 12510                                                         | 137,681                 |
| 1000                                                     | 20663                                      | 166,225                 | 14589                                                         | 139,871                 |
| 1100                                                     | 23704                                      | 169,121                 | 16667                                                         | 141,852                 |
| 1200                                                     | 26785                                      | 171,798                 | 18746                                                         | 143,661                 |
| <b>1300</b>                                              | <b>29907</b>                               | <b>174,294</b>          | <b>20825</b>                                                  | <b>145,324</b>          |
| 1400                                                     | 33073                                      | 176,637                 | 22903                                                         | 146,865                 |
| 1500                                                     | 36281                                      | 178,849                 | 24982                                                         | 148,299                 |
| 1600                                                     | 39533                                      | 180,946                 | 27060                                                         | 149,640                 |
| 1700                                                     | 42826                                      | 182,941                 | 29139                                                         | 150,900                 |
| <b>1800</b>                                              | <b>46160</b>                               | <b>184,846</b>          | <b>31218</b>                                                  | <b>152,089</b>          |
| 1900                                                     | 49532                                      | 186,670                 | 33296                                                         | 153,212                 |
| 2000                                                     | 52942                                      | 188,419                 | 35375                                                         | 154,279                 |
| 2200                                                     | 59865                                      | 191,719                 | 39532                                                         | 156,260                 |
| 2400                                                     | 66915                                      | 194,789                 | 43689                                                         | 158,069                 |
| <b>2600</b>                                              | <b>74082</b>                               | <b>197,659</b>          | <b>47847</b>                                                  | <b>159,732</b>          |
| 2800                                                     | 81355                                      | 200,355                 | 52004                                                         | 161,273                 |
| 3000                                                     | 88725                                      | 202,898                 | 56161                                                         | 162,707                 |
| 3200                                                     | 96187                                      | 205,306                 | 60318                                                         | 164,048                 |
| 3400                                                     | 103736                                     | 207,593                 | 64475                                                         | 165,308                 |
| <b>3600</b>                                              | <b>111367</b>                              | <b>209,773</b>          | <b>68633</b>                                                  | <b>166,497</b>          |
| 3800                                                     | 119077                                     | 211,856                 | 72790                                                         | 167,620                 |
| 4000                                                     | 126864                                     | 213,851                 | 76947                                                         | 168,687                 |
| 4400                                                     | 142658                                     | 217,612                 | 85261                                                         | 170,668                 |
| 4800                                                     | 158730                                     | 221,109                 | 93576                                                         | 172,476                 |
| <b>5200</b>                                              | <b>175057</b>                              | <b>224,379</b>          | <b>101890</b>                                                 | <b>174,140</b>          |
| 5600                                                     | 191607                                     | 227,447                 | 110205                                                        | 175,681                 |
| 6000                                                     | 208332                                     | 230,322                 | 118519                                                        | 177,114                 |

**Tabela A.13 (Continuação)** — Propriedades de várias substâncias (gases perfeitos e entropia relativa a 0,1 MPa)

| Óxido nítrico (NO)                            |                                            |                         | Dióxido de nitrogênio (NO <sub>2</sub> )      |                         |
|-----------------------------------------------|--------------------------------------------|-------------------------|-----------------------------------------------|-------------------------|
| $\bar{h}_{f,298}^0 = 90291 \text{ kJ / kmol}$ |                                            |                         | $\bar{h}_{f,298}^0 = 33100 \text{ kJ / kmol}$ |                         |
| $M = 30,006$                                  |                                            |                         | $M = 46,005$                                  |                         |
| $T$<br>K                                      | $(\bar{h} - \bar{h}_{f,298}^0)$<br>kJ/kmol | $\bar{s}^0$<br>kJ/kmolK | $(\bar{h} - \bar{h}_{f,298}^0)$<br>kJ/kmol    | $\bar{s}^0$<br>kJ/kmolK |
| 0                                             | -9192                                      | 0                       | -10186                                        | 0                       |
| 100                                           | -6073                                      | 177,031                 | -6861                                         | 202,563                 |
| 200                                           | -2951                                      | 198,747                 | -3495                                         | 225,852                 |
| 298                                           | 0                                          | 210,759                 | 0                                             | 240,034                 |
| <b>300</b>                                    | <b>55</b>                                  | <b>210,943</b>          | <b>68</b>                                     | <b>240,263</b>          |
| 400                                           | 3040                                       | 219,529                 | 3927                                          | 251,342                 |
| 500                                           | 6059                                       | 226,263                 | 8099                                          | 260,638                 |
| 600                                           | 9144                                       | 231,886                 | 12555                                         | 268,755                 |
| 700                                           | 12308                                      | 236,762                 | 17250                                         | 275,988                 |
| <b>800</b>                                    | <b>15548</b>                               | <b>241,088</b>          | <b>22138</b>                                  | <b>282,513</b>          |
| 900                                           | 18858                                      | 244,985                 | 27180                                         | 288,450                 |
| 1000                                          | 22229                                      | 248,536                 | 32344                                         | 293,889                 |
| 1100                                          | 25653                                      | 251,799                 | 37606                                         | 298,904                 |
| 1200                                          | 29120                                      | 254,816                 | 42946                                         | 303,551                 |
| <b>1300</b>                                   | <b>32626</b>                               | <b>257,621</b>          | <b>48351</b>                                  | <b>307,876</b>          |
| 1400                                          | 36164                                      | 260,243                 | 53808                                         | 311,920                 |
| 1500                                          | 39729                                      | 262,703                 | 59309                                         | 315,715                 |
| 1600                                          | 43319                                      | 265,019                 | 64846                                         | 319,289                 |
| 1700                                          | 46929                                      | 267,208                 | 70414                                         | 322,664                 |
| <b>1800</b>                                   | <b>50557</b>                               | <b>269,282</b>          | <b>76008</b>                                  | <b>325,861</b>          |
| 1900                                          | 54201                                      | 271,252                 | 81624                                         | 328,898                 |
| 2000                                          | 57859                                      | 273,128                 | 87259                                         | 331,788                 |
| 2200                                          | 65212                                      | 276,632                 | 98578                                         | 337,182                 |
| 2400                                          | 72606                                      | 279,849                 | 109948                                        | 342,128                 |
| <b>2600</b>                                   | <b>80034</b>                               | <b>282,822</b>          | <b>121358</b>                                 | <b>346,695</b>          |
| 2800                                          | 87491                                      | 285,585                 | 132800                                        | 350,934                 |
| 3000                                          | 94973                                      | 288,165                 | 144267                                        | 354,890                 |
| 3200                                          | 102477                                     | 290,587                 | 155756                                        | 358,597                 |
| 3400                                          | 110000                                     | 292,867                 | 167262                                        | 362,085                 |
| <b>3600</b>                                   | <b>117541</b>                              | <b>295,022</b>          | <b>178783</b>                                 | <b>365,378</b>          |
| 3800                                          | 125099                                     | 297,065                 | 190316                                        | 368,495                 |
| 4000                                          | 132671                                     | 299,007                 | 201860                                        | 371,456                 |
| 4400                                          | 147857                                     | 302,626                 | 224973                                        | 376,963                 |
| 4800                                          | 163094                                     | 305,940                 | 248114                                        | 381,997                 |
| <b>5200</b>                                   | <b>178377</b>                              | <b>308,998</b>          | <b>271276</b>                                 | <b>386,632</b>          |
| 5600                                          | 193703                                     | 311,838                 | 294455                                        | 390,926                 |
| 6000                                          | 209070                                     | 314,488                 | 317648                                        | 394,926                 |

**Tabela A.14** — Coeficientes viriais e constantes de força para o potencial de Lennard - Jones (6-12)

**Tabela A.14.1** — Coeficientes reduzidos e suas derivadas

| $T^*$ | $B^*$     | $B_1^* = T^* \frac{dB^*}{dT^*}$ | $C^*$    | $C_1^* = T^* \frac{dC^*}{dT^*}$ |
|-------|-----------|---------------------------------|----------|---------------------------------|
| 0,3   | -27,88061 | 76,60701                        |          |                                 |
| 0,4   | -13,79885 | 30,26698                        |          |                                 |
| 0,5   | -8,72022  | 16,92367                        |          |                                 |
| 0,6   | -6,19798  | 11,24883                        |          |                                 |
| 0,7   | -4,71004  | 8,25711                         | -3,44223 | 29,02471                        |
| 0,8   | -3,73423  | 6,45414                         | -0,87753 | 11,80911                        |
| 0,9   | -3,04712  | 5,26492                         | 0,06579  | 5,05023                         |
| 1,0   | -2,53809  | 4,42826                         | 0,42600  | 2,12100                         |
| 1,1   | -2,14638  | 3,81063                         | 0,55670  | 0,76761                         |
| 1,2   | -1,83595  | 3,33749                         | 0,59235  | 0,12051                         |
| 1,3   | -1,58411  | 2,96421                         | 0,58821  | -0,18965                        |
| 1,4   | -1,37585  | 2,66262                         | 0,56823  | -0,33189                        |
| 1,5   | -1,20089  | 2,41414                         | 0,54307  | -0,38813                        |
| 1,6   | -1,05191  | 2,20602                         | 0,51748  | -0,39994                        |
| 1,7   | -0,92362  | 2,02926                         | 0,49348  | -0,38906                        |
| 1,8   | -0,81203  | 1,87733                         | 0,47183  | -0,36719                        |
| 1,9   | -0,71415  | 1,74537                         | 0,45267  | -0,34065                        |
| 2,0   | -0,62763  | 1,62972                         | 0,43590  | -0,31290                        |
| 2,2   | -0,48171  | 1,43663                         | 0,40861  | -0,26013                        |
| 2,4   | -0,36358  | 1,28190                         | 0,38797  | -0,21492                        |
| 2,6   | -0,26613  | 1,15517                         | 0,37228  | -0,17792                        |
| 2,8   | -0,18451  | 1,04948                         | 0,36022  | -0,14821                        |
| 3,0   | -0,11523  | 0,96000                         | 0,35084  | -0,12454                        |
| 3,2   | -0,05579  | 0,88328                         | 0,34342  | -0,10574                        |
| 3,4   | -0,00428  | 0,81676                         | 0,33748  | -0,09081                        |
| 3,6   | 0,04072   | 0,75854                         | 0,33264  | -0,07895                        |
| 3,8   | 0,08033   | 0,70716                         | 0,32863  | -0,06955                        |
| 4,0   | 0,11542   | 0,66148                         | 0,32526  | -0,06209                        |
| 4,2   | 0,14668   | 0,62060                         | 0,32238  | -0,05619                        |
| 4,4   | 0,17469   | 0,58381                         | 0,31988  | -0,05154                        |
| 4,6   | 0,19990   | 0,55051                         | 0,31767  | -0,04789                        |
| 4,8   | 0,22268   | 0,52024                         | 0,31569  | -0,04506                        |
| 5,0   | 0,24334   | 0,49260                         | 0,31390  | -0,04288                        |
| 6,0   | 0,32290   | 0,38397                         | 0,30661  | -0,03831                        |
| 7,0   | 0,37609   | 0,30826                         | 0,30069  | -0,03899                        |
| 8,0   | 0,41343   | 0,25248                         | 0,29533  | -0,04152                        |
| 9,0   | 0,44060   | 0,20970                         | 0,29027  | -0,04456                        |
| 10,0  | 0,46088   | 0,17587                         | 0,28541  | -0,04758                        |
| 20,0  | 0,52538   | 0,02866                         | 0,24609  | -0,06402                        |
| 30,0  | 0,52693   | -0,01749                        | 0,21930  | -0,06728                        |

**Tabela A.14.1** — Constantes de força obtidos a partir dos coeficientes viriais

| Substância     | $\epsilon/k, K$ | $b_0, m^3/kmol$ | Substância       | $\epsilon/k, K$ | $b_0, m^3/kmol$ |
|----------------|-----------------|-----------------|------------------|-----------------|-----------------|
| Ne             | 35,8            | 0,0262          | CO               | 100,2           | 0,0675          |
| Ar             | 119,0           | 0,0502          | NO               | 131,0           | 0,0402          |
| Kr             | 173,0           | 0,0583          | CO <sub>2</sub>  | 186,0           | 0,118           |
| Xe             | 225,3           | 0,0854          | N <sub>2</sub> O | 193,0           | 0,118           |
| N <sub>2</sub> | 95,05           | 0,0635          | CH <sub>4</sub>  | 148,1           | 0,0698          |
| O <sub>2</sub> | 117,5           | 0,0578          | CF <sub>4</sub>  | 152,0           | 0,131           |

Tabela A.15 — Tabelas generalizadas de três parâmetros ( $T_r$ ,  $p_r$ ,  $\omega$ )

Tabela A.15.1 — Tabela generalizada para a região de saturação (fluido simples)

| $T_r$       | $\ln(p_r)$      | $Z_l$          | $Z_v$          | $\left(\frac{h^* - h}{RT_c}\right)_l$ | $\left(\frac{h^* - h}{RT_c}\right)_v$ | $\left(\frac{s_p^* - s_p}{R}\right)_l$ | $\left(\frac{s_p^* - s_p}{R}\right)_v$ | $\ln\left(\frac{f}{p}\right)$ |
|-------------|-----------------|----------------|----------------|---------------------------------------|---------------------------------------|----------------------------------------|----------------------------------------|-------------------------------|
| 0.30        | -13,14053       | 0.00000        | 0.99998        | 6,04616                               | 0.00002                               | 20,09953                               | 0.00005                                | -0.00002                      |
| 0.32        | -11,89025       | 0.00000        | 0.99993        | 5,99061                               | 0.00007                               | 18,06562                               | 0.00014                                | -0.00007                      |
| 0.34        | -10,79655       | 0.00001        | 0.99983        | 5,93515                               | 0.00018                               | 16,51869                               | 0.00035                                | -0.00017                      |
| 0.36        | -9,83281        | 0.00002        | 0.99963        | 5,87895                               | 0.00040                               | 16,01837                               | 0.00076                                | -0.00037                      |
| <b>0.38</b> | <b>-8,97801</b> | <b>0.00003</b> | <b>0.99927</b> | <b>5,82177</b>                        | <b>0.00085</b>                        | <b>15,31191</b>                        | <b>0.00150</b>                         | <b>-0.00073</b>               |
| 0.40        | -8,21540        | 0.00006        | 0.99865        | 5,76367                               | 0.00163                               | 14,41129                               | 0.00272                                | -0.00134                      |
| 0.42        | -7,53140        | 0.00012        | 0.99770        | 5,70481                               | 0.00291                               | 13,58378                               | 0.00463                                | -0.00230                      |
| 0.44        | -6,91492        | 0.00022        | 0.99628        | 5,64539                               | 0.00489                               | 12,82092                               | 0.00741                                | -0.00371                      |
| 0.46        | -6,35683        | 0.00038        | 0.99430        | 5,58558                               | 0.00781                               | 12,13784                               | 0.01129                                | -0.00568                      |
| <b>0.48</b> | <b>-5,84950</b> | <b>0.00061</b> | <b>0.99165</b> | <b>5,52553</b>                        | <b>0.01191</b>                        | <b>11,50344</b>                        | <b>0.01648</b>                         | <b>-0.00832</b>               |
| 0.50        | -5,38653        | 0.00095        | 0.98820        | 5,46534                               | 0.01745                               | 10,91801                               | 0.02317                                | -0.01173                      |
| 0.52        | -4,96253        | 0.00141        | 0.98389        | 5,40509                               | 0.02472                               | 10,37636                               | 0.03155                                | -0.01600                      |
| 0.54        | -4,57289        | 0.00204        | 0.97862        | 5,34481                               | 0.03399                               | 9,87361                                | 0.04176                                | -0.02118                      |
| 0.56        | -4,21367        | 0.00286        | 0.97233        | 5,28447                               | 0.04552                               | 9,40554                                | 0.05395                                | -0.02734                      |
| <b>0.58</b> | <b>-3,88146</b> | <b>0.00390</b> | <b>0.96498</b> | <b>5,22403</b>                        | <b>0.05958</b>                        | <b>8,96810</b>                         | <b>0.06823</b>                         | <b>-0.03449</b>               |
| 0.60        | -3,57331        | 0.00521        | 0.95652        | 5,16343                               | 0.07641                               | 8,55883                                | 0.08470                                | -0.04265                      |
| 0.62        | -3,28666        | 0.00682        | 0.94695        | 5,10255                               | 0.09626                               | 8,17415                                | 0.10344                                | -0.05182                      |
| 0.64        | -3,01926        | 0.00877        | 0.93623        | 5,04126                               | 0.11938                               | 7,81156                                | 0.12455                                | -0.06198                      |
| 0.66        | -2,76913        | 0.01110        | 0.92436        | 4,97940                               | 0.14601                               | 7,46873                                | 0.14811                                | -0.07312                      |
| <b>0.68</b> | <b>-2,53452</b> | <b>0.01384</b> | <b>0.91133</b> | <b>4,91678</b>                        | <b>0.17640</b>                        | <b>7,14358</b>                         | <b>0.17423</b>                         | <b>-0.08519</b>               |
| 0.70        | -2,31388        | 0.01705        | 0.89711        | 4,85318                               | 0.21084                               | 6,83415                                | 0.20302                                | -0.09817                      |
| 0.72        | -2,10584        | 0.02077        | 0.88170        | 4,78832                               | 0.24961                               | 6,53867                                | 0.23465                                | -0.11203                      |
| 0.74        | -1,90915        | 0.02504        | 0.86506        | 4,72190                               | 0.29309                               | 6,25549                                | 0.26934                                | -0.12674                      |
| 0.76        | -1,72272        | 0.02994        | 0.84712        | 4,65355                               | 0.34170                               | 5,98304                                | 0.30734                                | -0.14227                      |
| <b>0.78</b> | <b>-1,54554</b> | <b>0.03552</b> | <b>0.82782</b> | <b>4,58283</b>                        | <b>0.39595</b>                        | <b>5,71981</b>                         | <b>0.34902</b>                         | <b>-0.15861</b>               |
| 0.80        | -1,37672        | 0.04186        | 0.80704        | 4,50922                               | 0.45650                               | 5,46432                                | 0.39486                                | -0.17576                      |
| 0.82        | -1,21545        | 0.04906        | 0.78463        | 4,43203                               | 0.52418                               | 5,21508                                | 0.44552                                | -0.19373                      |
| 0.84        | -1,06097        | 0.05725        | 0.76036        | 4,35043                               | 0.60010                               | 4,97049                                | 0.50187                                | -0.21254                      |
| 0.86        | -0,91263        | 0.06658        | 0.73394        | 4,26329                               | 0.68574                               | 4,72880                                | 0.56514                                | -0.23224                      |
| <b>0.88</b> | <b>-0,76980</b> | <b>0.07727</b> | <b>0.70491</b> | <b>4,16906</b>                        | <b>0.78319</b>                        | <b>4,48793</b>                         | <b>0.63709</b>                         | <b>-0.25290</b>               |
| 0.90        | -0,63192        | 0.08961        | 0.67262        | 4,06548                               | 0.89550                               | 4,24517                                | 0.72040                                | -0.27461                      |
| 0.92        | -0,49847        | 0.10407        | 0.63605        | 3,94904                               | 1,02744                               | 3,99668                                | 0.81928                                | -0.29750                      |
| 0.94        | -0,36898        | 0.12143        | 0.59347        | 3,81358                               | 1.18719                               | 3,73613                                | 0.94120                                | -0.32176                      |
| 0.96        | -0,24301        | 0.14328        | 0.54146        | 3,64643                               | 1.39116                               | 3,45088                                | 1.10146                                | -0.34766                      |
| <b>0.98</b> | <b>-0,12014</b> | <b>0.17412</b> | <b>0.47112</b> | <b>3,41136</b>                        | <b>1,68360</b>                        | <b>3,10521</b>                         | <b>1,34235</b>                         | <b>-0,37560</b>               |
| 1.00        | 0.00000         | 0.29010        | 0.29010        | 2,58438                               | 2,58438                               | 2,17799                                | 2,17799                                | -0.40639                      |

Tabela A.15.2 — Fator de compressibilidade para fluido simples

| $T_r$       | $P_r$         |               |               |               |               |               |               |               |               |               |               |               |               |               |               |
|-------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|
|             | 0.10          | 0.20          | 0.40          | 0.60          | 0.80          | 1.00          | 1.20          | 1.40          | 1.70          | 2.00          | 2.50          | 3.00          | 5.00          | 7.00          | 10.00         |
| 0.30        | 0,0290        | 0,0579        | 0,1158        | 0,1737        | 0,2315        | 0,2892        | 0,3470        | 0,4047        | 0,4911        | 0,5775        | 0,7213        | 0,8648        | 1,4366        | 2,0048        | 2,8507        |
| 0.40        | 0,0239        | 0,0477        | 0,0953        | 0,1429        | 0,1904        | 0,2379        | 0,2853        | 0,3327        | 0,4036        | 0,4744        | 0,5921        | 0,7095        | 1,1758        | 1,6373        | 2,3211        |
| 0.50        | 0,0207        | 0,0413        | 0,0825        | 0,1236        | 0,1647        | 0,2056        | 0,2465        | 0,2873        | 0,3483        | 0,4092        | 0,5103        | 0,6110        | 1,0094        | 1,4017        | 1,9801        |
| 0.60        | 0,0186        | 0,0371        | 0,0741        | 0,1109        | 0,1476        | 0,1842        | 0,2207        | 0,2571        | 0,3115        | 0,3657        | 0,4554        | 0,5446        | 0,8959        | 1,2398        | 1,7440        |
| <b>0.70</b> | <b>0,0172</b> | <b>0,0344</b> | <b>0,0687</b> | <b>0,1027</b> | <b>0,1366</b> | <b>0,1703</b> | <b>0,2038</b> | <b>0,2372</b> | <b>0,2869</b> | <b>0,3364</b> | <b>0,4181</b> | <b>0,4991</b> | <b>0,8161</b> | <b>1,1241</b> | <b>1,5729</b> |
| 0.75        | 0,9165        | 0,0336        | 0,0670        | 0,1001        | 0,1330        | 0,1656        | 0,1981        | 0,2303        | 0,2784        | 0,3260        | 0,4046        | 0,4823        | 0,7854        | 1,0787        | 1,5047        |
| 0.80        | 0,9319        | 0,8539        | 0,0661        | 0,0985        | 0,1307        | 0,1626        | 0,1942        | 0,2255        | 0,2721        | 0,3182        | 0,3942        | 0,4690        | 0,7598        | 1,0400        | 1,4456        |
| 0.85        | 0,9436        | 0,8810        | 0,0661        | 0,0983        | 0,1301        | 0,1614        | 0,1924        | 0,2230        | 0,2684        | 0,3132        | 0,3868        | 0,4591        | 0,7388        | 1,0071        | 1,3943        |
| 0.90        | 0,9528        | 0,9015        | 0,7800        | 0,1006        | 0,1321        | 0,1630        | 0,1935        | 0,2235        | 0,2678        | 0,3114        | 0,3828        | 0,4527        | 0,7220        | 0,9793        | 1,3496        |
| <b>0.95</b> | <b>0,9600</b> | <b>0,9174</b> | <b>0,8206</b> | <b>0,6967</b> | <b>0,1410</b> | <b>0,1705</b> | <b>0,1998</b> | <b>0,2288</b> | <b>0,2717</b> | <b>0,3138</b> | <b>0,3827</b> | <b>0,4501</b> | <b>0,7092</b> | <b>0,9561</b> | <b>1,3108</b> |
| 1.00        | 0,9659        | 0,9300        | 0,8509        | 0,7574        | 0,6353        | 0,2901        | 0,2237        | 0,2459        | 0,2839        | 0,3229        | 0,3880        | 0,4522        | 0,7004        | 0,9372        | 1,2772        |
| 1.05        | 0,9707        | 0,9401        | 0,8743        | 0,8002        | 0,7130        | 0,6026        | 0,4437        | 0,3246        | 0,3182        | 0,3452        | 0,4014        | 0,4604        | 0,6956        | 0,9222        | 1,2481        |
| 1.10        | 0,9747        | 0,9485        | 0,8930        | 0,8323        | 0,7649        | 0,6880        | 0,5984        | 0,5003        | 0,4086        | 0,3953        | 0,4277        | 0,4770        | 0,6950        | 0,9110        | 1,2232        |
| 1.15        | 0,9780        | 0,9554        | 0,9081        | 0,8576        | 0,8032        | 0,7443        | 0,6803        | 0,6129        | 0,5227        | 0,4760        | 0,4718        | 0,5042        | 0,6987        | 0,9033        | 1,2021        |
| <b>1.20</b> | <b>0,9808</b> | <b>0,9611</b> | <b>0,9205</b> | <b>0,8779</b> | <b>0,8330</b> | <b>0,7858</b> | <b>0,7363</b> | <b>0,6856</b> | <b>0,6135</b> | <b>0,5605</b> | <b>0,5295</b> | <b>0,5425</b> | <b>0,7069</b> | <b>0,8990</b> | <b>1,1844</b> |
| 1.30        | 0,9852        | 0,9702        | 0,9396        | 0,9083        | 0,8764        | 0,8438        | 0,8111        | 0,7784        | 0,7316        | 0,6908        | 0,6467        | 0,6344        | 0,7358        | 0,8998        | 1,1580        |
| 1.40        | 0,9884        | 0,9768        | 0,9534        | 0,9298        | 0,9062        | 0,8827        | 0,8595        | 0,8367        | 0,8043        | 0,7753        | 0,7387        | 0,7202        | 0,7761        | 0,9112        | 1,1419        |
| 1.50        | 0,9909        | 0,9818        | 0,9636        | 0,9456        | 0,9278        | 0,9103        | 0,8933        | 0,8768        | 0,8536        | 0,8328        | 0,8052        | 0,7887        | 0,8200        | 0,9297        | 1,1339        |
| 1.60        | 0,9928        | 0,9856        | 0,9714        | 0,9575        | 0,9439        | 0,9308        | 0,9180        | 0,9059        | 0,8889        | 0,8738        | 0,8537        | 0,8410        | 0,8617        | 0,9518        | 1,1320        |
| <b>1.80</b> | <b>0,9955</b> | <b>0,9910</b> | <b>0,9823</b> | <b>0,9739</b> | <b>0,9659</b> | <b>0,9583</b> | <b>0,9511</b> | <b>0,9444</b> | <b>0,9353</b> | <b>0,9275</b> | <b>0,9176</b> | <b>0,9118</b> | <b>0,9297</b> | <b>0,9961</b> | <b>1,1391</b> |
| 2.00        | 0,9972        | 0,9944        | 0,9892        | 0,9842        | 0,9796        | 0,9754        | 0,9715        | 0,9680        | 0,9635        | 0,9599        | 0,9561        | 0,9550        | 0,9772        | 1,0328        | 1,1516        |
| 2.50        | 0,9994        | 0,9989        | 0,9981        | 0,9975        | 0,9971        | 0,9969        | 0,9970        | 0,9973        | 0,9982        | 0,9996        | 1,0031        | 1,0080        | 1,0395        | 1,0866        | 1,1763        |
| 3.00        | 1,0004        | 1,0008        | 1,0018        | 1,0030        | 1,0043        | 1,0057        | 1,0074        | 1,0091        | 1,0121        | 1,0153        | 1,0215        | 1,0284        | 1,0635        | 1,1075        | 1,1848        |
| 3.50        | 1,0008        | 1,0017        | 1,0035        | 1,0055        | 1,0075        | 1,0097        | 1,0120        | 1,0143        | 1,0181        | 1,0221        | 1,0292        | 1,0368        | 1,0723        | 1,1138        | 1,1834        |
| <b>4.00</b> | <b>1,0010</b> | <b>1,0021</b> | <b>1,0043</b> | <b>1,0066</b> | <b>1,0090</b> | <b>1,0115</b> | <b>1,0140</b> | <b>1,0166</b> | <b>1,0207</b> | <b>1,0249</b> | <b>1,0323</b> | <b>1,0401</b> | <b>1,0747</b> | <b>1,1136</b> | <b>1,1773</b> |
| 5.00        | 1,0012        | 1,0024        | 1,0048        | 1,0073        | 1,0098        | 1,0124        | 1,0150        | 1,0176        | 1,0217        | 1,0259        | 1,0331        | 1,0405        | 1,0722        | 1,1064        | 1,1611        |

Tabela A.15.3 — Desvio de entalpia para fluidos simples,  $(h^* - h) / RT_c$ 

| $T_r$       | $P_r$        |              |              |              |              |              |              |              |              |              |              |              |              |              |              |
|-------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
|             | 0.10         | 0.20         | 0.40         | 0.60         | 0.80         | 1.00         | 1.20         | 1.40         | 1.70         | 2.00         | 2.50         | 3.00         | 5.00         | 7.00         | 10.00        |
| 0.30        | 6,040        | 6,034        | 6,022        | 6,011        | 5,999        | 5,987        | 5,975        | 5,963        | 5,945        | 5,927        | 5,898        | 5,868        | 5,748        | 5,628        | 5,446        |
| 0.40        | 5,757        | 5,751        | 5,738        | 5,726        | 5,713        | 5,700        | 5,687        | 5,675        | 5,655        | 5,636        | 5,604        | 5,572        | 5,442        | 5,311        | 5,113        |
| 0.50        | 5,459        | 5,453        | 5,440        | 5,427        | 5,414        | 5,401        | 5,388        | 5,375        | 5,355        | 5,336        | 5,303        | 5,270        | 5,135        | 4,999        | 4,791        |
| 0.60        | 5,159        | 5,153        | 5,141        | 5,129        | 5,116        | 5,104        | 5,091        | 5,079        | 5,060        | 5,041        | 5,008        | 4,976        | 4,842        | 4,704        | 4,492        |
| <b>0.70</b> | <b>4,853</b> | <b>4,848</b> | <b>4,839</b> | <b>4,828</b> | <b>4,818</b> | <b>4,808</b> | <b>4,797</b> | <b>4,786</b> | <b>4,769</b> | <b>4,152</b> | <b>4,723</b> | <b>4,693</b> | <b>4,566</b> | <b>4,432</b> | <b>4,221</b> |
| 0.75        | 0,183        | 4,687        | 4,679        | 4,672        | 4,664        | 4,655        | 4,646        | 4,637        | 4,622        | 4,607        | 4,581        | 4,554        | 4,434        | 4,303        | 4,095        |
| 0.80        | 0,160        | 0,345        | 4,507        | 4,504        | 4,499        | 4,494        | 4,488        | 4,481        | 4,470        | 4,459        | 4,437        | 4,413        | 4,303        | 4,178        | 3,974        |
| 0.85        | 0,141        | 0,300        | 4,308        | 4,313        | 4,316        | 4,316        | 4,314        | 4,309        | 4,302        | 4,287        | 4,269        | 4,269        | 4,173        | 4,056        | 3,857        |
| 0.90        | 0,126        | 0,264        | 0,596        | 4,074        | 4,094        | 4,108        | 4,118        | 4,125        | 4,130        | 4,132        | 4,129        | 4,119        | 4,043        | 3,935        | 3,744        |
| <b>0.95</b> | <b>0,113</b> | <b>0,235</b> | <b>0,516</b> | <b>0,885</b> | <b>3,763</b> | <b>3,825</b> | <b>3,865</b> | <b>3,893</b> | <b>3,922</b> | <b>3,939</b> | <b>3,955</b> | <b>3,958</b> | <b>3,910</b> | <b>3,815</b> | <b>3,634</b> |
| 1.00        | 0,103        | 0,212        | 0,455        | 0,750        | 1,151        | 2,584        | 3,441        | 3,560        | 3,653        | 3,706        | 3,757        | 3,782        | 3,774        | 3,695        | 3,526        |
| 1.05        | 0,094        | 0,192        | 0,407        | 0,654        | 0,955        | 1,359        | 2,034        | 2,831        | 3,243        | 3,398        | 3,521        | 3,583        | 3,632        | 3,575        | 3,420        |
| 1.10        | 0,086        | 0,175        | 0,367        | 0,581        | 0,827        | 1,120        | 1,487        | 1,955        | 2,609        | 2,965        | 3,231        | 3,353        | 3,484        | 3,453        | 3,315        |
| 1.15        | 0,079        | 0,160        | 0,334        | 0,523        | 0,732        | 0,968        | 1,239        | 1,550        | 2,059        | 2,479        | 2,888        | 3,091        | 3,329        | 3,329        | 3,211        |
| <b>1.20</b> | <b>0,073</b> | <b>0,148</b> | <b>0,305</b> | <b>0,474</b> | <b>0,657</b> | <b>0,857</b> | <b>1,076</b> | <b>1,315</b> | <b>1,704</b> | <b>2,079</b> | <b>2,537</b> | <b>2,807</b> | <b>3,166</b> | <b>3,202</b> | <b>3,107</b> |
| 1.30        | 0,063        | 0,127        | 0,259        | 0,399        | 0,545        | 0,698        | 0,860        | 1,029        | 1,293        | 1,560        | 1,964        | 2,274        | 2,825        | 2,942        | 2,899        |
| 1.40        | 0,055        | 0,110        | 0,224        | 0,341        | 0,463        | 0,588        | 0,716        | 0,848        | 1,050        | 1,253        | 1,576        | 1,857        | 2,486        | 2,679        | 2,692        |
| 1.50        | 0,048        | 0,097        | 0,196        | 0,297        | 0,400        | 0,505        | 0,611        | 0,719        | 0,883        | 1,046        | 1,309        | 1,549        | 2,175        | 2,421        | 2,486        |
| 1.60        | 0,043        | 0,086        | 0,173        | 0,261        | 0,350        | 0,440        | 0,531        | 0,622        | 0,759        | 0,894        | 1,114        | 1,318        | 1,904        | 2,177        | 2,285        |
| <b>1.80</b> | <b>0,034</b> | <b>0,068</b> | <b>0,137</b> | <b>0,206</b> | <b>0,275</b> | <b>0,344</b> | <b>0,413</b> | <b>0,481</b> | <b>0,583</b> | <b>0,683</b> | <b>0,844</b> | <b>0,996</b> | <b>1,476</b> | <b>1,751</b> | <b>1,908</b> |
| 2.00        | 0,028        | 0,056        | 0,111        | 0,167        | 0,222        | 0,276        | 0,330        | 0,384        | 0,463        | 0,541        | 0,665        | 0,782        | 1,167        | 1,411        | 1,577        |
| 2.50        | 0,018        | 0,035        | 0,070        | 0,104        | 0,137        | 0,170        | 0,203        | 0,234        | 0,281        | 0,326        | 0,398        | 0,465        | 0,687        | 0,838        | 0,954        |
| 3.00        | 0,011        | 0,023        | 0,045        | 0,067        | 0,088        | 0,109        | 0,129        | 0,149        | 0,177        | 0,205        | 0,248        | 0,288        | 0,415        | 0,495        | 0,545        |
| 3.50        | 0,007        | 0,015        | 0,029        | 0,043        | 0,056        | 0,069        | 0,081        | 0,093        | 0,111        | 0,127        | 0,152        | 0,174        | 0,239        | 0,270        | 0,264        |
| <b>4.00</b> | <b>0,005</b> | <b>0,009</b> | <b>0,017</b> | <b>0,026</b> | <b>0,033</b> | <b>0,041</b> | <b>0,048</b> | <b>0,054</b> | <b>0,064</b> | <b>0,072</b> | <b>0,085</b> | <b>0,095</b> | <b>0,116</b> | <b>0,110</b> | <b>0,061</b> |
| 5.00        | 0,001        | 0,001        | 0,002        | 0,003        | 0,004        | 0,004        | 0,004        | 0,004        | 0,003        | 0,001        | -0,003       | -0,009       | -0,045       | -0,101       | -0,213       |

Tabela A.15.4 — Desvio de entropia para fluidos simples,  $(s^* - s) / RT_c$ 

| $T_r$       | $P_r$        |              |              |              |              |              |              |              |              |              |              |              |              |              |              |
|-------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
|             | 0.10         | 0.20         | 0.40         | 0.60         | 0.80         | 1.00         | 1.20         | 1.40         | 1.70         | 2.00         | 2.50         | 3.00         | 5.00         | 7.00         | 10.00        |
| 0,30        | 9,319        | 8,635        | 7,961        | 7,574        | 7,304        | 7,099        | 6,935        | 6,799        | 6,633        | 6,497        | 6,319        | 6,182        | 5,847        | 5,683        | 5,578        |
| 0,40        | 8,506        | 7,821        | 7,144        | 6,755        | 6,483        | 6,275        | 6,109        | 5,970        | 5,799        | 5,660        | 5,475        | 5,330        | 4,967        | 4,772        | 4,619        |
| 0,50        | 7,842        | 7,156        | 6,479        | 6,089        | 5,816        | 5,608        | 5,441        | 5,302        | 5,130        | 4,989        | 4,802        | 4,656        | 4,282        | 4,074        | 3,899        |
| 0,60        | 7,294        | 6,610        | 5,933        | 5,544        | 5,273        | 5,066        | 4,900        | 4,762        | 4,591        | 4,451        | 4,266        | 4,120        | 3,747        | 3,537        | 3,353        |
| <b>0,70</b> | <b>6,823</b> | <b>6,140</b> | <b>5,467</b> | <b>5,082</b> | <b>4,814</b> | <b>4,610</b> | <b>4,446</b> | <b>4,310</b> | <b>4,143</b> | <b>4,007</b> | <b>3,826</b> | <b>3,684</b> | <b>3,322</b> | <b>3,117</b> | <b>2,935</b> |
| 0,75        | 0,164        | 5,917        | 5,248        | 4,866        | 4,600        | 4,399        | 4,238        | 4,104        | 3,940        | 3,807        | 3,630        | 3,491        | 3,138        | 2,939        | 2,761        |
| 0,80        | 0,134        | 0,294        | 5,026        | 4,649        | 4,388        | 4,191        | 4,034        | 3,904        | 3,744        | 3,615        | 3,444        | 3,310        | 2,970        | 2,777        | 2,605        |
| 0,85        | 0,111        | 0,239        | 4,785        | 4,418        | 4,166        | 3,976        | 3,825        | 3,701        | 3,548        | 3,425        | 3,262        | 3,135        | 2,812        | 2,629        | 2,463        |
| 0,90        | 0,094        | 0,199        | 0,463        | 4,145        | 3,912        | 3,738        | 3,599        | 3,484        | 3,344        | 3,231        | 3,081        | 2,963        | 2,663        | 2,491        | 2,334        |
| <b>0,95</b> | <b>0,080</b> | <b>0,168</b> | <b>0,377</b> | <b>0,671</b> | <b>3,556</b> | <b>3,433</b> | <b>3,326</b> | <b>3,235</b> | <b>3,119</b> | <b>3,023</b> | <b>2,893</b> | <b>2,790</b> | <b>2,520</b> | <b>2,361</b> | <b>2,215</b> |
| 1,00        | 0,069        | 0,144        | 0,315        | 0,532        | 0,847        | 2,178        | 2,893        | 2,893        | 2,843        | 2,784        | 2,690        | 2,609        | 2,380        | 2,239        | 2,105        |
| 1,05        | 0,060        | 0,124        | 0,267        | 0,439        | 0,656        | 0,965        | 1,523        | 2,185        | 2,444        | 2,483        | 2,461        | 2,415        | 2,242        | 2,121        | 2,001        |
| 1,10        | 0,053        | 0,108        | 0,230        | 0,371        | 0,537        | 0,742        | 1,012        | 1,368        | 1,855        | 2,081        | 2,191        | 2,202        | 2,104        | 2,007        | 1,903        |
| 1,15        | 0,047        | 0,096        | 0,201        | 0,319        | 0,452        | 0,607        | 0,790        | 1,007        | 1,366        | 1,649        | 1,885        | 1,968        | 1,966        | 1,897        | 1,810        |
| <b>1,20</b> | <b>0,042</b> | <b>0,085</b> | <b>0,177</b> | <b>0,277</b> | <b>0,389</b> | <b>0,512</b> | <b>0,651</b> | <b>0,807</b> | <b>1,063</b> | <b>1,308</b> | <b>1,587</b> | <b>1,727</b> | <b>1,827</b> | <b>1,789</b> | <b>1,722</b> |
| 1,30        | 0,033        | 0,068        | 0,140        | 0,217        | 0,298        | 0,385        | 0,478        | 0,576        | 0,732        | 0,891        | 1,127        | 1,299        | 1,554        | 1,581        | 1,556        |
| 1,40        | 0,027        | 0,056        | 0,114        | 0,174        | 0,237        | 0,303        | 0,372        | 0,442        | 0,552        | 0,663        | 0,839        | 0,990        | 1,303        | 1,386        | 1,402        |
| 1,50        | 0,023        | 0,046        | 0,094        | 0,143        | 0,194        | 0,246        | 0,299        | 0,353        | 0,436        | 0,520        | 0,654        | 0,777        | 1,088        | 1,208        | 1,260        |
| 1,60        | 0,019        | 0,039        | 0,079        | 0,120        | 0,162        | 0,204        | 0,247        | 0,290        | 0,356        | 0,421        | 0,528        | 0,628        | 0,913        | 1,050        | 1,130        |
| <b>1,80</b> | <b>0,014</b> | <b>0,029</b> | <b>0,058</b> | <b>0,088</b> | <b>0,117</b> | <b>0,147</b> | <b>0,177</b> | <b>0,207</b> | <b>0,252</b> | <b>0,296</b> | <b>0,369</b> | <b>0,438</b> | <b>0,661</b> | <b>0,799</b> | <b>0,908</b> |
| 2,00        | 0,011        | 0,022        | 0,044        | 0,067        | 0,089        | 0,111        | 0,134        | 0,156        | 0,189        | 0,221        | 0,274        | 0,325        | 0,497        | 0,620        | 0,733        |
| 2,50        | 0,006        | 0,013        | 0,026        | 0,038        | 0,051        | 0,064        | 0,076        | 0,088        | 0,106        | 0,124        | 0,153        | 0,181        | 0,281        | 0,361        | 0,453        |
| 3,00        | 0,004        | 0,008        | 0,017        | 0,025        | 0,033        | 0,041        | 0,049        | 0,057        | 0,068        | 0,080        | 0,098        | 0,116        | 0,181        | 0,236        | 0,303        |
| 3,50        | 0,003        | 0,006        | 0,012        | 0,017        | 0,023        | 0,029        | 0,034        | 0,040        | 0,048        | 0,056        | 0,068        | 0,081        | 0,126        | 0,166        | 0,216        |
| <b>4,00</b> | <b>0,002</b> | <b>0,004</b> | <b>0,009</b> | <b>0,013</b> | <b>0,017</b> | <b>0,021</b> | <b>0,025</b> | <b>0,029</b> | <b>0,035</b> | <b>0,041</b> | <b>0,050</b> | <b>0,059</b> | <b>0,093</b> | <b>0,123</b> | <b>0,162</b> |
| 5,00        | 0,001        | 0,003        | 0,005        | 0,008        | 0,010        | 0,013        | 0,015        | 0,018        | 0,021        | 0,025        | 0,031        | 0,036        | 0,057        | 0,075        | 0,100        |

Tabela A.15.5 — Coeficiente de fugacidade para fluidos simples,  $\ln(f/p)$ 

| $T_r$       | $P_r$         |               |               |               |               |               |               |               |               |               |               |               |               |               |               |
|-------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|
|             | 0.10          | 0.20          | 0.40          | 0.60          | 0.80          | 1.00          | 1.20          | 1.40          | 1.70          | 2.00          | 2.50          | 3.00          | 5.00          | 7.00          | 10.00         |
| 0,30        | -10,815       | -11,479       | -12,114       | -12,462       | -12,692       | -12,857       | -12,981       | -13,078       | -13,185       | -13,261       | -13,340       | -13,378       | -13,313       | -13,076       | -12,576       |
| 0,40        | -5,887        | -6,556        | -7,202        | -7,559        | -7,800        | -7,975        | -8,110        | -8,216        | -8,339        | -8,431        | -8,535        | -8,599        | -8,638        | -8,506        | -8,164        |
| 0,50        | -3,077        | -3,749        | -4,401        | -4,766        | -5,012        | -5,194        | -5,335        | -5,448        | -5,581        | -5,682        | -5,803        | -5,883        | -5,989        | -5,923        | -5,682        |
| 0,60        | -1,304        | -1,979        | -2,635        | -3,003        | -3,254        | -3,440        | -3,586        | -3,703        | -3,842        | -3,950        | -4,082        | -4,173        | -4,323        | -4,304        | -4,133        |
| <b>0,70</b> | <b>-0,110</b> | <b>-0,786</b> | <b>-1,445</b> | <b>-1,816</b> | <b>-2,069</b> | <b>-2,258</b> | <b>-2,407</b> | <b>-2,527</b> | <b>-2,670</b> | <b>-2,782</b> | <b>-2,922</b> | <b>-3,021</b> | <b>-3,202</b> | <b>-3,215</b> | <b>-3,095</b> |
| 0,75        | -0,080        | -0,332        | -0,991        | -1,363        | -1,618        | -1,808        | -1,957        | -2,078        | -2,236        | -2,336        | -2,478        | -2,580        | -2,779        | -2,799        | -2,699        |
| 0,80        | -0,066        | -0,137        | -0,608        | -0,981        | -1,236        | -1,426        | -1,576        | -1,698        | -1,844        | -1,959        | -2,103        | -2,206        | -2,409        | -2,445        | -2,362        |
| 0,85        | -0,055        | -0,113        | -0,284        | -0,656        | -0,911        | -1,102        | -1,252        | -1,374        | -1,521        | -1,636        | -1,782        | -1,887        | -2,097        | -2,142        | -2,074        |
| 0,90        | -0,046        | -0,095        | -0,198        | -0,382        | -0,636        | -0,826        | -0,976        | -1,098        | -1,245        | -1,360        | -1,506        | -1,613        | -1,829        | -1,881        | -1,826        |
| <b>0,95</b> | <b>-0,039</b> | <b>-0,080</b> | <b>-0,166</b> | <b>-0,261</b> | <b>-0,405</b> | <b>-0,594</b> | <b>-0,742</b> | <b>-0,864</b> | <b>-1,009</b> | <b>-1,124</b> | <b>-1,270</b> | <b>-1,376</b> | <b>-1,596</b> | <b>-1,655</b> | <b>-1,610</b> |
| 1,00        | -0,034        | -0,068        | -0,140        | -0,218        | -0,303        | -0,406        | -0,548        | -0,667        | -0,809        | -0,923        | -1,067        | -1,173        | -1,394        | -1,457        | -1,422        |
| 1,05        | -0,029        | -0,059        | -0,120        | -0,185        | -0,254        | -0,329        | -0,414        | -0,511        | -0,644        | -0,753        | -0,893        | -0,997        | -1,217        | -1,284        | -1,256        |
| 1,10        | -0,025        | -0,051        | -0,103        | -0,158        | -0,215        | -0,276        | -0,340        | -0,410        | -0,517        | -0,615        | -0,747        | -0,847        | -1,063        | -1,131        | -1,110        |
| 1,15        | -0,022        | -0,044        | -0,089        | -0,136        | -0,184        | -0,235        | -0,287        | -0,341        | -0,425        | -0,507        | -0,626        | -0,719        | -0,929        | -0,997        | -0,981        |
| <b>1,20</b> | <b>-0,019</b> | <b>-0,038</b> | <b>-0,078</b> | <b>-0,118</b> | <b>-0,159</b> | <b>-0,202</b> | <b>-0,245</b> | <b>-0,289</b> | <b>-0,357</b> | <b>-0,425</b> | <b>-0,527</b> | <b>-0,612</b> | <b>-0,811</b> | <b>-0,879</b> | <b>-0,867</b> |
| 1,30        | -0,015        | -0,030        | -0,060        | -0,090        | -0,121        | -0,152        | -0,183        | -0,215        | -0,262        | -0,309        | -0,384        | -0,450        | -0,619        | -0,682        | -0,674        |
| 1,40        | -0,012        | -0,023        | -0,046        | -0,070        | -0,093        | -0,117        | -0,140        | -0,163        | -0,198        | -0,232        | -0,287        | -0,336        | -0,472        | -0,527        | -0,521        |
| 1,50        | -0,009        | -0,018        | -0,036        | -0,055        | -0,073        | -0,091        | -0,109        | -0,126        | -0,152        | -0,178        | -0,218        | -0,255        | -0,361        | -0,406        | -0,397        |
| 1,60        | -0,007        | -0,014        | -0,029        | -0,043        | -0,057        | -0,071        | -0,085        | -0,098        | -0,118        | -0,137        | -0,168        | -0,196        | -0,277        | -0,310        | -0,298        |
| <b>1,80</b> | <b>-0,005</b> | <b>-0,009</b> | <b>-0,018</b> | <b>-0,027</b> | <b>-0,035</b> | <b>-0,044</b> | <b>-0,052</b> | <b>-0,060</b> | <b>-0,072</b> | <b>-0,083</b> | <b>-0,100</b> | <b>-0,116</b> | <b>-0,159</b> | <b>-0,174</b> | <b>-0,152</b> |
| 2,00        | -0,003        | -0,006        | -0,011        | -0,016        | -0,022        | -0,027        | -0,032        | -0,036        | -0,043        | -0,049        | -0,058        | -0,067        | -0,086        | -0,086        | -0,055        |
| 2,50        | -0,001        | -0,001        | -0,002        | -0,003        | -0,004        | -0,005        | -0,005        | -0,006        | -0,006        | -0,006        | -0,006        | -0,005        | 0,006         | 0,026         | 0,072         |
| 3,00        | 0,000         | 0,001         | 0,002         | 0,003         | 0,004         | 0,005         | 0,006         | 0,007         | 0,009         | 0,011         | 0,016         | 0,020         | 0,042         | 0,070         | 0,121         |
| 3,50        | 0,001         | 0,002         | 0,003         | 0,005         | 0,007         | 0,009         | 0,011         | 0,013         | 0,016         | 0,019         | 0,025         | 0,031         | 0,058         | 0,089         | 0,141         |
| <b>4,00</b> | <b>0,001</b>  | <b>0,002</b>  | <b>0,004</b>  | <b>0,006</b>  | <b>0,009</b>  | <b>0,011</b>  | <b>0,013</b>  | <b>0,016</b>  | <b>0,019</b>  | <b>0,023</b>  | <b>0,029</b>  | <b>0,036</b>  | <b>0,064</b>  | <b>0,095</b>  | <b>0,146</b>  |
| 5,00        | 0,001         | 0,002         | 0,005         | 0,007         | 0,010         | 0,012         | 0,015         | 0,017         | 0,021         | 0,025         | 0,031         | 0,038         | 0,066         | 0,096         | 0,143         |

Tabela A.15.6 — Equação de estado de Lee-Kesler

A equação generalizada de estado de Lee-Kesler, Eq. 10.63, é:

$$Z = \frac{p_r v_r'}{T_r} = 1 + \frac{B}{v_r'} + \frac{C}{v_r'^2} + \frac{D}{v_r'^3} + \frac{c_4}{T_r^3 v_r'^2} \left( \beta + \frac{\gamma}{v_r'^2} \right) \exp \left( -\frac{\gamma}{v_r'^2} \right)$$

$$B = b_1 - \frac{b_2}{T_r} - \frac{b_3}{T_r^2} - \frac{b_4}{T_r^3}$$

$$C = c_1 - \frac{c_2}{T_r} + \frac{c_3}{T_r^3}$$

$$D = d_1 + \frac{d_2}{T_r}$$

onde:

$$T_r = \frac{T_r}{T_c} \quad p_r = \frac{p_r}{p_c} \quad v_r' = \frac{v}{RT_c/p_c}$$

Os dois grupos de constantes são os seguintes:

| Constante         | Fluido Simples   | Fluido de referência |
|-------------------|------------------|----------------------|
| $b_1$             | 0,1181193        | 0,2026579            |
| $b_2$             | 0,265728         | 0,331511             |
| $b_3$             | 0,154790         | 0,027655             |
| $b_4$             | 0,030323         | 0,203488             |
| $c_1$             | <b>0,0236744</b> | <b>0,0313385</b>     |
| $c_2$             | 0,0186984        | 0,0503618            |
| $c_3$             | 0,0              | 0,016901             |
| $c_4$             | 0,042724         | 0,041577             |
| $d_1 \times 10^4$ | 0,155488         | 0,48736              |
| $d_2 \times 10^4$ | <b>0,623689</b>  | <b>0,0740336</b>     |
| $\beta$           | 0,65392          | 1,226                |
| $\gamma$          | 0,060167         | 0,03754              |

Tabela A.16 — Entalpia de formação, função Gibbs de formação e entropia absoluta de várias substâncias a 25°C e 100 kPa

| Substância               | Fórmula                           | M             | Estado        | $\bar{h}_f^0$<br>kJ/kmol | $\bar{g}_f^0$<br>kJ/kmol | $\bar{s}_f^0$<br>kJ/kmolK |
|--------------------------|-----------------------------------|---------------|---------------|--------------------------|--------------------------|---------------------------|
| Água                     | H <sub>2</sub> O                  | 18,015        | gás           | -241826                  | -228582                  | 188,834                   |
| Água                     | H <sub>2</sub> O                  | 18,015        | líquido       | -285830                  | -237141                  | 69,950                    |
| Peróxido de hidrogênio   | H <sub>2</sub> O <sub>2</sub>     | 34,015        | gás           | -136106                  | -105445                  | 232,991                   |
| Ozônio                   | O <sub>3</sub>                    | 47,998        | gás           | +142674                  | +163184                  | 238,932                   |
| <b>Carbono (grafite)</b> | <b>C</b>                          | <b>12,011</b> | <b>sólido</b> | <b>0</b>                 | <b>0</b>                 | <b>5,740</b>              |
| Monóxido de carbono      | CO                                | 28,011        | gás           | -110527                  | -137163                  | 197,653                   |
| Dióxido de carbono       | CO <sub>2</sub>                   | 44,010        | gás           | -393522                  | -394389                  | 213,795                   |
| Metano                   | CH <sub>4</sub>                   | 16,043        | gás           | -74873                   | -50768                   | 186,251                   |
| Acetileno                | C <sub>2</sub> H <sub>2</sub>     | 26,038        | gás           | +226731                  | +209200                  | 200,958                   |
| <b>Eteno</b>             | <b>C<sub>2</sub>H<sub>4</sub></b> | <b>28,054</b> | <b>gás</b>    | <b>+52467</b>            | <b>+68421</b>            | <b>219,330</b>            |
| Etano                    | C <sub>2</sub> H <sub>6</sub>     | 30,070        | gás           | -84740                   | -32885                   | 229,597                   |
| Propeno                  | C <sub>3</sub> H <sub>6</sub>     | 42,081        | gás           | +20430                   | +62825                   | 267,066                   |
| Propano                  | C <sub>3</sub> H <sub>8</sub>     | 44,094        | gás           | -103900                  | -23393                   | 269,917                   |
| Butano                   | C <sub>4</sub> H <sub>10</sub>    | 58,124        | gás           | -126200                  | -15970                   | 306,647                   |

**Tabela A.16 (Continuação)** — Entalpia de formação, função Gibbs de formação e entropia absoluta de várias substâncias a 25°C e 100 kPa

| Substância          | Fórmula                             | <i>M</i> | Estado  | $\bar{h}_f^0$<br>kJ/kmol | $\bar{g}_f^0$<br>kJ/kmol | $\bar{s}_f^0$<br>kJ/kmolK |
|---------------------|-------------------------------------|----------|---------|--------------------------|--------------------------|---------------------------|
| Pentano             | C <sub>5</sub> H <sub>12</sub>      | 72,151   | gás     | -146500                  | -8208                    | 348,945                   |
| Benzeno             | C <sub>6</sub> H <sub>6</sub>       | 78,114   | gás     | +82980                   | +129765                  | 269,562                   |
| Hexano              | C <sub>6</sub> H <sub>14</sub>      | 86,178   | gás     | -167300                  | +28                      | 387,979                   |
| Heptano             | C <sub>7</sub> H <sub>16</sub>      | 100,205  | gás     | -187900                  | +8227                    | 427,805                   |
| <i>n</i> -Octano    | C <sub>8</sub> H <sub>18</sub>      | 114,232  | gás     | -208600                  | +16660                   | 466,514                   |
| <i>n</i> -Octano    | C <sub>8</sub> H <sub>18</sub>      | 114,232  | líquido | -250105                  | +6741                    | 360,575                   |
| Metanol             | CH <sub>3</sub> OH                  | 32,042   | gás     | -201300                  | -162551                  | 239,709                   |
| Etanol              | C <sub>2</sub> H <sub>5</sub> OH    | 46,069   | gás     | -235000                  | -168319                  | 282,444                   |
| Amônia              | NH <sub>3</sub>                     | 17,031   | gás     | -45720                   | -16128                   | 192,572                   |
| <i>T-T</i> -Diesel  | C <sub>14,4</sub> H <sub>24,9</sub> | 198,06   | líquido | -174000                  | +178919                  | 525,90                    |
| Enxofre             | S                                   | 32,06    | sólido  | 0                        | 0                        | 32,056                    |
| Dióxido de enxofre  | SO <sub>2</sub>                     | 64,059   | gás     | -296842                  | -300125                  | 248,212                   |
| Trióxido de enxofre | SO <sub>3</sub>                     | 80,058   | gás     | -395765                  | -371016                  | 256,769                   |
| Óxido de Nitrogênio | N <sub>2</sub> O                    | 44,013   | gás     | +82050                   | +104179                  | 219,957                   |
| Nitrometano         | CH <sub>3</sub> NO <sub>2</sub>     | 61,04    | líquido | -113100                  | -14439                   | 171,80                    |

**Tabela A.17** — Logarítmos na base *e* da constante de equilíbrio *K*

Para a reação  $\nu_A A + \nu_B B \rightleftharpoons \nu_C C + \nu_D D$ , a constante de equilíbrio *K* é definida por:

$$K = \frac{y_C^{\nu_C} y_D^{\nu_D}}{y_A^{\nu_A} y_B^{\nu_B}} \left( \frac{p}{p^0} \right)^{\nu_C + \nu_D - \nu_A - \nu_B}, \quad p^0 = 0,1 \text{ MPa}$$

| Temp.<br>K | H <sub>2</sub> ⇌ 2H | O <sub>2</sub> ⇌ 2O | N <sub>2</sub> ⇌ 2N | 2H <sub>2</sub> O ⇌ 2H <sub>2</sub> + O <sub>2</sub> | 2H <sub>2</sub> O ⇌ H <sub>2</sub> + 2OH | 2CO <sub>2</sub> ⇌ 2CO + O <sub>2</sub> | N <sub>2</sub> + O <sub>2</sub> ⇌ 2NO | N <sub>2</sub> + 2O <sub>2</sub> ⇌ 2NO <sub>2</sub> |
|------------|---------------------|---------------------|---------------------|------------------------------------------------------|------------------------------------------|-----------------------------------------|---------------------------------------|-----------------------------------------------------|
| 298        | -164,003            | -186,963            | -367,52             | -184,420                                             | -212,075                                 | -207,529                                | -69,868                               | -41,355                                             |
| 500        | -92,830             | -105,623            | -213,405            | -105,385                                             | -120,331                                 | -115,234                                | -40,449                               | -30,725                                             |
| 1000       | -39,810             | -45,146             | -99,146             | -46,321                                              | -51,951                                  | -47,052                                 | -18,709                               | -23,039                                             |
| 1200       | -30,878             | -35,003             | -80,025             | -36,363                                              | -40,467                                  | -35,736                                 | -15,082                               | -21,752                                             |
| 1400       | -24,467             | -27,741             | -66,345             | -29,222                                              | -32,244                                  | -27,679                                 | -12,491                               | -20,826                                             |
| 1600       | -19,638             | -22,282             | -56,069             | -23,849                                              | -26,067                                  | -21,656                                 | -10,547                               | -20,126                                             |
| 1800       | -15,868             | -18,028             | -48,066             | -19,658                                              | -21,258                                  | -16,987                                 | -9,035                                | -19,577                                             |
| 2000       | -12,841             | -14,619             | -41,655             | -16,299                                              | -17,406                                  | -13,266                                 | -7,825                                | -19,136                                             |
| 2200       | -10,356             | -11,826             | -36,404             | -13,546                                              | -14,253                                  | -10,232                                 | -6,836                                | -18,773                                             |
| 2400       | -8,280              | -9,495              | -32,023             | -11,249                                              | -11,625                                  | -7,715                                  | -6,012                                | -18,470                                             |
| 2600       | -6,519              | -7,520              | -28,313             | -9,303                                               | -9,402                                   | -5,594                                  | -5,316                                | -18,214                                             |
| 2800       | -5,005              | -5,826              | -25,129             | -7,633                                               | -7,496                                   | -3,781                                  | -4,720                                | -17,994                                             |
| 3000       | -3,690              | -4,356              | -22,367             | -6,184                                               | -5,845                                   | -2,217                                  | -4,205                                | -17,805                                             |
| 3200       | -2,538              | -3,069              | -19,947             | -4,916                                               | -4,401                                   | -0,853                                  | -3,755                                | -17,640                                             |
| 3400       | -1,519              | -1,932              | -17,810             | -3,795                                               | -3,128                                   | 0,346                                   | -3,359                                | -17,496                                             |
| 3600       | -0,611              | -0,922              | -15,909             | -2,799                                               | -1,996                                   | 1,408                                   | -3,008                                | -17,369                                             |
| 3800       | 0,201               | -0,017              | -14,205             | -1,906                                               | -0,984                                   | 2,355                                   | -2,694                                | -17,257                                             |
| 4000       | 0,934               | 0,798               | -12,671             | -1,101                                               | -0,074                                   | 3,204                                   | -2,413                                | -17,157                                             |
| 4500       | 2,483               | 2,520               | -9,423              | 0,602                                                | 1,847                                    | 4,985                                   | -1,824                                | -16,953                                             |
| 5000       | 3,724               | 3,898               | -6,816              | 1,972                                                | 3,383                                    | 6,397                                   | -1,358                                | -16,797                                             |
| 5500       | 4,739               | 5,027               | -4,672              | 3,098                                                | 4,639                                    | 7,542                                   | -0,980                                | -16,678                                             |
| 6000       | 5,587               | 5,969               | -2,876              | 4,040                                                | 5,684                                    | 8,488                                   | -0,671                                | -16,588                                             |

Fonte: Consistente com JANAF Thermochemical Tables, 3ª edição, Thermal Group, Dow Chemical U.S.A., Mid., MI 1985



**Tabela A.18** — Funções de escoamento compressível isentrópico unidimensional para um gás perfeito com calor específico constante e  $k = 1,4$ 

| $M$         | $M^*$          | $A/A^*$        | $p/p_0$            | $\rho/\rho_0$      | $T/T_0$        |
|-------------|----------------|----------------|--------------------|--------------------|----------------|
| 0,0         | 0,00000        | $\infty$       | 1,00000            | 1,00000            | 1,00000        |
| 0,1         | 0,10944        | 5,82183        | 0,99303            | 0,99502            | 0,99800        |
| 0,2         | 0,21822        | 2,96352        | 0,97250            | 0,98028            | 0,99206        |
| 0,3         | 0,32572        | 2,03506        | 0,93947            | 0,95638            | 0,98232        |
| <b>0,4</b>  | <b>0,43133</b> | <b>1,59014</b> | <b>0,89561</b>     | <b>0,92427</b>     | <b>0,96899</b> |
| 0,5         | 0,53452        | 1,33984        | 0,84302            | 0,88517            | 0,95238        |
| 0,6         | 0,63481        | 1,18820        | 0,78400            | 0,84045            | 0,93284        |
| 0,7         | 0,73179        | 1,09437        | 0,72093            | 0,79158            | 0,91075        |
| 0,8         | 0,82514        | 1,03823        | 0,65602            | 0,73999            | 0,88652        |
| <b>0,9</b>  | <b>0,91460</b> | <b>1,00886</b> | <b>0,59126</b>     | <b>0,68704</b>     | <b>0,86059</b> |
| 1,0         | 1,0000         | 1,00000        | 0,52828            | 0,63394            | 0,83333        |
| 1,1         | 1,0812         | 1,00793        | 0,46835            | 0,58170            | 0,80515        |
| 1,2         | 1,1583         | 1,03044        | 0,41238            | 0,53114            | 0,77640        |
| 1,3         | 1,2311         | 1,06630        | 0,36091            | 0,48290            | 0,74738        |
| <b>1,4</b>  | <b>1,2999</b>  | <b>1,11493</b> | <b>0,31424</b>     | <b>0,43742</b>     | <b>0,71839</b> |
| 1,5         | 1,3646         | 1,17617        | 0,27240            | 0,39498            | 0,68966        |
| 1,6         | 1,4254         | 1,25023        | 0,23527            | 0,35573            | 0,66138        |
| 1,7         | 1,4825         | 1,33761        | 0,20259            | 0,31969            | 0,63371        |
| 1,8         | 1,5360         | 1,43898        | 0,17404            | 0,28682            | 0,60680        |
| <b>1,9</b>  | <b>1,5861</b>  | <b>1,55526</b> | <b>0,14924</b>     | <b>0,25699</b>     | <b>0,58072</b> |
| 2,0         | 1,6330         | 1,68750        | 0,12780            | 0,23005            | 0,55556        |
| 2,1         | 1,6769         | 1,83694        | 0,10935            | 0,20580            | 0,53135        |
| 2,2         | 1,7179         | 2,00497        | 0,93522E-01        | 0,18405            | 0,50813        |
| 2,3         | 1,7563         | 2,19313        | 0,79973E-01        | 0,16458            | 0,48591        |
| <b>2,4</b>  | <b>1,7922</b>  | <b>2,40310</b> | <b>0,68399E-01</b> | <b>0,14720</b>     | <b>0,46468</b> |
| 2,5         | 1,8257         | 2,63672        | 0,58528E-01        | 0,13169            | 0,44444        |
| 2,6         | 1,8571         | 2,89598        | 0,50115E-01        | 0,11787            | 0,42517        |
| 2,7         | 1,8865         | 3,18301        | 0,42950E-01        | 0,10557            | 0,40683        |
| 2,8         | 1,9140         | 3,50012        | 0,36848E-01        | 0,94626E-01        | 0,38941        |
| <b>2,9</b>  | <b>1,9398</b>  | <b>3,84977</b> | <b>0,31651E-01</b> | <b>0,84889E-01</b> | <b>0,37286</b> |
| 3,0         | 1,9640         | 4,23457        | 0,27224E-01        | 0,76226E-01        | 0,35714        |
| 3,5         | 2,0642         | 6,78962        | 0,13111E-01        | 0,45233E-01        | 0,28986        |
| 4,0         | 2,1381         | 10,7188        | 0,65861E-02        | 0,27662E-01        | 0,23810        |
| 4,5         | 2,1936         | 16,5622        | 0,34553E-02        | 0,17449E-01        | 0,19802        |
| <b>5,0</b>  | <b>2,2361</b>  | <b>25,0000</b> | <b>0,18900E-02</b> | <b>0,11340E-01</b> | <b>0,16667</b> |
| 6,0         | 2,2953         | 53,1798        | 0,63336E-03        | 0,51936E-02        | 0,12195        |
| 7,0         | 2,3333         | 104,143        | 0,24156E-03        | 0,26088E-02        | 0,09259        |
| 8,0         | 2,3591         | 190,109        | 0,10243E-03        | 0,14135E-02        | 0,07246        |
| 9,0         | 2,3772         | 327,189        | 0,47386E-04        | 0,81504E-03        | 0,05814        |
| <b>10,0</b> | <b>2,3905</b>  | <b>535,938</b> | <b>0,23563E-04</b> | <b>0,49482E-03</b> | <b>0,04762</b> |
| $\infty$    | 2,4495         | $\infty$       | 0,0                | 0,0                | 0,0            |

**Tabela A.19** — Funções de choque normal unidimensional para um gás perfeito com calor específico constante e  $k = 1,4$ 

| $M_x$       | $M_y$          | $p_y/p_x$     | $\rho_y/\rho_x$ | $T_y/T_x$     | $p_{0y}/p_{0x}$ | $p_{0y}/p_x$  |
|-------------|----------------|---------------|-----------------|---------------|-----------------|---------------|
| 1,00        | 1,00000        | 1,0000        | 1,0000          | 1,0000        | 1,00000         | 1,8929        |
| 1,10        | 0,91177        | 1,2450        | 1,1691          | 1,0649        | 0,99893         | 2,1328        |
| 1,20        | 0,84217        | 1,5133        | 1,3416          | 1,1280        | 0,99280         | 2,4075        |
| 1,30        | 0,78596        | 1,8050        | 1,5157          | 1,1909        | 0,97937         | 2,7136        |
| <b>1,40</b> | <b>0,73971</b> | <b>2,1200</b> | <b>1,6897</b>   | <b>1,2547</b> | <b>0,95819</b>  | <b>3,0492</b> |
| 1,50        | 0,70109        | 2,4583        | 1,8621          | 1,3202        | 0,92979         | 3,4133        |
| 1,60        | 0,66844        | 2,8200        | 2,0317          | 1,3880        | 0,89520         | 3,8050        |
| 1,70        | 0,64054        | 3,2050        | 2,1977          | 1,4583        | 0,85572         | 4,2238        |

**Tabela A.19 (Continuação) — Funções de choque normal unidimensional para um gás perfeito com calor específico constante e  $k = 1,4$** 

| $M_x$       | $M_y$          | $P_y/P_x$     | $\rho_y/\rho_x$ | $T_y/T_x$     | $P_{0y}/P_{0x}$ | $P_{0y}/P_x$  |
|-------------|----------------|---------------|-----------------|---------------|-----------------|---------------|
| 1.80        | 0,61650        | 3,6133        | 2,3592          | 1,5316        | 0,81268         | 4,6695        |
| 1.90        | 0,59562        | 4,0450        | 2,5157          | 1,6079        | 0,76736         | 5,1418        |
| 2.00        | 0,57735        | 4,5000        | 2,6667          | 1,6875        | 0,72087         | 5,6404        |
| 2.10        | 0,56128        | 4,9783        | 2,8119          | 1,7705        | 0,67420         | 6,1654        |
| <b>2,20</b> | <b>0,54706</b> | <b>5,4800</b> | <b>2,9512</b>   | <b>1,8569</b> | <b>0,62814</b>  | <b>6,7165</b> |
| 2.30        | 0,53441        | 6,0050        | 3,0845          | 1,9468        | 0,58329         | 7,2937        |
| 2.40        | 0,52312        | 6,5533        | 3,2119          | 2,0403        | 0,54014         | 7,8969        |
| 2.50        | 0,51299        | 7,1250        | 3,3333          | 2,1375        | 0,49901         | 8,5261        |
| 2.60        | 0,50387        | 7,7200        | 3,4490          | 2,2383        | 0,46012         | 9,1813        |
| <b>2,70</b> | <b>0,49563</b> | <b>8,3383</b> | <b>3,5590</b>   | <b>2,3429</b> | <b>0,42359</b>  | <b>9,8624</b> |
| 2.80        | 0,48817        | 8,9800        | 3,6636          | 2,4512        | 0,38946         | 10,569        |
| 2.90        | 0,48138        | 9,6450        | 3,7629          | 2,5632        | 0,35773         | 11,302        |
| 3.00        | 0,47519        | 10,333        | 3,8571          | 2,6790        | 0,32834         | 12,061        |
| 4.00        | 0,43496        | 18,500        | 4,5714          | 4,0469        | 0,13876         | 21,068        |
| <b>5,00</b> | <b>0,41523</b> | <b>29,000</b> | <b>5,0000</b>   | <b>5,8000</b> | <b>0,06172</b>  | <b>32,653</b> |
| 10,00       | 0,38758        | 116,50        | 5,7143          | 20,387        | 0,00304         | 129,22        |
| $\infty$    | 0,37796        | $\infty$      | 6,0000          | $\infty$      | 0,0             | $\infty$      |

**Tabela A.20 — Massas atômicas (relativas ao  $^{12}\text{C}$ ), pontos de fusão e ebulição dos elementos**

| Nome             | Símbolo   | Número Atômico | Massa Atômica        | Ponto de fusão<br>°C | Ponto de ebulição<br>°C |
|------------------|-----------|----------------|----------------------|----------------------|-------------------------|
| Actínio          | Ac        | 89             | 227,028 <sup>a</sup> | 1050                 | 3200 ± 300              |
| Alumínio         | Al        | 13             | 26,9815              | 660,37               | 2467                    |
| Americio         | Am        | 95             | (243)                | 994 ± 4              | 2607                    |
| Antimônio        | Sb        | 51             | 121,75               | 630,74               | 1750                    |
| <b>Argônio</b>   | <b>Ar</b> | <b>18</b>      | <b>39,948</b>        | <b>-189,2</b>        | <b>-185,7</b>           |
| Arsênico         | As        | 33             | 74,9216              | 817 (28 atm)         | 613 (sub)               |
| Ástato           | At        | 85             | (210)                | 302                  | 337                     |
| Bário            | Ba        | 56             | 137,33               | 725                  | 1640                    |
| Berquélio        | Bk        | 97             | (247)                |                      |                         |
| <b>Berílio</b>   | <b>Be</b> | <b>4</b>       | <b>9,01218</b>       | <b>1278 ± 5</b>      | <b>2970 (5 mm)</b>      |
| Bismuto          | Bi        | 83             | 208,980              | 271,3                | 1560 ± 5                |
| Boro             | B         | 5              | 10,81                | 2079                 | 2550 (sub)              |
| Bromo            | Br        | 35             | 79,904               | -7,2                 | 58,78                   |
| Cádmio           | Cd        | 48             | 112,41               | 320,9                | 765                     |
| <b>Cálcio</b>    | <b>Ca</b> | <b>20</b>      | <b>40,08</b>         | <b>839 ± 2</b>       | <b>1484</b>             |
| Califórnio       | Cf        | 98             | (251)                |                      |                         |
| Carbono          | C         | 6              | 12,011               | 3652(sub)            | t                       |
| Cério            | Ce        | 58             | 140,12               | 798 ± 2              | 3257                    |
| Césio            | Cs        | 55             | 132,9054             | 28,40 ± 0,0 1        | 669,3                   |
| <b>Cloro</b>     | <b>Cl</b> | <b>17</b>      | <b>35,453</b>        | <b>-100,98</b>       | <b>-34,6</b>            |
| Cromo            | Cr        | 24             | 51,996               | 1857 ± 20            | 2672                    |
| Cobalto          | Co        | 27             | 51,9332              | 1495                 | 2870                    |
| Cobre            | Cu        | 29             | 63,546               | 1083,4 ± 0,2         | 2567                    |
| Cúrio            | Cm        | 96             | (247)                | 1340 ± 40            |                         |
| <b>Disprósio</b> | <b>Dy</b> | <b>66</b>      | <b>162,50</b>        | <b>1409</b>          | <b>2335</b>             |

<sup>a</sup> Estes valores são aplicáveis aos materiais de origem terrestre e aos artificiais.

Fonte: Handbook of Chemistry and Physics, 62ª edição, CRC Press, Boca Raton, FL, 1986.

**Tabela A.20 (Continuação) —** Massas atômicas (relativas ao  $^{12}\text{C}$ ), pontos de fusão e ebulição dos elementos

| Nome               | Símbolo   | Número Atômico | Massa Atômica  | Ponto de fusão<br>°C     | Ponto de ebulição<br>°C |
|--------------------|-----------|----------------|----------------|--------------------------|-------------------------|
| Eínstênio          | Es        | 99             | (252)          |                          |                         |
| Érbio              | Er        | 68             | 167,26         | 1522                     | 2510                    |
| Európio            | Eu        | 63             | 151,96         | 822 ± 5                  | 1597                    |
| Fémio              | Fm        | 100            | (257)          |                          |                         |
| <b>Flúor</b>       | <b>F</b>  | <b>9</b>       | <b>18,9984</b> | <b>-219,62</b>           | <b>-188,14</b>          |
| Frâncio            | Fr        | 87             | (223)          | (27)                     | (677)                   |
| Gadolínio          | Gd        | 64             | 157,25         | 1311 ± 1                 | 3233                    |
| Gálio              | Ga        | 31             | 69,72          | 29,78                    | 2403                    |
| Germânio           | Ge        | 32             | 72,59          | 937,4                    | 2830                    |
| <b>Ouro</b>        | <b>Au</b> | <b>79</b>      | <b>196,967</b> | <b>1064,434</b>          | <b>3080</b>             |
| Háfnio             | Hf        | 72             | 178,49         | 2227 ± 20                | 4602                    |
| Hélio              | He        | 2              | 4,00260        | -272,2 <sup>26 atm</sup> | -268,934                |
| Hólmio             | Ho        | 67             | 164,930        | 1470                     | 2720                    |
| Hidrogênio         | H         | 1              | 1,00794        | -259,14                  | -252,87                 |
| <b>Índio</b>       | <b>In</b> | <b>49</b>      | <b>114,82</b>  | <b>156,61</b>            | <b>2080</b>             |
| Iodo               | I         | 53             | 126,905        | 113,5                    | 184,35                  |
| Iridio             | Ir        | 77             | 192,22         | 2410                     | 4130                    |
| Ferro              | Fe        | 26             | 55,847         | 1535                     | 2750                    |
| Criptônio          | Kr        | 36             | 83,80          | -156,6                   | -152,30 ± 0,10          |
| <b>Lantânio</b>    | <b>La</b> | <b>57</b>      | <b>138,906</b> | <b>920 ± 5</b>           | <b>3454</b>             |
| Laurêncio          | Lr        | 103            | (260)          |                          |                         |
| Chumbo             | Pb        | 82             | 207,2          | 327,502                  | 1740                    |
| Lítio              | Li        | 3              | 6,941          | 180,54                   | 1342                    |
| Lutécio            | Lu        | 71             | 174,967        | 1656 ± 5                 | 3315                    |
| <b>Magnésio</b>    | <b>Mg</b> | <b>12</b>      | <b>24,305</b>  | <b>648,8 ± 0,5</b>       | <b>1090</b>             |
| Manganês           | Mn        | 25             | 54,9380        | 1244 ± 3                 | 1962                    |
| Mendelévio         | Md        | 101            | (258)          |                          |                         |
| Mercurio           | Hg        | 80             | 200,59         | -38,87                   | 356,58                  |
| Molibidênio        | Mo        | 42             | 95,94          | 2617                     | 4612                    |
| <b>Neodímio</b>    | <b>Nd</b> | <b>60</b>      | <b>144,24</b>  | <b>1010</b>              | <b>3127</b>             |
| Neônio             | Ne        | 10             | 20,1179        | -248,67                  | -246,048                |
| Neptúnio           | Np        | 93             | 237,048        | 640 ± 1                  | 3902                    |
| Níquel             | Ni        | 28             | 58,69          | 1453                     | 2732                    |
| Nióbio             | Nb        | 41             | 92,9064        | 2468 ± 10                | 4742                    |
| <b>Nitrogênio</b>  | <b>N</b>  | <b>7</b>       | <b>14,0067</b> | <b>-209,86</b>           | <b>-195,8</b>           |
| Nobelium           | No        | 102            | (259)          |                          |                         |
| Ósmio              | Os        | 76             | 190,2          | 3045 ± 30                | 5027 ± 100              |
| Oxigênio           | O         | 8              | 15,9994        | -218,4                   | -182,962                |
| Paládio            | Pd        | 46             | 106,42         | 1554                     | 3 140                   |
| <b>Fósforo</b>     | <b>P</b>  | <b>15</b>      | <b>30,9738</b> | <b>44,1 (branco)</b>     | <b>280 (branco)</b>     |
| Platina            | Pt        | 78             | 195,08         | 1772                     | 3827 ± 100              |
| Plutônio           | Pu        | 94             | (244)          | 641                      | 3232                    |
| Polônio            | Po        | 84             | (209)          | 254                      | 962                     |
| Potássio           | K         | 19             | 39,0983        | 63,25                    |                         |
| <b>Praseodímio</b> | <b>Pr</b> | <b>59</b>      | <b>140,908</b> | <b>931 ± 4</b>           | <b>3212</b>             |
| Promécio           | Pm        | 61             | (145)          | 1080 (approx)            | 2460 (?)                |
| Protactínio        | Pa        | 91             | 231,0359       | 1600                     |                         |
| Rádio              | Ra        | 88             | 226,025        | 700                      | 1140                    |
| Radônio            | Rn        | 86             | (222)          | -71                      | -61,8                   |
| <b>Rênio</b>       | <b>Re</b> | <b>75</b>      | <b>186,207</b> | <b>3180</b>              | <b>5627 (est.)</b>      |

**Tabela A.20 (Continuação)** — Massas atômicas (relativas ao  $^{12}\text{C}$ ), pontos de fusão e ebulição dos elementos

| Nome                | Símbolo      | Número Atômico | Massa Atômica  | Ponto de fusão<br>°C            | Ponto de ebulição<br>°C |
|---------------------|--------------|----------------|----------------|---------------------------------|-------------------------|
| Ródio               | Rh           | 45             | 102,906        | $1965 \pm 3$                    | $3727 \pm 100$          |
| Rubídio             | Rb           | 37             | 85,4678        | 38,89                           | 686                     |
| Rutênio             | Ru           | 44             | 101,07         | 2310                            | 3900                    |
| Samário             | Sm           | 62             | 150,36         | $1072 \pm 5$                    | 1778                    |
| <b>Escândio</b>     | <b>Sc</b>    | <b>21</b>      | <b>44,9559</b> | <b>1539</b>                     | <b>2832</b>             |
| Selênio             | Se           | 34             | 78,96          | 217                             | $684,9 \pm 1,0$         |
| Silício             | Si           | 14             | 28,0855        | 1410                            | 2355                    |
| Prata               | Ag           | 47             | 107,868        | 961,93                          | 2212                    |
| Sódio               | Na           | 11             | 22,9898        | $97,81 \pm 0,03$                | 882,9                   |
| <b>Estrôncio</b>    | <b>Sr</b>    | <b>38</b>      | <b>87,62</b>   | <b>769</b>                      | <b>1384</b>             |
| Enxofre             | S            | 16             | 32,06          | 112,8                           | 444,674                 |
| Tantálio            | Ta           | 73             | 180,9479       | 2996                            | $5425 \pm 100$          |
| Tecnécio            | Tc           | 43             | (98)           | 2172                            | 4877                    |
| Telúrio             | Te           | 52             | 127,60         | $449,5 \pm 0,3$                 | $989,8 \pm 3,8$         |
| <b>Térbio</b>       | <b>Tb</b>    | <b>65</b>      | <b>158,925</b> | <b>1360 <math>\pm</math> 4</b>  | <b>3041</b>             |
| Tálio               | Tl           | 81             | 204,383        | 303,5                           | $1457 \pm 10$           |
| Tório               | Th           | 90             | 232,038        | 1750                            | 4790 (aprox.)           |
| Túlio               | Tm           | 69             | 168,934        | $1545 \pm 15$                   | 1727                    |
| Estanho             | Sn           | 50             | 118,71         | $231,968 \pm 1$                 | 2270                    |
| <b>Titânio</b>      | <b>Ti</b>    | <b>22</b>      | <b>47,88</b>   | <b>1660 <math>\pm</math> 10</b> | <b>3287</b>             |
| Tungstênio          | W            | 74             | 183,85         | $3410 \pm 20$                   | 5660                    |
| Unnihexium          | (Unh)        | 106            | (263)          |                                 |                         |
| Unnilpentium        | (Unp)        | 105            | (262)          |                                 |                         |
| Unnilquadium        | (Unq)        | 104            | (261)          |                                 |                         |
| <b>Unnilseptium</b> | <b>(Uns)</b> | <b>107</b>     | <b>(262)</b>   |                                 |                         |
| Urânio              | U            | 92             | 238,029        | $1132 \pm 0,8$                  | 3818                    |
| Vanádio             | V            | 23             | 50,9415        | $1890 \pm 10$                   | 3380                    |
| Xenônio             | Xe           | 54             | 131,29         | -111,9                          | $-107,1 \pm 3$          |
| Itérbio             | Yb           | 70             | 173,04         | $824 \pm 5$                     | 1193                    |
| <b>Ítrio</b>        | <b>Y</b>     | <b>39</b>      | <b>88,9059</b> | <b>1523 <math>\pm</math> 8</b>  | <b>3337</b>             |
| Zinco               | Zn           | 30             | 65,39          | 419,58                          | 907                     |
| Zircônio            | Zr           | 40             | 91,224         | $1852 \pm 2$                    | 4377                    |