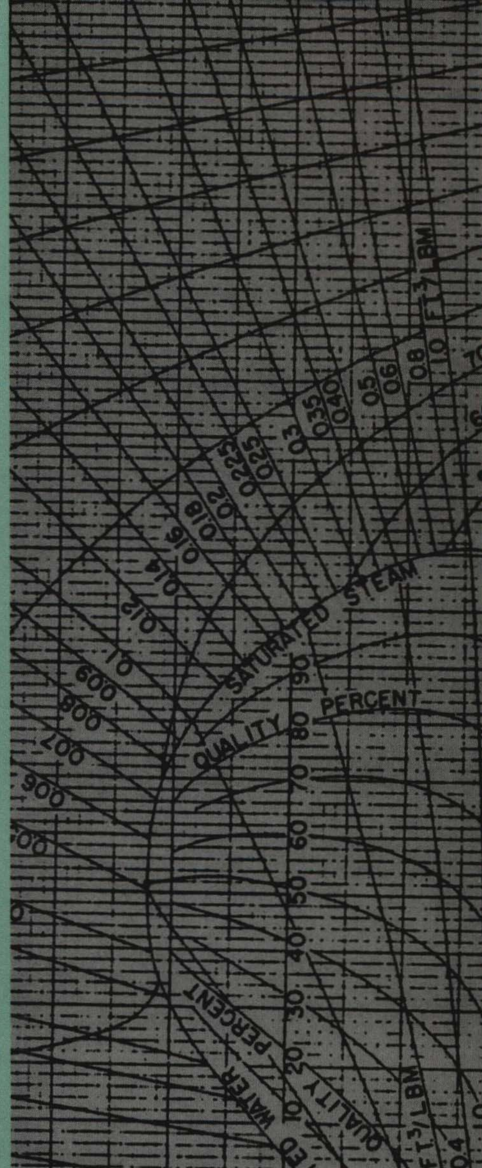
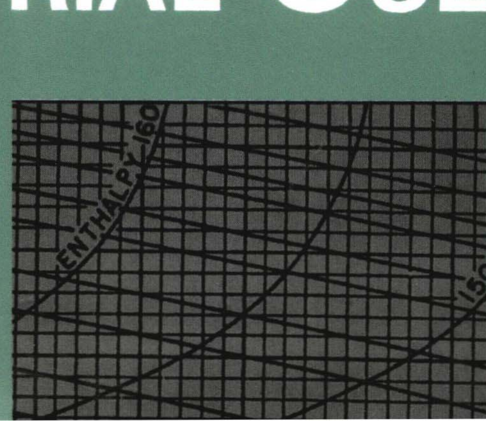


ASME International Steam Tables for Industrial Use

Third Edition



CRTD-VOL. 58

ASME INTERNATIONAL STEAM TABLES FOR INDUSTRIAL USE

Third Edition

Based on the
IAPWS Industrial Formulation 1997
for the Thermodynamic Properties of Water and Steam (IAPWS-IF97)

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ISBN: 978-0-7918-6036-6
Book no.: 860366

PREFACE TO FIRST EDITION

International standards for water and steam properties are set by the International Association for the Properties of Water and Steam (IAPWS). The IAPWS-IF97 formulation for thermodynamic properties used in this book was developed by an IAPWS Task Group chaired by Wolfgang Wagner of Germany. Testing of the formulation was the responsibility of a Task Group chaired by Kiyoshi Miyagawa of Japan. We begin by acknowledging the extraordinary efforts of these two groups, and especially their chairmen, in producing a formulation that is significantly improved over its predecessor in accuracy, internal consistency, and speed.

This book, like the previous *ASME Steam Tables* which date back to 1967, was produced by the efforts of the Properties of Steam Subcommittee of the ASME Research and Technology Committee on Water and Steam in Thermal Systems. In addition to the four people listed as authors, we particularly acknowledge the efforts of Subcommittee members Daniel Friend (NIST), Richard Jacobsen (University of Idaho), Johanna M. H. Levelt Sengers (NIST), Jan Sengers (University of Maryland), and Jesse Sewell (Siemens Westinghouse). Much of the programming of the ASME implementation of IAPWS-IF97 was performed by Joanne Chao (Keane). We also received logistical support from Howard Clark of the ASME Center for Research and Technology Development. Cynthia Clark and Tara Smith of the ASME Technical Publishing Department supervised the production of the book. Much of the financial support for the Subcommittee has been provided by the Electric Power Research Institute (EPRI).

One thing that became clear during this process was the necessity of retaining the knowledge of previous generations. We are grateful for support and advice we received from the surviving authors of the 1967 *ASME Steam Tables*: Ralph McClintock, George Silvestri, and especially Robert Spencer. Being able to profit from their accumulated wisdom spared us from reinventing solutions to problems they had previously solved. It is our hope that ASME will continue to maintain an infrastructure of expertise in the properties of steam to ensure that the next generation can build from this strong foundation when the time comes to revise or replace this book.

ASME Research and Technology Committee on Water and Steam
in Thermal Systems, Subcommittee on Properties of Steam

William T. Parry, Chairman
Allan H. Harvey, Secretary

September 1999

PREFACE TO SECOND EDITION

This Second Edition presents the same properties of water and steam as the First Edition (published in 2000), with two exceptions. In 2007, the International Association for the Properties of Water and Steam (IAPWS) adopted a new formulation for the high-temperature Region 5, extending the pressure range of validity of Region 5 from 10 MPa to 50 MPa in order to cover conditions that might be encountered in some proposed new power cycles. The new Region 5 formulation is reflected in new Tables S-4 and U-4. Also, in 2008, IAPWS adopted a new formulation for the viscosity of water and steam. This is reflected in new Tables S-8, S-10, U-8, and U-10, along with new Figures S-2, S-3, S-5, U-2, U-3, and U-5. We also took the opportunity to correct a few typographical errors and to update some of the background text and references.

ASME Research and Technology Committee on Water and Steam
in Thermal Systems, Subcommittee on Properties of Steam

Richard D. Harwood, Chair
Allan H. Harvey, Secretary

September 2008

PREFACE TO THIRD EDITION

The main update for this Third Edition is the incorporation of the new IAPWS formulation adopted in 2011 for the thermal conductivity of water and steam. This is reflected in new Tables S-9, S-10, U-9, and U-10, along with new Figures S-4, S-5, U-4, and U-5 and revision of Appendix B. The thermodynamic property information is unchanged from the Second Edition. We also made minor updates to some of the background text and references. We thank Prof. H.-J. Kretzschmar for his assistance with the thermal conductivity calculations.

ASME Research and Technology Committee on Water and Steam
in Thermal Systems, Subcommittee on Properties of Steam

Richard D. Harwood, Chair
Allan H. Harvey, Secretary

December 2013

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CHAPTER

1

INTRODUCTION

PURPOSE

Industrial steam tables exist to provide a standard set of properties of water and steam for manufacturers, customers, and other parties. Three desirable qualities for a set of industrial steam tables are accuracy, self-consistency, and stability. The properties must be reasonably accurate and self-consistent to support quality design of equipment. A formulation must remain the standard for many years, because the change from one standard to another is inconvenient and expensive. If the tables are represented by computer programs, those programs must be fast, since design software may call steam property routines millions of times. The *ASME International Steam Tables for Industrial Use* provide highly accurate and self-consistent steam properties, conforming to the constraint of representation by a fast computer program. They are based on the "Revised Release on the IAPWS Formulation 1997 for the Thermodynamic Properties of Water and Steam for Industrial Use," [1] adopted as an international standard by the International Association for the Properties of Water and Steam. They are suitable for calculations for current and anticipated power plants and are expected to remain the standard for at least 20 years.

HISTORY

Regnault [2] published the first steam tables in 1847. By 1921, the profusion of steam tables caused the American Society of Mechanical Engineers (ASME) to establish the ASME Research Committee on Thermal Properties of Steam. In the early 1920s, this committee was instrumental in stimulating and arranging support for fundamental research at government and university laboratories. Parallel efforts in England, Germany, Canada, and Czechoslovakia led to the First and Second International Steam-Table Conferences (London, 1929, and Berlin, 1930). These conferences constructed skeleton tables, which contained values of specific volume and enthalpy and their associated tolerances (uncertainty estimates) for each point on a coarse grid of temperatures and pressures. These values and tolerances were agreed upon by experts based on the best available data. Over the next few years, the tolerances in the skeleton tables were much reduced; a more complete skeleton table was produced by the Third International Steam Tables Conference (ASME Headquarters, New York, 1934). In 1936, Keenan and Keyes published their steam tables [3] which were based for the most part on the same data as the 1934 skeleton tables. These steam tables served as the industry standard for over 30 years.

IFC-67

At the Third International Steam Tables Conference, the need for continued research was recognized. By the 1950s, it became evident that a need existed for better thermodynamic information at higher pressures and temperatures. The tables in Keenan and Keyes have very sparse values above the critical point. New skeleton tables, extending into the higher pressure regions, were completed in 1963. At the same time, it was recognized that different methods of interpolation between points in the skeleton tables could produce important differences in the values in the more detailed tables. Therefore, the International Formulating Committee was formed, with the task of making standard equations to be used internationally. This committee produced "The 1967 IFC Formulation for Industrial Use," abbreviated IFC-67. This formulation was used for 30 years, and was the basis for ASME Steam Tables [4] through the 6th Edition. It consisted of several sets of equations that provided values of thermodynamic properties over the range of 0.000 61 MPa to 100 MPa (0.088 psia to 14 503.8 psia) and 0.01 °C to 800 °C (32.018 °F to 1472 °F). This range of pressures and temperatures was divided into six regions; each region had a set of equations. Considerable effort was required to keep calculated values reasonably consistent at region boundaries.

Although people had developed computer programs to reproduce the values in the Keenan and Keyes steam tables, an important extension of the IFC-67 formulation was the FORTRAN computer subroutines developed by ASME [5, 6]. These subroutines were used to produce the values both in many tabulations of steam properties and directly for industrial calculations. The subroutines were publicly available and ultimately became the foundation of the computer program distributed with the 6th Edition of the ASME Steam Tables.

Another important development was the recognition that a permanent organization was needed to guide steam research and maintain the steam tables. Thus, the International Association for the Properties of Steam (IAPS) was formed. IAPS has met annually and has conducted conferences approximately every five years. The organization recognized that there was a need for a stable industrial formulation and another, parallel formulation for scientific and general use, which could be updated more frequently to maintain a state-of-the-art representation without being constrained by considerations of stability or computing time. IAPS changed its name to The International Association for the Properties of Water and Steam (IAPWS) in 1989.

NEED FOR NEW FORMULATION

At the 11th International Conference on the Properties of Steam (Prague, 1989), there were discussions of the need and possible specifications for a new industrial formulation of the properties of water and steam. Advances in computer speed had made possible increasingly complex calculations, using many more calls to steam properties. The time spent calling steam routines had not declined significantly since 1967, and improvement in speed remained important. The discontinuities at the region boundaries of IFC-67 had created difficulties in simulation programs due to oscillations at the boundaries – for example, when a routine would estimate a value in one region, during iteration it would determine that it was in a second region, and during iteration in the second region determine that it was in the first region. Inaccuracies were also becoming apparent. Another important development at the time was personal computers, which were relatively slow; a faster formulation would allow more design calculations to be performed on PCs.

SPECIFICATION FOR NEW FORMULATION

At its 1990 annual meeting in Buenos Aires, IAPWS decided to proceed with both a new formulation for general and scientific use and a new formulation for industrial use. A specification for the industrial formulation was developed at the 1991 meeting in Tokyo and modified slightly in subsequent years. The values of specific volume and enthalpy were generally to agree with the new general and scientific formulation within the tolerances given in the International Skeleton Tables of 1985, except where these tolerances were exceptionally small (e.g., liquid water below 150 °C). Other calculated values were to be within the experimental uncertainty, except where that uncertainty was extremely small (e.g., vapor pressure below 100 °C). It was recognized that the new industrial formulation would have several regions. Continuity at region boundaries was to meet and preferably exceed the requirements that had been set for IFC-67 (which, unfortunately, IFC-67 itself did not always meet, especially for enthalpy and heat capacity). The computational speed was to be faster than the ASME IFC-67 software by at least a factor of three, except in the "supercritical" region. This speed was to be achieved by having "forward" equations that defined the values in each region in terms of its independent variables [e.g., $h(p, T)$ and $s(p, T)$], and also "backward" functions [e.g., $T(p, h)$ and $T(p, s)$], which would be so accurate that iterative checking using the corresponding forward functions would be unnecessary. The expected working life of the formulation was to be at least 20 years. The specification included a high temperature, low pressure region for combustion turbine work. Work on testing programs for speed and accuracy began immediately. From the beginning, this formulation was specified to be a computer program, usable on personal computers or mainframes, and written in FORTRAN.

DEVELOPMENT OF NEW FORMULATION

At the 1990 meeting, IAPWS formed a task group to generate the new industrial formulation. The task group consisted of twelve members from seven countries and was chaired by Prof. Wolfgang Wagner (Germany). Guidance would come from the IAPWS Industrial Calculations Working Subcommitee. Discussions of many of the challenges that faced the task group and details of their solutions may be found in the Proceedings of the 12th International Conference on the Properties of Water and Steam (Orlando, Florida, 1994) [7]. As work progressed, the task group found that the goal of three times the computational speed of IFC-67 was achievable, and the balance between speed and accuracy was reevaluated. As long as the speed was at least five times that of IFC-67, increased accuracy would be sought rather than pursuing further speed improvements. In 1995, IAPWS adopted the equations that would become the Release on the IAPWS Formulation 1995 for the Thermodynamic Properties of Ordinary Water Substance for General and Scientific Use (IAPWS-95) [8, 9], and work on the industrial formulation accelerated. By the annual meeting in 1996, a provisional version was available for testing.

TESTING

The international testing task group was led by Kiyoshi Miyagawa (Japan). The new formulation was tested against both the International Skeleton Tables of 1985 and against the IAPWS-95 Formulation for General and Scientific Use. As development and testing progressed, clarifications were made to the original specifications based on industrial input and the capabilities of preliminary formulations. One issue revealed by testing was the need for better handling of supersaturated steam (a metastable vapor state, where the equilibrium condition would be a vapor-liquid mixture, resulting from rapid expansion of steam). Ultimately, a special equation was developed to give properties believed to be the most reasonable for this region (see Chapter 3).

The final formulation met or exceeded all requirements associated with accuracy, continuity at region boundaries, and calculational speed. The accuracy and the consistency at the boundaries were both greatly improved over IFC-67. The speed of the new formulation was at least five times that of IFC-67 in the superheated steam and liquid water regions and along the saturation line. In the supercritical region, the new formulation was three times faster. The improved performance is described in detail in [10, 11].

ADOPTION

The IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam [1], abbreviated IAPWS-IF97, was adopted at the 1997 IAPWS annual meeting in Erlangen, Germany. However, the increased accuracy of some of the values produced commercially significant changes in the results of power plant heat rate calculations [12]. Other differences from IFC-67 are also given in reference [12]. Due to the significant differences, particularly in heat rate calculations, IAPWS decided to recommend a waiting period before the new formulation was to be used as the basis for contracts. This waiting period (which expired at the beginning of 1999) would allow users to become familiar with the effects of the new values on their design software.

As technology advanced and designs began to be considered for combustion turbines operating at higher pressures, IAPWS recognized the need to expand the pressure range of applicability of the high-temperature region (region 5) of IAPWS-IF97. A new region 5 formulation with an upper pressure limit of 50 MPa (increased from 10 MPa) was adopted by IAPWS in 2007 [1, 11]. The formulations for the other regions are still those of the original IAPWS-IF97.

THIS BOOK

The Subcommittee on Properties of Steam of the ASME Research and Technology Committee on Water and Steam in Thermal Systems is the United States National Committee for IAPWS. IAPWS authorizes each national committee to produce official implementations of IAPWS-IF97.

This book presents values produced from the IAPWS-IF97 formulation. Only the forward equations were used to compile the book. The backward equations are not needed to produce tables, only to compute quickly. Unlike previous versions of the ASME Steam Tables [4], this book includes both SI and U.S. customary units. Tables and figures in SI units are labeled "S-," while those in U.S. customary units are labeled "U-." It is hoped that this inclusion will promote familiarity with both sets of units in the United States and will serve an increasingly global industry.

The Subcommittee on Properties of Steam believed that essentially all important design work would use a computer. Therefore, this book should be small enough to carry in a briefcase and would be used for estimation rather than serious design. The tables have fewer points than in previous versions; they are intended for ready reference rather than precise interpolation. Each chart is limited to one page. Some of the infrequently used charts and tables from older versions of the steam tables have been omitted.

The Revised Release on the IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam [1] is the consensus standard. The computer program and code [13], available from ASME, represent the properties of water and steam for industrial purposes from that standard. This book reproduces values from the computer code.

A small booklet containing abbreviated versions of the thermodynamic property tables (in both SI and U.S. customary units) has also been produced [14]. This inexpensive booklet should be useful for quick reference (for example in a plant setting) and in educational settings where more detailed tables are not necessary.

CHAPTER

2

UNITS AND CONVERSIONS

INTERNATIONAL SYSTEM OF UNITS (SI)

The dominant system of units throughout the world is the International System of Units, abbreviated as SI. The SI provides a simple and coherent system for the expression of physical quantities. Even most "traditional" units such as the foot and the Btu are now officially defined in terms of SI units, so any discussion of units must begin with the SI.

The SI contains seven "base" units; these units and their combinations are used to express all physical quantities. These SI base units are given in Table 2-1. Other physical quantities are derived from appropriate combinations of these units; for example, speed is length divided by time and has units of m/s (equivalently written as $m \cdot s^{-1}$). In some cases, these combinations are given their own names and symbols. For example, force is mass times acceleration, and a $kg \cdot m \cdot s^{-2}$ is called a newton and is given the symbol N. Prefixes may be applied to SI units to indicate powers of ten. See Table 2-2 for the prefixes from 10^{18} to 10^{-12}.

More information on the use of the SI, including guidelines for the expression of quantities in written work, may be found in *Guide for the Use of the International System of Units (SI)*, by A. Thompson and B. N. Taylor, NIST Special Publication 811 [15].

Table 2-1. SI base units

	SI Base Unit	
Base Quantity	Name	Symbol
length	meter	m
mass	kilogram	kg
time	second	s
electric current	ampere	A
thermodynamic temperature	kelvin	K
amount of substance	mole	mol
luminous intensity	candela	cd

Table 2-2. SI prefixes

Factor	Prefix	Symbol
10^{18}	exa	E
10^{15}	peta	P
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto (rarely used)	h
10^{1}	deka (rarely used)	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

U.S. CUSTOMARY UNITS

In the United States, non-SI units continue to be in common use both in everyday life and in industry. Engineers in the U.S. have the added challenge of being conversant in multiple sets of units. The units most commonly encountered by U.S. mechanical engineers are defined in terms of SI counterparts; some of the most important conversions are listed below. Additional conversion factors from non-SI to SI units are listed in a variety of references, including NIST Special Publication 811 [15].

Length, area, and volume. One inch is defined as exactly 2.54 cm. Other length units (feet, etc.) proceed from this definition, as do units of area and volume (cubic feet, for example). One U.S. gallon is defined as exactly 231 cubic inches.

Mass and force. The pound mass (lb_m) is exactly 0.453 592 37 kg. The pound force (lb_f) is the product of the pound mass and the standard acceleration of gravity (9.806 65 $m \cdot s^{-2}$) and is approximately equal to 4.448 222 N.

Pressure. Pressure is force per unit area; the SI unit ($1\ N \cdot m^{-2}$) is the pascal (Pa). Common non-SI units include:

- the atmosphere (atm), defined as exactly 101.325 kPa
- the bar, exactly 100 kPa
- the pound force per square inch (psi or psia), approximately 6.894 757 kPa.

Pressures are occasionally expressed in terms of the weight (in standard gravity) of the particular height of fluid above a unit area, such as millimeters of mercury (mm Hg) or feet of water. Such units depend on the density of the fluid, which is a function of temperature and pressure. To avoid this complication, it is common (and we do so in this book) to use "conventional" definitions of these quantities so that the conversion factor will not change if the density of mercury or water is redetermined. The conventional millimeter of mercury (also called a torr) is defined as 1/760 atm, and the conventional millimeter of water is exactly 9.806 65 Pa.

Temperature. The kelvin is the unit of thermodynamic temperature; the temperature scale is fixed by defining the temperature of the triple point of pure water as exactly 273.16 K. For practical temperature measurements, the thermodynamic temperature must be approximated by standard procedures; the latest standard is the ITS-90 temperature scale [16]. The temperature in degrees Celsius (°C) is defined as the temperature in kelvins minus 273.15. Absolute temperature in degrees Rankine (°R) is the temperature in kelvins multiplied by 1.8. More common in U.S. customary usage is the degree Fahrenheit (°F); this is related to the Celsius temperature by $t/°C = (t/°F - 32)/1.8$.

Energy and work. The SI unit for energy and work is the joule (J), which in base units is 1 $m^2 \cdot kg \cdot s^{-2}$. Non-SI units in common use include the calorie (cal) and the British thermal unit (Btu). While these were originally defined as the amount of heat required to raise a specific mass of water (one gram for the calorie and one pound for the Btu) by one degree (Celsius for the calorie, Fahrenheit for the Btu), they are now defined in terms of SI units. The Fifth International Conference on the Properties of Steam (London, 1956) defined the International Table calorie as 4.1868 J. The International Table Btu is obtained from this by the conversions from grams to pounds and from °C to °F, and is approximately 1055.056 J. It should be noted that these values differ from the "thermochemical" values often used in physical chemistry, where the thermochemical calorie is defined by 1 $cal_{th} = 4.184$ J and there is a corresponding thermochemical Btu. This can lead to confusion, especially when quantities from non-SI steam tables are combined with physicochemical data from other sources. In this book, the International Table values for calories and Btu's are used exclusively.

CONVERSION TO MOLAR UNITS

The tables in this book give properties (such as enthalpy, entropy, and volume) per unit mass. Sometimes it is necessary to have quantities on a per mole basis. This is accomplished by multiplying by the molecular weight (a more proper term is "molar mass") of water.

While for precise scientific work one must take into account variations in the isotopic composition of water when assigning a molecular weight, these variations are not important for most engineering purposes. It suffices to use a "standard" isotopic composition. The established standard for water's isotopic composition is called Vienna Standard Mean Ocean Water [17], and has a molar mass of 18.015 268 g/mol.

TABLES OF CONVERSION FACTORS

Tables 2-3 through 2-9 contain factors for converting between commonly used units for quantities likely to be of interest to users of steam tables.

In the tables, the factor given in a table cell is applied to a quantity expressed in the units given in the leftmost column in order to obtain a result in the units given in the topmost row. This direction of operation is indicated by arrows in the table. When the conversion factor in a cell is exact, it is printed in bold type. Where it is practical, exact factors are also displayed as simple ratios.

Table 2-3. Conversion Factors for Pressure (Force/Area)

To obtain → / multiply by ↓	atm	bar	psia (lb_f/in^2)	in Hg (conventional)	mm Hg (conventional)	ft H_2O (conventional)	kPa	MPa
atm	1	**1.013 25**	14.695 95	**760/25.4** = 29.921 26	**760**	33.898 54	**101.325**	**0.101 325**
bar	**1/(1.013 25)** = $9.869\ 233\times10^{-1}$	1	14.503 77	29.529 99	**760/(1.013 25)** = 750.0617	33.455 26	**100**	**0.1**
psia (lb_f/in^2)	$6.804\ 596\times10^{-2}$	$6.894\ 757\times10^{-2}$	1	2.036 021	51.714 93	2.306 659	6.894 757	$6.894\ 757\times10^{-3}$
in Hg (conventional)	**25.4/760** = $3.342\ 105\times10^{-2}$	$3.386\ 388\times10^{-2}$	$4.911\ 541\times10^{-1}$	1	**25.4**	1.132 925	3.386 388	$3.386\ 388\times10^{-3}$
mm Hg (conventional)	**1/760** = $1.315\ 789\times10^{-3}$	**(1.013 25)/760** = $1.333\ 224\times10^{-3}$	$1.933\ 677\times10^{-2}$	**1/(25.4)** = $3.937\ 008\times10^{-2}$	1	$4.460\ 334\times10^{-2}$	**101.325/760** = $1.333\ 224\times10^{-1}$	**(0.101 325)/760** = $1.333\ 224\times10^{-4}$
ft H_2O (conventional)	$2.949\ 980\times10^{-2}$	$2.989\ 067\times10^{-2}$	$4.335\ 275\times10^{-1}$	$8.826\ 711\times10^{-1}$	22.419 85	1	2.989 067	$2.989\ 067\times10^{-3}$
kPa	**1/101.325** = $9.869\ 233\times10^{-3}$	**0.01**	$1.450\ 377\times10^{-1}$	$2.952\ 999\times10^{-1}$	**760/101.325** = 7.500 617	$3.345\ 526\times10^{-1}$	1	**0.001**
MPa	**1/(0.101 325)** = 9.869 233	**10**	145.0377	295.2999	**760/(0.101 325)** = $7.500\ 617\times10^{3}$	334.5526	**1000**	1

Table 2-4. Conversion Factors for Specific Volume (Volume/Mass)

To obtain → multiply by ↓	ft^3/lb_m	in^3/lb_m	US gal/lb_m	liter/kg (cm^3/g)	m^3/kg
ft^3/lb_m	1	1728	1728/231 = 7.480 519	$6.242\ 796\times10^{1}$	$6.242\ 796\times10^{-2}$
in^3/lb_m	1/1728 = $5.787\ 037\times10^{-4}$	1	1/231 = $4.329\ 004\times10^{-3}$	$3.612\ 729\times10^{-2}$	$3.612\ 729\times10^{-5}$
US gal/lb_m	231/1728 = $1.336\ 806\times10^{-1}$	231	1	8.345 404	$8.345\ 404\times10^{-3}$
liter/kg (cm^3/g)	$1.601\ 846\times10^{-2}$	$2.767\ 990\times10^{1}$	$1.198\ 264\times10^{-1}$	1	0.001
m^3/kg	$1.601\ 846\times10^{1}$	$2.767\ 990\times10^{4}$	$1.198\ 264\times10^{2}$	1000	1

Table 2-5. Conversion Factors for Specific Enthalpy and Specific Energy (Energy/Mass)

To obtain → multiply by ↓	Btu/lbm	ft·lbf/lbm	hp·h/lbm	kW·h/lbm	psia/(lbm/ft^3)	cal/g	kJ/kg
Btu/lbm	**1**	7.781 693×10^{2}	3.930 148×10^{-4}	2.930 711×10^{-4}	5.403 953	**1/1.8** = 5.555 556×10^{-1}	**4.1868/1.8 = 2.326**
ft·lbf/lbm	1.285 067×10^{-3}	**1**	**1/(1.98×10^{6})** = 5.050 505×10^{-7}	3.766 161×10^{-7}	**1/144** = 6.944 444×10^{-3}	7.139 264×10^{-4}	2.989 067×10^{-3}
hp·h/lbm	2.544 434×10^{3}	**1.98×10^{6}**	**1**	7.456 999×10^{-1}	**(1.98×10^{6})/144 = 1.375×10^{4}**	1.413 574×10^{3}	5.918 353×10^{3}
kW·h/lbm	3.412 142×10^{3}	2.655 224×10^{6}	1.341 022	**1**	1.843 905×10^{4}	1.895 634×10^{3}	7.936 641×10^{3}
psia/(lbm/ft^3)	1.850 497×10^{-1}	**144**	**144/(1.98×10^{6})** = 7.272 727×10^{-5}	5.423 272×10^{-5}	**1**	1.028 054×10^{-1}	4.304 256×10^{-1}
cal/g	**1.8**	1.400 705×10^{3}	7.074 266×10^{-4}	5.275 279×10^{-4}	9.727 116	**1**	**4.1868**
kJ/kg	**1/2.326** = 4.299 226×10^{-1}	3.345 526×10^{2}	1.689 659×10^{-4}	1.259 979×10^{-4}	2.323 282	**1/4.1868** = 2.388 459×10^{-1}	**1**