Understanding Psychrometrics

Third Edition

Donald P. Gatley

ASHRAE

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About the Author

Donald P. Gatley, PE, Fellow ASHRAE, is a 1954 mechanical engineering graduate of Vanderbilt University. His career includes 13 years with the Trane Company, 8 years in design/build mechanical contracting, and 30+ years in the practice of consulting engineering. Outside activities include service as chair of Georgia's building energy code committee and as president of the Southface Energy Institute. He is known for his work in the prevention and correction of building moisture problems, energy conservation in buildings, and with hotels. He is a recipient of the ASHRAE Distinguished Service Award and two ASHRAE International Energy Awards.

Gatley also authored the *EPRI Cool Storage Ethylene Glycol Design Guide* (1992), the *EPRI Cool Storage Open Hydronic Systems Design Guide* (1995) and two chapters of the *Mold & Mildew Handbook* published by the American Hotel and Motel Association (1991) and co-authored *Moisture and Mildew Control* (1992). He has written more than 30 articles on flow diagrams, central drinking water systems, the control of DX cooling coils, life-cycle cost of central chilled water plants, effective air-side design, gas phase filtration of exhaust air, thermal storage systems, quieting residential systems, moisture control in the home, and enhanced dehumidification systems.

In 2003, he joined with Professors Sebastian Herrmann and Hans-Joachim Kretzschmar of the Department of Technical Thermodynamics, Zittau/Goerlitz University of Applied Sciences, Zittau, Germany for four psychrometric research projects:

- Determination of a Twenty-First Century Molar Mass for Dry Air
- Determination of Thermodynamic and Transport Properties of Humid Air for Power-Cycle Calculations for PTB-Bericht
- RP-1485, Thermodynamic Properties of Real Moist Air, Dry Air, Steam, Water, and Ice for ASHRAE
- Real Humid Air Psychrometric Function Add-Ins named LibHuAirProp for Excel®, MATLAB®, Mathcad®, and EES®.

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This book is dedicated to those new to psychrometrics and to professionals and technicians who need information and underlying principles in convenient format.

May the form of presentation and contents save time and make your journeys into psychrometrics valuable and enjoyable.

Contents

Acknowledgments

I have attempted to give credit to authors for exact quotations used in the text. In a 40-year career in the air-conditioning and moisture fields, I have read the psychrometrics chapters of over 20–30 thermodynamic and meteorology texts and hundreds of articles on psychrometrics and related subjects. If readers discover exact quotations without credit to the original authors, please contact me so that credit can be given in future revisions.

Thanks to Steve Comstock, Publisher, ASHRAE, for permission to use figures, graphics, and tables from *ASHRAE Transactions*, *ASHRAE Journal*, and *ASHRAE Handbook–Fundamentals* and to Tim Padfield, Ph.D., of the Danish National Museum for permission to use graphics from his website and publications.

Many individuals deserve special thanks: Jack Chaddock, Ph.D., P.E., for his advice and counsel over the past 20 years and for his review of many chapters; Dave Knebel, P.E., for introducing me to Sandy Klein's EES Software, which eliminated the drudgery of calculating psychrometric properties; Doug Reindl, Ph.D., P.E., for demonstrating the calculus behind the NACA pressure vs. elevation equation; Rex Raiza, Dallas HVAC designer and software author, for sharing his knowledge on part-load psychrometrics; and Jason Leroy, Roy Crawford, Dick Cawley, Ed Keuper, Lew Harriman, and Manuel Conde-Petit for their constructive reviews.

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My wife, Jane, deserves the most thanks for putting up with endless breakfast and lunch discussions about fan temperature rise, dew-point temperature, saturation, and other equally thrilling topics, and for her role in grammar checking.

For any factual or grammatical errors that have crept into the text despite the efforts of those mentioned above, I am solely responsible.

The cover illustration for this edition is used with permission of the artist, Tim Padfield, Ph.D., who is an expert in the preservation of art and the microclimates of museums and historic buildings, the author of *Physics in Conservation*, and an artist of building-science-related paintings that include both message and humor. After career assignments at Victoria and Albert Museum, University of Leeds, Smithsonian Institution, National Museum of Denmark, and the Technical University of Denmark, he is now a freelance consultant in preventive conservation living in Harbertonford, Totnes, UK. Visit his website for more of his artwork and links to pages on conservation physics.

The illustration portrays Garry Thomson, author of the influential book *The Museum Environment*, as a figure in a Romanesque wall painting. He wields a sling psychrometer and a light meter while keeping a foot delicately poised on the head of the air-conditioning engineer in the basement. He repels the agents of decay—weather, radiation, and salt—by intoning the recommended protective museum environment: 50% RH, 20°C, and 100 lux.

Psychrometrics—the physics of moist air:
an applied science dealing with the properties and processes of moist air.

Preface

Psychrometrics is a subscience of physics dealing with the *properties* and *processes* of *moist air*. Moist air is defined as a mixture of two gases: *dry air* and *water vapour* (the gas phase of H_2O). *Dry air* within the troposphere is treated as a non-varying mixture of nitrogen (78.1%), oxygen (20.9%), argon (0.9%), and other trace gases, including carbon dioxide (<0.04%). Some broaden the definition of psychrometrics to cover mixtures of the gas of one substance (any *dry gas* component) and the condensable vapour of a second substance.

The clock in the margin of this paragraph and elsewhere in this book indicates text that should be read by a student or new user who wants to acquire most of the basics of psychrometrics in four to six hours of reading.

Psychrometrics is a basic science that underlies agricultural and aeronautical engineering; air conditioning; drying of crops, grains, and pharmaceuticals; dehydration; dehumidification; humidification; moisture control; meteorology; weather reporting; food science engineering; and piloting of aircraft. It is possible to work in these fields without a good understanding of fundamental-level psychrometrics by the use of shortcut formulae, tables, and charts. While it is true that designers can survive in these fields with minimal and incomplete psychrometric skills without creating many problems for themselves, their employers, and clients, there is no justification for this lack of knowledge when psychrometrics can be quickly learned.

Many readers are frustrated in their pursuit of fundamental psychrometric knowledge because existing texts are incomplete, overly complicated, not well organized into learning elements, or contain obsolete terms and calculations that have little relevance in today's world of fast personal computers, psychrometric software, and computer-generated psychrometric charts tailored to a site-specific barometric pressure or altitude.

Psychrometrics can be simply explained and is solidly based on: (1) the ideal gas equation, (2) Dalton's model of partial pressures, (3) conservation of energy, and (4) conservation of mass. In the author's opinion, there is every reason to pursue a solid foundation in psychrometrics when it takes less than four hours to acquire this background for a lifetime of use. Such knowledge may not be required in typical designs, but it can prevent costly mistakes when altitude or barometric pressure differ from standard sea level values, when subfreezing temperatures exist, or when the specific volume of the moist air differs substantially from that of *Standard Temperature and Pressure (STP)* air (arbitrarily fixed at 15°C and 101,325 Pa).

What is different about this psychrometric text? It is devoted solely to psychrometrics. Psychrometrics is usually covered in one or two chapters of a thermodynamics textbook. This text is written for ease of understanding and not with brevity in mind, but at the same time the information is presented in such a way that the reader can choose not only the chapters to explore but also the level of detail within each chapter. It also includes an extensive listing of the pioneers of psychrometrics.

The underlying reasons for this new psychrometric publication are: (1) to address the changes brought on by the shift from manual calculations and plotting on printed psychrometric charts to software-based psychrometric calculations and graphics, (2) to present in one text a thorough coverage of psychrometric fundamentals, and (3) to assist designers and practitioners in the transition to the Système International system of units and calculations. Therefore, the objectives of this publication are to:

- Provide a resource equivalent to a reference book as well as a basic refresher course for those who use psychrometrics on a recurring basis.
- Provide students and air-conditioning designers, meteorologists, process engineers, and other users with a four-hour *complete* psychrometrics learning module.
- Put to rest the impression that psychrometric calculations based on ideal gas formulations (at normal air-conditioning temperatures and pressures) are imprecise, inaccurate, or based largely on empirical formulae. The text includes comparative data for ideal gas calculations and the ultimate-in-accuracy real moist air formulations by Herrmann-Kretzschmar-Gatley (ASHRAE RP-1485). In contrast to statements in some texts, ideal-gas-based psychrometric calculations are far more accurate than heat gain, duct pressure loss, and other calculations used by air-conditioning engineers and meteorologists.

- Provide practitioners and those new to the field with multiple definitions of basic terms to help in their understanding and communication.
- Provide those fluent in *inch-pound* or *metric* psychrometric calculations with an easy transition to *Systéme International* psychrometrics.
- Provide *all* of the algorithms required for psychrometric calculations; e.g., few texts provide the correlation between barometric pressure and altitude, nor do they provide formulas for wet-bulb and dew-point temperatures below freezing. Algorithms can be input into hand-held programmable calculators and personal computers to aid engineers and meteorologists in their work.
- Motivate manufacturers of cooling coils and desiccant dehumidifiers to utilize proven algorithms in their selection and psychrometric software to eliminate inconsistency.

Endnote

Each reader will determine the degree to which this book meets the author's objectives. Once the basic principles are understood, the psychrometric practitioner will undoubtedly find progressively easier and more efficient ways to apply them in the solution of meteorological, air-conditioning, drying, dehumidification, humidification, and other problems. For the air-conditioning and drying industries, this may lead to the development of compound or hybrid cycles that are more efficient and less costly.

You, the reader, will be the ultimate test of my four-hour learning conviction. Hopefully, that conviction will prove true for the majority. For all, it is hoped that this book will be the resource that (1) takes the mystery out of psychrometric calculations, (2) makes a convincing case for the accuracy of calculations based on the ideal gas equation, (3) gives a far better grasp of dew-point, moisture, and psychrometric processes, and (4) allows practitioners to serve their clients and the public better.

Please e-mail suggested corrections, comments, and criticism to the author at don.gatley@mail.ashrae.org.

Donald P. Gatley, P.E.
January 2002 (1st edition)

Preface to the Third Edition

In the late 1990s, when the first edition of this book was written, psychrometrics was a mature science, and I thought that little if anything would change over the following century. Since then, the universal gas constant has been revised by CODATA, the molar mass of dry air has increased by 0.0001 kg/kmol every four to five years due to the increase of CO_2 in Earth's atmosphere, IAPWS has issued new models for the calculation of H_2O properties, and in 2009 ASHRAE replaced the 1983 Hyland-Wexler real-moist-air numerical model with the research project RP-1485 LibHuAirProp model. These changes have little effect on air-conditioning and meteorological psychrometric calculations, but students and practitioners should have a reference that agrees with the latest international standards.

The third edition includes the above changes, a straightforward and more elegant equation for the adiabatic saturation process in the wet-bulb temperature chapter, an appendix summarizing the 2009 RP-1485 ASHRAE research, as well as minor edits to the text.

Supporting Files

This publication is accompanied by a limited demonstration version of the ASHRAE LibHuAirProp add-in. Also included are the hw.exe program from the second edition and PDF files of 13 ultra-high-pressure and 12 existing ASHRAE psychrometric charts, plus 3 new 0°C to 400°C, 0–1.0 humidity ratio charts for 5.53, 101.325, and 2000 kPa.

The LibHuAirProp add-in allows for duplication of portions of the real moist-air psychrometric tables in *ASHRAE Handbook—Fundamentals* for both standard sea-level atmosphere pressure and pressures from 5 to 10,000 kPa. The hw.exe program is included to enable users to compare the 2009 ASHRAE numerical model real moist-air psychrometric properties with the 1983 ASHRAE-Hyland-Wexler properties.

These files can be downloaded at www.ashrae.org/UP3. If the files or information at the link are not accessible, please contact the publisher.

Introduction

Give a man a fish, provide food for a day.
Teach a man to fish, provide food for a lifetime.
—Chinese proverb

1 How to Use this Book

In general, each chapter is written as a stand-alone section so that it is possible to pick and choose chapters and, as such, the text serves as a reference for those with prior knowledge of psychrometrics.

The book also serves as a four- to six-hour introduction to the science of psychrometrics for those new to the subject, and this influenced the sequencing of chapters. The clock in the margin of this paragraph and elsewhere in this book indicates the text that should be read in a four- to six-hour learning session.

Since this book was written as both a learning module and a reference book, many of the definitions, physical phenomena, and equations are explained in more detail than found in a basic book. The reader should have a general background knowledge *equivalent* to a high school physics or general science course. For those somewhat familiar with psychrometrics in inch-pound (I-P) units, this text will not only provide an easy transition to psychrometrics in Système International (SI) units but also a quick refresher on the underlying principles of psychrometrics. Learning psychrometrics today is easier because of the SI coherent system of units, which eliminates duplicate units and conversions, and because of the personal computer and software that has all but eliminated not only manual computations using approximate formulae but also graphical solutions using the psychrometric chart.

Psychrometrics brings with it many new terms and concepts. Some texts introduce all of the terms and concepts in a single chapter. For many, including the author, this can produce brain overload and confusion and is an obstacle to the learning process, which is, after all, the goal. In this book, definitions and new concepts are introduced *as needed* and each psychrometric property is treated in a separate chapter. In general, equations that interrelate the properties are introduced with the property.

An exception to the *as needed* introduction of terms and concepts is Chapter 5, "Basics of the Psychrometric Chart," which precedes the individual chapters on psychrometric properties. The psychrometric chart is a convenient and useful tool for determining psychrometric properties and visualizing the changes to moist air properties in psychrometric processes. This early chapter is intended to give the reader an overview of the chart to help in overall understanding and to add clarity and meaning as each psychrometric property is developed and discussed in subsequent chapters.

The choice of whether or not to read Chapter 8, "Psychrometric Pioneers and Charts from the First 100 Years," is left to the reader. It may pique the reader's interest. It may help to explain the evolution of this science and the plethora of sometimes overlapping and confusing terms introduced into psychrometrics from the fields of meteorology, drying of materials, air conditioning, thermodynamics, chemical engineering, and agricultural engineering.

Each of the chapters dealing with individual psychrometric properties defines and discusses the property at several levels of detail. Those new to psychrometrics and those interested in a quick refresher or overview may want to read only the definitions and the first level of detail and then move on to the next chapter. In most cases, multiple definitions are provided. The first definition is suitable for general lay-person discussion. Subsequent definitions are more complete and technically more accurate. A definition serves no purpose unless it provides meaning and understanding for the reader. Multiple definitions allow the reader to choose the definitions that have the most meaning. Readers are encouraged to customize definitions.

A skeleton psychrometric chart highlighting only the isolines of the property under discussion is included in each property chapter.

Chapter 25 on *altitude effects* for locations other than sea level is required reading for those readers who live in or design for deep underground applications or applications for projects at high elevations; but, for most users concerned with psychrometrics within ±500 metres of sea level, this chapter can be scanned for future reference or skipped altogether. This chapter also illustrates the change in altitude (or local barometric pressure) effect on the appearance of the psychrometric chart.

JARGON

The two quotations below are from a paper presented by Frank C. Quinn at the *1985 International Symposium on Moisture and Humidity Control*. The first quotation suggests why psychrometrics has multiple and sometimes confusing terms. The second, as a consideration for students and occasional users of psychrometrics, may provide the motivation for others to use consistent terms and eliminate improper terminology.

There are many ways to measure and express moisture and humidity, and often the term, or value (units) used is a carryover from the early days of a particular industry.

The measurements and consequently appreciation for the influences of water are unnecessarily complicated by improper terminology (and symbols) and usage and the proliferation of measurement techniques which have led to ambiguity in the rationale of many moisture/humidity instruments.

Since psychrometrics evolved from many fields, it should come as no surprise that different or substitute words are often used to describe the same psychrometric property. This is unfortunately true in air-conditioning and meteorology psychrometrics. Much of the jargon is the result of pioneers approaching psychrometrics from the different fields of meteorology, agricultural engineering, air-conditioning, drying, aeronomy, and aeronautical engineering. Other jargon was introduced by theoretical scientists who borrowed and truncated technical terms from the allied sciences of chemistry and physics.

Some substitute words do not qualify as synonyms as defined by *Webster's International Dictionary*, *ASHRAE Terminology of HVAC&R*, meteorology books, or scientific dictionaries. This text uses only the author's preferred word, which is most often the meteorologist's and ASHRAE's preferred word. The goal is not to limit or restrict the reader or to redefine the technology; rather, it is felt that consistent word usage will eliminate possible reader confusion. Table 1-1 lists some preferred words and substitutes.

Table 1-1—Psychrometric Vocabulary

Preferred Word	Words Sometimes Used as Substitutes
air, *the mixture of two components: water vapour and dry air.* No subscript is used for mixture properties.	moist air (Consideration was given to the term *moist air*, which was not chosen because the abbreviation MA might be confused with *mixed air*, the blend of outside and return air.)
dry air, DA, *one of the two components of the mixture* air.	air (Since this could be confused with the previous term, *air*, this text will always use the term *dry air*.) Note that *dry air* in the troposphere has nearly constant constituents of 78% nitrogen, 21% oxygen, and 1% other gases. Also called "bone dry air."
water vapour, WV, *one of the two components of the mixture* air.	vapour, gas phase of water, humidity, moisture, moisture vapour, low pressure, or ultra low pressure steam

Table 1-1—Psychrometric Vocabulary (Continued)

Preferred Word	Words Sometimes Used as Substitutes
barometric pressure, p_{BAR}, units Pa (pascal)	total pressure, atmospheric pressure. (Note: if a process operates at significantly higher or lower pressure than the location average barometric pressure, then that process should be analyzed at actual pressure.)
humidity ratio, W, which equals m_{WV}/m_{DA}, units kg_{WV}/kg_{DA}	(a combination and contraction of *water vapour* (humidity) and *mixing ratio*), moisture content, mixing ratio, water vapour to dry air mixing ratio, and, incorrectly, specific humidity or absolute humidity
wet-bulb temperature, t_{WB}, units °C or K	thermodynamic wet-bulb temperature, temperature of adiabatic saturation (equals psychrometer wet-bulb temperature within 1% at 3 to 5 m/s air velocity across the sensing element)
water vapour pressure, p_{WV}, units Pa	partial pressure or partial pressure of water vapour
specific enthalpy, h, with units of energy/m_{DA}, which in SI units is kJ/kg_{DA}	enthalpy, total heat, and heat content (Heat is a form of energy crossing a boundary due to temperature difference; enthalpy is a composite of three properties: $h = u + p \cdot v$ where u is internal energy, p is pressure, v is specific volume, and the product "$p \cdot v$" is flow work. Enthalpy difference and heat transfer happen to be equal in a constant pressure steady flow process with no shaft work.)
specific volume, v_X, units of m^3/kg_{DA} (Note: The x of v_x can be DA for *dry air*, *WV* for *water vapour*, or none for air.)	the reciprocal of density, ρ; i.e., $v_{DA}=1/\rho_{DA}$ (Note: When dealing with a gas or a vapour, specific volume is generally used in preference to density. To avoid confusion, do not use both. *Important:* If density is used in psychrometrics, its units are mass of dry air per unit volume of the moist air.)
adiabatic process	a process with no transfer of heat (due to temperature difference in either direction) across the system boundary. An adiabatic process may include shaft work or "$p \cdot v$" flow work. For an open system, an adiabatic process may include mass transfer of substance(s) across the system boundary.

Obsolete Words and Words That Should Not Be Used Because of Dual Meanings

In the last 100 years, authors, scientists, researchers, and manufacturers have used various words to describe the many psychrometric properties. Some of these words have dual meanings and their use is

Table 1-2

Word	Reason That Use of the Word Is Discouraged
specific humidity, units of $kg_{WV}/kg_{(DA+WV)}$	Dual meaning. ASHRAE and the World Meteorological Organization define specific humidity as the ratio of the mass of water vapour in moist air to the total mass of the dry-air and water-vapour components. It is also used incorrectly as the ratio of water vapour in moist air to mass of dry air, i.e., *humidity ratio*.
absolute humidity, units of kg_{WV}/m^3	Possible dual meaning. Absolute humidity is the water vapour density expressed as the mass of water vapour per unit volume. Today it is a rarely used term. In some cases it has also been used synonymously with *humidity ratio*.
degree of saturation, $\mu = m_{WV}/m_{WVS}$, units none (Also called *percentage humidity* and *saturation ratio*; a decimal ratio.)	Now rarely used. It was an important property used in interpolation of tabular statepoint properties. *Degree of saturation* is the ratio of the humidity ratio at a defined statepoint to the humidity ratio at saturation at the same dry-bulb temperature. It is equal to relative humidity only at 100% and 0%. It differs from relative humidity by several percent in the 50% RH range. Many people and some texts incorrectly use the definition of degree of saturation as the definition for relative humidity.
Sigma function	Now rarely used. This term was an aid in the days of manual psychrometric calculations. *Sigma function* is the enthalpy at the saturated wet-bulb temperature less the enthalpy of liquid water at the same temperature. Its need has been superseded by psychrometric charts with enthalpy edge scales or enthalpy deviation curves and by software algorithms and personal computers.

discouraged. Some are still accurate terms; however, they are no longer needed in instruction or calculations. These were valuable to the user in the pre-handheld calculator, pre-personal computer era when a printed psychrometric chart and a table of property values were indispensable. This text is confined to terms that are in common everyday psychrometric use today. The terms in Table 1-2 are not used in this text.

Subscripts

Multiple letter subscripts are used in many equations. The intent is not to influence the science of psychrometrics or naming conventions but rather to aid in faster recognition for the first-time reader.

PSYCHROMETRIC ALGORITHMS

Chapter 26, "Psychrometric Program Listing and Comparison Table," includes a listing of SI algorithms for calculation of statepoint properties along with SI to IP conversion equations. The algorithms can be solved by equation solver software such as EES (Engineering Equation Solver from F-Chart Software) or they can be reconfigured into FORTRAN or some other language. They can also be modified and used in spreadsheet software. Looping or iteration routines are required for the solution of some properties. Tables of selected accurate property values are included so that the user can verify the accuracy of these and other algorithms or psychrometric software.

PHYSICAL LAWS, MODELS, ASSUMPTIONS, AND THE ACCURACY OF PSYCHROMETRIC CALCULATIONS

Equations in this text are based on *ideal (perfect) gas* behavior for (1) the *dry air* component, (2) the *water-vapour* component, and (3) the moist air mixture of the two components. This requires that the behavior of each constituent of the mixture can be modeled by the perfect gas equation:

$$p_X \cdot v_X = R_X \cdot T_X$$

The equations use Dalton's model (also called Dalton's law or rule) of an ideal gas mixture, which states that the gas and water-vapour molecules share the same volume and that the total pressure of the mixture is equal to the sum of the pressures of the individual components. Each of the constituent gases exerts a pressure (called partial pressure), which is the pressure that the constituent gas would exert if it alone occupied the volume.

Air-conditioning psychrometric processes are almost always modeled as steady flow, constant pressure processes.

Dry air, *water vapour*, and the combined moist air mixture closely follow perfect gas behavior in the temperature range of –40°C to 65°C and at total pressures up to 300 kPa.

Additional accuracy is built into the equations in the appendix by the use of a correction factor (enhancement factor) to account for the slight interaction of *dry air* and *water vapour* molecules. In addition, the specific heat capacity of water vapour in the enthalpy algorithm is based on curve fits of the ASHRAE RP-1485 (2009) moist-air-enthalpy values as opposed to the use of Keenan, Keyes, and Moore low-pressure-steam-table values. RP-1485 values are more accurate in psychrometrics because they account for the slight influence of N_2 and O_2 molecules.

The tables in Chapter 26, "Psychrometric Program Listing and Comparison Table," attest to the accuracy of ideal gas-based psychrometric calculations in the –40°C to 65°C temperature range.

Looking for an excuse to avoid psychrometrics? Webster's Dictionary does not even list psychrometrics as a word!

Psychrometrics—the science that involves the properties of moist air (a mixture of dry air and water vapour) and the processes in which the temperature and/or the water vapour content of the mixture are changed.

2 Etymology

THE ETYMOLOGY OF "PSYCHRO" AND ITS DERIVATIVE WORDS

Psychrometer

The beginning of the word *psychrometrics* occurred in 1825 when Ernest Ferdinand August of Germany named his wet-bulb thermometer a psychrometer using the Latin words *psychro*, to make cold, and *meter*, to measure. Today a psychrometer includes both dry-bulb and wet-bulb thermometers and is classified as a form of a hygrometer. A hygrometer is used to measure the humidity in the atmosphere. Thus, there is a contradiction of sorts: the name of the instrument suggests the measurement of cold and yet the instrument is used to measure humidity. The answer to this contradiction is: The difference between psychrometer dry-bulb and wet-bulb readings is called the wet-bulb depression, which can be interpreted as additional coldness (*psychro*—to make cold).

Psychrometry

The suffix *metry* converts a word such as *psychrometer* to *the science of using a psychrometer*. Psychrometry as a science is, therefore, the science of measurement of dry-bulb and wet-bulb temperatures using a psychrometer. Gradually the word was also applied to the scientific theory underlying the thermodynamic wet-bulb temperature in an adiabatic saturator.

Webster's Third New International Dictionary, published in 1993, lists *psychrometry* as a noun and defines it as *the science dealing with the physical laws governing the mixture of air and water vapour*. ASHRAE defines psychrometry as *that branch of physics concerned with the measurement or determination of atmospheric conditions, particularly the moisture in the air.*