



# Authors' Manual

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This is a contextual document. It is not meant to be read straight from beginning to end. Instead, navigate the pages via the **blue** hyperlinks as you would a web page.

Some pages include key words in **orange**. Mouse over these words to see additional information about a relevant topic.

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## NOTICES

This manual should not be used when writing for *Science and Technology for the Built Environment*.

Please refer to the Authors' Manual for STBE for guidance when writing for that publication.

This manual should not be used when writing for *ASHRAE Journal*. Please contact the editor for guidance when writing for that publication.

## Before You Begin...

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**Plagiarism** is the act of taking other people's words or images and passing them off as your own. Plagiarism is discouraged because it not only affects the reputation of the author and publication but also may encourage others to plagiarize your work and lessen its impact. Plagiarism is also considered intellectual theft, whether it is done intentionally or accidentally.

**EXAMPLES OF PLAGIARISM AND HOW TO CORRECT IT:**

1. Copying text from another source word for word without **attribution**. *Direct quotations from another source should be in quotation marks and include citation attribution:*
  - “The best chance we have of addressing the combined challenges of energy supply and demand, climate change and energy security is to accelerate the introduction of new technologies for energy supply and use and deploy them on a very large scale” (Friedman 2008, p. 34).
2. Copying data from another source without citing the original source. *Data from another source should include citation attribution:*
  - For reference, estimates of water-related energy use range from 4% to 13% of U.S. electricity use (Copeland 2014).
3. Reproducing images from another publication, an industry source, or the Internet without **attribution**. *All images not created by you need permission from the copyright holder to be included. See [Obtaining Permissions](#) for more details and see [Images Showing Appropriate Attribution](#) for examples for examples of crediting the sources of photographs, diagrams, charts, etc.*
4. Using data from another source in an image or table without **attribution** to the original source of the data. *If the data was not collected by the authors publishing the work, it must be cited. See [Images and Tables Showing Appropriate Attribution](#) for examples of crediting the sources of data.*

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Images and data from ASHRAE publications can generally be used in subsequent ASHRAE publications. However, you still must obtain permission to reprint these images and data from ASHRAE, and these images and data must still be cited appropriately in text, in images, and in tables. To request permission to use ASHRAE copyrighted content, visit [ASHRAE's website](#).

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The principle of fair use applies to certain material used in criticism, comment, news reporting, teaching, scholarship, and research. Fair use generally applies to information replicated in an educational setting without intent to distribute or profit from the information, or information that is changed significantly from its original source. **It is better to err on the side of caution and try to obtain permission rather than risk plagiarism.** More information can be found in the Copyright Basics and What is Not Protected by Copyright circulars at [www.copyright.gov/circs](http://www.copyright.gov/circs).

**Authors should never assume that material taken from software or downloaded from the Internet may be used without obtaining permission.** See [Avoiding Plagiarism](#) for more information.

Requesting permission to reproduce photographs, figures, charts, diagrams, graphs, and other visual elements from other sources is the responsibility of the author, as is payment of any fees the copyright holder may require before granting permission. Please note that as stated in one published author's [Recommendations and Lessons Learned](#), obtaining permissions may take some time, so it is best to start on this aspect sooner rather than later.

It is also the responsibility of the author to provide appropriate [citations](#) and [attribution](#) for the original sources of the figures and tables reprinted in your manuscript. See [Images Showing Appropriate Attribution](#) and [Images and Tables Showing Appropriate Attribution](#) for examples of how to accomplish this.

1. Permission to reproduce material **must be obtained** during the writing stage.
2. Classify all **information** from another source as either “in the public domain” or “requires copyright permission.” See [Figure Permission Scenarios](#) for examples of situations to help you decide which classification applies to the type of information you have.
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  - Material from **private publishers**—including publishers of **your own previously published work**—**requires copyright permission**. (See [Figure Permission Scenarios](#) for examples.) If permission is not granted, you cannot use the material in your manuscript.
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  - **NOTE:** Table data do not require copyright permission *as long as the table is reformatted*. However, *the material must still be cited*, so **reference** information is required.
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5. Submit permission-granted letters with the **completed manuscript**. Material cannot be published without permission, and ***no editing or layout work will begin on the manuscript until all permissions have been received.***

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- to allow use of the paper by the author's employer for posting on the employer's website, for use by the employer in training or educational courses offered by the employer, for internal research work that is conducted by the employer, and for internal publications published by the employer;
- to include the paper in full or in part in a thesis or dissertation;
- to include the paper in a printed compilation of works of the author, such as collected writings or lecture notes; and
- to prepare other derivative works, such as extending the paper into book-length form, or to otherwise re-use portions or excerpts in other works, providing there is acknowledgement of its publication by ASHRAE.

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Others wishing to use ASHRAE copyrighted content should visit [ASHRAE's website](#) for more information and to make their request.

1. Original figures or other artwork should be submitted with the manuscript whenever possible. For information on reprinting a figure from another source, see [Obtaining Permissions](#).
2. Use only 1 point (0.014 in. [0.35 mm]) or thicker lines—smaller lines will not reproduce well.
3. Figures to be reproduced in black and white should use [patterns or shapes](#) to distinguish sections instead of coloring and shading. Figures to be reproduced in color should have [touching colors that differ significantly](#) so that there can be no confusion in understanding the data. (Note that papers are published in color as part of the ASHRAE Winter or Annual Conference Papers in the [ASHRAE Technology Portal](#) and in black and white in *ASHRAE Transactions*.)
4. Each figure should have a brief legend or [descriptive labels](#), as appropriate. **Any text included in a figure (except the figure caption) should be embedded as part of the image file and not contained in a separate text box that is not part of the image file.**
5. Provide [dual units](#) for all [measurements](#), preferably as two figures.
6. All figures must be provided to ASHRAE as individual TIF (preferred) or EPS files in either CMYK mode (for color) or Grayscale mode (for black and white). All images should be saved at high resolution (600 dpi for line art ; 300 dpi for photographs) and at least 4 in. (102 mm) size or greater. See [Converting Graphics Created in Excel or Word](#) for instructions on graphic conversion. Figure files should be clearly labeled (i.e., Figure1.tif, Fig2.tif, Fig3-2, etc.). Multiple-part figures, such as a figure with [parts](#) (a) and (b), must be submitted as [one file](#) with all parts included.
7. Every figure must be referenced in the text by name/number, where “Figure” is capitalized (e.g., “...as shown in Figure 2.”).
8. Figures must be numbered consecutively as they appear in the text.
9. Prepare a list of captions for figures and place it at the end of the manuscript **(this applies to papers only; it is not applicable for book projects)**.

## Formatting Tables

1. All **table** titles should be descriptive but concise.
2. Original tables should be submitted with the manuscript whenever possible. For information on reprinting a table from another source, see [Obtaining Permissions](#).
3. Titles appear above the tables, and every major word in the title is capitalized.
4. Number tables consecutively and in the order they are mentioned in the text.
5. Tables used in the manuscript should **not** be **image files** but should be *editable* tables (such as those created in Word, Excel, Framemaker, InDesign, etc.).
6. Use only 1 point (0.014 in. [0.35 mm]) or thicker lines—smaller lines will not reproduce well.
7. Vertical and horizontal lines should be avoided except to delineate the top and bottom of a table and to separate the heading row from the data, unless lines are otherwise necessary for clarity or organization of the data.
8. Label each column with a heading and include units of measurement and other necessary qualifying information. Units should be set off with a comma (e.g., “Velocity, m/s”).
9. Provide **dual units** for all **measurements**.
10. Every table must be referenced in the text by name/number, where “Table” is capitalized (e.g., “as provided in Table 5”).

## Units of Measurement

ASHRAE policy requires dual units of measurement—inch-pound (I-P) and International System of Units (SI). You are required to provide dual units when submitting manuscripts; ASHRAE staff will not convert units for you. See ASHRAE's *SI Guide for HVAC&R* for comprehensive guidance on using SI units. Some **guidelines** are as follows:

1. The units used in calculating the work being reported should be listed first with the alternate system of units **following in parentheses**.
2. Always spell out all units when they are used without a number.
3. Do not mix **symbols and names** in the same expression.
4. Do not express **plurals** by adding an “s”.
5. Do not use **periods** with units of measurement.
  - **EXCEPTION:** in. for inch
6. Leave a **space** between the numerical value and the unit of measurement.
  - **EXCEPTION:** There is no space between number and degree of plane angle or degrees of temperature (45°, 62°F, 20°C) or the number and the percent symbol (5%).
7. “L” is the symbol for litre, not lowercase “ell” or script “ell.”
8. “Centi-” is not an acceptable SI prefix, and the use of **cm** should be avoided.
9. For currency, include the monetary unit of the country where the research is based followed by the U.S. dollar conversion in parentheses.

As noted in one published author's **Recommendations and Lessons Learned**, converting I-P units to SI units may take some time, so it is best to complete these conversions during the writing of the work instead of after all the writing has been completed.

Each significant **equation or formula** should be displayed on a separate line. Center equations and place consecutive equation numbers flush right in parentheses.

**EXAMPLE:**

$$a^2 + b^2 = f^2 \quad (1)$$

where

$a^2$  = apples

$b^2$  = bananas

$f^2$  = fruit salad

If an equation requires more than one line, break it before an **operational sign**, and align the operational signs on the left.

**EXAMPLE:**

$$E = (a + b + c)/(m + n + o) \quad (2)$$
$$\times d + e + f$$

If two or more displayed equations are grouped together, leave space between the individual equations:

$$a + b = c \quad (3)$$

$$D = f - ab^2 \quad (4)$$

$$mon + rst \quad (5)$$

Spell out the word “equation” and capitalize it in the text when **referring** to specific, numbered equations. In a highly mathematical or theoretical work, consider developing equations in appendices rather than in the body of the manuscript.

**Please note that all equations must be retyped in our pagemaking program—this is one reason we require a hard copy of the manuscript—and therefore should be checked thoroughly by the author at the proofreading stage.**

# ASHRAE Authors' Manual

## Book Publication Process

Many books are the result of an [ASHRAE research project](#). A subcommittee may be designated to handle the review process of a [committee-sponsored](#) project, using committee members or other persons with expertise in the area of concern.

The ASHRAE submittal, review, and publication process proceeds as follows:

1. The author indicates intent to submit a manuscript to [Special Publications](#) and receives the [Authors' Manual](#) and may make use of any of the other resources available in the [Authoring Tools for Books](#) section of the ASHRAE website.
2. The author prepares the manuscript, including artwork, according to this Authors' Manual.
3. The cognizant ASHRAE Technical Committee selects qualified reviewers.
4. Reviewers send [reviews and comments](#) to the author.
5. The author revises the manuscript and/or rebuts comments and provides a revised manuscript or rebuttal to the cognizant Technical Committee.
6. Reviewers complete an additional review.
7. The review process continues until the manuscript is accepted or rejected for publication by the cognizant Technical Committee.
8. After the manuscript is approved for publication, the author submits a final [Microsoft® Word](#) file and separate figure files [electronically](#) to [Special Publications](#) (see [Book Submission Guidelines](#)) and the author is informed of a tentative publication schedule.
9. Special Publications editors edit the manuscript for grammar, punctuation, clarity, and consistency with ASHRAE policies, as well as completeness of parts. It is then laid out into pages, with the figures and tables incorporated.
10. The editors send a PDF proof to the author, often including queries that require responses from the author. The author [proofreads](#) the manuscript and returns replies to the editors' queries within a mutually agreed upon (hopefully short) timeframe.
11. The book is published and offered for sale in the [ASHRAE Bookstore](#) as both the physical, printed book and a PDF available for download.
12. The author receives a complimentary copy of the published book.

# ASHRAE Authors' Manual

## Paper Publication Process

Technical Paper and Conference Paper submittal, review, and publication activity is coordinated by the [ASHRAE Conference Program Administrator](#). The papers publication process proceeds as follows:

1. The author indicates intent to submit a paper to the ASHRAE Conference Program Administrator and receives instructions and the [Authors' Manual](#).
2. The author [prepares](#) the paper, including artwork, according to the Authors' Manual and the [Author's Template for Technical Papers](#) or the [Author's Template Conference Papers](#).
3. The author uploads the paper through the applicable website as indicated in the [Technical Papers Submission Requirements](#) and [Conference Papers Submission Requirements](#).
4. The ASHRAE Conference Program Administrator selects qualified reviewers.
5. The reviewers carefully review the paper and submit reviews online.
6. The author receives [reviews and comments](#). The author revises the paper and/or rebuts the comments and uploads a revised paper or rebuttal.
7. The reviewers are notified that a revised paper requires additional review.
8. The review process continues until the paper is accepted or rejected.
9. After the paper is accepted, the author uploads the final paper through the applicable website in the appropriate format as indicated in the [Technical Papers Submission Requirements](#) and [Conference Papers Submission Requirements](#).
10. The accepted paper is scheduled for presentation at an ASHRAE Winter or Annual Conference or a Topical Conference.
11. ASHRAE staff editors edit and format the Technical Paper and send a PDF to the author, who [proofreads](#) the paper and returns responses to the editors' queries by the supplied deadline, or staff editors scan the Conference Paper for adherence to the [Author's Template for Conference Papers](#) and the author addresses any noted errors and provides a revised PDF by the supplied deadline.
12. After the conference editors may send the author of a Technical Paper [comments and questions](#) generated at an ASHRAE Winter or Annual Conference. The author returns responses to the editors.
13. Technical Papers are available as preprint PDFs in the ASHRAE Winter or Annual Conference Papers in the [ASHRAE Technology Portal](#) and published as final paper with the questions and comments and authors' responses in *ASHRAE Transactions*, Conference Papers are published as final PDFs in the ASHRAE Winter or Annual Conference Papers in the [ASHRAE Technology Portal](#), and papers for Topical Conferences are published as PDFs on flash drives or downloads for the individual conferences. All papers are available for purchase from the [ASHRAE Bookstore](#) as downloadable PDFs.

The following materials are required for book manuscript **submission**:

1. The complete manuscript in **Microsoft® Word** and the **figures** provided as separate TIF or EPS files saved at **high resolution**. **Tables should be editable and NOT submitted as images.**
2. A laser printout of the complete manuscript including text, tables, and graphics. With the printout, include a cover sheet with the following information:
  - Proposed title of the book
  - Whether the book will include supplemental materials online (Excel spreadsheets, PDFs, Word files, etc.)
  - Sponsoring ASHRAE Technical Committee and/or ASHRAE research project number, as applicable
  - Author names in desired order with (if applicable) ASHRAE membership grade, academic degrees at the **doctoral level**, and professional **certifications** for each author
  - An “About the Authors” **paragraph**
  - Complete contact information for the corresponding author, including mailing address, phone and fax numbers, and email address
  - A paragraph describing the book (to be used on the back of the book, in the bookstore, and in marketing materials)
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4. The completed **Marketing Questionnaire**

See **Document Formatting** and **Book Organization** for additional requirements.

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180 Technology Parkway, Peachtree Corners, GA 30092 USA  
[cmichaels@ashrae.org](mailto:cmichaels@ashrae.org)  
Telephone: 678-539-1187

**Book Publication Process** provides information on how the process will proceed after submission of the manuscript to Special Publications.

# ASHRAE Authors' Manual

## Technical Papers Submission Requirements

Technical Papers most often report on ASHRAE-sponsored research and unsolicited research in HVAC&R technical areas.

All Technical Papers undergo critical, **double-blind** peer review by three or more competent **specialists** to ensure high quality of content. A paper must be accepted by three reviewers to be approved for an **ASHRAE Winter or Annual Conference**. The Technical Paper review activity is coordinated by the **ASHRAE Conference Program Administrator**, who can be contacted if you have any questions during the paper submission and review process. **File submission is done online via Manuscript Central**. **Manuscript Central Upload Instructions** are available in the “Instructions & Forms” section of that website.

The Technical Paper submission requirements are as follows:

1. Upload an **Agreement to Publish** form that is signed by the main author.
2. Download the **Authors' Template for Technical Papers** for a Microsoft® Word file to use when writing the paper; also see an **example paper**.
3. Typed manuscripts for Technical Papers **must not** exceed 30 double-spaced pages (including references and tables) and can contain a **maximum** of 12 figures. **Dual units of measurement** should be included in the text, tables, and figures. See **Document Formatting** for additional requirements. Upload the paper as a **Microsoft® Word** file for review. Authors should NOT identify themselves in manuscript files to enable reviewers to maintain a blind review.
4. Upload an author's list as a separate Word file that includes the following:
  - The **title** of the paper
  - Author names in desired order, principal author first, with (if applicable) ASHRAE membership grade, academic degrees at the **doctoral level**, and professional **certifications** for all authors.
  - An **author note** with job title, affiliation, and **address** for each author.
  - Complete **contact information** for all authors.

Reviews will be done using ASHRAE's online review process, and ASHRAE staff editors will edit and lay out the accepted Technical Paper. (See **Paper Publication Process** for more information.)

# ASHRAE Authors' Manual

## Conference Papers Submission Requirements

Conference Papers presented at [ASHRAE Winter or Annual Conferences](#) report on research in progress, applications, case studies, and other topics in HVAC&R technical areas. Conference Papers presented at [Topical Conferences](#) report on specific technical areas within HVAC&R, depending on the conference.

Annual/Winter and Topical Conference Papers undergo [single-blind](#) review (unless otherwise indicated in the call for papers) by two or more reviewers to ensure high quality of content. A paper must be accepted by two reviewers to be approved for a conference. The Conference Paper review activity is coordinated by the [ASHRAE Conference Program Administrator](#), who can be contacted if you have any questions during the paper submission and review process. **File submission is done online via ConfTool or Conference Exchange (2019 Annual Conference only) using the link provided for each individual conference.**

The Conference Paper submission requirements are as follows:

1. Upload an [abstract](#) for review. The abstract must be accepted before the paper can be submitted. When you upload your abstract you will be assigned an ID# for your submission (one ID# for both the abstract and the paper).
2. Upon acceptance of the abstract, submit the paper based off of the accepted abstract.
  - Download the [Authors' Template for Conference Papers](#) for a Microsoft® Word file to use when writing the paper; also see an [example paper](#).
  - Conference Papers must not exceed eight single-spaced pages in length (including references, tables, and figures) and must include an [author note](#) at the bottom of page 1. [Dual units of measurement](#) should be included in the text, tables, and figures. See [Document Formatting](#) for additional requirements. Conference Papers being submitted should be considered "[Final](#)" by the author. Upload the Conference Paper as a [PDF](#) with your assigned ID# as the file name.
  - **Please note that adherence to the Author's Template and to the requirements set forth in this Authors' Manual are significant factors in determining the acceptance of your Conference Paper.**
3. Upload an [Agreement to Publish](#) form signed by the presenting author.

Reviews will be done using ASHRAE's online review process. (See [Paper Publication Process](#) for more information.)

# ASHRAE Authors' Manual

## Extended Abstract Submission Requirements

Extended Abstracts presented as part of the Research Track at [ASHRAE Annual Conferences](#) report on research in progress, applications, case studies, and other topics in HVAC&R technical areas. Extended Abstracts are intended to be preliminary research results that will eventually be expanded into a full paper.

Extended Abstracts undergo **single-blind** review by two reviewers to ensure high quality of content. An abstract must be accepted by two reviewers to be approved for a conference. The Conference Paper review activity is coordinated by the [ASHRAE Conference Program Administrator](#), who can be contacted if you have any questions during the paper submission and review process. **File submission is done online via ConfTool using the link provided for each individual conference.**

The Extended Abstract submission requirements are as follows:

1. Upload an **abstract** for review. The abstract must be accepted before the Extended Abstract can be submitted. When you upload your abstract you will be assigned an ID# for your submission (one ID# for both the abstract and the Extended Abstract).
2. Upon acceptance of the abstract, submit the Extended Abstract based off of the accepted abstract.
  - Download the [Authors' Template for Conference Papers](#) for a Microsoft® Word file to use when writing the paper; also see an [example paper](#).
  - Extended Abstracts must not exceed three single-spaced pages in length (including references, tables, and figures) and must include an **author note** at the bottom of page 1. **Dual units of measurement** should be included in the text, tables, and figures. See [Document Formatting](#) for additional requirements. Extended Abstracts being submitted should be considered **“Final”** by the author. Upload the Extended Abstract as a **PDF** with your assigned ID# as the file name.
  - **Please note that adherence to the Author's Template and to the requirements set forth in this Authors' Manual are significant factors in determining the acceptance of your Extended Abstract.**
3. Upload an [Agreement to Publish](#) form signed by the presenting author.

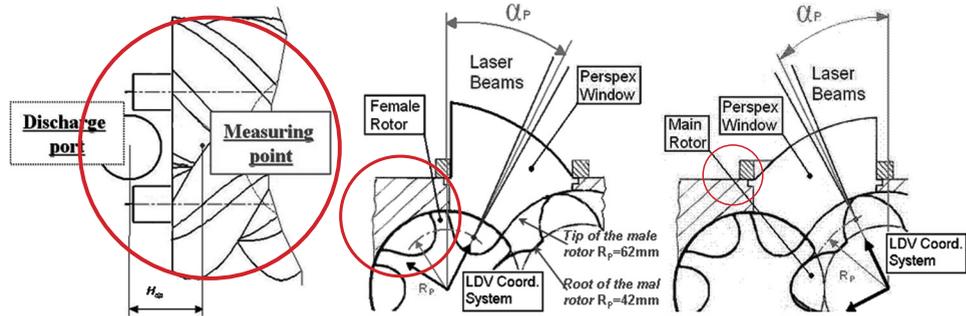
Reviews will be done using ASHRAE's online review process. (See [Paper Publication Process](#) for more information.)

Extended Abstract authors must give an oral presentation based on the accepted work as part of the ASHRAE Annual Conference Research Track. Accepted Extended Abstracts will be published in Part 2 of *ASHRAE Transactions*.

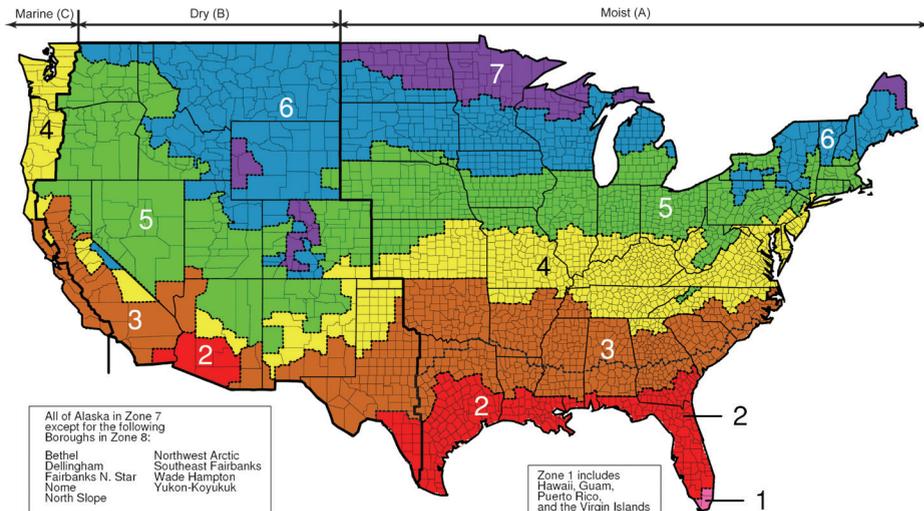
# ASHRAE Authors' Manual

## Sample Figures

“Figures to be reproduced in black and white should use **patterns** or **shapes** to distinguish sections instead of coloring and shading.”



“Figures to be reproduced in color should have **touching colors that differ significantly** so that there can be no confusion in understanding the data.”



# ASHRAE Authors' Manual

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This is a typical figure attribution line: it includes the figure number from the original source document, the citation for that source document that is included in the references, and then the fact that we did get permission to reprint it in your book.

**Figure 4.1** Frequency  
(Figure 7.1, Price 2011; Reprinted with permission of Price Industries)

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Figure 2-9 CAISO net load "duck curve" showing the over-generation risk and ramp rate for March 31st.

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If a figure from any source has been modified from its original for publication in your book, you must 1) make sure the modification is noted on the permission request form that you send to the copyright holder and 2) note in the text of your book that the image has been modified.

**Figure 1-3** Pressure Changes During Flow in Ducts  
(Adapted from ASHRAE 2017, Figure 7)

This is the author of a paper published in ASHRAE Transactions. So ASHRAE has the authority to permit reprinting of the image, but the credit goes to the author as listed in the references section.

**Figure 3.2** Components  
(Figure 1, Graves 1986)



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**Figure 4.3** Types of demand management.  
Source: DOE (2019)

Images obtained from image repositories such as iStockphoto or Shutterstock sometimes have specific language that must be included in their attribution.

**FIGURE 2.3** Outdoor air inlet and fire pit within a kiva. (Roof not present.)

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**Figure 2** (a) Biagini et al. 2006 (b) Iossifova et al. 2007 (c) Iossifova et al. 2009  
This is an example of attribution when an individual contributed a figure that hasn't been published elsewhere. Effects and three-level scores for Asthma, Hayfever, Atopy, and Sensitized Childhood Allergy and Air Pollution Study (CCAAPS), as reported by Biagini et al. (2006) and Iossifova et al. (2007, 2009). (Courtesy M.J. Mendell)

**Figure 10** Museum of Modern Art, New York City. The prudent humidity limit to avoid condensation depends on air tightness and the R-values of all the components, including window frames. In this building, the 50°F (10°C) DPT was too high to avoid persistent condensation. (Courtesy Mason-Grant Consulting)

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# ASHRAE Authors' Manual

## Images and Tables Showing Appropriate Attribution

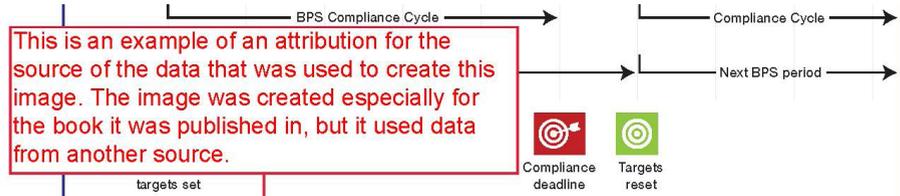


Figure 4.7 Example overlap of codes and BPS compliance cycles, based on a St. Louis BEPS Compliance Pathways Fact Sheet. (Data Source: City of St. Louis 2022)

Table 2.4 Indicative Embodied Specific Carbon Footprints for Materials and Resources Commonly Used in Refrigerated Facilities and Associated Equipment<sup>1</sup>

Material	Embodied CF, kg CO <sub>2eq</sub> /kg (lb <sub>m</sub> CO <sub>2eq</sub> /lb <sub>m</sub> )	Source and Comments
Aggregate (gravel)	0.003; 0.0052	EPLCA (2016); Hammond and Jones (2011)
Aluminum		
• Construction	9.2; 11 (virgin)	Hammond and Jones (2011); IBU (2016)
• Manufactured equipment	12.6 (virgin), 0.63 (recycled)	IIR (2016) (typically 67% for recycled)
Asphalt (6% bitumen)	0.076	Hammond and Jones (2011)
Cardboard packaging	1.0	Hammond and Jones (2011); Burke (2016)
Concrete	0.11–0.15	Hammond and Jones (2011); EPLCA (2016)
+ Reinforcing	+ 0.077	Hammond and Jones (2011)
+ Casting	+ 0.029	Hammond and Jones (2011)
Copper		
• Tube	0.98–2.7	Copper Alliance 2015; IBU (2016); Hammond and Jones (2011)
• Manufactured equipment	3.0 (virgin) 2.46 (recycled)	IIR (2016) (typically 40% for recycled)

Table 4.3 Indicative Conductivity Values for Several Insulation Materials<sup>1</sup>

Material	Thermal Conductivity <sup>2</sup>	
	W/m·K	Btu/h·ft·°F
Polyurethane board	0.026	0.015
Polysocyanurate	0.027	0.016
Polystyrene, extruded	0.035	0.020
Polystyrene, expanded	0.037	0.021
Fiberglass	0.044	0.025

1. Based on ASHRAE Handbook—Refrigeration, Chapter 24, Table 1 (ASHRAE 2018).

2. Based on materials aged for 180 days.

**Sample Table**

**Table 1. Review of the Research on the Two-Phase Heat Transfer at Micro Scale**

<b>Researcher</b>	<b>Working Liquid</b>	<b>Dimension of the Channel</b>	<b>Single/Array of Microchannel(s)</b>	<b>Heat Transfer Coefficient, W/(cm<sup>2</sup>/K)</b>
Munkejord et al. (2002)	Peopane	63–155 $\mu\text{m}$	Array of microchannels	7.1 ~ 8.4
Cuta et al. (1996)	Water	Width: 100~300 $\mu\text{m}$ Depth: 1 mm	Array of microchannels	1 ~ 2
Darabi and Ekula (2003)	HFE-7100		Single channel	1.8
Qu and Ma (2002)	Water	About 10 $\mu\text{m}$	Single channel	25
Brooks et al. (1999)	Water	Width: 50~200 $\mu\text{m}$ Depth: 0.5~3 mm	Array of microchannels	25 W/cm <sup>2</sup> (heat flux)
Park and Lee (2003)	Water	150 $\mu\text{m}$	Single channel	1.4
Tran et al. (1996)	R-12	2.46 mm	Single channel	0.2 ~ 1
Bao et al. (2000)	R-11	1.95 mm	Single channel	0.7~1.4
Bao et al. (2000)	R-123	1.95 mm	Single channel	0.5~1.4
Lin et al. (2001)	R-141b	1.1 mm	Single channel	0.2~0.6
Lazarek and Black (1982)	R-113	3.1 mm	Single channel	0.7-1.1
Wambsganss et al. (1993)	R-113	2.92 mm	Single channel	0.1~0.5

### PERFORMANCE EVALUATION FUNCTION

First Level

The performance of any air-conditioning system depends on two factors:

- a. thermal comfort
- b. energy consumption

Second Level

#### Thermal Comfort

The most important variables that influence the condition of thermal comfort are air temperature, water vapor pressure in ambient air, relative air velocity, mean radiant temperature, activity level (heat production in the body), thermal resistance of the clothing, and purity of the air. Fanger (1970) defined a thermal sensation index by considering air temperature, water vapor pressure in ambient air, relative air velocity, mean radiant temperature, activity level, and thermal resistance of the clothing. PMV is the thermal sensation index given by Fanger (1970) and is internationally standardized. It is easy to use PMV when controlling an air-conditioning system because PMV is an index of human thermal sensation with one value for all seasons and is effective for all temperatures that are neither extremely high nor extremely low. PMV ranges from  $-3$  (cold) to  $+3$  (hot). When PMV is zero, then thermal sensation will be neutral, i.e., neither cold nor hot. Broadly speaking, when PMV approaches zero then thermal comfort increases.

The first term on the right-hand side of Equation 14 indicates the mass of moisture in the incoming air, which comes in contact with the evaporator wall, and the mass of moisture in the outgoing air. The humidity of the incoming air is calculated from a psychrometric chart with the help of the second-order curve-fitting method. The multiplying factor,  $(1 - b)$ , corresponds to the bypass factor of the evaporator. The second term amounts to mass of moisture in the incoming air bypassed through the evaporator and the mass of moisture in the outgoing air. The multiplying factor  $b$  corresponds to the bypass factor of the evaporator. The rate of change of specific humidity of supply air when the evaporator wall temperature is more than the dew-point temperature is given by

$$(\rho_a V_d) dW_s / dt = v \rho_a ((1 - \xi) W_3 + \xi W_0 - W_s) . \quad (1)$$

The first two terms on the right-hand side of Equation 15 correspond to absolute or specific humidity of incoming air, and the third term corresponds to outgoing supply air humidity.

**Specific Humidity of Thermal Space.** The rate of change of the specific humidity of the thermal space is given by

Third Level

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- relative amounts of heating and cooling loads.

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