INVITATION TO SUBMIT A RESEARCH PROPOSAL ON AN ASHRAE RESEARCH PROJECT

0003-TRP, Design Guide for Radiant Heating and Cooling Systems

Attached is a Request-for-Proposal (RFP) for a project dealing with a subject in which you, or your institution have expressed interest. Should you decide not to submit a proposal, please circulate it to any colleague who might have interest in this subject.

Sponsoring Committee: TC 6.5 Radiant Heating and Cooling

Budget Range: $100,000 may be more or less as determined by value of proposal and competing proposals.

Scheduled Project Start Date: **April 1, 2025** or later.

All proposals must be received at ASHRAE Headquarters by 8:00 AM, EST, December 16, 2024. NO EXCEPTIONS, NO EXTENSIONS. Electronic copies must be sent to rpbids@ashrae.org. Electronic signatures must be scanned and added to the file before submitting. The submission title line should read: 0003-TRP, Design Guide for Radiant Heating and Cooling Systems, and *"Bidding Institutions Name"* (electronic pdf format, ASHRAE's server will accept up to 10MB)

If you have questions concerning the Project, we suggest you contact one of the individuals listed below:

For Technical Matters
Technical Contact
Dove Feng
E-Mail: JFeng@trccompanies.com,
Phone: 510-366-3139.

For Administrative or Procedural Matters:
Manager of Research & Technical Services (MORTS)
Steve Hammerling
ASHRAE, Inc.
180 Technology Parkway, NW
Peachtree Corners, GA 30092
Phone: 404-636-8400
Fax: 678-539-2111
E-Mail: MORTS@ashrae.net

Contractors intending to submit a proposal should notify, by mail or e-mail, the Manager of Research by December 1st, 2024 in order that any late or additional information on the RFP may be furnished to them prior to the bid due date.

All proposals must be submitted electronically. Electronic submissions require a PDF file containing the complete proposal preceded by signed copies of the two forms listed below in the order listed below. **ALL electronic proposals are to be sent to rpbids@ashrae.org.**

All other correspondence must be sent to ddaniel@ashrae.org. In all cases, the proposal must be submitted to ASHRAE by 8:00 AM, EST, December 16, 2024.
NO EXCEPTIONS, NO EXTENSIONS.

The following forms (Application for Grant of Funds and the Additional Information form have been combined) must accompany the proposal:

(1) ASHRAE Application for Grant of Funds (electronic signature required) and
(2) Additional Information for Contractors (electronic signature required) ASHRAE Application for Grant of Funds (signed) and

ASHRAE reserves the right to reject any or all bids.

State of the Art (Background)

Radiant heating and cooling systems provide an opportunity to achieve significant energy savings, peak demand reduction, and load-shifting improvements compared to conventional all-air systems. As a result, the application of these systems has increased in recent years, particularly in zero-net-energy (ZNE) and other advanced low-energy buildings. The New Building Institute (newbuildings.org) has been compiling and maintaining a list of 581 (as of 2019) verified and emerging ZNE buildings. They have observed a trend away from forced-air heating, ventilation, and air-conditioning (HVAC) systems and increased adoption of radiant systems by these exemplary buildings (Hobart 2019; Khanolkar 2022). Olesen published several earlier papers where he discussed the principles of designing energy-efficient, high-thermal mass radiant cooling systems, including load shifting, the use of operative temperature for comfort control, and cooling capacity (Olesen 1997, 2008, 2012). Recent research has verified that radiant buildings are more energy efficient (Higgins and Carbonnier 2017) and have a tendency toward improved thermal comfort (Karmann, Schiavon, et al. 2017) compared to conventional all-air buildings. Furthermore, radiant systems only address the sensible loads of the building, requiring secondary ventilation systems to address latent loads, pollutants, and the mitigation of airborne diseases. However, this provides an opportunity for radiant designers to optimize the ventilation systems to best suit their building and occupant needs (Zhang et al. 2020).

Despite this growth, completed installations of radiant systems to date have demonstrated that controls and operation of radiant systems can be challenging due to a lack of familiarity with HVAC design and operations professions, often involving new concepts (particularly related to the slow response in high thermal mass radiant systems). Furthermore, recent research (https://cbe.berkeley.edu/research/optimizing-radiant-systems-energy-efficiency-comfort/) has shown that the fundamental differences between radiant and all-air systems require new and/or revised definitions and methods for the design, sizing, and control of successful and effective radiant cooling and heating systems. These differences have created a situation where radiant systems are being designed, installed, and operated with only limited guidance and often inappropriate tools to assist the designer and building operator.

Objectives

The goal is to develop a comprehensive guide that describes radiant heating and cooling system technology and its benefits and provides key guidance related to its design, installation, commissioning, and control. The design guide will reach the audience through ASHRAE's publication distribution network including its online platforms. Promotion of the design guide can be done through TC 6.5 sponsored seminars which have been successfully proposed and accepted in the past.

Audience/Publication Need:

Targeted Audience: Building engineers, designers, contractors, consultants, and other building stakeholders

In a recent research study, eleven prominent professionals with substantial experience in the design, construction and operation of radiant buildings in North America were interviewed to better understand current design practices for high thermal mass radiant systems (Paliaga et al. 2017). These professionals collectively have designed more than 330 radiant system buildings. The results showed that there was a wide variety of design solutions with little standardization. One of the key findings was that although most designers were aware of the potential benefits, they omitted significant potential energy performance improvements, such as precooling, load-shifting, reduced plant sizes, lower cooling/higher heating water temperatures, and waterside economizing, due to lack of design tools, existing successful case study examples, availability of reliable controls to achieve the design intent, and project-specific constraints. A second similar survey of Canadian consulting engineering firms was conducted by CanmetENERGY. It also found inexperience in the design of radiant systems and a lack of understanding of the effects inherent in radiant systems such as the thermal mass (Tardif 2019).

Currently available design guidance on radiant systems includes the REHVA Guidebook #7 (Babiak et al. 2009) REHVA Guidebook #20 (Bockelmann et al. 2013), several guides from manufacturers (priceindustries.com, uponorpro.com), ISO 11855 (ISO 2021) that focuses on embedded radiant systems, ISO 18566 (ISO 2017) that focuses on radiant panels, and an earlier design guide by Watson (2002). None of the above guides contain new relevant findings from research conducted during recent years – in fact, it has been more than a dozen years since the most relevant REHVA Guidebook #7 was published. Among the key topics that are missing from the existing design literature on radiant systems are the load-shifting capabilities of high thermal mass radiant systems, as well as their intersection with the need for energy storage on the electricity grid. Some recent research has begun to address

this need, for example, Bauman et al., (2019), but no standardized design guidelines have yet to be developed. There are several relevant mechanical codes that have specific requirements for radiant heating/cooling systems. These codes have been updated in the past 5 years to include some useful and enforceable radiant language (CSA 2021; IAPMO 2018a, 2018b). It will be important for the new radiant design guide to acknowledge relevant code requirements.

Due to the lack of up-to-date design guidance containing the results of new ASHRAE research and from other sources, as well as experience from recent radiant projects, there is a strong need for a comprehensive design guide for radiant heating and cooling systems containing all relevant information in one location. This will address the current situation where ASHRAE members often have to seek guidance from a variety of sources with different advice. Since radiant technology is still relatively new and unfamiliar to the practicing engineering design community at large, new projects are more frequently undertaken by designers with experience. The new guide will help radiant design more accessible to the wider ASHRAE membership that might have little experience with designing such systems. As radiant systems have been acknowledged in the literature to provide improved energy performance and a tendency towards improved thermal comfort compared to conventional air distribution systems, the new guide will help support the ASHRAE strategic plan by enabling the design of buildings that are both energy-efficient and have high indoor environmental quality.

One of the main deliverables of this project is a comprehensive design guide on radiant heating and cooling systems. ASHRAE and general society will greatly benefit from this project because it will coalesce the research describing radiant HVAC systems, their benefits, and implementation to achieve high-performing buildings. Designers will be able to use this guide to extract key guidance related to the design, installation, commissioning, and controls of radiant systems.

Proposed Table of Contents:

Content:

The design guide will describe radiant system technology and its benefits and provide key guidance related to the design, installation, commissioning, and control of radiant systems. In addition to providing guidance specifically about radiant systems, the design guide will address whole-building HVAC system integration issues that are unique to the application of radiant heating and cooling. For example, the design guide will address issues that should be considered in the design and control of the heating and cooling plant, and the required secondary ventilation systems (typically dedicated outdoor air systems, DOAS) that operate in buildings with radiant heating and cooling, opportunities to enable operational flexibility to support grid-interactivity and resilience, and design strategies to reduce barriers to adoption e.g. mitigation strategies for acoustical issues, limited heating and cooling capacity.

Proposed Outline:

It is suggested that the proposed content of the guide include, but not necessarily be limited to, the elements laid out in the outline in this section. This could form a rough draft of the table of contents, but the guide is not strictly fixed to this structure.

1. Introduction
    a. Background
    b. Purpose and scope
    c. Other resources
2. Process for the reader
    a. Description of audience. The primary aim for this, and the rest of the guide, is listed in *Audience* above.
    b. Description of how the various audiences will use and benefit from the use of this guide.
    c. Commercial/institutional/industrial focus. Residential optional.
3. Foundational guidance. Some key principles of heat transfer mechanisms related to radiant heating and cooling systems and their impact on occupants and heat gains.
    a. Typical system description and characteristics (fluids, piping types, other major components)
    b. Thermal comfort and IEQ
    c. Reasons for using radiant heating and cooling systems
        i. High-temperature cooling, low-temperature heating

4. Design guidance.
    a. Radiant system type selection (including zoning options, pump vs valves for control at zone level, etc.)
    b. Ventilation system type selection referring to other guides and resources as appropriate
    c. Supplementary heating and cooling system type selection
    d. Zonal and system layout and distribution options (e.g. zonal layout, size of zones, 2-pipe vs 4-pipe, how to combine thermal zones into groups receiving the same water temperature)
    e. Plant system design conditions and discuss other potential synergies between radiant systems and system selection.
    f. Sizing the various HVAC system components
    g. Air movement considerations (ceiling fan integration)
    h. Load-shifting and equipment capacity reduction leveraging high thermal mass radiant systems
    i. Design consideration for sequences of operation for various HVAC system components (Refer to a different chapter for more detailed information on controls)
        i. Radiant system, ventilation, supplementary system, plant, ceiling fan, etc
5. Condensation considerations for radiant cooling systems (referencing other standards as appropriate, e.g. ASHRAE 62.1 and 55).
6. Acoustical considerations and design strategies for mitigating its impacts on indoor environmental quality.
7. Installation/construction guidance.
    a. Installation methods
        i. Onsite vs offsite/prefabrication considerations
    b. Tubing
        i. Specifications/installation
    c. Insulation considerations
    d. Coordination of various trades considerations
    e. Repairability considerations
8. Control of radiant system guidance
    a. Impact of climate zone
    b. Impact of building vintage and type
    c. Illustration of various controls that aid with energy efficiency, carbon emissions reduction, improved occupant comfort, and capital and operational cost reductions.
9. Commissioning guidance
    a. Balancing of manifolds and individual circuits
    b. Controls commissioning
10. Operation and Maintenance guidance.
11. Existing building considerations for radiant applications
12. Design examples
    a. Worked design calculations at the zone level for selecting a manifold, design flow rates, etc.
    b. Worked design calculations at the building level for sizing and selecting heating and cooling equipment

If there are any nonprint resources that would be useful for readers, such as animations, videos, or spreadsheet tools, or if there are any checklists, forms, or other print materials that would be useful for readers external to the printed guide, such resources or materials may also be included as supplemental materials online, as long as these resources or materials do not infringe upon another entity's intellectual property or copyright, or as long as the copyright holder grants ASHRAE permission to include their copyrighted material as a supplement to the guide.

Suggested Approach:

Prepare an expanded/annotated outline for review by the Monitoring Committee.

1. Review the outline draft with the Monitoring Committee.
2. Address all review comments and reach agreement on the organization and content of the document.
3. Compile a list of relevant literature, organizations, regulations, and other resources that should be referenced in the guide. Review this with the Monitoring Committee.
4. Review compiled literature and guidance relevant to the proposed design guide.

5. Consider supplementing the guidance with high-level calculation or shoebox modeling and simulation.
6. Prepare a draft of the manual for review by the Monitoring Committee. Authors should refer to the ASHRAE Interactive Author's Manual for Books and Papers, which can be supplied to the Author by the Society and is available on the ASHRAE website at https://www.ashrae.org/technical-resources/authoring-tools.
7. Review the draft with the Monitoring Committee. Address all review comments and reach agreements on the substance of each change.
8. Develop formatting and graphics to produce the guide for publication by ASHRAE.
9. Develop the table of contents, composing each page, and providing consistent headers and footers.
10. Submit the document for final review and approval by ASHRAE to verify that changes have been accurately implemented.
11. Submit the project files, including the compete final manuscript, source documents, editable tables, separate figure files, permissions to reproduce others' work, and supplemental materials as applicable, for publication of the document by ASHRAE

Deliverables:
Progress and Financial Reports, Complete Final Manuscript including editable tables, separate figure files, and permissions to reproduce others' work, and Data shall constitute the deliverables ("Deliverables") under this Agreement and shall be provided as follows:

a. Progress and Financial Reports

Progress and Financial Reports, in a form approved by the Society, shall be made to the Society through its Manager of Research and Technical Services (MORTS) at quarterly intervals; specifically on or before each January 1, April 1, June 10, and October 1 of the contract period.

The following deliverables shall be provided to the Project Monitoring Subcommittee (PMS) as described in the Scope/Technical Approach section above, as they are available:

Furthermore, the Institution's Principal Investigator/Main Author, subject to the Society's approval, shall, during the period of performance and after the Final Report has been submitted, report in person to the sponsoring Technical Committee/Task Group (TC/TG) at the annual and winter meetings, and be available to answer such questions regarding the research as may arise.

b. Complete Final Manuscript

Author agrees to deliver to the Society a complete, final manuscript of the Work that incorporates all changes required by the Society's review process and that covers the subject matter as specified by the Society, with all editable tables, separate figure files, appendices, supplemental online material, and permission forms as detailed below.

The complete final manuscript consists of the following:

- An electronic copy (via email or file sharing website) of the complete manuscript in a single- or double-spaced single-column format in Microsoft Word (PDFs and LaTeX files not accepted).
  - The text must be in dual units, with the units used in calculating the work first and the other units following.
  - Number, supply captions for, and refer to all figures in the text. Figures must provide values in both I-P and SI units.
  - Number, supply titles for, and refer to all tables in the text. Tables must be editable Word or Excel tables and NOT submitted as uneditable images (TIF, JPG, GIF, BMP). Tables must provide values in both I-P and SI units.
  - Although staff editors will format headings for the published book, please use consistent heading formats for clarity.
  - The complete final manuscript should include the following parts, all labeled clearly in the file names:
    - List of abbreviations and acronyms frequently used in the manuscript (**optional**)

- Foreword (**optional**; usually written by someone other than the author)
- Preface (**optional**; the author's approximately 500-word statement about the Work, including reasons for undertaking it, the method of research, the book's origins and goals and intended audience, etc.)
- Acknowledgments (**optional but recommended**; may acknowledge authors involved in the development of the content of the guide and special assistance, including sources of financial aid, as well as the help of ASHRAE technical committees, individuals, or other groups)
- Introduction (**optional but recommended**; an overview of the Work; the definition of the problem should be set in the appropriate framework for the solution that will follow in the main body of the text)
- Chapters (with short, descriptive titles; material should be presented in a logical order that is easy to follow, keeping the prospective audience in mind)
- Appendices (**optional**; may include supporting data, sample calculations, examples, etc.)
- Glossary of terms and their definitions (**optional**)
- Reference list of citations for all sources cited in the text
- List of words that will be compiled to create an index (**optional**; staff editors will set the page numbers)
- Supplemental materials to be included online (**optional**; submit via email or file sharing website)

- Figures

  Electronic copies (via email or file sharing website) of all figures, clearly labeled for both I-P and SI versions. Each figure should be provided as a separate TIF, EPS, or JPG file saved at high resolution (600 dpi for line art; 300 dpi for photographs). Graphics embedded in Word or PowerPoint are not acceptable.

- Permissions Forms

  Electronic or printed copies of signed agreements granting ASHRAE permission to reproduce material from other sources in this guide.

c. Project Synopsis

A written synopsis totaling approximately 100 words in length and written for a broad technical audience, which documents 1. Main findings of research project, 2. Why findings are significant, and 3. How the findings benefit ASHRAE membership and/or society in general shall be submitted to the Manager of Research and Technical Services (MORTS) by the end of the Agreement term for publication in ASHRAE Insights

The Society may request the Institution submit a technical article suitable for publication in the Society's ASHRAE JOURNAL. This is considered a voluntary submission and not a Deliverable. Technical articles shall be prepared using dual units; e.g., rational inch-pound with equivalent SI units shown parenthetically. SI usage shall be in accordance with IEEE/ASTM Standard SI-10.

Level of Effort

This guide is expected to be 100-200 pages in length. The selected contractor is expected to complete the project within 24 months of the award of the contract. The total cost of the project is anticipated to be approximately $100,000.

Proposal Evaluation Criteria:

No.	Proposal Review Criterion	Weighting Factor
1	Contractor's understanding of the Work Statement and approach to complete the project, as demonstrated in the proposal.	25%
2	Past performance writing user-oriented guidance	20%
3	Contractor's experience with radiant heating and cooling HVAC systems; designing, installation/construction; commissioning, and controlling.	35%
4	Qualifications and experience of personnel for the project.	20%

Project Milestones:

No.	Major Project Completion Milestone	Deadline Month
1	Outline of the guide	Qtr 1-2
2	Bullet point details for the guide	Qtr 2-3
3	A preliminary working draft of the guide	Qtr 4-5
4	The complete final manuscript, including all parts as defined in the Deliverables section	Qtr 6-8
5	Editable tables and separate figure files as defined in the Deliverables section	Qtr 6-8
6	Timely communication with Publications staff regarding editorial queries, which must be addressed by the Author to the Society's satisfaction, and the delivery of copies of permission forms as defined in the Deliverables section	xx

References

1. Babiak, J., B. Olesen, and D. Petras. 2009. REHVA guidebook No. 7: Low temperature heating and high temperature cooling. Brussels, Belgium: Federation of European Heating and Air-Conditioning Associations.
2. Bauman, F., P. Raftery, S. Schiavon, C. Karmann, J. Pantelic, C. Duarte, J. Woolley, M. Dawe, L. Graham, D. Miller, H. Cheng, J. (Dove) Feng, D. Heinzerling, C. Higgins, K. Carbonnier, G. Paliaga, A. Pande, and F. Farahmand. 2019. Optimizing Radiant Systems for Energy Efficiency and Comfort (No. EPC-14-009). Sacramento, CA: California Energy Commission.
3. Bauman, F., T. Webster, S. Schiavon, H. Zhang, and E. Arens. 2012. Advanced Design and Commissioning Tools for Energy-Efficient Building Technologies. Berkeley, CA: Center for the Built Environment, University of California, Berkeley.
4. Bockelmann, F., S. Plesser, and H. Soldaty. 2013. REHVA Guidebook No. 20: Advanced System Design and Operation of GEOTABS Buildings. Brussels, Belgium: Federation of European Heating and Air-Conditioning Associations.
5. CSA. 2021. CSA B214-21: Installation code for hydronic heating systems. CSA Group.
6. Higgins, C., and K. Carbonnier. 2017. Energy Performance of Commercial Buildings with Radiant Heating and Cooling.
7. Hobart, S. 2019, May 9. 2019 Zero Energy Buildings Count Nears 600, New Dynamic Tool Offers Online Access to Project Details.
8. IAPMO. 2018a. Uniform Mechanical Code. International Association of Plumbing and Mechanical Officials.
9. IAPMO. 2018b. Uniform Solar, Hydronics and Geothermal Code. International Association of Plumbing and Mechanical Officials.
10. ISO. 2017. ISO 18566:2017 - Design, test methods and control of hydronic radiant heating and cooling panel systems. Geneva, Switzerland: International Organization for Standardization.
11. ISO. 2021. ISO 11855:2021 - Building environment design-Design, dimensioning, installation and control of embedded radiant heating and cooling systems. Geneva, Switzerland: International Organization for Standardization.

12. Karmann, C., F. Bauman, P. Raftery, S. Schiavon, W. H. Frantz, and K. P. Roy. 2017. Cooling capacity and acoustic performance of radiant slab systems with free-hanging acoustical clouds. Energy and Buildings, 138:676–686.
13. Karmann, C., S. Schiavon, L. T. Graham, P. Raftery, and F. Bauman. 2017. Comparing temperature and acoustic satisfaction in 60 radiant and all-air buildings. Building and Environment, 126:431–441.
14. Khanolkar, A. 2022, March 17. The promise of hydronic systems in building decarbonization. Mechanical Business.
15. Ning, B., S. Schiavon, and F. S. Bauman. 2017. A novel classification scheme for design and control of radiant system based on thermal response time. Energy and Buildings, 137:38–45.
16. Olesen, B. W. 1997. Possibilities and limitations of radiant floor cooling. ASHRAE Transactions, 103(1):42–48.
17. Olesen, B. W. 2008. Radiant floor cooling systems. ASHRAE Journal, 50:16–22.
18. Olesen, B. W. 2012. Using Building Mass to Heat and Cool. ASHRAE Journal, 54(2).
19. Paliaga, G., F. Farahmand, P. Raftery, and J. Woolley. 2017. TABS Radiant Cooling Design & Control in North America: Results from Expert Interviews. eScholarship.
20. Tardif, M. 2019. Survey on the Design of Radiant Systems for Commercial Buildings in Canada. Canada: CanmetENERGY.
21. Watson, R. D. 2002. Radiation Heat Transfer. In Radiant Heating and Cooling Handbook. San Francisco: McGraw-Hill.
22. Zhang, C., M. Pomianowski, P. K. Heiselberg, and T. Yu. 2020. A review of integrated radiant heating/cooling with ventilation systems- Thermal comfort and indoor air quality. Energy and Buildings, 223:110094.