INVITATION TO SUBMIT A RESEARCH PROPOSAL ON AN ASHRAE RESEARCH PROJECT

1566-TRP, Equations to estimate evaporation rates from heated water pools in indoor recreational aquatic facilities" (Re-bid)

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 8.10, Mechanical and Desiccant Dehumidification Equipment, Heat Pipes and Components; Co-sponsored by: TC 9.8, Large Building and Air Conditioning Application

Budget Range: $200,000 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 16th, 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: 1566-TRP, Equations to estimate evaporation rates from heated water pools in indoor recreational aquatic facilities", 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
Alois Malik
Phone: 910) 859-1016
E-Mail: amalik@corcopro.com

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 16th, 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)

Information contained in the ASHRAE Handbook for estimating water surface evaporation loads is inadequate for real-world application.

The current publication of the *ASHRAE Handbook—HVAC Applications*, lists an evaporation formula that was developed by Willis Carrier in a laboratory setting during 1918. Field experience has shown that the evaporation rate for a given body of water can vary by a factor of eight (8) or more from the basic Carrier formula listed in the handbook. Experience has also proven that in some applications the evaporation rate can be reduced by one half as calculated using this formula. Application-based engineering judgment in the form of "Activity Factors" was finally added to that equation 80 years later, in time for the 1999 volume. However, these adjustment factors are not backed by actual measured values.

The activity factors were agreed upon through an informal consensus of the swimming pool dehumidifier manufacturers who participate in ASHRAE TC 8.10. The adjustments were an attempt to provide designers with some means of coming closer to estimating moisture removal rates, which would be consistent with informal observations of the volume of condensate leaving dehumidifiers during actual operation of swimming pool HVAC systems. There has been no attempt to validate the accuracy of these adjustment factors.

More than 90 years after Willis Carrier's laboratory efforts with steady-state conditions over still water with two fixed-but-improbable air flow directions, the engineering community is still basically making an educated guess at evaporation rates in real-world situations.

Justification and Value to ASHRAE

This overall project will have several deliverables, of which the final one is paramount. Namely, the research contractor will generate text, equations and/or tables with supporting graphics which will be inserted into the ASHRAE Handbook—Applications. Designers will use this new information to more accurately calculate the evaporation loads in pool enclosures.

One of the principal justifications for this project is the reduction of health and safety risks from damp buildings. However, strong secondary benefits include reducing the construction cost of buildings that need dehumidification systems, and reducing their lifetime energy use.

Current health and safety issues include:

1. Reducing the current risk of building collapse. When swimming pool enclosures are not adequately dehumidified, fasteners corrode and wooden structural members decay. Each year, snow loads and or rain loads on such weakened structures cause roof collapses. For one current example, consider that during 2008, the 30-year-old swimming pool building at Brown University in Providence, RI was demolished rather than repaired. The structure was so decayed from excess moisture accumulation that there was no point to renovating the building—it was structurally unsound and a life-threatening hazard to occupants.

2. Reducing the current health risk from damp buildings. As established by the National Institutes of Medicine in 2003, there is a significant health risk from damp buildings. In 2007, the Lawrence Berkeley National Laboratory, working for the U.S. Department of Environmental Protection, calculated the cost of those risks to be between $2.3 and 4.5 billion per year. With more accurate calculation of internal water evaporation load, those that reflect the real world, the risks of damp buildings can be reduced through appropriate design of air conditioning and dehumidification systems.

Current construction cost and energy waste issues include:

1. Without a better means of estimating loads, dehumidification equipment may be oversized or undersized or the need for such equipment ignored entirely. Competitive offerings cannot be fairly evaluated, leading to higher than necessary costs in some cases, inadequate performance in others, and in extreme cases, equipment failure and structural collapse.
2. Without adequate quantification of evaporation loads, equipment will operate inefficiently, leading to excessive energy consumption.

Objectives

The primary objective of this work is to design and perform a set of laboratory experiments that will examine evaporation from wetted surfaces under characteristics of an indoor swimming pool and spas. These experiments will establish a set of formulas for the engineering community to use for calculating latent loads in natatoriums and commercial/industrial buildings.

Scope:
The scope of this project outlines the steps that will ultimately result in the development of a method for accurately predicting the evaporation rates from water pools in aquatic facilities. Successful proposals will address each of the tasks listed in thi section.

Task 1 – Literature review:
The successful contractor shall research existing methods for evaporation rate calculations, then summarize and evaluate them on their own and finally compare them to the Willis Carrier research. The evaluation of existing calculation methods shal include but not limited to the physical/theoretical bases of the method and comparisons with all pertinent test data collected The contractor shall also include discussions on the physical phenomena involved, what parameters could be important, and possible analytical approaches. Methods examined should include the following, plus at least three (3) more that can be found In particular, the PMS is interested in additional studies which include values for evaporation rates measured in the field a well as in the laboratory.
1. Bowen Method
2. Dalton's Law – Mass Transfer Method
3. PenMan Method
4. Priestley – Taylor Method
5. De Bruin Method
6. Willis Carrier Method – 1918
7. Rohwer, 1931
8. Biasin, Von, Krummere
9. Dr. Mirza Shah

With the review, in this Task 1, the contractor will further document all of the variables in all of the various formulas above in order to determine the final variables and range of those variable conditions in the Experimental design in Task 2.
As part of the literature review, the contractor will also interview a sample of HVAC Designers who have had experience designing HVAC systems for swimming pool enclosures. Determine what data they have, readily available, at the time o design, and what methods they can, as a practical matter, afford the time to learn and apply when estimating evaporation rate from pools and complex wetted surfaces. The research contractor shall interview six (6) HVAC designers, six (6) HVAC design-build contractors and three (3) Manufacturers that are involved in the dehumidification business. The contractor shal then prepare a written report describing the results of the interviews, and a candidate list of input variables to be used in the equations and tables developed by the research contractor.

Task 2 – Experimental Design
Based on the information gathered, the contractor will design a set of laboratory experiments using appropriately scaled model to examine the evaporation rates from wetted surfaces and features. Variables of interest and ranges to be tested:
Pool Surfaces Variables and Range of Experimentation
o Open water surface agitation/activity ▪ 3 levels of agitation/activity simulating bather loading/density and its effect on evaporation
▪ Agitation levels and method of control of such would be researched by contractor and proposed to PMS.

o Average air velocity over surface. ▪ Range of interest is 30 to 90 fpm

o Water temperatures
▪ Range of interest will be 76°F to 104°F
o Air temperature
▪ Range of interest will be 80°F to 90°F
o Air humidity
▪ Range of interest will be 30% RH to 70% RH
o Others variables identified in Task 1 and ranges agreed upon with the PMS

Due to the number of variables and relatively wide range of each involved, the design of experiment would be critical in limiting the number of experiment iterations while performing results. During the experimentation phase, the experimental design phase, the first task will be for the contractor to formally complete the design of experiment and identify which variables are likely to be independent and those that are independent.

Task 3 – Laboratory Testing and Analysis
The contractor will perform the set of experiments agreed upon in Task 2 and analyze the data using sound scientific principles to develop mathematical models that characterize the results.
PMS committee will review first results with contractor from initial testing 1st activity level and air velocity (Line 1 of Table 2 shown in Task 2 or equivalent stage in final experimental procedure). Contractor will document the instrumentation, methods, and other aspects of the experimental setup for PMS review. Contractor will prepare a preliminary comparison of the experimental results and each of the formulas referenced in Task 1. Upon preparation of a preliminary report, the contractor will immediately review these with the PMS before proceeding to further experimentation. It is expected that the PMS will make the full committee available for discussion of that report immediately such that experimentation can continue as uninterrupted as possible.
Upon completion of the remaining activity levels and air velocities, contractor will update the preliminary report with the comparison of all existing theoretical and empirical formulas as researched in Task 1 and forward to the PMS for review. Contractor will suggest a proposal for determination of appropriate formula for use or the development of an empirical formula that correlates with the experimental data before starting final report.

Task 4 – Reporting
The successful contractor shall submit a draft report to the PMS for comments on a quarterly basis and at the end of each Task. The PMS reserves the right to request more detailed information before the next Task is started and the report is accepted. The final report must be approved and accepted before any technical paper or journal article is written and submitted.
Subsequent to the compilation of the report update and meeting with the PMS to determine the formula to be recommended, a final report is to be generated detailing the means and methods for experimentation, data analysis, and recommendations on most appropriate equations to estimate evaporation rates from heated water pools in indoor recreational aquatic facilities.
Summary of reporting activities:

- Subsequent to Task 1, the contractor shall prepare a written report describing the results of the interviews, and a candidate list of input variables to be used in the equations and tables developed by the research contractor.
- Subsequent to Task 2, contractor will review their suggested Design of Experiment with PMS.
- During Task 3, the contractor will prepare a preliminary comparison of the experimental results and each of the formulas referenced in Task 1 and review with PMS before proceeding.
- Subsequent to Task 3, contractor will update the preliminary report with the comparison of all existing theoretical and empirical formulas as researched in Task 1 and forward to the PMS for review.
- Subsequent to the compilation of the report update and meeting with the PMS to determine the formula to be recommended, a final report is to be generated detailing the means and methods for experimentation, data analysis, and recommendations on most appropriate equations to estimate evaporation rates from heated water pools in indoor recreational aquatic facilities.
- In addition to the specific milestone reports above, the contractor will meet with the PMS one every quarter to discuss the on-going work and exception reports as appropriate.

Deliverables:
Progress, Financial and Final Reports, Technical Paper(s), 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 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, 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. Reports, results, proposed methodologies and publication-ready materials as defined in tasks 1 through 8 above

Print-ready Handbook Material Upon approval by the PMS, the PI will submit the final text and graphic files to the chair of the PMS. The PI shall also provide all files (text, tables, and supporting graphics) on CD-ROM, in the format required by ASHRAE Handbook staff for the current printed edition. Note that this material shall include separate sets of text, equations, tables and supporting graphics for both SI and I-P units, suitable for insertion into the I-P and SI editions of the Handbook

c. Final Report

A written report, design guide, or manual, (collectively, "Final Report"), in a form approved by the Society, shall be prepared by the Institution and submitted to the Society's Manager of Research and Technical Services by the end of the Agreement term, containing complete details of all research carried out under this Agreement, including a summary of the control strategy and savings guidelines. Unless otherwise specified, the final draft report shall be furnished, electronically for review by the Society's Project Monitoring Subcommittee (PMS).

Tabulated values for all measurements shall be provided as an appendix to the final report (for measurements which are adjusted by correction factors, also tabulate the corrected results and clearly show the method used for correction).

Following approval by the PMS and the TC/TG, in their sole discretion, final copies of the Final Report will be furnished by the Institution as follows:

-An executive summary in a form suitable for wide distribution to the industry and to the public.
-Two copies; one in PDF format and one in Microsoft Word.

d. *Science & Technology for the Built Environment* or ASHRAE Transactions Technical Papers

One or more papers shall be submitted first to the ASHRAE Manager of Research and Technical Services (MORTS) and then to the "ASHRAE Manuscript Central" website-based manuscript review system in a form and containing such information as designated by the Society suitable for publication. Papers specified as deliverables should be submitted as either Research Papers for HVAC&R Research or Technical Paper(s) for ASHRAE Transactions. Research papers contain generalized results of long-term archival value, whereas technical papers are appropriate for applied research of shorter-term value, ASHRAE Conference papers are not acceptable as deliverables from ASHRAE research projects. The paper(s) shall conform to the instructions posted in "Manuscript Central" for an ASHRAE Transactions Technical or HVAC&R Research papers. The paper title shall contain the research project number (1566-RP) at the end of the title in parentheses, e.g., (1566-RP).

All papers or articles prepared in connection with an ASHRAE research project, which are being submitted for inclusion in any ASHRAE publication, shall be submitted through the Manager of Research and Technical Services first and not to the publication's editor or Program Committee.

e. Data

Data is defined in General Condition VI, "DATA"

f. 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 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

The anticipated level of effort is 24 professional-months with a total cost of $200,000.

Project Milestones:

No.	Major Project Completion Milestone	Deadline Month
1	Literature review and report	2
2	Design of experiment and detailed proposal	4
3	Secure final location and equipment for experimentation	6
4	Review of initial results from testing 1st activity level and air velocity	8
5	Completed testing and report raw data	18
6	Complete final report	20
7	Create Technical Paper, Handbook Material, and Project Synopsis	14

Proposal Evaluation Criteria

Proposals submitted to ASHRAE for this project should include the following minimum information:

No.	Proposal Review Criterion	Weighting Factor
1	Contractor(s) understanding of evaporation and the goals and tasks of the research project.	35%
2	Proposed list of research projects that will be evaluated	10%
3	Evaluation of the facilities that will be used to perform the work	30%
4	Contractor's qualifications	20%
5	Student involvement	5%

References

1. "Swimming upstream: Rotting roof beams and the early demise of the Smith Swim Center". Brown University Alumni Magazine, July-August 2007.
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3. US Department of Agriculture - Food Safety & Inspection Service - “Ohio Firm Recalls Pork Products for Possible Listeria Contamination” October 12, 2006. Recall release number FSIS-RC-030-2006 CLASS I RECALL - HEALTH RISK: HIGH
4. Mudari, David and Fisk, William J.; “Public health and economic impact of dampness and mold.” Indoor Air, June 2007. Volume 17, Issue 3. pp 226-235. Journal of the International Society of Indoor Air Quality and Climate, Blackwell Publishing, www.blackwellpublishing.com
5. Lotz, William A., P.E. Fellow, ASHRAE “Indoor pool design: avoid the potential for disaster.” HPAC Engineering, November 1995
6. West, Mike, Ph.D, P.E., “Natatoriums: What can go wrong—and did: value engineering, lack of preventative maintenance and mother nature undermine an otherwise state-of-the-art Florida health club.” HPAC Engineering, August 2005
7. Shah, Mohammed, Ph.D, P.E., “Calculating evaporation from indoor water pools: An evaluation of available methods and recommendations for their use.” HPAC Engineering, March 2004.
8. Pauker, Tang, Jeter et al. “A novel method for measuring water evaporation into still air.” ASHRAE Transactions, 1993, V.99, Pt.1
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10. ASHRAE Handbook, HVAC Applications – Natatorium Section
11. Carrier, W. H. 1918. The temperature of evaporation. ASHVE Transactions 24:25-50
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16. Richter Dieter (1973) A comparison of various methods used for the determination of evaporation from free water surfaces. Hydrology of Lakes, pp. 235-238: IAHS Publ. No. 109
17. Smith, C.C., et al. 1993, “Energy requirements and potential savings for heated indoor pools,”, ASHRAE Trans. Vol. 99, part2, pp.864-876.
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19. M.M Shah 2008, “Analytical formulas for evaporation from pools,” ASHRAE Transaction, part2., pp. 610-618