INVITATION TO SUBMIT A RESEARCH PROPOSAL ON AN ASHRAE RESEARCH PROJECT

1850-TRP, "Evaluation of ASHRAE's Design Day Procedure Against Recorded Weather Data"

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 4.2 Climatic Information
Co-sponsored by: TC 4.1 Loads Calculations & TC 6.5 Radiant Heating and Cooling

Budget Range: $60,000 may be more or less as determined by value of proposal and competing proposals.

Scheduled Project Start Date: **September 1, 2020** or later.

All proposals must be received at ASHRAE Headquarters by 8:00 AM, EDT, May 15, 2020. 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: 1850-TRP, "Evaluation of ASHRAE's Design Day Procedure Against Recorded Weather Data", ***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
Drury Crawley
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For Administrative or Procedural Matters:
Manager of Research & Technical Services (MORTS)
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Contractors intending to submit a proposal should so notify, by mail or e-mail, the Manager of Research and Technical Services, (MORTS) by May 4, 2020 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 and mvaughn@ashrae.org. In all cases, the proposal must be submitted to ASHRAE by 8:00 AM, EDT, May 15, 2020. 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)

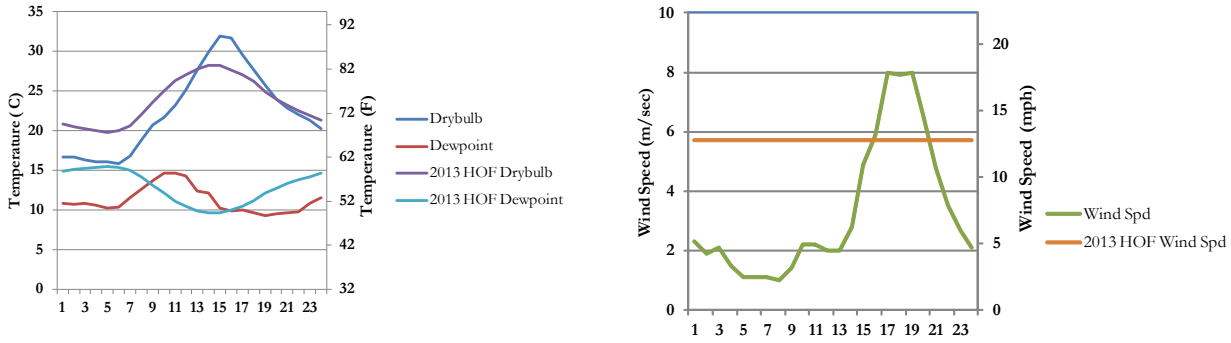
ASHRAE reserves the right to reject any or all bids.

State of the Art (Background)

The ASHRAE Design Day procedure has evolved over time from using single Design Temperatures to calculate heating and cooling design loads, to a proliferation of hypothetical Design Days. For cooling Design Days, the Design Temperature is used as the peak temperature of the day occurring at 2 pm, with the temperatures of the remaining hours derived by fitting a standard daily temperature profile to the average daily temperature range for the hottest month. Humidity conditions are similarly based on the mean coincident wet-bulb temperature to the design temperature, although there has been debate whether the dew point temperature should have a hourly profile or be constant. ASHRAE RP-1363 ("Generation of Hourly Design-Day Weather Data") looked extensively into this topic and concluded "Dew point temperature variations were found to be highly variable, such that no single profile can provide reliable predictions." (GARD 2012). Other rules are used to define the solar radiation, which is assumed to be always clear sky conditions, wind speed and direction, which are assumed to be the constant average wind speed and prevailing direction of the hottest month. There are similar sets of rules to define other cooling and heating Design Day conditions.

It is important to recognize that while there are statistical bases for the near-extreme design parameters and their mean coincident cohort parameters, there is little statistical basis for the conditions on the off-peak hours 1 and none whatsoever for the ASHRAE Design Days in their entirety. A number of studies have found the coincidence of peak temperatures with clear sky conditions is not correct, so this assumption in the current ASHRAE design procedures can lead to oversized air-conditioning systems (Levermore 2008, Chen et. al. 2007, 2008). A state-of the-art ASHRAE engineer has opined that "...design conditions are often more theoretical than practical and frequently lead to either over-designed capacities or poorly conceived operational dynamics driven by excessive assumptions of design conditions." (Carpenter 2018). TC 6.5 expressed interest in co-sponsoring this Work Statement because they had found that the ASHRAE Design Day procedure produced such high nighttime wet bulb temperatures in northern California that evaporative pre-cooling strategies for mass radiant systems or chilled water storage would have been completely ineffective, whereas using actual historical weather data showed otherwise. Huang (2014) confirmed this discrepancy, which was due to using the average daily range of the hottest month to derive the nighttime dry-bulb and dew point temperatures:

0.4% Design Day temperature and wind speed profiles for San Francisco extracted from historical records compared with 2013 ASHRAE Handbook values (Huang 2014)



[1] Even the use of the hourly percentile temperatures, i.e., 0.4%, 1% cooling, 99.6% heating, etc., as the maximum or minimum for the ASHRAE Design Day is methodologically inconsistent, since not all those hours are necessarily the highest or lowest temperature of the day. Huang (2014) found that peak daily Design Temperatures were consistently a few degrees lower than peak hourly Design Temperatures due to the multiple-counting of hours on days where temperatures exceed the percentile temperature.

Now that so much long-term historical weather data are available, the path forward is to utilize the data to first evaluate the validity of the current design day procedure, and then to either improve that procedure or replace it altogether with a data-driven approach. The Integrated Surface Database (ISD) maintained by the National Center

for Environmental Information (NCEI) contains the hourly climatic records of up to 13,600 weather stations around the world spanning several decades. These data so far have been used only to extract hourly design conditions, e.g., 0.4% cooling Design Temperature, etc. The same data can also be used to extract the entire 24-hour record surrounding these peak conditions to produce *real* Design Days (Huang 2014).

Objective

The proposed project will answer the following questions:

1. How different are the proposed real Design Days compared to the current hypothetical Design Days?
2. What is the impact if the proposed real Design Days are used in place of the current hypothetical Design Days?
3. What is the frequency distribution of HVAC sizing loads based on the long-term climatic data?
4. What are the actual frequencies of occurrence in the long-term building load time-series of the design loads calculated using the proposed real and the current hypothetical Design Days?
5. What are the problem areas in using the proposed *real* Design Days, and how can these be overcome?

Scope:

The technical approach to the project is to (1) obtain the long-term hourly weather data, (2) extract or calculate from them *real* and current *hypothetical* Design Days and compare them to each other, (3) do building energy simulations with the long-term weather data to produce the actual historical distribution of heating and cooling loads, (4) repeat the simulations with both the *real* and current *hypothetical* Design Days, (5) compare the design loads calculated using the two Design Day formulations to the historical distribution to derive their actual frequency of occurrence or stringency, and (6) based on the analysis, recommend any improvements or revisions to the current ASHRAE Design Day procedure.

All tasks should be applied to 100 climate locations (33 US and 66 international) covering the range of ASHRAE 90.1 Climate Zones and/or Köppen Climate Classifications, and up to five building types (office, retail, hotel, hospital, and laboratory) but no less than three.

Task 1: Obtain or develop 25 year time-series (1990-2017) for 100 selected locations. The weather files should have at least an average of 400 observations per month for dry-bulb and dew point temperature, pressure, wind speed and direction, and include satellite-derived solar radiation.

Task 2: Develop both monthly and annual proposed *real* and ASHRAE's current *hypothetical* Design Days for the 100 locations based on the 25 year time-series. The *real* Design Days should include all the annual design conditions listed in the ASHRAE Handbook of Fundamentals, as well as the monthly design conditions for temperature and humidity. Part of this task includes the development and testing of a procedure to derive a single (*real*) Design Day from the multiple *real* Design Days obtained from the 25 year time-series.

Task 3: Obtain or develop reference building models for up to five building types (office, retail, hotel, hospital, and laboratory) but no less than three. Building variations by climate and geographical region are welcomed, but not essential to the analysis since the main focus is on the relative loads using the Design Day formulations to the historical time-series. On the other hand, the relative importance of getting the 'right' climatic values (drybulb vs wet bulb) and hourly profiles will change depending on the HVAC system type. For example, selecting and sizing a radiant system cooled entirely at night using a waterside economizer (i.e. a cooling tower) depends on the night time wetbulb temperature, which is very different than a traditional HVAC system (e.g. a VAV system with an air-cooled chiller). Therefore, it would be important to vary the HVAC system type significantly among the 3-5 building models to test the validity of various climate parameters on Design Days and over the long term. Lastly, to address concerns that building simulations may not accurately capture actual building loads, it is recommend obtaining models from DOE's Validation project being considered by SSPC140 for inclusion as an empirical test combining both accurate models of buildings with openly-available measured data.

Task 4: Use building energy simulations to calculate 25-year time-series of building heating and cooling loads for the 3-5 building types in the 100 locations

Task 5: Compare the building loads calculated using the two formulations of Design Days to the 25 year time-series of building loads to determine their frequency of occurrence or stringency.
Task 6: Recommend the path forward for the Design Day formulation .

Deliverables:

a. Technical Deliverables

Tasks 1 &2. Technical report describing the selection of locations and the climate characters of their 25-year time-series, and the extracted or calculated real and current hypothetical Design Days.
Tasks 3, 4, and 5. Technical report describing the building models used and the calculated Cumulative Frequency Distribution (CFD) of loads, and where the calculated Design Loads fall on that CFD.
Task 6: Technical report with observations comparing the two Design Day formulations and recommendations on the path forward in ASHRAE's design day procedures.

Progress, Financial and Final Reports, Technical Paper(s), and Data shall constitute the deliverables ("Deliverables") under this Agreement and shall be provided as follows:

b. 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.

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.

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 *Science & Technology for the Built Environment* or *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 (1850-RP) at the end of the title in parentheses, e.g., (1850-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 documenting: (i) the main findings of the research project, (ii) why the findings are significant, and (iii) how the findings benefit ASHRAE membership and/or society in general.

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 project is planned to have 9 month duration (spread over 2 society meetings) with an approximate budget of $60,000. It is expected that 2 person-months of Principle Investigator and 5 person-months of researcher effort are required to complete the project.

Evaluation Criteria

No.	Proposal Review Criterion	Weighting Factor
1	Contractor's understanding of Work Statement as revealed in proposal	15%
2	Quality of methodology proposed for conducting research	20%
3	Contractor's capability in terms of facilities	20%
4	Qualifications of personnel for this project	15%
5	Student involvement	15%
6	Probability of meeting the objectives and schedule of the Work Statement	15%

Project Milestones:

No.	Major Project Completion Milestone	Deadline Month
1	Task 1	**1**
2	Task 2	**2**
3	Task 3	**4**
4	Task 4	**5**
5	Task 5	**6**
6	Task 6	**7**

References

1. Carpenter, S. 2018. E-mail message to TC 42 Group.
2. Chen, Y.M., T.Y. Chen, and W.H. Yik 2008. "Statistic Selection of Coincident Solar Irradiance, Dry-bulb and Wet-bulb Temperatures for Determining Design Cooling Loads", *Proceedings of Clima 2007 WellBeing Indoors*, 2007, available at https://www.irbnet.de/daten/iconda/CIB7646.pdf
3. Chen, Y.M., T.Y. Chen, and W.H. Yik 2007. "Rational selection of near-extreme coincident weather data with solar irradiance for risk-based air-conditioning design", Energy and Buildings 39(12):1193-1201, Publication link: https://www.researchgate.net/publication/245196798_Rational_selection_of_near-extreme_coincident_weather_data_with_solar_irradiance_for_risk-based_air-conditioning_design
4. GARD Analytics 2012. "Generation of Hourly Design-Day Weather Data", Final Report for 1363-RP, ASHRAE, Atlanta GA.
5. Huang, Y. J. 2014. "An Evaluation of ASHRAE's Climatic Design Conditions Against Actual Long-Term Recorded Weather Data", ASHRAE Conference Paper, presented at the ASHRAE Annual Meeting in Seattle, June 2014.
6. Levermore, Geoffrey 2006. "Solar irradiation and coincident dry bulb temperature selection for load calculations", *ASHRAE Transactions* 112, 690-696. Publication link: 4d2452ae-1f23-4d4e-b278-2f7b3bf52bd7