Discussions for the Technical Papers from the 2017 ASHRAE Annual Conference in Long Beach, California

This is a compilation of the written questions and comments submitted to authors by attendees at the 2017 ASHRAE Annual Conference in Long Beach, California. All authors were given the opportunity to respond.

The questions/comments and authors' responses are published with the papers in the hardbound volume of *ASHRAE Transactions*, Vol. 123, Part 2.

LB-17-002

First-Year Calibration of a Design Energy Model at a Medical Office Building

Thomas Langran, PE

Michael Weller

Dennis R. Landsberg, President, L&S Energy Services, Inc., Henderson, NV: It would be helpful to separate the differences in energy use between the model and that building into two categories: the differences in how the building was built and the differences in how the building was utilized by the occupants. Clearly there is a boiler control issue, but were you able to determine infiltration differences between the model and the building?

Thomas Langran: During the calibration of the energy model, infiltration differences were considered a potential source of the variance. However, due to limited time and resources, we have not been able to follow up on this particular item yet.

LB-17-003 (RP-1651)

Development of Maximum Technically Achievable Energy Targets for Commercial Buildings

Jason Glazer, PE, BEMP
Member ASHRAE

Daniel Villa, Mechanical Engineer, Sandia National Laboratories, Edinburgh, TX: Did you use a standard method to estimate future technological growth?

Jason Glazer: No estimate for future technological growth was needed in the analysis, so no standard method was used. The only criterion for including a measure in the list of possible measures was that it was "either currently available or can be reasonably expected to be available by 2030, by at least two manufacturers."

LB-17-004

Performance Monitoring of Chilled-Water Distribution Systems Using HVAC-Cx

Natascha Milesi Ferretti, PE
Member ASHRAE

Michael A. Galler
Member ASHRAE

Steven T. Bushby
Fellow ASHRAE

Mark Kedzierski, Mechanical Engineer, National Institute of Standards and Technology, Gaithersburg, MD: 1) Is HVAC-Cx able to handle an old installation that hasn't been commissioned and has faulty sensors? 2) How are sensors calibrated, rigorously or by rule of thumb?

Natascha Milesi Ferretti: 1) Yes, HVAC-Cx can handle an old installation that has not been commissioned, but the quality of the results can be negatively impacted. In fact, the field site analyzed for this paper was not commissioned prior to applying HVAC-Cx expert rules. The extent of the performance assessment with HVAC-Cx is limited by the availability of design data (e.g., control requirements and sequencing strategy) and operational data including set point values, sensor measurements, and control signals. If a sensor is broken, this will eliminate the ability of HVAC-Cx to apply any rules that depend on that sensor reading. However, HVAC-Cx does have the capability to test for consistency of sensor readings. The first eight rules are parametric checks that compare the minute data to the acceptable range of values for the system. The next 10 rules are based on the expected temperature relationships that must be maintained during normal operation. The findings in this paper included Finding 4, which identified that the plant chilled-water supply temperature Twcps was consistently out of range.

2) HVAC-Cx does not have accuracy requirements beyond those needed for control purposes. Best practice is to calibrate sensors that serve as inputs to the energy management decisions, such as flowmeters, using a calibrated reference standard. In contrast, other sensors can be field-calibrated by adjusting readings to match accurate handheld instrument readings.

LB-17-006

Low-Cost Control System Built Upon Consumer-Based Electronics for Supervisory Control of a Gas-Operated Heat Pump

Randall Wetherington

Ahmad Abu-Heiba
Associate Member ASHRAE

Isaac Mahderekal, PhD
Member ASHRAE

Ed Vineyard
Fellow ASHRAE

Donghun Kim, Research Assistant Professor, Purdue University, West Lafayette, IN: Why are there two different microprocessors on the suggested control architecture?

Ahmad Abu-Heiba: One microprocessor was used for control functions while the other handled data logging and network operations. We decided not to use the microprocessor used for control for networking because it had limited memory. We also did not want to use the microprocessor used for networking for operational control because it ran a Linux OS and it would not be deterministic. It would also be more complex to program for control operations.

Randall Wetherington: And, the Linux processor provided a secure means of communications using Secure Shell (SSH) encryption. This provided a secure means of remotely accessing data and programming the units when they were in the field. We accessed the field units locally from the Las Vegas metropolitan area as well as from Oak Ridge, Tennessee.

LB-17-013 (RP-1544)

Hot-Water Use in Hotels: Part 5—Updated Hotel Hot-Water System Design Techniques

Carl C. Hiller, PhD, PE
Fellow ASHRAE

Russell Johnson
Member ASHRAE

Larry Spielvogel, Consulting Engineer, Bala Cynwyd, PA: How will the hot-water system designer know whether a hotel is for travel or business? What other types of hotels are there? How many types of food service are there in hotels?

What does a designer do if a travel hotel has meeting rooms, and how does that affect hot-water sizing? What does a designer do if a travel hotel has food service, and how does that affect hot-water sizing?

Are data from the tests of a single sample of one type of hotel in California and a single second sample of another type of hotel in Colorado sufficient to allow designers to size all water heaters for all similar hotels of any shape or size anywhere in the country?

As the author of the 1969 ASHRAE Water Heater Sizing Method referenced by the authors as the "recovery rate method," I believe it is important for readers to understand that the original work was confined to and is based on tests of 15 "pure motels," not any hotels, and it did not include any food service facilities. The original 1969 ASHRAE reports were provided to the authors.

How can the authors explain that the 1969 ASHRAE recovery rate sizing method for motels (not hotels) that has been in use for almost 50 years remains unchanged in the *ASHRAE Handbook—HVAC Applications*? Yet, the authors conclude that this method "produces designs that could be considered undersized especially with regard to needed heating rates." Can they explain why there is no documented or published evidence in actual buildings to support that conclusion?

This paper does not provide sufficient comfort to hot-water system designers for using the proposed method for sizing water heating systems in hotels anywhere. The authors do not provide their recommended text or charts from their work for consideration for inclusion in the next *ASHRAE Handbook* chapter on sizing hot-water heating systems.

Which (if any) of the four sizing methods from the *ASHRAE Handbook* referenced by the authors is in common use today? Are there any others methods commonly used by designers?

Before comparing this new method with other hot-water sizing methods, it is important to understand the hot-water design methods used in the industry. The authors' references do not include "Service Hot Water Sizing Methods" from *Air Conditioning, Heating and Ventilating* (Spielvogel 1968) which showed survey results from 116 hot-water designers from the American Society of Plumbing Engineers and the Plumbing Designers Association that used an average of 1.8 sizing methods, of which one of those in the pre-1969 *ASHRAE Handbooks* was the most popular. Nor were there any comparisons or evaluations of the dozens of other current published and used sizing methods.

Why did the authors not reference or compare some of the commonly and widely used hot-water sizing methods (1) referenced in the *Domestic Water Heating Design Manual* of the American Society of Plumbing Engineers (ASPE 2003) and (2) referenced in Chapter 6 of the *Plumbing Engineering Design Handbook* (ASPE 2014)?

How do the authors' results compare with the *Domestic Water Heating Design Manual*'s (ASPE 2003) detailed descriptions and classifications of hotel hot-water sizing, which are: (1) Convention Hotel or Motel, (2) Business Travelers Hotel or Motel, (3) Resort Hotel or Motel, and (4) General Occupancy Hotel or Motel?

What is the subject of the as-yet unpublished Part 6 of the authors' papers?

Carl C. Hiller: There are several questions and statements related to hot-water system sizing methods, which we will address independently. As a general comment, though, many of the previously developed (and still currently in use) hot-water system sizing methods focus on sizing the hot-water system based on loads estimated over an arbitrary time period, such as one hour.

There is no reason why measuring hot-water use over one hour is an appropriate time period for sizing systems. In fact, when studying heating rate versus storage volume trade-offs, it is clear that one hour has little to do with system sizing. Systems having small storage volumes and high heating rates must be sized for peak flow rates, which often occur over a matter of a few minutes. Systems that have ample storage and lower heating rates are sized by what happens over periods of many hours. Additionally, and most importantly, many of the old sizing methods apply rules of thumb, resulting in a recommendation of a single heating rate plus storage volume combination. In reality, all hot-water systems have a "design curve," where there are many different combinations of heating rate plus storage volume, all of which will satisfy the selected design hot water use pattern. The realization that there are many different combinations of heating rate plus storage volume that will work for any particular hot-water system design is one of the important facts we are striving to get designers to understand. Failing to recognize the heating rate versus storage volume trade-offs that can be made eliminates many advanced-technology water heating systems from consideration. For example, systems whose operating costs are low but whose capital costs per unit of heating capacity are large in comparison to conventional alternatives (e.g., solar, waste heat recovery, and heat pumps) favor designs with lower heating rates and larger storage volumes than conventional alternatives.

To answer the first question, hopefully the people commissioning the design of the hotel will know the target market for whom it is being designed and what, if any, special amenities and hot-water-using fixtures will be used. For example, whenever spa tubs or any other large-volume hot-water-using tubs or fixtures will be used, special considerations to accommodate these fixtures must be implemented. This is true in both residential and commercial applications.

The four most common categories of hotel/motel hot-water use are bathing, room cleaning, and common area cleaning; laundry; food service and kitchen; and unusual loads. Someone must provide the designer with information about the general nature of the loads to be served (e.g., will sheets and towels be washed on site or off site? Will there be a food service/commercial kitchen or not?). Moreover, it is up to the hot-water system designer, in concert with the client, to decide how many separate hot-water systems the hotel will have. Our paper provides information on how to size water heating systems for multiple different combinations of hot-water loads.

Hopefully, the commissioners of the hotel's design will know what types of food service they anticipate and the times of day the associated hot-water loads are predicted to occur. Design information for proper sizing of food service hot-water systems is not all that readily available, and none of the existing sizing methods does a particularly accurate job. Our unscientific impression is that most workable commercial kitchen hot-water systems are probably somewhat oversized to compensate for the unknowns in timing and variability of commercial kitchen hot-water loads. The RP-1544 field test only examined one hotel with a commercial kitchen. While we learned a lot from that test, particularly regarding variables that did not seem to strongly influence kitchen hot-water system sizing, data from more commercial kitchens in a wider variety of applications will be needed before significant improvements can be made in commercial kitchen hot-water system sizing methods.

Think of hotel/motel hot-water use falling into six categories; the first three categories we normally combine and call them the main guest room circuit. The six categories are (1) bathing, (2) guest room cleaning, (3) common area cleaning, (4) laundry, (5) food service, and (6) unusual uses. Of these six common hot-water uses, bathing is by far the largest; in fact, it is usually larger than all the others combined. Guest room cleaning hot-water use is normally fairly low. Common area cleaning varies widely from day to day when meeting rooms are present, because meetings may or may not be happening on a given day. Even on days when common area cleaning hot-water use is large, it is still much smaller than bathing hot-water use. Common area cleaning hot-water use is usually quite low if there are no meeting rooms (and hence the hotel would only have small common areas). From the RP-1544 research, we now understand bathing and guest room cleaning hot-water use reasonably well. Common area cleaning hot-water use is much more variable. It would be good to have data from more hotels for that portion of hotel/motel hot-water use, especially for hotels having large common areas with many meeting rooms. Until such additional information is available, we will need to estimate the common area cleaning baseload hot-water use (the hot-water use that is not proportional to occupancy) from data collected at the business hotel of the field test. We show two methods of doing that in the paper. Laundry hot-water use is much larger if sheets and towels are washed on site compared to such washing being contracted to outside services. Food service hot-water use is also highly variable, but we learned that much of the food service hot-water use is probably cleaning dominated. Significant data on food service hot-water use are available from other ASHRAE and non-ASHRAE funded research projects. It would be beneficial to fund a separate research project to study information from those multiple other laboratory and field tests to produce normalized cumulative volume versus time interval (CVdt) curves for food service facilities. That was beyond the scope of the RP-1544 project, so we simply worked with the data we had from the RP-1544 results to show the technique.

We believe the RP-1544 field test results give us the confidence to predict bathing and guest room cleaning related hot-water loads and their timing reasonably well. There were significant similarities in bathing hot-water use between the two different types of hotels tested, and those findings agree with findings from many residential hot-water use field tests.

From the RP-1544 field test data we could understand what some of the common area cleaning hot-water uses were, such as common area bathroom cleaning, coffee serving and clean up, floor and carpet cleaning, and more. There were probably some unanticipated hot-water uses that we could not identify in the test hotel that had meeting rooms. For example, we saw spa filling with potable hot water in the hotel that did not have meeting rooms. There is no guarantee that the non-occupancy-related (what we called the baseload) hot-water use in the hotel with meeting rooms (what we called the business hotel) was representative. However, the uncertainty of using the information on baseload hot-water use we did gather from a business hotel is no worse than any of the other common hotel/motel hot-water system sizing methods that either didn't have such information at all or had similarly limited information.

In regards to the question about how food service affects hot-water sizing, we believe that the people commissioning the design of the hotel and food service facilities should have some knowledge of how the hotel and the food service facilities will be used. For example, will breakfasts be served? Will dinner be served? Is the food service fast food (e.g., throw-away plates and utensils) or full service (e.g., requiring a dishwasher)? That being said, the food service hot-water use from this one field test cannot be claimed to be representative of all food service. Additional data from more food service facilities, analyzed using the same CVdt approach, would be beneficial.

In the paper, we show how the CVdt sizing approach can be applied to a travel hotel that has food service. In this case, we assume that the CVdt curves for the kitchen circuit of the business hotel are also representative of the example travel hotel's food service. Such curves, in normalized form, can be used to size equipment for food service facilities of differing sizes, but limited information is currently available on how food service hot-water use scales with food service facility size and fixtures present. The field test shows that food service hot-water use does not seem to scale well with respect to number of meals served, suggesting that there are other drivers such as cleaning and sanitation requirements and uncontrolled (but controllable with user awareness) simultaneous batch-fill hot-water uses that dictate much of how food service hot water is used. The paper shows how to size separate hot-water circuits for each major hot-water use category (guest room circuit, food service circuit, and laundry circuit) and how to combine the various loads on a single circuit.

While this method is not perfect given the shortage of information on food service hot-water use analyzed using the CVdt approach, the technique is still better than many of the common hotel hot-water system sizing techniques, which do not even mention whether food service was included in the design information.

Regarding your question about our data: given the similarity of the bathing hot-water use between the two hotels in the paper to data from hundreds of residential field tests (cited in the References section) and the fact that bathing hot-water use appears to be the single largest hotel hot-water use category, we believe that at least the bathing/guest room cleaning portion of hotel hot-water use (the part proportional to occupancy) can be used to determine the hot-water use and hot-water draw profiles for hotels and motels almost anywhere. The only unknown is potential differences of design-day occupancy, where, for example, some high-traffic hotels and motels near major tourist attractions might have average higher numbers of occupants per room on the design day compared to what might be seen in more rural areas. Interestingly, the peak design-day number of simultaneous bathing events and the time distribution of bathing events of both hotels, and of numerous combinations of residential field test sites, all seem to show similar CVdt curves when normalized, at least for the early parts of the CVdt curves, which are bathing dominated.

However, the portion of hot-water use that is not proportional to occupancy (e.g., for cleaning meeting rooms and common area bathrooms in hotels with meeting rooms) was observed to be quite variable from day to day for hotels that had meeting rooms, depending on whether or not meetings were happening, among other factors. It would be good to have better understanding about how this baseload varies and why (i.e., to what is it proportional?).

Lacking better information, scaling the baseload hot-water use using the methods shown in the paper should work well if one knows whether or not meeting rooms are present. Of course, there are often unusual hot-water uses that must also be accounted for, such as refilling swimming pools and spas from the potable hot-water system, or otherwise used in unusual amenities.

Even though the hotel data using the CVdt technique in our paper are from only two hotels, the number of hotels represented in the currently available older design and sizing methods did not have data from many sites either—usually less than ten to fifteen at best, and sometimes only one or two.

The commenter is to be acknowledged for his original work that helped lead designers recognize that there were multiple combinations of heating rate and storage volume that would work for any given hot-water system design. As the commenter knows, he provided us with his original raw data so we could apply our CVdt analysis method to it and compare it to the new data for hotels. We found that when the differences in flow rates of older versus newer shower heads were accounted for, the data were very similar to the new data when normalized. The biggest difference was that the commenter's original data seemed to suggest much lower design-day occupancy levels than we saw in the RP-1544 field test (around 1.5 people per room versus 2.5–2.8 people per room). This difference in design-day occupancy could be due to any number of factors, such as motels versus hotels (but given that the travel hotel of the RP-1544 field test was somewhat similar to older motels, we doubt this was the biggest factor), location in more rural areas, or simply perhaps more people are traveling now than in the 1960s.

We analyzed the commenter's original data and had phone conversations with the commenter when we first recognized the sizing discrepancy to better understand the basis for the recovery rate method results in the *ASHRAE Handbook*. We learned several important things, some of which are discussed in the paper.

First, the design methodology used in the travel hotel example in the paper uses the largest design day for sizing, whereas we learned that the commenter's plots are based on load curves that are somewhat less than the peak design day. (It appeared something like 90% to 95% of days did not exceed levels of hot-water use). This made us realize that it is not really necessary to size for the peak design day as long as some redundancy is built into the sizing. For example, one could provide redundancy by providing one system that is capable of serving the whole hot-water load by itself, then provide another system of equal size as backup in case of failure of the primary system (resulting in 100% oversizing). Another alternative would be to provide three equally sized systems, any two of which could satisfy the whole hot-water load, with the third unit available as backup in case of failure of one of the other two systems (resulting in 50% oversizing). Another alternative would be to provide four equally sized systems, any three of which could satisfy the whole hot-water load, with the fourth unit available as backup in case of failure of one of the other three systems (resulting in 25% oversizing).

The fact that the original recovery rate sizing method seems to work fairly well is probably indicative that it may be acceptable to provide a total water heating capacity, including the backup redundancy portion that is just able to serve the total load, on the highest use day. As long as multiple (around three or more) equally sized portions of the system are provided and kept in good working order, the probability of failure of any one part of the system on the highest use day is low. Moreover, some amount of the hot-water use is under control of the hotel/motel operators, so if a problem occurs with one part of the water heating system, hot-water use patterns can be altered to minimize hot-water shortages until the problem portion is repaired.

Regarding our supporting of the conclusion that the recovery rate method might result in hot-water system undersizing, we applied the recovery rate method to both hotels monitored during the RP-1544 field test. In both cases, the recovery rate method would have produced a system that would have experienced hot-water shortages on quite a few days (greater than 10%), even with a fair amount of redundant capacity (e.g., 25% to 50%) added. This finding resulted from the fact that the design-day room occupancy from the field test was quite a bit higher than what was evident in the commenter's original data (2.5–2.8 guests per room, with all rooms occupied as compared to around 1.5–1.8 guests per room, with all rooms occupied) and was approached more frequently.

Given that most of the old hotel hot-water system sizing methods appear to significantly oversize systems (the recovery rate method being the exception), we believe the CVdt method is a superior method for sizing hotel hot-water systems, although it would be beneficial to have more information on what makes up baseload hot-water uses. Moreover, using the CVdt method over the recovery rate method in hotel/motel design would produce systems that are larger in heating rate, storage volume, or both, meaning that running out of hot water would be less likely with the CVdt approach, which should increase designer comfort with the technique.

Moreover, this very paper is intended to be the reference document for updated hotel hot-water system sizing information to be included in the "Service Water Heating Systems" chapter in next edition of *ASHRAE Handbook—HVAC Appli-*

cations. The authors are on the Handbook subcommittee responsible for the chapter.

All four sizing methods are in common use today, even though use of the CVdt method is limited because the necessary plots for various applications have not yet been generated. One of the authors was the Service Water Heating Handbook subcommittee chair for eight years and fielded inquiries about the chapter for ASHRAE. Feedback from Handbook users highlighted the fact that dramatically different water heating system heating rate plus storage volume combinations were produced by the different methods, leaving designers confused about which sizing approach was appropriate. In response to user inquiries, the Handbook was updated to reflect the extreme ages of most of the sizing methods, most being created well before the mandate of water- and energy-efficient fixtures and appliances. The various sizing methods tend to work but usually produce oversized systems, sometimes substantially so. The exception is the recovery rate sizing method, because ASHRAE did not receive many inquiries about that method.

We suspect that some design firms that have sized water heating systems for multiple hotels have learned by trial and error which heating rate plus storage volume combinations work for certain types of hotels in certain locations. That information is not usually made available to the general public.

There are anecdotal stories about hotels and motels providing massive amounts of hot water over short periods of time in response to unusual events, such as local disasters or multi-day concerts, when rooms were rented for short periods so people could bathe. These heroic abilities reveal that the water heating systems in those facilities were significantly oversized for normal use.

The survey of the 116 designers and its findings that the commenter mentions (and authored) was discussed in one of the references in the paper. That reference talks about the significant oversizing that often results from the many hot-water system sizing techniques, most of which are based on limited laboratory and field test data—portable computers and sophisticated data loggers did not exist in that era—plus a lot of "statistical analysis" (i.e., guesswork about how coincident hot-water uses might be). That reference mentions that over the years designers recognized that commonly used hot-water system sizing techniques were producing oversized systems, leading practitioners to provide various "adjustment" factors, which better represented the time coincidence of hot-water end uses than the original assumptions.

The commenter's work (which resulted in the recovery rate sizing method in the *ASHRAE Handbook*) was a major step forward in using real field test data as opposed to statistical guesswork to account for hot-water use coincidence. The commenter provided the authors with some of the original data from his research, to which we applied modern analysis methods as mentioned earlier in this response.

While the CVdt method is not perfect, and there are still only a few building categories for which CVdt data are available, the CVdt method is a significant advancement in hot-water system design techniques, especially because it is based on modern field test data, not statistical guesswork. (The CVdt plots inherently contain experimentally determined hot-water use coincidence information). This method represents modern water- and energy-efficient fixtures and appliances.

Regarding not comparing or evaluating other hot-water system sizing methods: most published sizing methods can be traced back to being modifications of the original work on water system sizing (from the 1920s to 1940s) as described in the *ASHRAE Handbook* and this paper. We limited the comparisons of this paper to just the hot-water system design techniques listed in the "Service Water Heating Systems" Handbook chapter.

The hot-water system sizing techniques in the American Society of Plumbing Engineers (ASPE) references are very similar to what is in the *ASHRAE Handbook*, and the sizing techniques come from similarly old data.

The ASPE's *Domestic Water Heating Design Manual* describes the four hotel/motel categories as follows:

1. **Convention Hotel or Motel.** Has guest rooms, meeting rooms and ballrooms, food service, and other amenities that would allow holding of large conventions or meetings.

   This category is comparable to the business hotel in the RP-1544 work. The biggest differences will be in how large the baseload hot-water use (the part not proportional to guest room occupancy) is, which will be a function of how the meeting rooms and food service are operated. We have stated that more information is needed on hotel and food service baseload hot-water use to better understand how to predict design conditions from a wider variety of hotels. Remember that the peak baseload hot-water use is still much lower than the peak bathing hot-water use.
2. **Business Travelers Hotel or Motel.** Has desk, phones, and other amenities in the rooms to allow business travelers to conduct work from their rooms. Does not necessarily have meeting rooms.

   This category is comparable to the travel hotel of the RP-1544 work, with the assumption that no meeting rooms are present. Nearly all hotel/motels now have the necessary desk, phone, and Internet connection abilities.
3. **Resort Hotel or Motel.** Typically located near theme parks, beaches, and other attractions catering to enjoyment.

   Theoretically such hotel/motels could experience slightly different hot-water use coincidence behaviors than those seen in either the travel or business hotels in the RP-1544 work. Given that the business and travel hotels demonstrated very similar, normalized bathing behaviors, if meeting rooms are not present, normalized hot-water use in these hotels would be similar to those of the travel hotel in the RP-1544 research. Both the test travel and business hotels demonstrated relatively small increases in peak hot-water use coincidence as the number of guests increased. Rather, as the number of guests increased, hot-water use spread over longer time periods because of each room typically having only one shower/bath, requiring sequential, as opposed to simultaneous, bathing.

A slight exception to this assumption is when the enjoyment/attraction may have time-of-day factors that shift timing of hot-water use (e.g., evening events as opposed to daytime events). However, this would still not shift the normalized CVdt curves very much, because they are not based on time of day but rather on variously sized time intervals throughout the day.

4. **General Occupancy Hotel or Motel.** Does not have ballrooms or a large number of meeting rooms that would cause concentrated periods of high hot-water use

This category is comparable to the travel hotel of the RP-1544 work, assuming no meeting rooms are present. Again, the CVdt curves are not derived based on time of day but rather from variously sized time intervals throughout the day, meaning that they are relatively independent of time of day. However, when combining several water heating circuits together, such as laundry, food service, and guest room circuits, some knowledge must be provided as to appropriate times shifts in order to do the addition; one should not just use the 90 minute guideline from the RP-1544 research.

Finally, we are waiting for feedback from readers on what they need that the RP-1544 work could shed more light on before we write the sixth paper. ASHRAE requires only one technical paper be written for ASHRAE-funded research. We have done five so far.

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LB-17-014

Interpreting Occupant-Building Interactions for Improved Office Building Design and Operation

Sara Gilani
Student Member ASHRAE

William O'Brien, PEng, PhD
Associate Member ASHRAE

Juan Sebastián Carrizo
Member ASHRAE

Jaya Mukhopadhyay, Assistant Professor, Montana State University, Bozeman, MT: What were the issues you saw with measuring operative temperature?

Sara Gilani: For measuring operative temperature, mean radiant temperature is a required input, for which black-globe thermometers can be used. However, a black-globe thermometer should be located close to occupants, which may be intrusive to occupants' activities in long-term in-situ monitoring studies. It is worth mentioning that the inventions of some previous researchers (e.g., Konis [2013]) through designing mini-stations can alleviate these limitations in measuring the globe temperature.

Peter McDonnell, McClure Engineering, St. Louis, MO: I suggest comparing the room loads (heating and cooling) with the percentage of peak loads. Did you measure and correlate ceiling lighting levels with levels at the work surfaces?

Sara Gilani: Correlating indoor illuminance on the workplane and ceiling is necessary future work. However, correlating indoor illuminance measured on the workplane and ceiling can be very case-sensitive. For instance, occupant location, office layout, surface material, and window transmittance can affect the statistical relationship between workplane and ceiling illuminance. Therefore, researchers must document case studies thoroughly to inform other researchers if their correlation coefficients are applicable to other case studies.

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