M I N U T E S

DRAFT / UNOFFICIAL

TECHNICAL COMMITTEE 8.7

2024 Winter Conference

January 22, 2024

Note: These draft minutes have not been approved and not the official, approved record until approved by the Technical Committee.

1791 Tullie Circle, N.E./Atlanta, GA 30329
404-636-8400

DRAFT

TC/TG/MTG/TRG MINUTES COVER SHEET

(Minutes of all Meetings are to be distributed to all persons listed below within 60 days following the meeting.)

TC/TG/MTG/TRG No. 8.7 DATE

TC/TG/MTG/TRG TITLE Variable Refrigerant Flow

DATE OF MEETING January 22, 2024 LOCATION Chicago, IL

MEMBERS PRESENT	YEAR APPTD	MEMBERS ABSENT	YEAR APPTD	EX-OFFICIO MEMBERS AND ADDITIONAL ATTENDANCE
Shawn Andrews, Chair	2022			
Scott McGinnis, Vice Chair	2022			
Douglas Tucker, Secretary	2021			
Kyle Gluesenkamp	2022			
Walter Hunt	2022			
Badri Patel	2022			
Christopher Williams	2022			

DISTRIBUTION: ***All Members of TC/TG/MTG/TRG plus the following:***	
TAC Section Head:	SH8@ashrae.net Where x is the section number
All Committee Liaisons As Shown On TC/TG/MTG/TRG Rosters (Research, Standards, ALI, etc.)	See ASHRAE email alias list for needed addresses.
Mike Vaughn, Manager Of Research & Technical Services	MORTS@ashrae.net

1. **Call to Order**
   The meeting was called to order at 1:05pm.

2. **ASHRAE Policies**
   a. **Code of Ethics –** The Chair reviewed the ASHRAE Code of Ethics statement.
   b. **Anti-Trust Policy –** The Chair reviewed the ASHRAE Anti-Trust statement.
   c. **Recording Policy –** Recording (audio, video, screenshots) of ASHRAE meetings, including online meetings, is strictly prohibited.

3. **Welcome / Introductions**
   Introductions were made.

4. **Minutes**
   a. No minutes were distributed from the previous two meetings. Draft minutes from the Atlanta and Tampa meetings were prepared by the secretary but the meetings were "unofficial" because the roster issues had not yet been sorted out. Doug has sent all draft minutes from these meetings to the chair for review and distribution prior to the meeting in Indianapolis.

5. **Agenda Review / Updates**
   a. The agenda was reviewed and accepted during the meeting. John Cummings will be leaving early so the committee agreed to start with liaison reports.

6. **Liaison reports**
   a. 90.1: John Cummings attended the Mechanical Subcommittee and full committee meetings. Predominantly introduction of new concepts for 90.1 to consider: enforcing energy recovery, fault detection/diagnostics, ventilation for residential acceptable IAQ. Of interest to TC 8.7 may be the proposed insulation thicknesses for hot gas pipes - watch 90.1 to see the recommendation. Another topic is the effort by 90.1 to update efficiency tables, also introduce Air-to-Water efficiencies, possibly.
   b. 189.1: No change; VRF tables removed from the standard, now only a reference to 90.1.
   c. 205: Jeff Whitelaw reported that the PC is now working on VRF, had a general discussion in Chicago on whether to use a systems or component approach to modeling. What variables are needed, i.e., refrigerant quantity, etc. What to do if OEMs do not provide performance curves?
   d. MTG.LowGWP: Doug reported on the MTG activities related to Low GWP refrigerants.

7. **Subcommittee Reports**
   a. **Handbook**: Chris Williams was not present. The VRF chapter was recently revised and will be published in the 2024 HVAC Systems and Equipment handbook. The TC asked for volunteers to take over this leadership role. Ned Bent, Fujitsu, volunteered. Brian Bogden recommended that the VRF chapter be revised to bring it in alignment with ASHRAE Guideline 41-2023.
   b. **Membership**: Madhav Kashinath, Membership Subcommittee Chair, reported that a transition is imminent. Shawn's term as chair ends this society year (end of June 2024), and the chair position rolls to Scott; there is an opening for vice chair. Doug volunteered.
   c. **Programs**: Badri Patel, Program Subcommittee Chair, reported on the program tomorrow at the AHR Expo, 1:30-3:00pm. Three potential topics can be submitted for the Annual Conference in Indianapolis. The RP and Research submissions passed; others due February 26.
   d. **Research**: Chris Laughman presented on a potential research project "Cloud-Based Coupled Building/Equipment System Evaluation" (see end of meeting report). Chris walked through his

research idea and estimated the costs at $100-$120k. This is at the feedback stage so please contact Chris if you have any questions or additional research ideas.

e. **Standards**: Chandra Gollapudi was not present.
f. **ALI.** Brian Bogdan reported that the VRF training class will be held in Chicago but he has no idea of attendance number. There has been less request for online courses, so maybe less interest.
g. **Webmaster** Currently nothing much on the website, so there is an opportunity to volunteer to be webmaster to replace Badri; Chris Laughman volunteered.

8. **Old Business**
   a. No old business

9. **New Business**
   a. Jeff Whitelaw informed the TC on the Technology Transition rulemaking under the AIM Act, and that VRF will be prohibited on 1/1/2026 unless EPA grants a one-year (or more) sell-through similar to what was granted to residential systems. OEMs and engineers need certainty. For example, core and shell construction buildings may not be built out with indoor units for tenants for multiple years after the outdoor units have been installed. The TC recommended that this goes through AHRI.

10. **Adjourn**
    a. The meeting was adjourned at 3:00pm.

TC 8.7: Prospective Research Project Notes

Chris Laughman (laughman@merl.com)
Mitsubishi Electric Research Laboratories
21 January 2024

Motivation: Background

One significant challenge in reducing the energy consumption of buildings and improving occupant comfort is the difficulty of using simulation to accurately predict whole building dynamic thermal behavior and energy consumption. While there are a variety of extensively developed methods for predicting the energy consumption of individual systems, e.g., building envelope, HVAC systems, appliances, etc., the fact that the energy consumption of the whole building depends on difficult-to-characterize interactions between these systems imposes a barrier to system-of-systems type assessments. Such barriers are due to a wide variety of factors, including software complexity, numerical challenges related to the wide variety of timescales under study, and the need to couple together many different physical domains (e.g., mechanical, thermal, electrical, chemical). Current building energy simulation software (e.g., EnergyPlus) is not well-suited to addressing these challenges because its equipment models use a quasi-static load-based approach for simulating thermal loads and the HVAC response. Moreover, next generation grid-connected efficient buildings add new layers of complexity to these challenges due to the inclusion of distributed and renewable energy systems to these already complicated systems.

A variety of benefits would accrue with new capabilities of being able to simulate the coupled behavior of buildings and the associated equipment. Perhaps most importantly, such a capability would improve predictions of the energy performance over a extended periods of time, allowing mechanical engineers to understand the practical effects of equipment selection and sizing on the dynamic building performance. Such models could also be used in the design of building-level controls to avoid the undesired behaviors such as conflicting setpoints or improper sequences. In addition, such capabilities could also provide services that add new value, such as performance contracting for building HVAC systems, that are aligned with widespread policy goals of monetizing good building performance and reducing energy consumption. Other trends motivated by these policy goals, such as load-based rating tests in which the system rating or performance is evaluated with active controls (e.g., CSA EXP07), complement such capabilities well; for example, an improved simulation model that captures interactions between the building envelope and equipment could potentially be used for preliminary rating evaluations that are difficult to do in experiment due to the time and cost required (defrost cycles, etc.). Such methods would allow more repeatable scenario evaluation.

Motivation: Enabling Technical Advances

These technical challenges and opportunities for whole building dynamic simulation are well-known, and have attracted research interest because of the value of solving these problems. One significant effort that has taken place since 2016 is the development of a next-generation building energy simulation engine, a recently (2023) release tool called the Spawn of EnergyPlus (Spawn). Spawn improves upon EnergyPlus by providing a means for simulating the dynamics and interactions of building systems with the behavior of the envelope, enabling these studies of building dynamics coupled to HVAC systems. The function of Spawn is enabled by the Modelica language, which is an advanced language for multiphysical system simulation (e.g., vapor compression cycles, interconnecting thermal/electrical/mechanical domains). This also leverages extensive work on the Modelica Buildings library, which is a library of many building components that can be used to build complex energy system models, as well as Open Building Control and the Control Description Language, which code ASHRAE building operation sequences into a testable form. These technologies are coupled with the Functional Mockup Interface, which allows EnergyPlus models of the building envelope to be connected to Modelica models of the building systems, thereby leveraging the advantages of each technology. Given these advances in tools that enable building envelope models to be coupled with dynamic and control-oriented equipment models, there is a significant opportunity to advance equipment simulation technology for complex equipment (e.g., VRF systems) that can be interfaced to this the more flexible building simulation platform of Spawn. This will allow the interactions between the systems under automatic control to be studied and used for system design and evaluation in next-generation energy efficient buildings. This could build on the variety of distinct equipment models developed recently, which have improved to the point that they can reproduce the time-varying and nonlinear behavior of equipment (switching between heating and cooling, on/off cycling, defrost, etc.) so that product-type controls with hybrid continuous/discrete logic and state machines can be implemented to look at real closed-loop system performance.

Problem: Proprietary Equipment and Controls Models

Perhaps the most straightforward use of this new technology would be for equipment manufacturers to build and publicly distribute models of their equipment, such as VRF systems, that include high-accuracy models of the automatic control systems governing the system behavior. Such models could connect to building models and describe the dynamic interactions that take place between the envelope and equipment, and would describe the realistic behavior of the coupled dynamical system. This would enable the construction of a detailed portrait of the time-varying behavior of the building under variations in weather, occupancy, and so forth with the equipment (e.g., compressor and fan speeds, valve positions) responding to measured data. These equipment models could then be provided to building designers, regulators, and other interested parties to connect to their building and other equipment models to conduct performance assessments of coupled building systems.

While this is theoretically possible, competitive forces actively disincentivize manufacturers from providing such equipment models for unfettered public distribution because of the proprietary nature of the automatic controls, as well as the potential for competitors to easily and rapidly conduct detailed assessments of equipment performance using such models. This would be particularly true for equipment models that are decoupled from a building, as the causal equipment behavior of the equipment could be directly observed by actuating system variables and looking at the resulting system behavior. Competitors would thus be able to compare their own equipment performance with the details of the publicly available models and incorporate this information in their equipment design processes. Moreover, there is potential for these equipment models to be used in other unforeseen or unexpected manners that were not contemplated by the original model designers, and which could also have long-term detrimental consequences for the manufacturers. Moreover, significant investment is typically required to create accurate equation-based models of many types of equipment (e.g., vapor-compression cycles in VRF systems) as well as the associated hybrid continuous/discrete control systems, which also limits the appeal of making such models available to the public. Consequently, there is little internal incentive on the part of the manufacturers to make their models publicly available, despite the opportunities available from building level system simulation, analysis, and design.

Solution: Cloud-Based Coupled Building/Equipment System Evaluation

As manufacturers have to manage the tradeoff between model privacy and evaluation functionality, we propose an RP to design and construct a prototype implementation of a service in which a prospective building model can be uploaded to a manufacturer's cloud-based tool which hosts detailed equipment models, and define an API whereby the hosted equipment models could be connected to the uploaded building models to simulate the dynamic interactions between the equipment and the building envelope for the purposes of scenario evaluation and performance analysis. Such an approach would allow manufacturers to manage the privacy and access of their detailed equipment models private and manage access to these detailed equipment models, while enabling more accurate integrated building simulations to provide detailed assessments of thermal comfort and energy consumption. Such models would capture the actual part-load performance of these systems in realistic conditions, demonstrating the performance benefits of different types of equipment.

This is described in more detail as follows. A conventional model of the building envelope can be built using the existing standard simulation tool EnergyPlus. This model will include elements such as the building envelope, the boundary conditions (building orientation, boundary conditions, etc.), and occupant/load schedules, but will omit the equipment models. This model will then be imported into Modelica via Spawn to accurately describe the interactions between the EnergyPlus envelope models and acausal dynamic models of the air behavior. While general-purpose equipment component models (pumps, fans, simple air-to-water heat exchangers) are available from the Modelica Buildings library to construct built-up HVAC system models using Spawn, we do not expect detailed equipment models for complex systems (e.g., VRF, multi-functional heat pumps) to be publicly available. However, many manufacturers may have such models for internal product development and evaluation processes, and can define a set of use cases for which their use is permitted, such as whole building energy simulation. These manufacturers could make these models accessible via a cloud-based service for managing simulations and permissions, so that the details of the internal equipment operation is obscured but the equipment model is connected to the Spawn building model. In such a scenario, a user (mechanical engineer) could upload their Spawn model to a manufacturer's website and configure a selected set of equipment models to plug into the building model for specific indoor spaces. After configuring the coupled building/equipment model, cloud-based simulations could be conducted to assess the thermal performance of the building with these detailed equipment models for the purposes of system and control design, as well as estimating the overall system energy performance. Such information could be used to iteratively improve equipment sizing, understand the energy implications of tradeoffs between facade construction and equipment design, and provide targets for building energy consumption and performance contracting.

The development items in this project would be focused on using prototype system and building envelope models to define an interface between these two types of models. This would involve the description of interfaces for the building models and terminals that can be exposed using FMI for equipment models, as well as the corresponding interfaces that are exposed by the equipment models via FMI. In addition, a systematic and simple method for connecting specific equipment models to equipment spaces is essential, as is the definition of the backend that would need to be supported by the manufacturers for the purposes of system simulation and recording of simulation output. Finally, a complete demonstration of a complete simple prototype would serve to evaluate the overall technology readiness for such an integrated software package, and identify areas of development for further improvement. Such a project is well-suited to an ASHRAE research project because it has a well-defined scope, would serve to integrate a variety of technologies that are interoperable for achieving higher building-level performance, and would provide prototypes that could be used to accelerate technology innovation from manufacturers to achieve lower building-level energy consumption.