BSR/ASHRAE Standard 229P

Public Review Draft

Protocols for Evaluating Ruleset Application in Building Performance Models

First Public Review (April 2024)
(Complete Draft for Full Review)

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Foreword

Building energy codes such as ASHRAE Standard 90.1 "Energy Standard for Buildings Except Low-Rise Residential Buildings" typically include both prescriptive and performance options for demonstrating compliance. The performance option requires the use of building performance modeling software to demonstrate that the building's expected energy performance compares favorably to that of a reference or baseline building. Examples of compliance pathways that use the performance approach include ASHRAE 90.1 Energy Cost Budget and Performance Rating Method ("Appendix G"), California Title 24's Alternative Calculation Method and RESNET Home Energy Rating System (HERS).

The process for representing a proposed design in building performance modeling software, and for configuring the baseline building model from the proposed building model is defined by the set of *rules* (a *ruleset*) included in the energy code. A *ruleset* contains both simple *rules* like the requirement for lighting power density for different space types but also more complicated *rules* such as the HVAC system type and controls based on the building use type, size, climate zone, etc. In most cases, *rulesets* are quite detailed, and their application is tedious. Modelers may apply them inconsistently due to differences in interpretation or human error. To reduce modeler effort and error, some building performance modeling software either partially or completely automates the application of *rulesets* and the creation of baseline models. These automated software implementations may be inconsistent with one another for the same reasons.

The possibility of error and inconsistency requires building officials or other adopting authorities to whom models are submitted to ensure appropriate *ruleset* application via manual review. Like the *ruleset* application process itself, the *ruleset* application review process is tedious and inconsistent. It can be a significant bottleneck for jurisdictions and a barrier to adoption of performance-based compliance.

ASHRAE Standard 229 is motivated by the desire to improve the rigor and consistency of *ruleset* application, to reduce the cost of performance-path compliance submittal review, and in doing so to encourage the adoption and implementation of performance-based codes.

While ASHRAE Standard 140, "Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programs," tests some of the physics involved in building performance modeling, there is no standard method for testing the application of *rulesets* to *building performance models*.

There are two basic ways to improve the consistency and rigor of *ruleset* application. The first is to test and certify *ruleset* application software and then trust that baseline models generated by this software are correct. This is the path supported by ASHRAE Standard 140 which defines test suites and acceptance ranges for building performance simulation engines that could be used to support simulation engine certification. Implementing this approach for *rulesets* would require a large test suite of complex models which, to be practical, would require a level of model interoperability that does not currently exist. It would also not cover baseline models that are created manually.

Standard 229 takes an alternative approach of supporting the partial automation of the model and *ruleset* application review process. Standard 229 defines a reporting schema called the *Ruleset Evaluation Schema*. The *ruleset evaluation schema* describes buildings at the same level of detail in

which *rulesets* describe them and is intended to be both simulation-engine and *ruleset* agnostic. Building performance modeling software exports individual models in *ruleset evaluation schema* format. To comply with 229, building performance modeling software must only be able to export models in *ruleset evaluation schema* format, it need not automate *ruleset* application.

Ruleset evaluation schema files corresponding to proposed and baseline buildings models—or a different set of models depending on the *ruleset* –can then be checked by a *ruleset*-specific *Ruleset Checking Tool*. A *ruleset checking tool* produces a standard report that lists which rules were checked, which passed, which failed and why, and which areas of the model could not be checked automatically and must be reviewed manually. The *ruleset checking tool* allows a model reviewer to make the best use of their time by directing their attention to areas of the model that require manual review. It is intended that the *ruleset checking tool* be made available to both reviewers and modelers so that modelers may use it prior to submission to address issues that are flagged and to provide documentation for issues that cannot be addressed. By allowing modelers to check and tighten their models prior to submission, the *ruleset checking tool* also has the potential to reduce review iterations. Figure 1 shows the intended use of 229-compliant building performance modeling software and the *ruleset checking tool* by the modeler and reviewer.

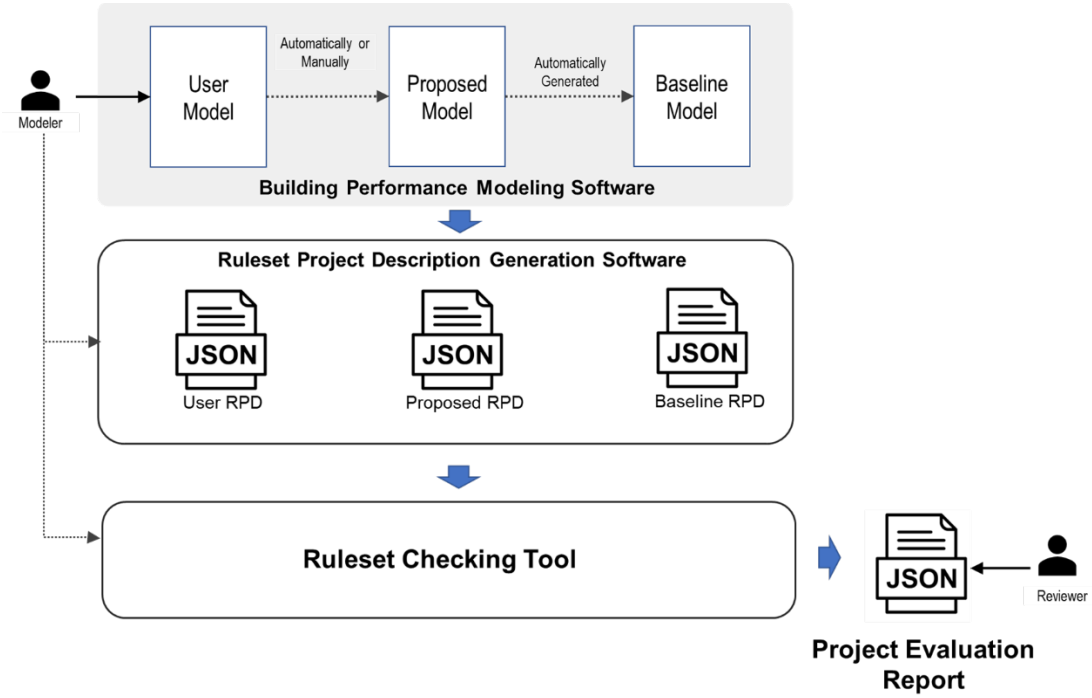


Figure 1: Project Checking Workflow as Defined by Standard 229

To support this workflow, Standard 229 defines the following:

- A *Ruleset Evaluation Schema*
- Compliance requirements and tests for building performance modeling software that exports models in *ruleset evaluation schema* format.
- Compliance requirements and tests for a *Ruleset Checking Tool*.

The data formats and procedures specified by Standard 229 are developed under ASHRAE and ANSI consensus processes with participation of jurisdictions, application software developers, and engineering practitioners.

This first version of Standard 229 lays the groundwork for developing and defining standardized approaches for partially automated verification of *ruleset* application in *building performance models*. Compliance with Standard 229 may require substantial work by application software developers. Their experiences applying the standard will inform its future direction.

Standard Project Committee (SPC) 229 is expected to be reconstituted as a Standing Standard Project Committee (SSPC) and anticipates creating addenda, including:

- *Ruleset* checking specification for additional *rulesets*.
- Improvements to data schemas to make data models more accurate and representative of industry practices, and to accommodate additional *rulesets*.
- Additional tests to improve functionality of *ruleset checking tool*s and *ruleset evaluation schema* exports from building performance modeling software.

The first publication public review version of the Standard excludes the *ruleset project description* files created for the *rule tests* defined in Normative Appendix E and the *ruleset project description* files for the *ruleset project description generation software* tests defined in Informative Appendix F. These will be added for the second public review.

1 Purpose

This standard establishes tests and acceptance criteria for application of *rulesets* and related reporting in *building performance models*.

2 Scope

This standard applies to evaluation of the implementation of *rulesets* associated with new or existing buildings, their systems, controls, sites, and other aspects described by the *ruleset*. It establishes requirements for:

2.1 building performance modeling software

2.2 software that evaluates *building performance models* and associated information to check the application of a *ruleset*.

3 Definitions, Abbreviations, and Acronyms

3.1 General

Certain terms, abbreviations, and acronyms are defined in this section for the purposes of this standard. When the tense or plurality of the term is different than the defined term, the definition still applies. These definitions are applicable to all sections of this standard, wherever italicized. Terms that are not italicized shall have their ordinarily accepted meanings within the context in which they are used. Ordinarily accepted meanings shall be based on American standard English language usage as documented in an unabridged dictionary accepted by the adopting authority.

3.2 Definitions

building performance model: a computer representation of a building and how it functions including aspects of the building that impact energy use, water use, or occupant comfort.

rule: A requirement for inputs or performance metric calculation of a protocol that uses modeling for assessing building performance.

rule test: A procedure for verifying *ruleset checking tool* capability to correctly evaluate one or more *rules*.

ruleset: A collection of rules for demonstrating adherence with a protocol that uses modeling for assessing building performance.

ruleset checking specification: A set of requirements, specific to a *ruleset*, for documenting compliance of a *ruleset checking tool* and a *ruleset project description generation software* with the standard.

ruleset checking tool: a software tool that evaluates whether a *ruleset project description* is consistent with a *ruleset* and reports each *rule* evaluation outcome.

ruleset evaluation schema: schema that describes elements of *building performance models* that are relevant to *rulesets*.

ruleset model type: a *ruleset*-specific classification of *building performance models* for demonstrating compliance with a ruleset Informative note: For example, Normative Appendix E1 defines user model, proposed model, and baseline model ruleset model types for Standard 90.1-2019 Appendix G

ruleset project description: a file consistent with the *ruleset evaluation schema* representing a specific building project for the purpose of demonstrating compliance with a *ruleset*.

ruleset project description generation software: software used to create a *ruleset project description* based on one or more *building performance models*. Informative note: *Ruleset project description generation software* may be part of the building performance modeling software or a separate software tool.

3.3 Abbreviations and Acronyms

ACM	alternative calculation method
AFUE	annual fuel utilization efficiency
AHJ	authority having jurisdiction
bhp	brake horsepower
Btu	British thermal unit
Btu/h	British thermal unit per hour
Btu/ft2·°F	British thermal unit per square foot per degree Fahrenheit
Btu/h·ft2	British thermal unit per hour per square foot
Btu/h·ft·°F	British thermal unit per hour per linear foot per degree Fahrenheit
Btu/h·ft2·°F	British thermal unit per hour per square foot per degree Fahrenheit
cfm	cubic feet per minute
CHW	chilled water
CHWST	chilled-water supply temperature
COP	coefficient of performance
DOAS	dedicated outdoor air system
DX	direct expansion
EER/EER2	energy efficiency ratio
E_t	thermal efficiency

°F	Fahrenheit
HW	heating water
HVAC	heating, ventilating, and air conditioning
IEER	integrated energy efficiency ratio
LPD	lighting power density
OA	outdoor air
OAT	outdoor air temperature (dry-bulb unless wet-bulb is specified)
PSZ-AC	packaged single-zone air conditioner
PSZ-HP	packaged single-zone heat pump
PTAC	packaged terminal air conditioner
PTHP	packaged terminal heat pump
RESNET	residential energy savings network
SHGC	solar heat gain coefficient
SZ	single zone
VAV	variable air volume
W	watt

4 Utilization

4.1 General

This section describes the pathways for utilizing the standard for verifying *ruleset* implementation in *building performance models*.

4.2 Project Checking Path

Project checking path verifies the implementation of *ruleset* requirements in *building performance models*. The project checking path requires the following:

a. Project shall use a *ruleset project description generation software* that complies with the requirements specified in Section 7.

b. *Ruleset project description* shall be checked using a *ruleset checking tool* that complies with the requirements in Section 8.

Informative Notes:

1. Sections 7 and 8 include references to a *ruleset checking specification*, which includes, for example, a list of *rules* that need to be evaluated by the *ruleset checking tool* and testing requirements for a *ruleset checking tool* and *ruleset project description generation software*. The required content of a *ruleset*

checking specification is described in Section 6. Normative Appendix E1 provides a *ruleset checking specification* for Standard 90.1-2019, Appendix G, Performance Rating Method.

2. Project compliance with a *ruleset* may be determined based on review of reports generated by the *ruleset checking tool* and review of other aspects of the submittal which are not within the scope of the *ruleset checking tool* as defined by the *ruleset checking specification*. Informative Appendix D provides an example project checking summary report.

4.3 Software Checking Path

This section is not used.

Informative Note:

This edition of the standard does not include a checking path for software such as building performance modeling software that automatically implements *ruleset* requirements. A software checking path would typically define the minimum capabilities and testing requirements for a software to verify if it correctly implements *ruleset* requirements in an automatically generated baseline or reference model.

For example, California Energy Commission has defined a process for software checking path which is defined in a document called the alternative calculation method (ACM) Approval Manual. Similarly, residential energy savings network (RESNET) has defined procedures for verification and accreditation of software tools used to calculate home energy rating for single family and multi family dwelling units.

5 Ruleset Evaluation Schema

Building performance modeling software shall produce a *ruleset project description* consistent with the *ruleset evaluation schema* described in this section.

5.1 Format

The *ruleset evaluation schema* shall be in JSON format following the rules described in Standard 205 Sections 5 except 5.1, 5.7, and 5.8; Section 6 except 6.1, 6.2, 6.3, 6.7, and 6.8; and Section 7.

Informative note: when ASHRAE Standard 232P is published, the reference above may change to that standard.

5.2 Data Groups and Elements

The *ruleset project description* shall contain the data groups and elements are described at: http://data.ashrae.org/standard229/schema

[**Note to Reviewers:**

a. This webpage doesn't exist yet and will be added when the standard is approved for publication.
b. The schema development continues at: https://github.com/open229/ruleset-model-description-schema.
   This will move to an ASHRAE GitHub repository when the standard is approved for publication.
c. Tables presented in Normative Appendix A should be consistent with the schema.]

5.3 Data Group Hierarchy (informative)

The hierarchy of the data groups are shown in Figure 5.3

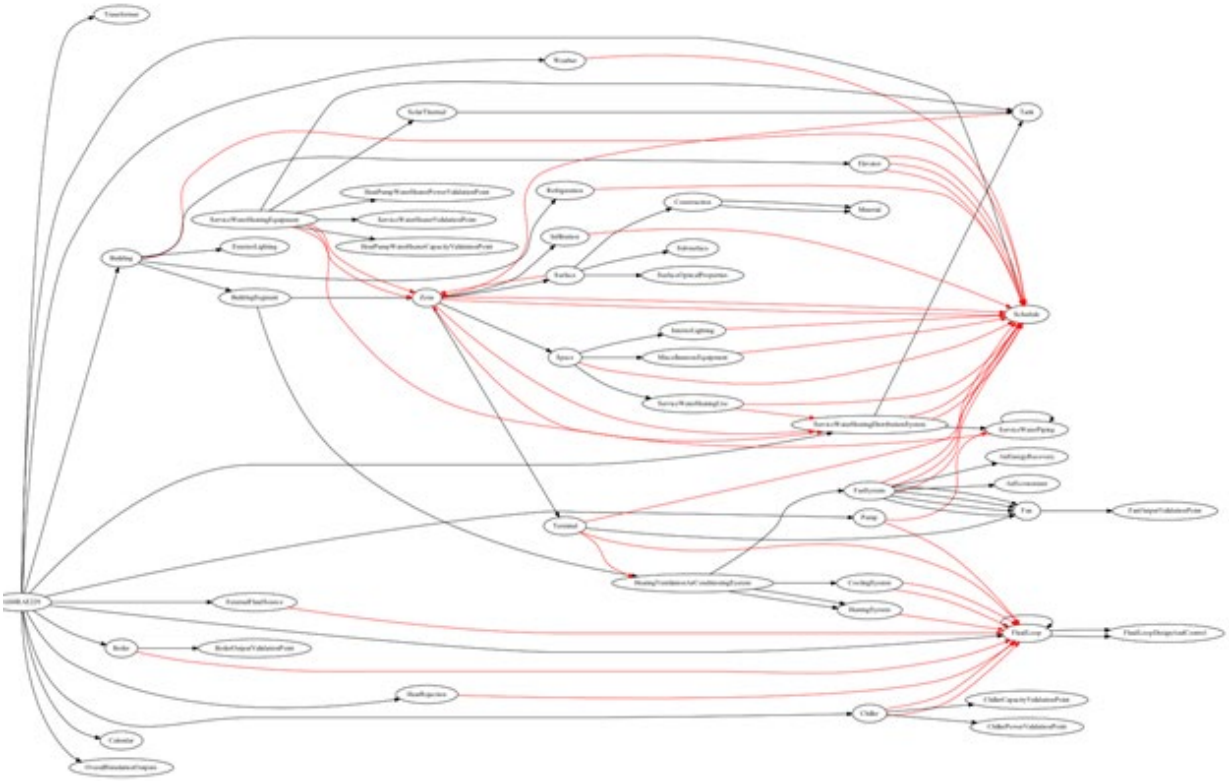
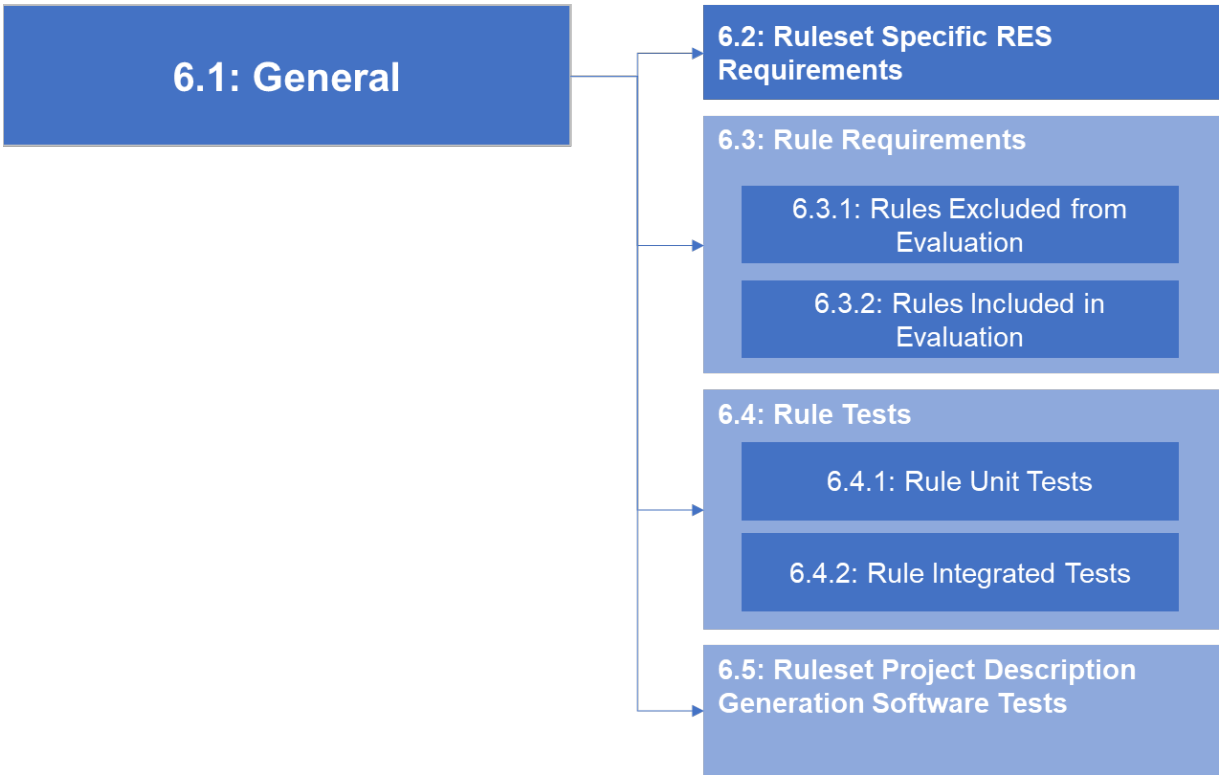


Figure 5.3 Data Group Hierarchy

6 Ruleset Checking Specification Requirements



6.1 General

6.1.1 Scope

This section describes information that shall be included in the *ruleset checking specification* for a given *ruleset*.

- **Informative Note:** The *ruleset checking specification* may be part of this standard or external to it. Normative Appendix E1 provides the *ruleset checking specification* for Standard 90.1-2019.

6.1.2 Minimum Required Content

Ruleset checking specification shall include the following:

a. The approach being used to test compliance with a *ruleset*, based on the utilization paths specified in Section 4.
b. Definitions of applicable *ruleset model types*. **Informative Note**: For example, 90.1-2019 Appendix G *ruleset checking specification* in Appendix E of this standard defines user, proposed, and baseline *ruleset model types.*
c. Version of the *ruleset evaluation schema* used in the ruleset checking specification.
d. *Ruleset* specific *ruleset evaluation schema* attributes following Section 6.2
e. The data groups or elements of the *ruleset evaluation schema* required for evaluating *rules*.
f. List of the r*ules* within a *ruleset* that are required to be evaluated by the *ruleset checking tool* and *rules* that are excluded from evaluation following Section 6.3.1 and Section 6.3.2

g. Applicable *rule* evaluation outcomes, if different from Section 6.3.2.2
h. *Rule* evaluation precision, as described in Section 6.3.2.3
i. *Rule tests*, as described in Section 6.4
j. *Ruleset project description generation software* compliance requirements, as described in Section 6.5.

6.2 Ruleset Specific Ruleset Evaluation Schema Attributes

Section 5 describes the *ruleset evaluation schema* to be used by the *ruleset checking tool* for verifying *ruleset* implementation. Additional *ruleset* specific *ruleset evaluation schema* attributes, if applicable, shall be specified in the *ruleset checking specification* and may include one or more of the following:

a. *Ruleset* specific enumerations such as lighting space types
b. *Ruleset* specific output schema
Informative Note: All *rulesets* are required to use the schema as specified in Section 5. If additional data elements are needed for a specific *ruleset*, the same shall be added to the schema through the continuous maintenance process as an addendum.

6.3 Rule Requirements

The *ruleset checking specification* shall identify the *rules* and sections within a *ruleset* which are evaluated and the ones which are excluded from evaluation.

6.3.1 Requirements for Rules Excluded from Evaluation

Sections and *rules* within the *ruleset* that are explicitly excluded from the evaluation by the *ruleset checking tool* shall be identified.

Informative notes:

a. A *ruleset checking specification* might choose to exclude certain *rules* from evaluation due to reasons including challenges associated with verifying a certain *rule*, the fact that requirements related to a rule cannot be represented in a *building performance model* and hence be translated into the *ruleset evaluation schema*, or the general need to focus on specific sections within a *ruleset* or limit the scope of *rules* being evaluated.
b. An authority having jurisdiction (AHJ) might require additional *rules* to be evaluated. However, adding *rules* would require updates to the *ruleset checking specification* with the corresponding *rule tests* and updates to the *ruleset evaluation schema*. The *ruleset checking tool* would need to demonstrate compliance with the updated *ruleset checking specification.*

6.3.1.1 Minimum Specifications

For *rules* and sections excluded from evaluation, the *ruleset checking specification* shall identify, at a minimum, the following:

- *Ruleset* Reference: Reference to the section within the *ruleset* where the *rule* is defined.
- Description: Summary of the corresponding *ruleset* requirement

6.3.2 Requirements for the Rules Included in Evaluation

6.3.2.1 Minimum Specifications

Rules within a *ruleset* that shall be evaluated by the *ruleset checking tool* shall be identified and documented in the *Ruleset Checking Specification*. For each *rule* being evaluated by the *ruleset checking tool*, the following information shall be provided in the *ruleset checking specification*:

1. *Rule* ID: A unique ID for the *rule* being evaluated.
    I. Informative note: A *rule* ID should be a unique id, not related to the *rule* numbering or section numbering within the *ruleset*.
2. *Ruleset* Reference: Reference to the section within the *ruleset* where the *rule* is defined.
3. *Ruleset model type* to which the *rule* applies (for example: the proposed model, the baseline model, or the user model).
4. *Rule* description summarizing the corresponding *ruleset* requirement.
5. Whether the *rule* is required to be fully evaluated or evaluated only for applicability by the *ruleset checking tool*. Section 6.4 specifies the requirements related to *rules* fully evaluated and *rules* evaluated only for applicability.
   Informative Note: Based on Section 8, *ruleset checking tool* must be capable of evaluating 100% of the *rules* which are not excluded from evaluation. It may be difficult or impractical to fully evaluate a *rule* through the *ruleset checking tool*, but it may still be useful for the *ruleset checking tool* to determine whether the *rule* is applicable to the project being evaluated. This applicability information may be useful to, for example, an ahj by informing them that a manual review of a *rule's* implementation may be appropriate. *Rules* might be only checked for applicability due to reasons such as the following:
   - Data elements needed for verifying the *rule* are not included in the schema (e.g., *rules* related to minimum requirements for the building performance modeling software).
   - Data elements needed for verifying the *rule* are included in the schema but are unlikely to be populated by the building performance modeling software.
   - *Rule* evaluation logic is too complex.
   - *Rule* applies to a small fraction of projects (e.g., Standard 90.1-2019 Appendix G *rules* for projects that use district heating or cooling.)

Informative Note: Example *Rule*

Rule ID	Ruleset Reference	Ruleset Model Type	Rule Description	Evaluation
ENV-1	Table G3.1(5) Baseline Building Performance (a)	Baseline Model	Baseline Performance is the average of 4 rotations if vertical fenestration area per each orientation differ by more than 5%	Full
ENV-2	Table G3.1(5) Baseline Building Performance (a)	Baseline Model	Baseline building must be modeled so that it doesn't shade itself	Applicability

6.3.2.2 Rule Evaluation Outcomes

Rule evaluation outcome shall include but not be limited to these following options.

a. Pass: the *ruleset checking tool* is capable of fully evaluating the rule and determines that the *ruleset project description* complies with the *rule*. The 'pass' outcome shall be provided when the *ruleset project description* exactly matches the prescribed requirement, while accounting for any tolerance for numeric quantities specified in the *ruleset checking specification*.
b. Fail: the *ruleset checking tool* is capable of fully evaluating the *rule* and determines that the *ruleset project description* does not comply with the *rule*. A 'fail' outcome shall be provided when the data in the *ruleset project description* does not match the requirement(s) prescribed in the *rule* and for numeric values is outside of the tolerance specified in the *ruleset checking specification*.
c. Not Applicable: The *ruleset checking tool* software determined that the *rule* is not applicable to the *ruleset project description*. A 'not applicable' outcome shall be provided only when the *rule* is not relevant to the *ruleset project description*.
d. Undetermined: An 'undetermined' outcome shall be provided when the *ruleset checking tool* is not able to establish 'pass', 'fail', or 'not applicable' outcome. The scenarios resulting in an 'undetermined' outcome shall be limited to the following.
    a. The *ruleset checking tool* lacks functionality to fully evaluate the *rule*.
    b. The *ruleset project description* is missing data elements required to evaluate a *rule* or to determine its applicability.
    c. The complete set of necessary data elements do not exist in the *ruleset evaluation schema*.

    For a *rule* that applies to multiple components in a building (for example, a *rule* which defines the requirements for interior lighting power density for space types), the *rule* evaluation shall be provided by the *ruleset checking tool* for each applicable component. The rating authority shall decide the mechanism for aggregating *rule* evaluations at a component level, to the *rule* level. Informative Appendix D of the standard provides an example report which demonstrates a methodology for converting component level *rule* evaluations to a whole building level *rule* evaluation.

    Informative Note: A *rule* evaluation outcome may include an optional message explaining the outcome and identifying additional verification that might be done by the AHJ or additional input that could be provided by the modeler to enable evaluation of the *rule*.

6.3.2.3 Rule Evaluation Precision

The *ruleset checking specification* shall identify the number of significant digits and the maximum allowed deviation from the expected numeric values evaluated by a *rule* based on *ruleset* requirements. If nothing is provided in the *ruleset*, then the value needs to equal the expected numeric value when rounded to the appropriate number of significant digits.

6.4 Rule Tests

Rule tests shall be included in the *ruleset checking specification* which verify the intended behavior of the *ruleset checking tool* for evaluating each *rule* included in evaluation.

Section 6.4.1 specifies the requirements for *rule* unit tests, and Section 6.4.2 specifies the requirements for integrated *rule tests*.

6.4.1 Rule Unit Tests

6.4.1.1 Minimum Required Rule Unit Tests

Rule Unit tests facilitate evaluating *ruleset checking tool* implementation of a single *rule* within a *ruleset*. For each evaluated *rule*, the following rule unit tests shall be included in the *ruleset checking specification*.

1. For each *rule* which is required to be fully evaluated, the following *rule* unit tests shall be provided.
   a. At least one *rule* unit test with 'Pass' *rule* evaluation outcome.
   b. At least one *rule* unit test with 'Fail' *rule* evaluation outcome.
   c. Where a *rule* includes parameters with multiple enumerations, like space types for lighting, space conditioning categories and climate zones for envelope, *rule unit tests* shall be defined for a minimum of two enumerations for each such parameter with *Rule Unit Tests* specified to evaluate at least one 'pass' and one 'fail' outcome for each enumeration.
2. For all other *rules* which are required to be evaluated only for applicability, rule unit tests with at least one 'undetermined' and one 'not applicable' rule evaluation outcome shall be included.

6.4.1.2 Rule Unit Test Specifications

For each *rule* unit test, the following information shall be included in the *ruleset checking specification*.

1. *Rule* Unit Test ID
2. *Rule* ID for which the test case has been defined.
3. The description of the project scenario represented by the test case.

Informative Note: For example, project is located in climate zone 5A, baseline model includes a residential zone served by a cooling and heating system of a given capacity and has an exterior wall of a certain U-factor.

4. The *ruleset project description* files corresponding to the test case description and containing information required to determine the outcome of the *rule* being evaluated.
5. Expected *rule* unit test evaluation outcome based on the options allowed in Section 6.3.2.2

Informative Note: Example Rule Unit Test

***Rule* ID**	***Rule* Unit Test ID**	**Test Case Description**	**Expected *Rule* Unit Test Outcome**	***Rule* Unit Test JSON**
6-2	6-2-a	The proposed building has one building segment with one zone and one space. The lighting space type is hotel/motel guest rooms, LPD is higher than the minimum value prescribed by Standard 90.1-2019 Table 9.6.1 Hotel/Motel Guest Room >= 0.41 W/sq.ft.	pass	Rule Test JSON 6-2
6-2	6-2-b	The proposed building has one building segment with one zone and one space. The lighting space type is hotel/motel guest rooms, LPD is lower than the minimum value prescribed by Standard 90.1-2019 Table 9.6.1.	fail	Rule Test JSON 6-2

6.4.2 Rule Integrated Tests

An integrated *rule test* shall evaluate a *ruleset project description* for two or more interacting *rules*.

Informative Note: Integrated *rule tests* are not required to be included in the *ruleset checking specification*. However, if included, the integrated *rule tests* may specify the building description, applicable *rules,* and the expected *rule* evaluation outcome.

6.5 *Ruleset Project Description Generation Software* Tests

The *ruleset checking specification* shall, at the minimum, include the following content to supplement Section 7.3, Minimum Capabilities, Section 7.4, Testing Requirements, and Section 7.5, Reporting Requirements:

1. The *ruleset project description generation software* compliance requirements specific to the *ruleset*.
2. The following information for each *ruleset project description generation software* test:
    a. Test ID
    b. Test description including the building performance modeling software simulation inputs necessary to create the *ruleset project description* file for the test case.
    c. The expected *ruleset project description* file containing the correct values of the data elements and correct relationships between the data groups.
3. A *ruleset project description generation software* testing report template meeting requirements of Section 7.5 for each test case and including a tabulated list of the relevant data elements. The reporting template shall identify the evaluation criteria for all data elements being evaluated, including the following:
    a. Data elements whose values are required to match the corresponding value in the test case specification shall have the evaluation criteria denoted as “value”.
    b. Data elements that are required to be present, but whose values cannot be checked, shall have the evaluation criteria denoted as “present”.
    c. Data elements whose values are required to match the name of the object that corresponds to the object that is named in the test case specification shall have the evaluation criteria denoted as “reference”.

    Informative Note: The r*uleset evaluation schema* defines specific relationships between classes of components. For example, all surfaces must be in a list associated with a zone. These relationships are represented using "references", using the names of objects that appear in the model as values for certain data fields. For example, the requirement that all surfaces must be in a list that is associated with a zone is implemented using a list that contains names of surface objects. These relationships, shown in Section 5.3, and the values of attributes such as surface U-factor and area, must align in the *ruleset project descriptions* generated by the candidate *ruleset project description generation software* and the expected *ruleset project descriptions* included in the *ruleset checking specification*. A "value" data field is aligned if it matches the value of the corresponding data field in the test case specification directly. A "reference" data field is aligned if its value is the name of the object that corresponds to the object named by the field in the test case specification.

7 Ruleset Project Description Generation Software Compliance

7.1 Scope

The requirements of this section apply to *ruleset project description generation software*.

Informative Note: The procedures described in this section help verify that the *ruleset project description* is consistent with the building performance modeling software user inputs and simulation outputs.

7.2 Compliance

The *ruleset project description generation software* shall be permitted to comply with the standard for one or more building performance modeling software tools. Compliance shall be demonstrated separately for each building performance modeling software tool. The *ruleset project description generation software* shall meet the following requirements:

1. Comply with Section 7.3, "Minimum Capabilities"
2. Comply with Section 7.4, "Testing Requirements"
3. Comply with Section 7.5, "Reporting Requirements"
4. Meet any additional *ruleset project description generation software* requirements in the r*uleset checking specification* for the applicable ruleset.
   Informative Note: *Ruleset project description generation software* acceptance may be determined by an AHJ based on review of reports and documentation provided in accordance with Section 7.5. The AHJ may also replicate tests using the building performance modeling software and use the *ruleset project description generation software* to ensure that independently produced building performance modeling inputs, building performance modeling outputs, and *ruleset project description* files are identical to those publicly posted as required by Section 7.5.

7.3 Minimum Capabilities

Ruleset project description generation software shall, at a minimum, be capable of generating a *ruleset project description* that:

1. Conforms with the *ruleset evaluation schema* requirements in Section 5 and in the *ruleset checking specification* for the applicable *ruleset(s)*.
2. Reflects the inputs used by the building performance modeling software calculation engine that performs the building performance simulation calculations and the simulation outputs.
   Informative Note: Scenarios where user inputs may not align with the inputs used by the building performance modeling software calculation engine include if the building performance modeling software includes input interface that processes the simplified user inputs and passes them to the building performance modeling calculation engine or if the calculation engine overrides or prioritizes certain user inputs over others.

   Exceptions: The *ruleset project description generation software* shall be permitted to make the following adjustments to the simulation inputs and outputs to meet schema requirements in Section 5 and the *ruleset checking specification*:

   a. Perform unit conversions.

Informative Note: Unit conversions in Standard 90.1-2019 Appendix G *ruleset checking specification* in the Normative Appendix E1 of this standard are based on the ASHRAE SI Guide for HVAC&R. Atlanta, Georgia: ASHRAE, 2013. https://www.ashrae.org/technical-resources/ashrae-handbook/the-si-guide and Python unit conversion library Pint version 0.18 https://pint.readthedocs.io/en/0.18/

b. Allow user to specify accessory inputs that are not used in the simulation and do not impact simulation results.
Informative Note: Examples of accessory inputs include, but are not limited to, the ruleset-specific lighting space types and project climate zone.

c. Perform other computations necessary to convert *building performance model* inputs to the *ruleset project description* data elements.
Informative Note: Examples of such computations include, but are not limited to, determining the overall surface U-factors written to the *ruleset project description* based on detailed description of materials making up the surface or the zone-level infiltration rate written to the *ruleset project description* based on the modeled space-level infiltration rate.

7.4 Testing Requirements

7.4.1 Testing Procedure

The ruleset project description generation software shall produce *ruleset project description* for the test cases specified in the *ruleset checking specification* for each applicable *ruleset*. The following steps shall be followed to demonstrate compliance:

1. Model each test case listed in the *ruleset checking specification* using the applicable building performance modeling software for which the *ruleset project description generation software* is demonstrating compliance. Building performance modeling software inputs for all test cases shall reflect the prescribed values.
Exceptions:
   a. The prescribed inputs that do not apply to the input structure of the building performance modeling software shall be disregarded.
   b. Where the building performance modeling software does not allow direct input of the specified values, or where input of specified values causes instabilities in a program's calculations, equivalent inputs shall be used that match the intent of the test specification as nearly as the software being tested allows. Such equivalent inputs shall be developed based on the data provided in the test specification, have a mathematical, physical, or logical basis, and applied consistently throughout the test cases. The equivalent modeling inputs shall be documented.
   c. Where the building performance modeling software does not support the prescribed input method, an alternative supported method shall be used. Differences in the inputs compared to the prescribed values shall be documented.
2. Use the qualifying *ruleset project description generation software* to create a *ruleset project description* for each test case.
3. Compare the *ruleset project description* created by the qualifying *ruleset project description generation software* to the corresponding *ruleset project description* included in the *ruleset checking specification*.

7.5 Reporting Requirements

7.5.1 General Requirements

The *ruleset project description* tests reporting documentation shall be posted on a publicly available website and shall include the following:

1. General Information
    a. Submission date.
    b. Name and version of the *ruleset project description generation software*.
    c. Name and version of the building performance modeling software that the *ruleset project description generation software* supports.
    d. Version of the *ruleset evaluation schema* supported by the *ruleset project description generation software*.
    e. Name of the *ruleset* for which compliance is demonstrated.
    f. Name of *ruleset checking specification* for which compliance is demonstrated.
2. A completed *ruleset project description* generation software testing report template for each test case, including the following.
    a. Name of the *ruleset project description* file created by the *ruleset project description generation software*.
    b. Names of all user and software created files utilized by the *ruleset project description generation software* to produce the values used in creating the associated *ruleset project description*.
    c. Documentation when exceptions to Section 7.4.1 (1) were used.
    d. Compliance outcome for each evaluated data element shall be recorded using one of the following strings:
        i. "match" shall be used where the required type of alignment (value, present, or relationship) between the expected *ruleset project description* file and the *ruleset project description* file created by the candidate *ruleset project description generation software* is achieved.
        ii. "differ" shall be used for the data elements where the required type of alignment is not achieved.
        iii. "Not implemented" shall be used when the data group is not supported by the *ruleset project description generation software*.

    Informative Note: Reasons for "not implemented" may include building performance modeling tool not supporting the relevant simulation inputs or the necessary functionality not implemented or not correctly implemented in *ruleset project description generation software*.

3. The following supporting documentation:
    a. All user and software created files utilized by the submitted *ruleset project description generation software* to create the associated *ruleset project description* as listed in the *ruleset project description* reporting template.

        Informative note: Submissions must include all user inputs so that a third-party reviewer can reproduce a *ruleset project description* using the submitted tool or tools and related user inputs and compare that *ruleset project description* to: a) the reference *ruleset project description* (see Section 6.5), and b) the submitted *ruleset project*

description. Submissions must include all software generated files (including files generated by the sizing run) so that a third party can trace the execution steps use of the tool or each of tools in the creation of a *ruleset project description*.

b. Alternative equivalent simulation inputs used when the building performance modeling software does not allow direct input of the values specified in the test case description.
c. *Ruleset project descriptions* for all completed tests
d. List of omitted test cases with explanation.

8 Ruleset Checking Tool Compliance

8.1 Scope

The requirements of this section apply to *Ruleset Checking Tool* software.

Informative Note: The procedures described in this section help verify that a *ruleset checking tool* correctly evaluates whether a *ruleset project description* is consistent with a *ruleset* and reports each *rule* evaluation outcome.

8.2 Compliance

1. A *ruleset checking tool* shall comply with the standard for one or more *rulesets*. Compliance shall be demonstrated separately for each *ruleset*.
2. A *ruleset checking tool* shall meet the following requirements for each applicable *ruleset*:
    a. Comply with the minimum capabilities for project checking in Section 8.3.
    b. Comply with *ruleset checking tool* testing requirements in Section 8.4.
    c. Comply with the project checking requirements in Section 8.3.

8.3 Minimum Capabilities

A *ruleset checking tool* shall have the following minimum capabilities:

1. Accept the *ruleset project description* and verify its compliance with the *ruleset evaluation schema* requirements in Section 5.
2. Evaluate all *rules* defined in *the ruleset checking specification* as they apply to the *ruleset project description*.

    Informative Note: If a *ruleset checking tool* evaluates *rules* or requirements in addition to those required to be evaluated in the *ruleset checking specification*, then it should identify those *rules* and their corresponding outcomes in the project evaluation report.
3. Generate a project evaluation report, as defined in Normative Appendix C, listing the outcomes for all evaluated *rules*.

    Informative Note. The project evaluation report may include additional information such as warning messages and quality assurance flags.

8.4 Ruleset Checking Tool Testing Requirements

1. A *ruleset checking tool* shall be tested in accordance with a *ruleset checking specification* for the applicable *ruleset* and shall produce correct *rule* evaluation outcomes for all *rule tests*.

2. A *ruleset checking tool* shall produce a software testing report as described in Normative Appendix B
3. A *ruleset checking tool* shall meet additional requirements in the *ruleset checking specification.* **Informative note**: Normative Appendix E1 is a *ruleset checking specification* for ASHRAE Standard 90.1-2019 Appendix G.

9 Software Checking Path

This section is not used.

10 Normative References

Reference		Section
ANSI/ASHRAE Standard 205-2023	Representation of Performance Data for HVAC&R and Other Facility Equipment	Sections 5 except 5.1, 5.7, and 5.8; Section 6 except 6.1, 6.2, 6.3, 6.7, and 6.8; Section 7.
ANSI/ASHRAE/IES Standard 90.1-2019	Energy Standard for Buildings Except Low-Rise Residential Buildings (IP Edition)	Normative Appendix G

Normative Appendix A: Ruleset Evaluation Schema Tables

- The *ruleset evaluation schema* is described at http://data.ashrae.org/standard229/schema-source/ in a file name called "ASHRAE229_schema".
  [**Note to reviewers:**
  - This webpage doesn't exist yet and will be added when the standard is approved for publication.
  - The schema development continues at: https://github.com/open229/ruleset-model-description-schema. This will move to an ASHRAE GitHub repository when the standard is approved for publication.
    - The schema is located at https://github.com/open229/ruleset-model-description-schema/tree/main/docs229
      - JSON:https://github.com/open229/ruleset-model-description-schema/blob/main/docs229/ASHRAE229.schema.json
      - PDF: https://github.com/open229/ruleset-model-description-schema/blob/main/docs229/ASHRAE229.schema.pdf]
  -

Normative Appendix B: Ruleset Checking Tool Software Testing Report Schema

The *ruleset checking tool* shall produce an output report in JSON file format consistent with the *ruleset checking tool* software testing output report schema described in this appendix. The report shall contain the detailed results for all the *rule tests* defined by the *ruleset checking specification* for the *ruleset*.

B.1 Format

The *ruleset checking tool* software testing report schema shall be in JSON format following the rules described in Standard 205 Section 5 except 5.1, 5.7, and 5.8; Section 6 except 6.1, 6.2, 6.3, 6.7, and 6.8; and Section 7.

[Note to reviewers: when ASHRAE Standard 232P is published, the reference above may change to that standard]

B.2 Data Group Hierarchy (informative)

The hierarchy of the data groups is shown in the figure below.

Figure 2: Hierarchy of Data Groups in *ruleset checking tool* software testing output report schema

B.3 Data Groups and Elements

The *ruleset checking tool* software testing report schema shall contain the data groups and elements described at http://data.ashrae.org/standard229/schema-source in a file name called "RCT_software_output_test_report.schema.yaml"

[Note to Reviewer:

a. This webpage doesn't exist yet and will be added when the standard is approved for publication.
b. The schema development continues at: https://github.com/open229/ruleset-model-description-schema. This will move to an ASHRAE GitHub repository when the standard is approved for publication.
c. The schema is located at https://github.com/open229/ruleset-model-description-schema/blob/main/docs229/RCT_software_output_test_report.schema.json]
d. All appendices are provided in a zip folder along with the PPR draft.

B.4 Data Group and Element Tables

[Note to reviewer:

- The text of this PDF will be added here: https://github.com/open229/ruleset-model-description-schema/blob/main/docs229/RCT_software_output_test_report.schema.pdf
- All appendices are provided in a zip folder along with the PPR draft]

Normative Appendix C: Ruleset Checking Tool Project Evaluation Report Schema

The *ruleset checking tool* shall produce a project evaluation report in JSON file format consistent with the *ruleset checking tool* project evaluation report schema described in this appendix. The report shall contain the detailed results for all *rule* evaluations conducted during an evaluation of a set of *ruleset project description* files.

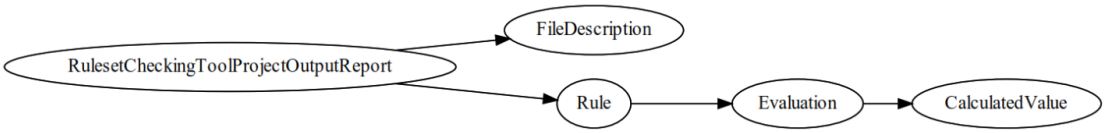
C.1 Format

The *ruleset checking tool* project evaluation report schema shall be in JSON format following the rules described in Standard 205 Section 5 except 5.1, 5.7, and 5.8; Section 6 except 6.1, 6.2, 6.3, 6.7, and 6.8; and Section 7.

Informative note: when ASHRAE Standard 232P is published, the reference above may change to that standard.

C.2 Data Group Hierarchy (informative)

The hierarchy of the data groups is shown in the figure below.



C.3 Data Groups and Elements

The *ruleset checking tool* project evaluation report schema shall contain the data groups and elements described at http://data.ashrae.org/standard229/schema-source in a file name called "RCT_project_output_test_report.schema.yaml"

[Note to reviewer:

a. This webpage doesn't exist yet and will be added when the standard is approved for publication.
b. The schema development continues at: https://github.com/open229/ruleset-model-description-schema. This will move to an ASHRAE GitHub repository when the standard is approved for publication.
c. The schema is located at https://github.com/open229/ruleset-model-description-schema/blob/main/docs229/RCT_project_output_test_report.schema.json
d. All appendices are provided in a zip folder along with the PPR draft.]

C.4 Log of Exception Messages

A log shall be produced by the *ruleset checking tool* that shall include a log of exceptional messages and shall include a JSON object that identifies if the *ruleset checking tool* encountered an error. The *ruleset checking tool* shall generate a log file that identifies all *rules* that failed processing and the error that was encountered.

Informative note. The developer of the *ruleset checking tool* should have a process for users to submit test files when errors occur, including ways to submit log and other files.

C.5. Data Group and Element Tables

[Note to Reviewer:

a. The text of this PDF will be added here:https://github.com/open229/ruleset-model-description-schema/blob/main/docs229/RCT_project_output_test_report.schema.pdf
b. All appendices are provided in a zip folder along with the PPR draft.]

Informative Appendix D: Project Checking Summary Report

[**Note to reviewer:**

a. The report at this location will be added here: https://github.com/pnnl/ruleset-checking-tool/tree/develop/examples/output, name of the file 'ashrae901_2019_summary_report.pdf'
b. All appendices are provided in a zip folder along with the PPR draft.]

Normative Appendix E: Ruleset Checking Specification

E1 Ruleset Checking Specification for ASHRAE Standard 90.1-2019

E1.1 Utilization

This *ruleset checking specification* has been developed for Standard 90.1 2019 Appendix G, Performance Rating Method, IP version, and applies to the project checking path, as described in Section 4.2

E1.2 Ruleset Model Types

The *ruleset checking tool* shall be capable of evaluating the following *ruleset model types*: -

- **User model:** a *ruleset model type* that reflects specified or existing building systems, components and controls and anticipated or actual operating conditions.
- **Proposed model:** *ruleset model type* of a hypothetical design obtained by transforming the user model as required by ASHRAE Standard 90.1 Performance Rating Method
- **Baseline model:** a *ruleset model type* of a hypothetical design obtained by transforming the proposed model as required by ASHRAE Standard 90.1 Performance Rating Method. Four baseline *ruleset models*, one for each of the four orientations, are required by ASHRAE Standard 90.1 Performance Rating Method for most projects.

E1.3. Ruleset Evaluation Schema

Ruleset evaluation schema attributes, specific to Standard 90.1 2019 Appendix G include the following-

a. Standard 90.1-2019 enumerations described at http://data.ashrae.org/standard229/schema-source
   [Note to reviewers:
   - This webpage doesn't exist yet and will be added when the standard is approved for publication.
   - The schema development continues at : https://github.com/open229/ruleset-model-description-schema/blob/main/docs229/Enumerations2019ASHRAE901.schema.json.
   - This will move to an ASHRAE GitHub repository once the standard is approved for publication
   - All appendices are provided in a zip folder along with the PPR draft]

b. Standard 90.1-2019 output schema described at http://data.ashrae.org/standard229/schema-source
   [**Note to reviewers:**
   - This webpage doesn't exist yet and will be added when the standard is approved for publication.
   - The schema development continues at: https://github.com/open229/ruleset-model-description-schema/blob/main/docs229/Output2019ASHRAE901.schema.json
   - This will move to an ASHRAE GitHub repository once the standard is approved for publication]

c. Schema data elements required for evaluating *rules*, schema data elements required to be the same between the user model and proposed model, and schema data elements required to be the same between proposed model and baseline model. The schema is described at http://data.ashrae.org/standard229/schema-source

[**Note to reviewers:**

- This webpage doesn't exist yet and will be added when the standard is approved for publication.
- The schema development continues at: https://github.com/open229/ruleset-model-description-schema/blob/main/docs229/ASHRAE229_extra.schema.json.
- This will move to an ASHRAE GitHub repository once the standard is approved for publication]

E1.4. Rules

This section identifies *rules* within the *ruleset* that are excluded from evaluation and the *rules* which are required to be evaluated by the *ruleset checking tool*.

E1.4.1 Rules Excluded from Evaluation

Rules excluded from evaluation are listed at MasterListofRules_V3.xlsx.

[Note to reviewers: This will eventually be hosted at https://data.ashrae.org/]

Informative Note: Table E1.4.1.1 includes additional requirements of Appendix G which are not *rules* according to the definition in the standard and but which, for clarity, are noted here as also being excluded from evaluation.

Table E1.4.1.1 Requirements in Standard 90.1-2019 Excluded from Evaluation

Section Name	Standard 90.1-2019 Reference	Section Description
Performance Rating Method Scope	G1.1	This section describes the scope of the PRM approach as a pathway to demonstrate performance that exceeds the requirements of the standard.
Submittals	G1.3	This section specifies the submittal requirements for verifying compliance with the PRM approach.
Simulation General Requirements- Performance Calculations	G2.1	Section specifies the requirements related to the simulation program used for calculating the proposed and baseline building performance
Simulation Program	G2.2	Section specifies the minimum required capabilities of the simulation program used for calculating the proposed and baseline building performance
Climatic Data	G2.3	Section specifies requirements related to the climatic data used for the simulation.
Exceptional Calculation Methods	G2.5	Section specifies conditions in which an exceptional calculation method may be used and the documentation required to support the same.

E1.4.2 Rules Included in Evaluation

Rules required to be included in evaluation are identified through unique *rule* identifiers. *Rule* identifiers use a pre-fix determined by the Appendix G section they belong in.

Informative Note: Different *rules* might be grouped together if they apply to the same component. For example, Appendix G Section 1.2.1 identifies mandatory requirements and includes a rule which applies to lighting systems. That specific rule has been grouped under rule identifier 6, lighting.

Table E1.4.2: Rule Identifier Mapping to Ruleset

Rule Identifier Prefix	Ruleset Section Title	Ruleset Reference
CALC	Compliance calculations and Design Model	Section 4, Table G3.1(1)
ENV	Building Envelope	Table G3.1(5)
LTG	Lighting	Table G3.1(6), G1.2.1(b)
HVAC-SYS	Baseline HVAC System Selection	Section G3.1.1
HVAC-GEN	General Baseline HVAC System Requirements	Section G3.1.2
HVAC-SPEC	System-Specific Baseline HVAC System Requirements	Section G3.1.3 (Except the rules for hot water, chilled water and condenser water loop)
HVAC-HW	Baseline HVAC-Water Side Requirements: Hot Water	Section G3.1.3 (Rules for hot-water loop)
HVAC-CHW	Baseline HVAC-Water Side Requirements: Chilled Water	Section G3.1.3 (Rules for chilled water and condenser water loop)

The *ruleset checking tool* shall be capable of evaluating *rules* listed at MasterListofRules_V3.xlsx.

*[**Note to reviewers:** this will eventually be hosted at https://data.ashrae.org/]*

E1.5 Rule Tests

The *rule tests* for evaluating the *rules* included in evaluation are listed at MasterListofRuleTests_V1.xlsx

*[**Note to reviewers:** this will eventually be hosted at https://data.ashrae.org/]*

E1.6 *Rule* Evaluation Precision

For *rule* evaluations that check for an expected value, the *ruleset checking tool* shall round values to match the number of digits as the expected value is specified in the *ruleset*. The *ruleset checking tool* shall evaluate the *rule* for an exact match against the expected value.

Informative note:

In the scenario where the *ruleset checking tool* evaluates a threshold, the threshold value should not be rounded. For example, in Standard 90.1 2019 Appendix G, the baseline is required to be modeled with a single boiler if the conditioned floor area is equal to or less than 15,000 ft2 and with two boilers if the conditioned floor area is greater than 15,000 ft2. In this scenario, where the evaluation is based on the threshold of conditioned floor area, the floor area should not be rounded.

E1.7. Ruleset Project Generation Software Testing

E1.7.1 General

Ruleset project description generation software shall be tested as required in Section 7. The *ruleset project description generation software* tests required for compliance with the *ruleset checking specification* for Standard 90.1-2019, are listed in Table E1.7.1.

Table E1.7.1: Tests for Ruleset Project Description Generation Software Compliance

Test ID	Test Description	File
E1	Base Test Description + HVAC Test Case 1 (Packaged Single Zone Heat Pump)	Test 1

E2	Base Test Description + HVAC Test Case 2 (Chilled Water VAV with Hot Water Reheat)	Test 2
E3	Base Test Description + HVAC Test Case 3 (Packaged VAV with Reheat and Baseboard Supplementary Heating)	Test 3

The base test case shall be specified based on the requirements in Section E1.7.2, and the HVAC test cases shall the specified based on the requirements in Section E1.7.3.

[Note to reviewer: the *ruleset project description* files for the *ruleset project description generation software* tests listed in Table E1.7.1 will be added for the 2nd PPR]

E1.7.2 Base Ruleset Project Description Generation Software Test Description

The base test case shall be an office building, as defined in this section. Building characteristics defined in this section shall be used for all *ruleset project description generation software* tests. The *ruleset project description generation software* shall meet the following requirements while defining the *ruleset project description generation software* tests:

1. Where a system, device, or parameter is not described, it shall not exist in the *ruleset project description*.
2. All schedules shall be expressed as hourly values. ScheduleSequenceOptions: EVENT shall not be used.
3. SurfaceConstructionOptions: LAYERS shall be used if at least one material making up a construction is specified using detailed properties.

Informative note:

To reduce the number of tests and simplify the testing process, the base test case defined in this section covers a variety of systems and components, a range of component properties, and various simulation input methods. For example, the base test case includes exterior walls with different construction types and U-factors and multiple methods of modeling infiltration (such as constant flow or weather dependent algorithms) for different zones. HVAC system configurations to be tested are defined in Section E1.7.3.

E1.7.2.1 Site and Weather

Table 1: Site and Weather Summary

Parameter Description	Specification – SI Units (IP Units)
Weather file type	TMY3
Location	Denver, CO
Climate zone	5B
Simulation year	2021
Holidays	None
Daylight savings	None
Ground temperature schedule	Constant, 10°C (50°F)
Cooling design day type	1.0% annual cumulative frequency of occurrence
Heating design day type	99.0% annual cumulative frequency of occurrence

E1.7.2.2 Building Geometry

a. The building's geometry shall be as specified in Figures 1-3 and Table 2.
b. If the *building performance modeling* software includes surface thickness in a three-dimensional definition of the building geometry, then wall, roof, and floor thicknesses

shall be defined such that the interior air volume of the building model remains as specified. The thicknesses shall extend exterior to the currently defined internal volume.

Figure 1: Building Floor Plan

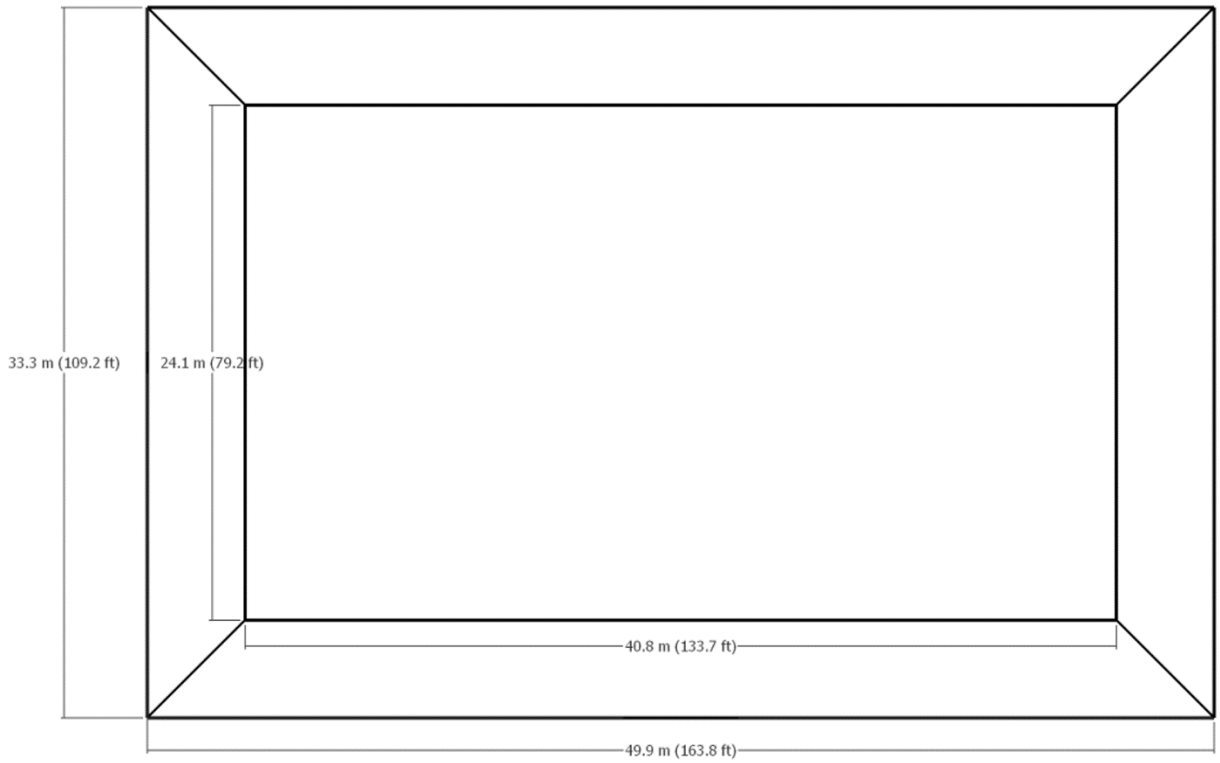


Figure 2: North/South Building Elevations

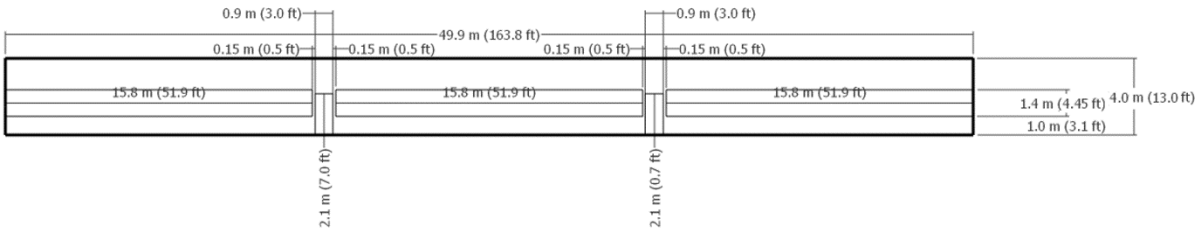


Figure 3: East/West Building Elevations

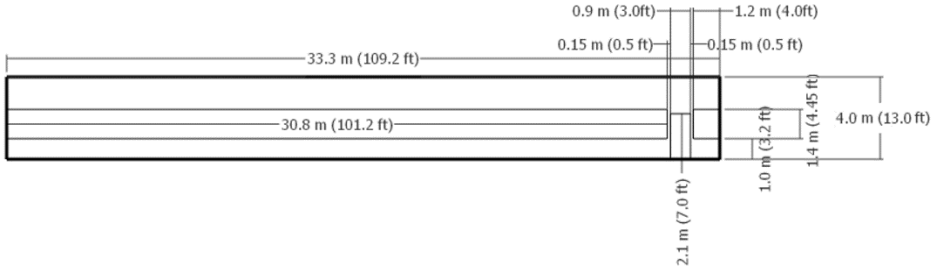


Table 2: Building Geometry Summary

Parameter Description	Specification – SI Units (IP Units)
Total Floor Area	1,660 m2 (17,867 ft2)
Dimensions	49.9 m x 33.3 m (163.8 ft x 109.2 ft)
Aspect Ratio	1.5
Number of Floors	1
Window Fraction (Window-to-Wall Ratio)	31% See Figures 2&3 for detailed dimensions
Window and Door Locations	See Figures 2&3 for detailed dimensions
Window Dimensions	See Figures 2&3 for detailed dimensions
Shading	None
Azimuth	Long axis along East/West
Thermal Zoning	The building has four perimeter zones and one core zone. Perimeter zone depth: 4.57 m (15 ft)
Building height	3.96 m (13 ft)
Floor-to-ceiling height	3.96 m (13 ft)
Door dimensions	0.91 m x 2.13 m (3 ft x 7 ft) See Figures 2&3 for quantities
Foundation	Slab-on-grade

E1.7.2.3 Envelope Properties

E1.7.2.3.1. Envelope Opaque Surfaces

a. Envelope shall be modeled with surface constructions specified in Table 3 through Table 5. Materials specified for constructions exposed to exterior are shown in the tables, ordered from inside to outside.
b. The interior air film resistance shall be as shown in Table 6.
c. Surface-to-surface thermal resistance of interior wall assembly shall be 1.99 m2-K/W (SI) / 0.35 h·ft2·°F/Btu (IP).
d. The exterior air-film resistance for roof and exterior walls shall be 0.97 m2-K/W (SI) / 0.17 h·ft2·°F/Btu (IP). Where the exterior air-film resistance is not a user input and is determined during the hourly simulation, the overall roof and exterior wall assembly air-to-air u-factors reported in the *ruleset project description* shall be based on the exterior air film resistance of 0.97 m2-K/W (SI) / 0.17 h·ft2·°F/Btu (IP).
e. The solar (visible and ultraviolet wavelengths) absorptances and infrared emittances of the opaque surfaces shall be as specified in Table 7.

Informative Note: The specified opaque envelope model inputs test the following aspects of the *ruleset project description* generation:

i. Identifying the applicable Construction.surface_construction_input_option
ii. Determining the Construction.u_factor based on detailed properties of individual materials
iii. Populating Material.thickness, Material.thermal_condictivity, Material.density, Material.specific_heat, Material.r_value
iv. Populating SurfaceOpticalProperties

Table 3: Roof Construction Summary

Roof Type 1: Construction assembly is described layer-by-layer where detailed properties are provided for built-up roofing, continuous insulation, and metal roof deck layers. **Assigned to:** Core Zone 1, Perimeter Zone 1, Perimeter Zone 2		
Layer Description	**Parameter Description**	**Specification – SI Units (IP Units)**
Metal Deck	Thickness	0.0008 m (0.003 ft)
	Conductivity	45.28 W/m ·K (26.162 Btu·ft/[h·ft2·°F])
	Density	7,824 kg/m3 (489 lb/ft3)
	Specific Heat	500 J/kg·K (0.119 Btu/[lb·°F])
Continuous Insulation	Thickness	0.053 m (0.173 ft)
	Conductivity	0.020 W/m·K (0.012 Btu·ft/[h·ft2·°F])
	Density	32.000 kg/m3 (2.000 lb/ft3)
	Specific Heat	922.308 J/kg·K (0.220 Btu/[lb·°F])
Built-up roofing	Thickness	0.0095 m (0.031 ft)
	Conductivity	0.16 W/m·K (0.092 Btu·ft/[h·ft2·°F])
	Density	1,120 kg/m3 (70 lb/ft3)
	Specific Heat	1,460 J/kg·K (0.349 Btu/[lb·°F])
Roof Type 2: Assembly is described layer-by-layer identically to Roof Type 1, except as specified below where the thickness of continuous insulation is increased and overall thermal resistance is provided for built-up-roofing. **Assigned to:** Perimeter Zone 3		
Layer Description	**Parameter Description**	**Specification – SI Units (IP Units)**
Continuous Insulation	Thickness	0.106 m (0.346 ft)
Built-up roofing	Total Thermal Resistance	0.059 m2-K/W (0.337 h·ft2·°F/Btu)
Roof Type 3: Assembly is described as a total surface-to-surface thermal resistance without thermal mass **Assigned to:** Perimeter Zone 4		
Simplified Input Description		**Specification – SI Units (IP Units)**
Total surface-to-surface thermal resistance		2.66 m2-K/W (15.09 h·ft2·°F/Btu)

Table 4: Exterior Wall Construction Summary

Exterior Wall Type 1: Assembly is described layer-by-layer from exterior to interior with detailed properties provided for each layer **Assigned to:** Perimeter Zone 1		
Layer Description	**Parameter Description**	**Specification – SI Units (IP Units)**
Stucco	Thickness	0.0254 m (0.083 ft)
	Conductivity	0.72 W/[m·K] (0.416 Btu·ft/[h·ft2·°F])
	Density	1856 kg/m3 (116 lb/ft3)
	Specific Heat	840 J/kg·K (0.201 Btu/[lb·°F])
Gypsum Board	Thickness	0.0159 m (0.052 ft)
	Conductivity	0.16 W/[m·K] (0.092 Btu·ft/[h·ft2·°F])
	Density	800 kg/m3 (50 lb/ft3)
	Specific Heat	1090 J/kg·K (0.26 Btu/[lb·°F])

Insulation	Thickness	0.062 m (0.204 ft)
	Conductivity	0.037 W/[m·K] (0.021 Btu·ft/[h·ft2·°F])
	Density	9.600 kg/m3 (0.600 lb/ft3)
	Specific Heat	838.462 J/kg·K (0.200 Btu/[lb·°F])
Gypsum Board	Thickness	0.0159 m (0.052 ft)
	Conductivity	0.16 W/[m·K] (0.092 Btu·ft/[h·ft2·°F])
	Density	800 kg/m3 (50 lb/ft3)
	Specific Heat	1090 J/kg·K (0.26 Btu/[lb·°F])
Exterior Wall Type 2: Assembly is the same as Exterior Wall Type 1 except as specified below. **Assigned to:** Perimeter Zone 2		
Layer Description	**Parameter Description**	**Specification – SI Units (IP Units)**
Insulation	Thickness	1.020 m (0.588 ft)
Gypsum Board	Overall Thermal Resistance	0.099 m2-K/W (0.565 h·ft2·°F/Btu)
Exterior Wall Type 3: Assembly is described as an overall thermal resistance without thermal mass **Assigned to:** Perimeter Zone 3 & 4		
Simplified Input Description		**Specification – SI Units (IP Units)**
Total surface-to-surface thermal resistance		1.95 m2-K/W (11.05 h·ft2·°F/Btu)

Table 5: Floor Construction Summary

Slab-on-grade Type 1: Assembly is described with detailed properties **Assigned to:** Core Zone 1, Perimeter Zone 1 & 2		
Layer Description	**Parameter Description**	**Specification – SI Units (IP Units)**
Concrete	Thickness	0.1016 m (0.333 ft)
	Conductivity	2.31 W/[m·K] (1.335 Btu·ft/[h·ft2·°F])
	Density	2322 kg/m3 (145.125 lb/ft3)
	Specific Heat	832 J/kg·K (0.199 Btu/[lb·°F])
Slab-on-grade Type 2: Assembly is the same as Slab-on-grade Type 1 except with additional insulation as described below **Assigned to:** Perimeter Zone 3 & 4		
Layer Description	**Parameter Description**	**Specification – SI Units (IP Units)**
Insulation (Note 1)	Thickness	0.1143 m (0.375 ft)
	Conductivity	0.04 W/[m·K] (0.025 Btu·ft/[h·ft2·°F])
	Density	91.31 kg/m3 (5.700 lb/ft3)
	Specific Heat	J/[kg·K] (0.200 BTU/[lb·°F])

Note 1: Insulation placement shall be as shown in Figure 4.

Table 6: Interior Air Film Resistance Summary

Construction	**Specification – SI Units (IP Units)**
Roof	0.11 m2·K/W (0.61 h·ft2·°F/Btu)
Wall	0.12 m2·K/W (0.68 h·ft2·°F/Btu)
Floor	0.16 m2·K/W (0.92 h·ft2·°F/Btu)

Figure 4: Slab Insulation for Ground Floor Perimeter Zone 3 & 4 Slab

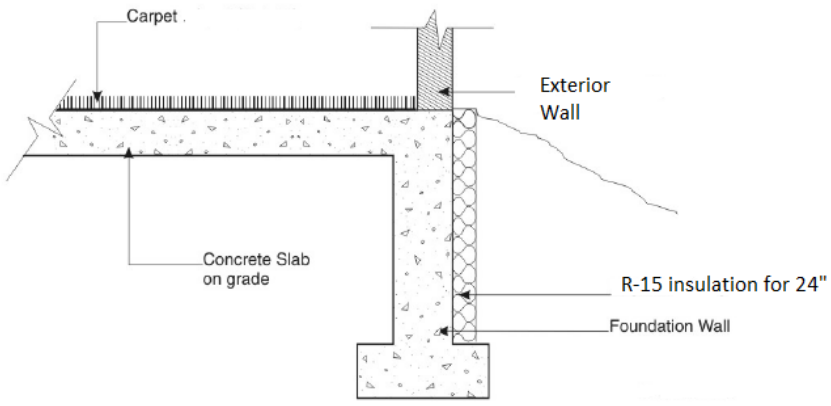


Table 7: Opaque Surface Radiative Property Summary

	Interior Surface			Exterior Surface		
	Thermal Absorptance	**Solar Absorptance**	**Visible Absorptance**	**Thermal Absorptance**	**Solar Absorptance**	**Visible Absorptance**
Exterior Roof	0.9	0.7	0.7	0.9	0.7	0.7
Exterior Wall	0.9	0.7	0.7	0.9	0.7	0.7
Exterior Door	0.9	0.7	0.7	0.9	0.7	0.7
Interior Walls	0.9	0.7	0.7	NA	NA	NA
Interior Floors	0.9	0.7	0.8	NA	NA	NA
Ceiling	0.9	0.7	0.2	NA	NA	NA

E1.7.2.3.2. Fenestration

a. Fenestration properties are based on product dimensions for an individual product shown in Table 8.

b. Fenestration test cases are described in Table 9 and include references to Window program output files. *[note to reviewers: these will eventually be hosted at https://data.ashrae.org/. For the purposes of letter ballot, Window program output files have been included as supplemental text files]*

c. Each exterior wall shall include window elements as shown in Figures 2&3 that reflect the performance requirements for each test case.

Table 8: Window Dimension Summary

Parameter Description	**Specification – SI Units (IP Units)**
Window height (including frame)	1.25 m (4.09 ft)
Window width (including frame)	1.22 m (4.00 ft)

Table 9: Window Property Summary

Vertical Fenestration Type 1: Assembly is described using overall performance properties **Assigned to:** All Windows	
Parameter Description	**Specification – SI Units (IP Units)**
U-factor	3.290 W/m2-K (0.579 Btu/h-ft2-F)
SHGC	0.387
V-T	0.417
Window 7.8 output file reference	[see attached file "229 RPD Test Product 1.txt"]

E1.7.2.3.3. Infiltration

a. Air leakage rate for each zone shall be modeled using rates and modeling method specified in Table 10**Error! Reference source not found.**. Infiltration schedule shall be as specified in Table 12.
b. The infiltration rates specified in Table 10 are not based on measurement (i.e., there are no blower door test values.)

Table 10: Infiltration Flow Rate Summary

Infiltration Method 1: The amount of air leakage is determined for each simulation timestep using the specified infiltration flow rate adjusted to account for the specified schedule and weather conditions. The weather adjustment may be based on windspeed, zone height, and the difference between indoor and outdoor temperature. Informative note: This should map to weather_driven infiltration method. **Assigned to:** Core Zone 1 and Perimeter Zone 1		
Core Zone 1	Air changes per hour (ACH)	0
Prm Zone 1		0.5
Infiltration Method 2: Air leakage constant at each time step as specified below without weather or schedule adjustment. Informative note: This should map to constant infiltration method **Assigned to:** Perimeter Zone 2		
Prm Zone 2	Flow per exterior wall area	0.5862 l/s·m2 (0.1154 cfm/ft2)
Infiltration Method 3: Air leakage during each time step is equal to the rate specified below for each zone multiplied by the infiltration schedule fraction from Table 12. Informative note: This should map to constant_scheduled infiltration method **Assigned to:** Perimeter Zone 3 and 4		
Prm Zone 3	Flow per floor area	0.3884 l/s·m2 (0.07646 cfm/ft2)
Prm Zone 4		0.4091 l/s·m2 (0.08053 cfm/ft2)

E1.7.2.4 Internal Loads

The section provides modeling inputs for occupants, lighting, and plug and elevator loads.

a. Internal loads shall be modeled as specified in Table 11 for all zones, unless noted.
b. The internal loads shall be modeled using the schedules in Table 12
c. Internal gains from occupants shall be 55% sensible, 45% latent.

d. No daylighting and occupancy sensor controls shall be modeled.
e. Internal gains from miscellaneous equipment shall be 100% sensible, 0% latent.

Table 11: Internal Load Summary

Parameter Description	Specification – SI Units (IP Units)
Occupancy	
People/Floor Area	0.05382 person/m2 (0.005 person/ft2)
Total Heating Rate per person	120 W (409.457 Btu/h)
Lighting	
Power Density	11.03 W/m2 (1.025 W/ft2)
Miscellaneous Equipment	
Fuel type	Electricity
Equipment/Floor Area	8.07 W/m2 (2.558 Btu/h·ft2)
Elevator	
Equipment/Floor Area	39.63 W/m2 (12.563 Btu/h·ft2)

Table 12: Schedule Summary

Type	Day of Week	Hour of the Day																						
		0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24
Occupancy																									
Fraction	Weekdays	0	0	0	0	0	0	0.1	0.2	0.95	0.95	0.95	0.95	0.5	0.95	0.95	0.95	0.95	0.3	0.1	0.1	0.1	0.1	0.05	0.05
Fraction	Saturday	0	0	0	0	0	0	0.1	0.1	0.3	0.3	0.3	0.3	0.1	0.1	0.1	0.1	0.1	0.05	0.05	0	0	0	0	0
Fraction	Sunday	0	0	0	0	0	0	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0	0	0	0	0	0
Lighting																									
Fraction	Weekdays	0	0	0	0	0	0	0.1	0.2	0.95	0.95	0.95	0.95	0.5	0.95	0.95	0.95	0.95	0.3	0.1	0.1	0.1	0.1	0.05	0.05
Fraction	Saturday	0	0	0	0	0	0	0.1	0.1	0.3	0.3	0.3	0.3	0.1	0.1	0.1	0.1	0.1	0.05	0.05	0	0	0	0	0
Fraction	Sunday	0	0	0	0	0	0	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0	0	0	0	0	0
Plug Load																									
Fraction	Weekdays	0.31	0.31	0.31	0.31	0.31	0.31	0.38	0.38	0.86	0.86	0.86	0.86	0.76	0.86	0.86	0.86	0.86	0.48	0.38	0.38	0.38	0.38	0.38	0.38
Fraction	Saturday	0.23	0.23	0.23	0.23	0.23	0.23	0.38	0.38	0.48	0.48	0.48	0.48	0.33	0.33	0.33	0.33	0.33	0.29	0.29	0.23	0.23	0.23	0.23	0.23
Fraction	Sunday	0.23	0.23	0.23	0.23	0.23	0.23	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.23	0.23	0.23	0.23	0.23	0.23
Elevator																									
Fraction	Weekdays	0	0	0	0	0	0	0	0.35	0.69	0.43	0.37	0.43	0.58	0.48	0.37	0.37	0.46	0.62	0.12	0.04	0.04	0	0	0
Fraction	Saturday	0	0	0	0	0	0	0	0.16	0.14	0.21	0.18	0.25	0.21	0.13	0.08	0.04	0.05	0.06	0	0	0	0	0	0
Fraction	Sunday	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Heating Thermostat Setpoints																									
Fraction	Weekdays	15.6	15.6	15.6	15.6	15.6	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	15.6	15.6
Fraction	Saturday	15.6	15.6	15.6	15.6	15.6	21	21	21	21	21	21	21	21	21	21	21	21	15.6	15.6	15.6	15.6	15.6	15.6	15.6
Fraction	Sunday	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6
Cooling Thermostat Setpoints																									
Fraction	Weekdays	26.7	26.7	26.7	26.7	26.7	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	26.7	26.7
Fraction	Saturday	26.7	26.7	26.7	26.7	26.7	24	24	24	24	24	24	24	24	24	24	24	24	26.7	26.7	26.7	26.7	26.7	26.7	26.7
Fraction	Sunday	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7

E1.7.3 HVAC System Configuration Description

E1.7.3.1. Overview

The *ruleset project description generation software* shall analyze the base test description individually with each of the HVAC system tests described in Sections E1.7.3.1.1 through E1.7.3.1.3.

Informative Notes:

The HVAC system configuration tests evaluate the presence of key data elements, also described below.

1. The specified HVAC system tests evaluate the following aspects of the *ruleset project description generation software*:
   (ii) Ability to populate schema elements to accurately represent common HVAC system types.
   (iii) Ability to populate schema elements from sizing runs including, sensible heating and cooling capacity, design airflows, design electric power for fans and pumps.
   (iv) Ability to populate the system efficiency for various efficiency metrics.
   (v) Ability to determine if the systems are sized based on design day sizing runs.
2. The *ruleset project description* for the baseline building for ASHRAE 90.1-2019 Performance Rating Method must have the design capacity for the heating system specified and the design sensible cooling capacity for the cooling systems specified for the associated airside systems. The design capacities are used to determine the conditioning status of zones served by the system.
3. The *ruleset project description* for the baseline building for ASHRAE 90.1-2019 Performance Rating Method with DX cooling systems, furnace heating systems, heat pump heating systems, chillers and boilers must have the rated capacity specified for the associated heating or cooling system. The rated capacity is used to determine the expected efficiency rating for each system.

E1.7.3.1.1 HVAC Test Case 1: Packaged Single Zone Heat Pump (Standard 90.1-2019, Performance Rating Method, Baseline System 4)

Each zone shall be modeled with a dedicated packaged single-zone heat pump (PSZ-HP) system. HVAC components shall include the typical single-zone fan system, cooling system, heating system, zones, and terminals as specified in Table **Error! Reference source not found.**.

Table 13: Test Case 1 - Air-Side System Parameters

Parameter Description	Specification (typical for all systems/zones)
System Service	Dedicated System per Zone
Cooling System Type	Direct Expansion
Cooling Capacity Sizing	Determined Based on Design Day Run
Rated Total Cooling Capacity	Shall be populated, but value is not checked
Design Sens. Cooling Capacity	Shall be populated, but value not checked
Cooling Oversizing Factor	15%
Cooling Efficiency, Full Load	3.1 COPnfcooling
Preheat System Type	Omitted, or NONE
Heating System Type	Heat Pump
Heating Capacity Sizing	Determined Based on Design Day Run
Rated Heating Capacity	Shall be populated, but value is not checked
Design Heating Capacity	Shall be populated, but value not checked
Heating Oversizing Factor	25%
Heating Efficiency, Full Load	3.1 COPnfheating
Auxiliary Heat Type	Electric
Auxiliary Heat Lockout Temp	4.4°C (40°F)
Heat Pump Low Lockout Temp	-23.3°C (-10°F)
Supply Fan Operation	Occupied: Continuous

	Unoccupied: Cycling to maintain temperature setpoints
Supply Fan Control	Constant Volume
Supply Fan Power	0.64 W·s/L (0.3 W/CFM)
Supply Fan Flow Sizing	Determined Based on Design Day Run
Design Supply Fan Airflow	Shall be populated, but value is not checked
Design Cooling Thermostat Temperature	Scheduled – per Table 12
Design Heating Thermostat Temperature	Scheduled – per Table 12
Ducted Supply	True
Terminal Type	Constant Volume
Design Cooling Supply Air Temperature	12.8°C (55°F)
Design Heating Supply Air Temperature	32.2°C (90°F)
Terminal Fan	Omitted, or {}
Terminal Cooling	Omitted, or NONE
Terminal Heating	Omitted, or NONE
Terminal Minimum Outdoor Airflow	0.61 L/(s·m^2) (0.12 CFM/ft^2)
Economizer	Differential dry-bulb temperature
Economizer Locks Out Compressor	False
Exhaust Air Energy Recovery	Enthalpy HX
Energy Recovery Operation	On when Minimum OA
Energy Recovery Leaving Air Temp Control	Fixed Setpoint
Sensible Recovery Effectiveness	50%
Latent Recovery Effectiveness	50%

E1.7.3.1.2. HVAC Test Case 2: Chilled Water VAV with Hot Water Reheat (Performance Rating Method Baseline System 7)

A chilled water VAV air handler shall be modeled serving all zones, and hot water reheat shall be modeled at each terminal. HVAC components and plant systems shall include a hot water heating loop with two boilers and two pumps, a primary chilled water loop with two chillers and two pumps, a secondary chilled water loop with one pump, and a condenser water loop with one heat rejection device. System parameters shall be based on Tables **Error! Reference source not found.**A-B.

Table 14A: Test Case 2 - Air-Side System Parameters

Parameter Description	Specification (typical for all systems/zones)
System Service	1 System Serves All Zones
Cooling System Type	Chilled Water
Rated Total Cooling Capacity	87,921 W (300,000 Btu/h)

Design Sens. Cooling Capacity	Shall be populated, but value not checked
Preheat System Type	Hot Water
Preheat Capacity Sizing	Input as Specified (Not Determined Based on Design Day Run)
Rated Heating Capacity	87,921 W (300,000 Btu/h)
Design Heating Capacity	Shall be populated, but value not checked
Preheat Leaving Air Temp	10°C (50°F)
Heating System Type	Omitted, or NONE
Supply Fan Operation	Occupied: Continuous Unoccupied: Off
Supply Fan Control	Variable Speed Drive
Supply Fan Flow Sizing	Input as Specified (Not Determined Based on Design Day Run)
Design Supply Fan Airflow	4,720 L/s (10,000 CFM)
Design Fan Pressure Rise	871 Pa (3.5 in. W.G.)
Fan Total Efficiency	60%
Fan Output Validation - Airflow	Shall be populated, but value not checked
Fan Output Validation - Fan Power	Shall be populated, but value not checked
Supply Air Temp Setpoint	12.8°C (55°F)
Supply Air Temp Control	Load Reset – 15.6°C (60°F) at minimum load
Supply Flow Reset	Operating Capacity Reset
Design Return Fan Flow Rate	4,248 L/s (9,000 CFM)
Ducted Return	True
Air Filter(s)	MERV 13
Terminal Type	Variable Volume
Design Cooling Thermostat Temperature	Scheduled – per Table 12
Design Heating Thermostat Temperature	Scheduled – per Table 12
Design Thermostat Heating Setpoint	21.1°C (70°F)
Design Heating Supply Air Temperature	32.2°C (90°F)
Design Thermostat Cooling Setpoint	23.9°C (75°F)
Design Cooling Supply Air Temperature	12.8°C (55°F)
Ducted Supply	True
Primary Airflow	943.9 L/s (2,000 CFM)
Terminal Minimum Airflow	141.6 L/s (300 CFM)
Terminal Minimum Outdoor Airflow	94.4 L/s (200 CFM)
Air Distribution Effectiveness	1.2
Terminal Fan	Omitted, or {}
Terminal Cooling	Omitted, or NONE
Terminal Heating	Hot Water
Terminal Heat Capacity Sizing	Input as Specified (Not Determined Based on Design Day Run)

Rated Heating Capacity	1,758 W (6,000 Btu/h)
Design Heating Capacity	Shall be populated, but value not checked
Economizer	21.1°C (70°F) high-limit shutoff
Economizer Locks Out Compressor	True
Demand Control Ventilation	Return Air CO2 Sensor
Exhaust Air Energy Recovery	Enthalpy Wheel
Energy Recovery Operation	Interlocked with Supply Fan
Energy Recovery Leaving Air Temp Control	Mixed Air Reset
Sensible Recovery Effectiveness	50%
Latent Recovery Effectiveness	50%
Humidification Type	Steam (Non-Adiabatic)
Dehumidification Type	Mechanical Cooling

Table 14B: Test Case 2 – Water-Side System Parameters

Parameter Description	Specification
Loop Type	**Hot Water**
Loop Operation	Intermittent/On-Demand
Loop Sized Based on Coincident Loads	False
Loop Flow Control	Variable Flow
Loop Pump Speed Control	Variable Speed
Pump Quantity	2
Pump Flow Sizing	Determined Based on Design Day Run
Pump Design Flow	Shall be populated, but value is not checked
HW Supply Temperature (HWST) Reset	None
Boiler Quantity	2
Boiler Type	Gas-Fired Natural Draft
Boiler Capacity Sizing	Determined Based on Design Day Run
Boiler Rated Capacity	Shall be populated, but value not checked
Boiler Staging	As required by load
Boiler Minimum Load Ratio	33%
Boiler Efficiency	90% E_c
Boiler Output Validation - Loop Load	Shall be populated, but value not checked
Boiler Output Validation - Consumption	Shall be populated, but value not checked
Loop Type	**Chilled Water (Primary Loop)**
Child Loops	[{Secondary Loop ID}]
Loop Sized Based on Coincident Loads	True
Loop Operation	Continuous
Loop Flow Control	Constant Flow
Loop Pump Speed Control	Fixed Speed
Loop Pump Power	143 W·s/L (9 W/GPM)

Pump Quantity	2
Pump Flow Sizing	Determined Based on Design Day Run
Pump Design Flow	Shall be populated, but value is not checked
Pump Interlocked with Chiller	False
Chiller Quantity	2
Chiller 1 Type	Water-cooled Centrifugal
Chiller 2 Type	Screw Chiller
Chiller Capacity Sizing	Determined Based on Design Day Run
Chiller Rated Capacity	Shall be populated, but value not checked
Chiller Design Capacity	Shall be populated, but value not checked
Chiller Part Load Efficiency	0.5 IPLV
Chiller Minimum Load Ratio	0.25
Chiller Capacity Output Validation – Chilled Water Supply Temperature	Shall be populated, but value not checked
Chiller Capacity Output Validation – Condenser Temperature	Shall be populated, but value not checked
Chiller Capacity Output Validation – Capacity	Shall be populated, but value not checked
Chiller Power Output Validation – Chilled Water Supply Temperature	Shall be populated, but value not checked
Chiller Power Output Validation – Condenser Temperature	Shall be populated, but value not checked
Chiller Power Output Validation – Loop Load	Shall be populated, but value not checked
Chiller Power Output Validation – Consumption	Shall be populated, but value not checked
Loop Type	**Chilled Water (Secondary Loop)**
Child Loops	Omitted, or []
Loop Sized Based on Coincident Loads	True
Loop Operation	Continuous
Loop Flow Control	Variable Flow
Loop Minimum Flow Ratio	0.25
Loop Design Supply Temperature	6.7°C (44°F)
Loop Design Return Temperature	13.3°C (56°F)
Supply Temperature (CHWST) Reset	**OAT < 15.6°C (60°F):** CHWST 12.2°C (54°F) **OAT 15.6-26.7°C (60-80°F):** CHWST ramped linearly 6.7-12.2°C (44-54°F) **OAT > 26.7°C (80°F):** CHWST 6.7°C (44°F)
Loop Pump Speed Control	Variable Speed
Loop Pump Power	206 W·s/L (13 W/GPM)
Pump Quantity	1

Pump Flow Sizing	Determined Based on Design Day Run
Pump Design Flow	Shall be populated, but value not checked
Pump Design Power	Shall be populated, but value not checked
Integrated Waterside Economizer	True
Loop Type	**Condenser Water**
Loop Flow Control	Constant Flow
Loop Pump Speed Control	Fixed Speed
Loop Pump Power	301 W·s/L (19 W/GPM)
Pump Quantity	1
Pump Flow Sizing	Determined Based on Design Day Run
Pump Design Flow	Shall be populated, but value not checked
Pump Design Power	Shall be populated, but value not checked
Pump Interlocked with Chiller	False
Heat Rejection Type	Open-Circuit with Axial Fan
Heat Rejection Fan Control	Variable Speed
Heat Rejection Rated Water Flow Rate	Shall be populated, but value not checked
Leaving Water Setpoint Temperature	21.1°C (70°F)
Design Wetbulb Temperature	25°C (77°F)
Heat Rejection Approach	3.9 K (7°F)
Heat Rejection Range	5.6 K (10°F)

E1.7.3.1.3. Test Case 3: Packaged VAV with Reheat and Baseboard Supplementary Heating

A packaged VAV system shall be modeled serving all zones with hot water reheat coils at each terminal and hot water baseboard supplementary heating. HVAC components and plant systems shall include parameters as specified in Tables **Error! Reference source not found.**A-B. The hot water heating loop shall be modeled with one boiler and pump, and the chilled water loop shall be modeled as primary-only with one air-cooled chiller and a pump.

Table 15A: Test Case 3 – Air-Side System Parameters

Parameter Description	Specification (typical for all systems/zones)
System Service	1 System Serves All Zones
Cooling System Type	Direct Expansion
Cooling Efficiency, Full Load	3.0 COP
Rated Total Cooling Capacity	87,921 W (300,000 Btu/h)
Design Sens. Cooling Capacity	Shall be populated, but value not checked
Preheat System Type	Hot Water
Preheat Capacity Sizing	Input as Specified (Not Determined Based on Design Day Run)
Rated Heating Capacity	43,961 W (150,000 Btu/h)
Design Heating Capacity	Shall be populated, but value not checked
Preheat Leaving Air Temp	10°C (50°F)
Heating System Type	Omitted, or NONE

Supply Fan Operation	Occupied: Continuous Unoccupied: Off
Supply Fan Control	Variable Speed Drive
Fan System Supply Air Temperature Control	Constant
Supply Fan Flow Sizing	Input as Specified (Not Determined Based on Design Day Run)
Design Supply Fan Airflow	4,720 L/s (10,000 CFM)
Supply Fan Brake Horsepower	10 bhp
Supply Fan Motor Efficiency	90%
Fan Output Validation – Airflow	Shall be populated, but value not checked
Fan Output Validation – Fan Power	Shall be populated, but value not checked
Supply Air Temp Control	Zone Reset
Supply Flow Reset	Design Load Reset
Design Cooling Thermostat Temperature	Scheduled – per Table 12
Design Heating Thermostat Temperature	Scheduled – per Table 12
Terminal 1 Type	Variable Volume
Primary Airflow	943.9 L/s (2,000 CFM)
Terminal Minimum Outdoor Airflow	94.4 L/s (200 CFM)
Air Distribution Effectiveness	0.8
Design Cooling Supply Air Temperature	12.8°C (55°F)
Design Heating Supply Air Temperature	32.2°C (90°F)
Terminal 1 Fan	Omitted, or {}
Terminal 1 Cooling	Omitted, or NONE
Terminal 1 Heating	Hot Water
Terminal 1 Heat Capacity	7,034 W (24,000 Btu/h)
Terminal 2 Type	Baseboard
Air Distribution Effectiveness	0.7
Design Heating Supply Air Temperature	32.2°C (90°F)
Terminal 2 Fan	Omitted, or {}
Terminal 2 Cooling	Omitted, or NONE
Terminal 2 Heating	Hot Water
Terminal 2 Heat Capacity	1,758 W (6,000 Btu/h)
Economizer	Differential Enthalpy
Economizer Locks Out Compressor	False
Exhaust Air Energy Recovery	Sensible Heat Wheel
Energy Recovery Operation	Scheduled On/Off

Energy Recovery Leaving Air Temp Control	Fixed Setpoint
Sensible Recovery Effectiveness	80%
Outside Airflow	471.9 L/s (1,000 CFM)
Exhaust Airflow	424.8 L/s (900 CFM)
Humidification Type	Adiabatic
Dehumidification Type	Desiccant

Table 15B: Test Case 3 - Water-Side System Parameters

Parameter Description	Specification
Loop Type	Hot Water
Child Loops	Omitted, or []
Loop Sized Based on Coincident Loads	True
Loop Operation	Scheduled, but schedule values not checked
Loop Flow Control	Constant Volume
Loop Pump Speed Control	Fixed Speed
Loop Pump Power	301 W·s/L (19 W/GPM)
Loop Design Supply Temperature	82.2°C (180°F)
Loop Design Return Temperature	54.4°C (130°F)
Pump Quantity	1
Pump Flow Sizing	Input as Specified (Not Determined Based on Design Day Run)
Pump Design Flow	1.26 L/s (20 GPM)
Pump Design Power	380 W
HW Supply Temperature (HWST) Reset	Load Reset
Boiler Type	Forced Draft
Boiler Capacity Sizing	Input as Specified (Not Determined Based on Design Day Run)
Boiler Rated Capacity	87,921 W (300,000 Btu/h)
Boiler Efficiency	90% Et
Boiler Output Validation - Loop Load	Shall be populated, but value not checked
Boiler Output Validation - Consumption	Shall be populated, but value not checked

Informative Appendix F: Additional Ruleset Project Description Generation Software Tests

F1. Additional HVAC Test Case Variations

This informative appendix provides additional *ruleset project description generation software* tests for multiple HVAC system configurations. Each test utilizes the base *ruleset project description* test defined in Section E1.7.2. The additional HVAC system tests are listed in Table 1.

Table 1: HVAC System Tests

Test ID	HVAC System Designation	HVAC System Description	Fan Control	Cooling Type	Heating Type	App G Baseline System #
100	PTAC	Packaged terminal air conditioner	Constant volume	Direct expansion	Hot-water fossil fuel boiler	1
110	PTHP	Packaged terminal heat pump	Constant volume	Direct expansion	Electric heat pump	2
120	PSZ-AC	Packaged rooftop air conditioner	Constant volume	Direct expansion	Fossil fuel furnace	3
130	Packaged VAV with reheat	Packaged rooftop VAV with reheat	VAV	Direct expansion	Hot-water fossil fuel boiler	5
140	Packaged VAV with PFP boxes	Packaged rooftop VAV with parallel fan power boxes and reheat	VAV	Direct expansion	Electric resistance	6
150	VAV with PFP boxes	VAV with parallel fan powered boxes and reheat	VAV	Chilled water	Electric resistance	8
160	Heating and ventilation	Warm air furnace, gas fired	Constant volume	None	Fossil fuel furnace	9
170	Heating and ventilation	Warm air furnace, electric	Constant volume	None	Electric resistance	10
180	SZ-VAV	Single-zone VAV	VAV	Chilled water	Electric resistance or boiler	11
190	SZ-CV-HW	Single-zone system	Constant volume	Chilled water	Hot-water fossil fuel boiler	12
200	SZ-CV-ER	Single-zone system	Constant volume	Chilled water	Electric furnace	13
210	FCU	Fan-coil unit	Constant Volume	Chilled water	Hot-water fossil fuel boiler	NA
220	FCUP	Fan-coil unit with purchased heat/CHW	Constant volume	Purchased CHW	Purchased HW	NA
230	WSHP	Water-source heat pump	Constant volume	DX	DX	NA
240	WSHP+DOAS	Water-source heat pump + constant volume dedicated outdoor air unit	Constant volume	DX	DX	NA

To minimize repetition of HVAC parameter specifications, typical system components have been established in Tables 3-10. Test cases reference these typical system components as a basis for the system specifications, then modify parameters or specify additional parameters to be applied to the respective test case. Table 2 provides a visual representation of the typical system components that are used in each test case.

Table 2: Typical System Components by Test Case

	Typical System Components							
Test ID	**Single-Zone Fan**	**Multi-Zone Fan**	**Cooling**	**Heating**	**Zone/Terminal**	**Chilled Water Loop**	**Hot Water Loop**	**Condenser Water Loop**
100	✓		✓	✓	✓		✓	
110	✓		✓	✓	✓			
120	✓		✓	✓	✓			
130		✓	✓		✓		✓	
140		✓	✓		✓			
150		✓	✓		✓	✓		
160	✓			✓	✓			
170	✓			✓	✓			
180	✓		✓	✓	✓	✓		
190	✓		✓	✓	✓	✓	✓	✓
200	✓		✓	✓	✓			
210	✓		✓	✓	✓		✓	
220	✓		✓	✓	✓			
230	✓		✓	✓	✓		✓	✓
240	✓		✓	✓	✓		✓	

Table 3: Typical Single-Zone HVAC Fan System (Parameters may be overridden in Test Cases)

Parameter Description	Specification
Supply Fan Operation	Occupied: Continuous Unoccupied: Off

Supply Fan Control	Constant Volume
Supply Fan Flow Sizing	Input as Specified (Not Determined Based on Design Day Run)
Supply Fan Power, Full Load	600 W
Design Supply Fan Airflow	943.9 L/s (2,000 CFM)

Table 4: Typical Multi-Zone HVAC Fan System (Parameters may be overridden in Test Cases)

Parameter Description	Specification
Fan System Supply Air Temperature Control	Constant
Supply Fan Operation	Occupied: Continuous Unoccupied: Off
Supply Fan Control	Variable Speed Drive
Supply Fan Flow Sizing	Input as Specified (Not Determined Based on Design Day Run)
Supply Fan Power, Full Load	10,000 W
Design Supply Fan Airflow	4,720 L/s (10,000 CFM)

Table 5: Typical Cooling System (Parameters may be overridden in Test Cases)

Parameter Description	Specification
Cooling Capacity Sizing	Input as Specified (Not Determined Based on Design Day Run)
Rated Total Cooling Capacity	17,584 W (60,000 Btu/h)
Design Sens. Cooling Capacity	Shall be populated, but value not checked

Table 6: Typical Heating System (Parameters may be overridden in Test Cases)

Parameter Description	Specification
Preheat System Type	Omitted, or NONE
Heating Capacity Sizing	Input as Specified (Not Determined Based on Design Day Run)
Rated Heating Capacity	17,584 W (60,000 Btu/h)
Design Heating Capacity	Shall be populated, but value not checked

Table 7: Typical Zone/Terminal (Parameters may be overridden in Test Cases)

Parameter Description	Specification
Design Cooling Thermostat Temperature	Scheduled – per Table 12
Design Heating Thermostat Temperature	Scheduled – per Table 12
Ducted Supply	True
Terminal Type	Constant Volume
Design Cooling Supply Air Temperature	12.8°C (55°F)

Design Heating Supply Air Temperature	32.2°C (90°F)
Terminal Fan	Omitted, or {}
Terminal Cooling	Omitted, or NONE
Terminal Heating	Omitted, or NONE
Primary Airflow	943.9 L/s (2,000 CFM)
Terminal Minimum Outdoor Airflow	94.4 L/s (200 CFM)
Air Distribution Effectiveness	0.8

Table 8: Typical Primary Chilled Water Loop (Parameters may be overridden in Test Cases)

Parameter Description	Specification
Child Loops	Omitted, or []
Loop Sized Based on Coincident Loads	True
Loop Operation	Continuous
Loop Flow Control	Variable Flow
Loop Minimum Flow Ratio	0.25
Loop Design Supply Temperature	6.7°C (44°F)
Loop Design Return Temperature	13.3°C (56°F)
Supply Temperature (CHWST) Reset	**OAT < 15.6°C (60°F):** CHWST 12.2°C (54°F) **OAT 15.6-26.7°C (60-80°F):** CHWST ramped linearly 6.7-12.2°C (44-54°F) **OAT > 26.7°C (80°F):** CHWST 6.7°C (44°F)
Loop Pump Speed Control	Variable Speed
Loop Pump Power	349 W·s/L (22 W/GPM)
Pump Flow Sizing	Input as Specified (Not Determined Based on Design Day Run)
Pump Design Flow	3.79 L/s (60 GPM)
Pump Design Power	1,320 W
Pump Interlocked with Chiller	False
Chiller Type	Screw Chiller
Chiller Condensing Loop	{Condenser Water Loop ID}
Chiller Capacity Sizing	Input as Specified (Not Determined Based on Design Day Run)
Chiller Design Capacity	87,921 W (25 tons)
Design Condenser Entering Temp	29.4°C (85°F)
Design Evaporator Leaving Temp	10°C (50°F)
Chiller Capacity Output Validation – Chilled Water Supply Temperature	Shall be populated, but value not checked
Chiller Capacity Output Validation – Condenser Temperature	Shall be populated, but value not checked

Chiller Capacity Output Validation – Capacity	Shall be populated, but value not checked
Chiller Power Output Validation – Chilled Water Supply Temperature	Shall be populated, but value not checked
Chiller Power Output Validation – Condenser Temperature	Shall be populated, but value not checked
Chiller Power Output Validation – Loop Load	Shall be populated, but value not checked
Chiller Power Output Validation – Consumption	Shall be populated, but value not checked

Table 9: Typical Hot Water Loop & Boiler (Parameters may be overridden in Test Cases)

Parameter Description	Specification
Child Loops	Omitted, or []
Loop Sized Based on Coincident Loads	True
Loop Operation	Continuous
Loop Flow Control	Variable Flow
Loop Minimum Flow Ratio	0.25
Supply Temperature (HWST) Reset	**OAT < -6.7°C (20°F):** HWST 82.2°C (180°F) **OAT -6.7-10°C (20-50°F):** HWST ramped linearly 82.2-65.6°C (180-150°F) **OAT > 10°C (50°F):** HWST 65.6°C (150°F)
Loop Pump Speed Control	Variable Speed
Loop Pump Power	301 W·s/L (19 W/GPM)
Loop Design Supply Temperature	82.2°C (180°F)
Loop Design Return Temperature	54.4°C (130°F)
Pump Flow Sizing	Input as Specified (Not Determined Based on Design Day Run)
Pump Design Flow	1.26 L/s (20 GPM)
Pump Design Power	380 W
Boiler Type	Gas-Fired Natural Draft
Boiler Capacity Sizing	Input as Specified (Not Determined Based on Design Day Run)
Boiler Rated Capacity	87,921 W (300,000 Btu/h)
Boiler Output Validation - Loop Load	Shall be populated, but value not checked
Boiler Output Validation - Consumption	Shall be populated, but value not checked

Table 10: Typical Condenser Water Loop and Heat Rejection (Parameters may be overridden in Test Cases)

Parameter Description	Specification
Child Loops	Omitted, or []
Loop Operation	Continuous

Loop Flow Control	Variable Flow
Loop Pump Speed Control	Variable Speed
Loop Pump Power	301 W·s/L (19 W/GPM)
Pump Flow Sizing	Input as Specified (Not Determined Based on Design Day Run)
Pump Design Flow	4.73 L/s (75 GPM)
Pump Design Power	1,425 W
Pump Interlocked with Chiller	True
Heat Rejection Type	Open-Circuit with Axial Fan
Heat Rejection Fan Control	Variable Speed
Heat Rejection Rated Water Flow Rate	4.73 L/s (75 GPM)
Leaving Water Setpoint Temperature	21.1°C (70°F)
Design Wetbulb Temperature	25°C (77°F)
Heat Rejection Approach	3.9 K (7°F)
Heat Rejection Range	5.6 K (10°F)

F3.2. Test Case 100: Packaged Terminal Air Conditioner (App G Baseline System 1)

Each zone shall be modeled with a dedicated packaged terminal air conditioner (PTAC) system. HVAC components shall include the typical single-zone fan system, cooling system, heating system, zones, and terminals, and hot water heating loop with one boiler and pump. Typical component parameters shall be based on Tables 3-10 with additional parameters and/or parameter modifications as specified in Tables 11A-B.

Table 11A: Test Case 100: Air-Side System Parameters

Parameter Description	Specification (typical for all systems/zones)
System Service	Dedicated System per Zone
Cooling System Type	Direct Expansion
Cooling Efficiency, Full Load	3.1 COPnfcooling
Heating System Type	Hot Water
Ducted Supply	False

Table 11B: Test Case 100: Water-Side System Parameters

Parameter Description	Specification
Loop Type	Hot Water
Boiler Efficiency	84% AFUE

F3.3. Test Case 110: Packaged Terminal Heat Pump (PTHP) (App G Baseline System 2)

Each zone shall be modeled with a dedicated packaged terminal heat pump (PTHP) system. HVAC components shall include the typical single-zone fan system, cooling system, heating system, zones, and

terminals. System parameters shall be based on Tables 3-10 with additional parameters and/or parameter modifications as specified in Table 12A.

Table 12A: Test Case 110: Air-Side System Parameters

Parameter Description	Specification (typical for all systems/zones)
System Service	Dedicated System per Zone
Cooling System Type	Direct Expansion
Cooling Efficiency, Full Load	12.3 IEER
Heating System Type	Heat Pump
Heating Efficiency, Full Load	8.0 HSPF
Auxiliary Heat Type	Gas Furnace
Supply Fan Operation	Occupied: Continuous Unoccupied: Continuous
Ducted Supply	False
Minimum Outdoor Airflow	283.2 L/s (600 CFM)
Max. Outdoor Airflow	943.9 L/s (2,000 CFM)

F3.4. Test Case 120: Packaged Single Zone (PSZ) (App G Baseline System 3)

All zones shall be modeled with a dedicated packaged single-zone air conditioning (PSZ) system. HVAC components shall include the typical single-zone fan system, cooling system, heating system, zones, and terminals. Typical component parameters shall be based on Tables 3-10 with additional parameters and/or parameter modifications as specified in Table 13A.

Table 13A: Test Case 120 - Air-Side System Parameters

Parameter Description	Specification (typical for all systems/zones)
System Service	Dedicated System per Zone
Cooling System Type	Direct Expansion
Cooling Efficiency, Full Load	3.0 COP
Heating System Type	Furnace
Heating Efficiency, Full Load	78% AFUE
Exhaust Air Energy Recovery	Sensible HX
Energy Recovery Operation	Interlocked with Supply Fan
Energy Recovery Leaving Air Temp Control	Fixed Setpoint
Sensible Recovery Effectiveness	80%

F3.5. Test Case 130: Packaged VAV with Hot Water Reheat (App G Baseline System 5)

A packaged VAV air handler shall be modeled serving all zones, and hot water reheat shall be modeled at each terminal. HVAC components shall include the typical multi-zone fan system, cooling system, zones, and terminals, and hot water heating loop with one boiler and pump. Typical component

parameters shall be based on Tables 3-10 with additional parameters and/or parameter modifications as specified in Tables 14A-B.

Table 14A: Test Case 130 - Air-Side System Parameters

Parameter Description	Specification (typical for all systems/zones)
System Service	1 System Serves All Zones
Cooling System Type	Direct Expansion
Cooling Efficiency, Full Load	10.0 EER
Rated Total Cooling Capacity	87,921 W (300,000 Btu/h)
Preheat System Type	Hot Water
Preheat Capacity Sizing	Input as Specified (Not Determined Based on Design Day Run)
Rated Heating Capacity	43,961 W (150,000 Btu/h)
Preheat Leaving Air Temp	Scheduled
Heating System Type	Omitted, or NONE
Fan Output Validation - Airflow	Shall be populated, but value not checked
Fan Output Validation - Fan Power	Shall be populated, but value not checked
Terminal Type	Variable Volume
Terminal Minimum Airflow	141.6 L/s (300 CFM)
Terminal Heating	Hot Water
Terminal Heat Capacity	8,792 W (30,000 Btu/h)

Table 14B: Test Case 130 - Water-Side System Parameters

Parameter Description	Specification
Loop Type	**Hot Water**
Boiler Efficiency	84% AFUE

F3.6. Test Case 140: Packaged VAV with Parallel Fan-Powered Boxes (App G Baseline System 6)

A packaged VAV air handler shall be modeled serving all zones, and parallel fan-powered boxes shall be modeled at each terminal. HVAC components shall include the typical multi-zone fan system, cooling system, zones, and terminals. Typical component parameters shall be based on Tables 3-10 with additional parameters and/or parameter modifications as specified in Table 15A.

Table 15A: Test Case 140 - Air-Side System Parameters

Parameter Description	Specification (typical for all systems/zones)
System Service	1 System Serves All Zones
Cooling System Type	Direct Expansion
Cooling Efficiency, Full Load	11.0 CEER
Rated Total Cooling Capacity	87,921 W (300,000 Btu/h)
Preheat System Type	Electric Resistance

Preheat Capacity Sizing	Input as Specified (Not Determined Based on Design Day Run)
Rated Heating Capacity	43,961 W (150,000 Btu/h)
Preheat Leaving Air Temp	10°C (50°F)
Heating System Type	Omitted, or NONE
Fan Output Validation - Airflow	Shall be populated, but value not checked
Fan Output Validation - Fan Power	Shall be populated, but value not checked
Terminal Type	Variable Volume
Terminal Minimum Airflow	141.6 L/s (300 CFM)
Terminal Fan	1 Fan in Parallel Configuration
Terminal Heating	Electric Resistance
Terminal Heat Capacity	8,792 W (30,000 Btu/h)
Supply Air Temp Control	Scheduled: 5AM-5PM: (55°F), 5PM-5AM: (65°F)

F3.7. Test Case 150: Chilled Water VAV with PFP Boxes (App G Baseline System 8)

A chilled water VAV air handler shall be modeled serving all zones, and parallel fan-powered boxes shall be modeled at each terminal. HVAC components shall include the typical multi-zone fan system, cooling system, zones, and terminals. Plant systems shall include a typical primary chilled water heating loop with one air-cooled chiller and pump. Typical component parameters shall be based on Tables 3-10 with additional parameters and/or parameter modifications as specified in Tables 16A-B.

Table 16A: Test Case 150 – Air-Side System Parameters

Parameter Description	Specification (typical for all systems/zones)
System Service	1 System Serves All Zones
Cooling System Type	Chilled Water
Rated Total Cooling Capacity	87,921 W (300,000 Btu/h)
Preheat System Type	Electric Resistance
Preheat Capacity Sizing	Input as Specified (Not Determined Based on Design Day Run)
Rated Heating Capacity	87,921 W (300,000 Btu/h)
Heating System Type	Omitted, or NONE
Central Heat Operation	Locked Out During Unoccupied Hours
Fan Output Validation – Airflow	Shall be populated, but value not checked
Fan Output Validation – Fan Power	Shall be populated, but value not checked
Terminal Type	Variable Volume
Terminal Minimum Airflow	141.6 L/s (300 CFM)
Terminal Fan	1 Fan in Parallel Configuration
Terminal Heating	Electric Resistance
Exhaust Air Energy Recovery	Heat Pipe
Energy Recovery Operation	Interlocked with Supply Fan
Energy Recovery Leaving Air Temp Control	Fixed Setpoint

Sensible Recovery Effectiveness	50%
Dehumidification Type	Series Heat Recovery

Table 16B: Test Case 150 – Water-Side System Parameters

Parameter Description	Specification
Loop Type	**Chilled Water**
Chiller Part Load Efficiency	0.5 NPLV
Chiller Condensing Loop	Omitted
Heat Rejection Type	Air-Cooled Condenser
Heat Rejection Fan Control	Two-speed

F3.8. Test Case 160: Gas-Fired Heating and Ventilation (App G Baseline System 9)

Each zone shall be modeled with a dedicated gas-fired heating and ventilation system. HVAC components shall include the typical single-zone fan system, heating system, zones, and terminals. Typical component parameters shall be based on Tables 3-10 with additional parameters and/or parameter modifications as specified in Table 17A.

Table 17A: Test Case 160 – Air-Side System Parameters

Parameter Description	Specification (typical for all systems/zones)
System Service	Dedicated System per Zone
Cooling System Type	Non-mechanical
Non-Mechanical Cooling Fan Flow	118.0 L/s (250 CFM)
Heating System Type	Furnace
Heating Efficiency, Full Load	78% AFUE
Design Cooling Supply Air Temperature	Omitted
Zonal Exhaust Fan	23.6 L/s (50 CFM) design airflow; 100% motor heat to airflow, 0% motor heat to zone

F3.9. Test Case 170: Electric Resistance Heating and Ventilation (App G Baseline System 10)

Each zone shall be modeled with a dedicated electric resistance heating and ventilation system. HVAC components shall include the typical single-zone fan system, heating system, zones, and terminals. Typical component parameters shall be based on Tables 3-10 with additional parameters and/or parameter modifications as specified in Table 18A.

Table 18A: Test Case 170 – Air-Side System Parameters

Parameter Description	Specification (typical for all systems/zones)
System Service	Dedicated System per Zone
Cooling System Type	Omitted, or NONE
Heating System Type	Electric Resistance

Heating Efficiency, Full Load	100% E_t
Design Cooling Supply Air Temperature	Omitted

F3.10. Test Case 180: Single-Zone VAV (App G Baseline System 11)

Each zone shall be modeled with a dedicated single-zone VAV system. HVAC components shall include the typical single-zone fan system, cooling system, heating system, zones, and terminals. Typical component parameters shall be based on Tables 3-10 with additional parameters and/or parameter modifications as specified in Tables 19A-B.

Table 19A: Test Case 180 – Air-Side System Parameters

Parameter Description	Specification (typical for all systems/zones)
System Service	Dedicated System per Zone
Cooling System Type	Chilled Water
Heating System Type	Electric Resistance
Heating Efficiency, Full Load	100% E_t
Supply Fan Control	Variable Speed Drive
Fan Output Validation – Airflow	Shall be populated, but value not checked
Fan Output Validation – Fan Power	Shall be populated, but value not checked
Terminal Type	Variable Volume
Terminal Minimum Airflow	141.6 L/s (300 CFM)

Table 19B: Test Case 180 – Water-Side System Parameters

Parameter Description	Specification
Loop Type	**Chilled Water**
Chiller Part Load Efficiency	0.5 NPLV
Chiller Condensing Loop	Omitted
Heat Rejection Type	Air-Cooled Condenser

F3.11. Test Case 190: Single-Zone CV w/ CHW & HW Coils (App G Baseline System 12)

Each zone shall be modeled with a dedicated single-zone constant volume system with chilled water and hot water coils. HVAC components shall include the typical single-zone fan system, cooling system, heating system, zones, and terminals. Typical component parameters shall be based on Tables 3-10 with additional parameters and/or parameter modifications as specified in Tables 20A-B.

Table 20A: Test Case 190 – Air-Side System Parameters

Parameter Description	Specification (typical for all systems/zones)
System Service	Dedicated System per Zone
Cooling System Type	Chilled Water
Heating System Type	Hot Water
Economizer	High limit shutoff of (28 Btu/lb) of dry air

Economizer Locks Out Compressor	False

Table 20B: Test Case 190 – Water-Side System Parameters

Parameter Description	Specification
Loop Type	**Hot Water**
Boiler Efficiency	84% AFUE
Loop Type	**Chilled Water**
Chiller Part Load Efficiency	0.5 NPLV
Loop Type	**Condenser Water**
Heat Rejection Type	Closed-circuit cooling tower/fluid cooler
Heat Rejection Fan Control	Two-speed

F3.12. Test Case 200: Single-Zone CV w/ CHW & Electric Resistance (App G Baseline System 13)

Each zone shall be modeled with a dedicated single-zone constant volume system with chilled water and electric resistance coils. HVAC components shall include the typical single-zone fan system, cooling system, heating system, zones, and terminals. Typical component parameters shall be based on Tables 3-10 with additional parameters and/or parameter modifications as specified in Tables 21A-B.

Table 21A: Test Case 200 – Air-Side System Parameters

Parameter Description	Specification (typical for all systems/zones)
System Service	Dedicated System per Zone
Cooling System Type	Chilled Water
Heating System Type	Electric Resistance
Heating Efficiency, Full Load	100% E_t

Table 21B: Test Case 200 – Water-Side System Parameters

Parameter Description	Specification
Loop Type	**Chilled Water**
Chiller Part Load Efficiency	0.5 NPLV
Chiller Condensing Loop	Omitted
Heat Rejection Type	Air-Cooled Condenser

F3.13. Test Case 210: Fan Coil Unit with Chilled Water/Hot Water

Each zone shall be modeled with a dedicated single-zone fan coil unit with hot water and chilled water coils. HVAC components shall include the typical single-zone fan system, cooling system, heating system, zones, and terminals. Plant systems shall include a typical hot water heating loop with one boiler and pump, and a typical primary chilled water loop with one air-cooled chiller and pump. Typical component parameters shall be based on tables 3-10 with additional parameters and/or parameter modifications as specified in Tables 22A-B.

Table 22A: Test Case 210 – Air-Side System Parameters

Parameter Description	Specification (typical for all systems/zones)
System Service	Dedicated System per Zone
Cooling System Type	Chilled Water
Heating System Type	Hot Water

Table 22B: Test Case 210 – Water-Side System Parameters

Parameter Description	Specification
Loop Type	**Hot Water**
Boiler Efficiency	84% AFUE
Loop Type	**Chilled Water**
Chiller Part Load Efficiency	0.5 NPLV
Chiller Condensing Loop	Omitted
Heat Rejection Type	Air-Cooled Condenser

F3.14. Test Case 220: Fan Coil Unit with Purchased Chilled Water/Hot Water

Each zone shall be modeled with a dedicated single-zone fan coil unit served by a purchased hot water loop and a purchased chilled water loop. HVAC components shall include the typical single-zone fan system, cooling system, heating system, zones, and terminals. Typical component parameters shall be based on Tables 3-10 with additional parameters and/or parameter modifications as specified in Tables 23A-B.

Table 23A: Test Case 220 – Air-Side System Parameters

Parameter Description	Specification (typical for all systems/zones)
System Service	Dedicated System per Zone
Cooling System Type	Chilled Water
Heating System Type	Hot Water

Table 23B: Test Case 220 – Water-Side System Parameters

Parameter Description	Specification
Loop Type	**Purchased Hot Water**
Loop Type	**Purchased Chilled Water**

F3.15. Test Case 230: Water-Source Heat Pump

Each zone shall be modeled with a dedicated single-zone water-source heat pump system. HVAC components shall include the typical single-zone fan system, cooling system, heating system, zones, and terminals. Plant systems shall include a typical condenser water loop (heat pump loop) with one heat rejection device and a typical hot water heating loop with one boiler and pump. Typical component

parameters shall be based on Tables 3-10 with additional parameters and/or parameter modifications as specified in Tables 24A-B.

Table 24A: Test Case 230 – Air-Side System Parameters

Parameter Description	Specification (typical for all systems/zones)
System Service	Dedicated System per Zone
Cooling System Type	Water-source Heat Pump
Cooling Efficiency, Full Load	13.0 EER
Heating System Type	Water-source Heat Pump
Heating Efficiency, Full Load	4.3 COP_H

Table 24B: Test Case 230 – Water-Side System Parameters

Loop Type	**Condenser Water**
Loop Type	**Hot Water**
Boiler Efficiency	84% AFUE

F3.16. Test Case 240: Water-Source Heat Pump with Dedicated Outdoor Air System

Each zone shall be modeled with a dedicated single-zone water-source heat pump system with ventilation provided by a dedicated outdoor air system. HVAC components shall include a multi-zone fan system with 100% outdoor air, and typical single-zone fan systems, cooling systems, heating systems, zones, and terminals. Plant systems shall include a typical condenser water loop (heat pump loop) with one heat rejection device and a typical hot water heating loop with one boiler and pump. Typical component parameters shall be based on Tables 3-10 with additional parameters and/or parameter modifications as specified in Tables 25A-B.

Table 25A: Test Case 240 - Air-Side System Parameters

DOAS System Service	1 System Serves All Zones
Cooling System Type	Water-source Heat Pump
Cooling Efficiency, Full Load	13.0 EER
Heating System Type	Water-source Heat Pump
Heating Efficiency, Full Load	4.3 COP_H
Minimum Outdoor Airflow	471.9 L/s (1,000 CFM)
Maximum Outdoor Airflow	471.9 L/s (1,000 CFM)
Supply Air Temp Control	Constant
Supply Fan Operation	Occupied: Continuous Unoccupied: Off
Supply Fan Control	Variable Volume
Supply Fan Flow Sizing	Input as Specified (Not Determined Based on Design Day Run)
Supply Fan Power, Full Load	1,000 W
Design Supply Fan Airflow	471.9 L/s (1,000 CFM)
WSHP System Service	Dedicated System per Zone

Cooling System Type	Water-source Heat Pump
Cooling Efficiency, Full Load	13.0 EER
Heating System Type	Water-source Heat Pump
Heating Efficiency, Full Load	4.3 COP_H

Table 25B: Test Case 240 - Water-Side System Parameters

Loop Type	**Condenser Water**
Loop Type	**Hot Water**
Boiler Efficiency	84% AFUE

Informative Appendix G

INFORMATIVE REFERENCES

This appendix contains informative references for the convenience of users of Standard 229P and to acknowledge source documents when appropriate. Some documents are also included in Section 10, "Normative References," because there are other citations of those documents within the standard that are normative.

Reference		Section
ANSI/ASHRAE Standard 232P		
ASHRAE SI Guide for HVAC&R	ASHRAE Handbook: SI Guide for HVAC&R	
ANSI/ASHRAE/IES Standard 90.1-2019	Energy Standard for Buildings Except Low-Rise Residential Buildings	Normative Appendix G
ACM Approval Manual	Title 24 Alternative Calculation Method Approval Manual	