American Council for an Energy-Efficient Economy

2018 Hot Water Forum

Wednesday, March 21, 2018

Energy Simulation of DHW

ASHRAE 90.1, 140, and V&V

Session 1B. Verification and Validation of Hot Water System Simulations

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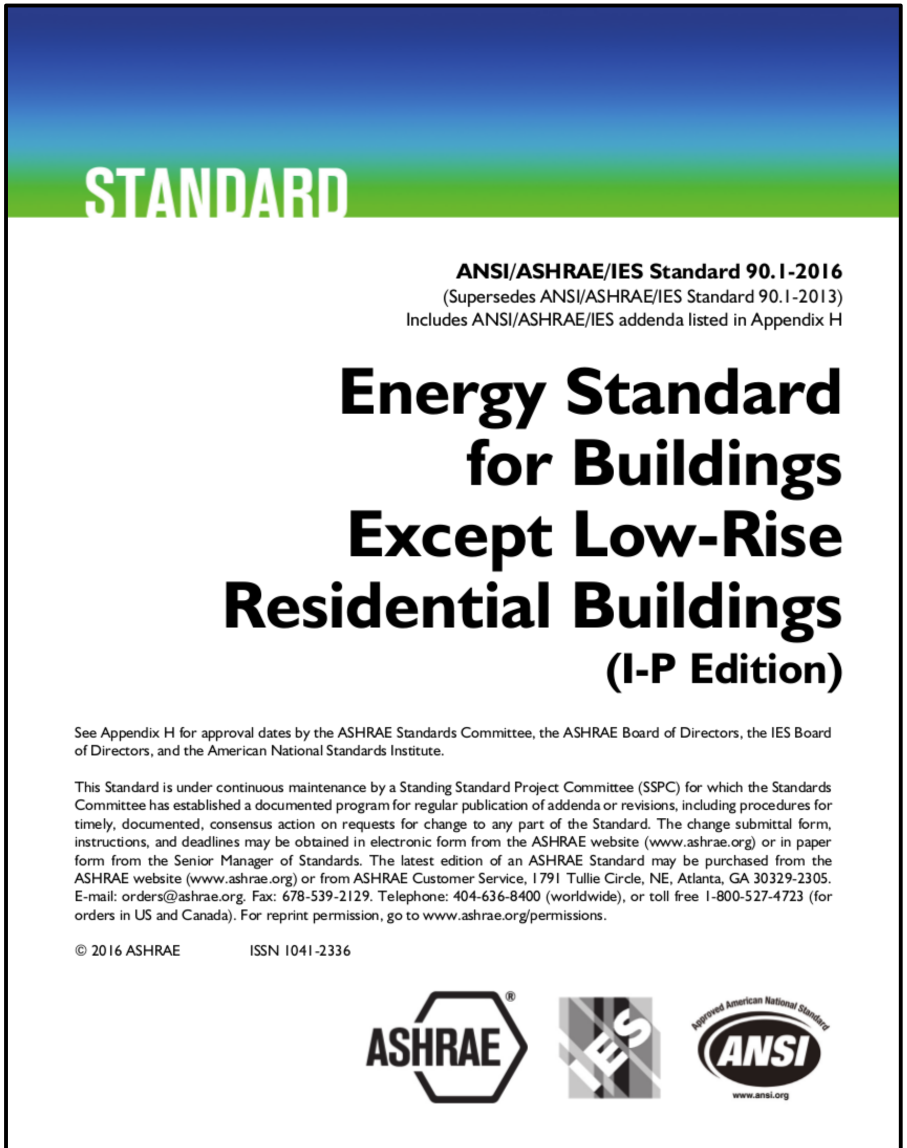
ASHRAE Standard 90.1

Energy Standard for Buildings
Except Low-Rise Residential Buildings


STANDARD

ANSI/ASHRAE/IES Standard 90.1-2016
(Supersedes ANSI/ASHRAE/IES Standard 90.1-2013)
Includes ANSI/ASHRAE/IES addenda listed in Appendix H

Energy Standard for Buildings Except Low-Rise Residential Buildings
(I-P Edition)

See Appendix H for approval dates by the ASHRAE Standards Committee, the ASHRAE Board of Directors, the IES Board of Directors, and the American National Standards Institute.

This Standard is under continuous maintenance by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the Standard. The change submittal form, instructions, and deadlines may be obtained in electronic form from the ASHRAE website (www.ashrae.org) or in paper form from the Senior Manager of Standards. The latest edition of an ASHRAE Standard may be purchased from the ASHRAE website (www.ashrae.org) or from ASHRAE Customer Service, 1791 Tullie Circle, NE, Atlanta, GA 30329-2305. E-mail: orders@ashrae.org. Fax: 678-539-2129. Telephone: 404-636-8400 (worldwide), or toll free 1-800-527-4723 (for orders in US and Canada). For reprint permission, go to www.ashrae.org/permissions.

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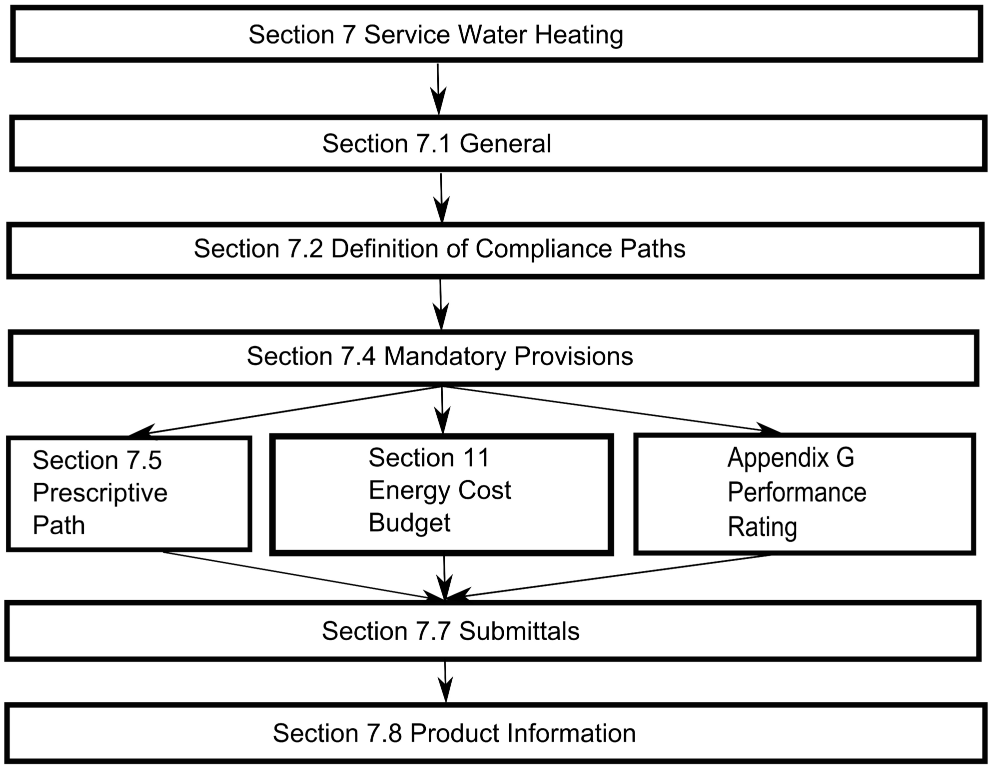
Standard 90.1 has been a benchmark for commercial building energy codes in the United States and a key basis for codes and standards around the world for more than 35 years.

Service Water Heating in 90.1



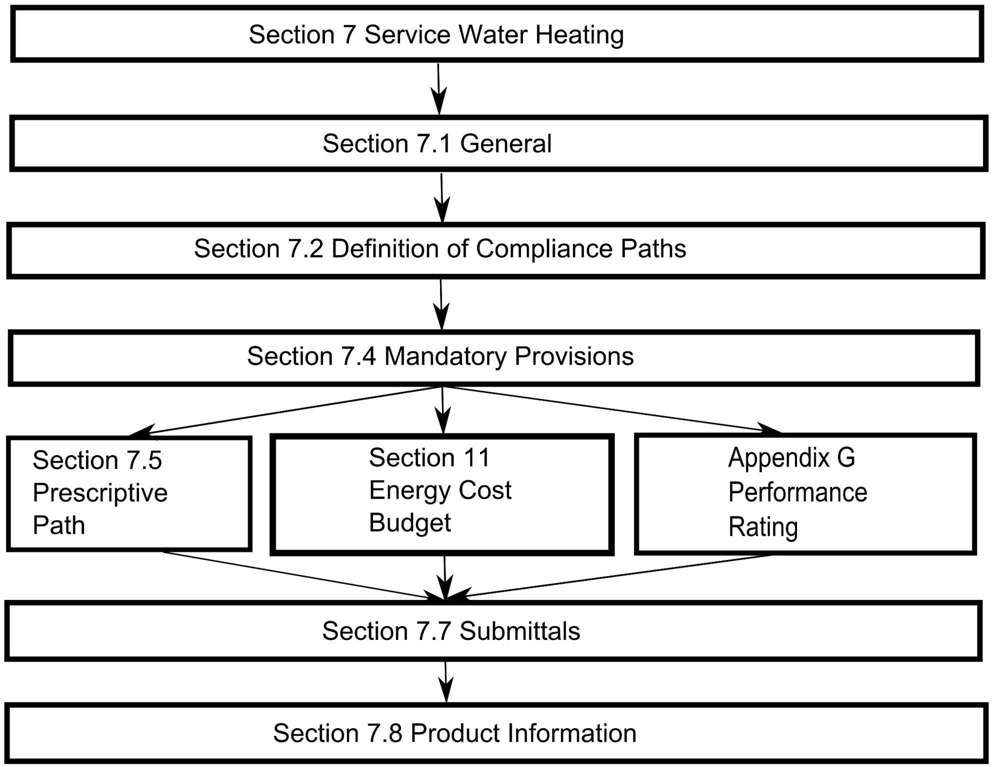
<u>7.4 Mandatory Provisions</u>:

- Load Calculations
  - manufacturers' sizing guidelines, or
  - generally accepted engineering standards and handbooks (ASHRAE Handbook)
- Listed Equipment Efficiency
- Service Hot-Water Piping Insulation
- Service Water-Heating System Controls

<u>7.5 Prescriptive Path:</u>

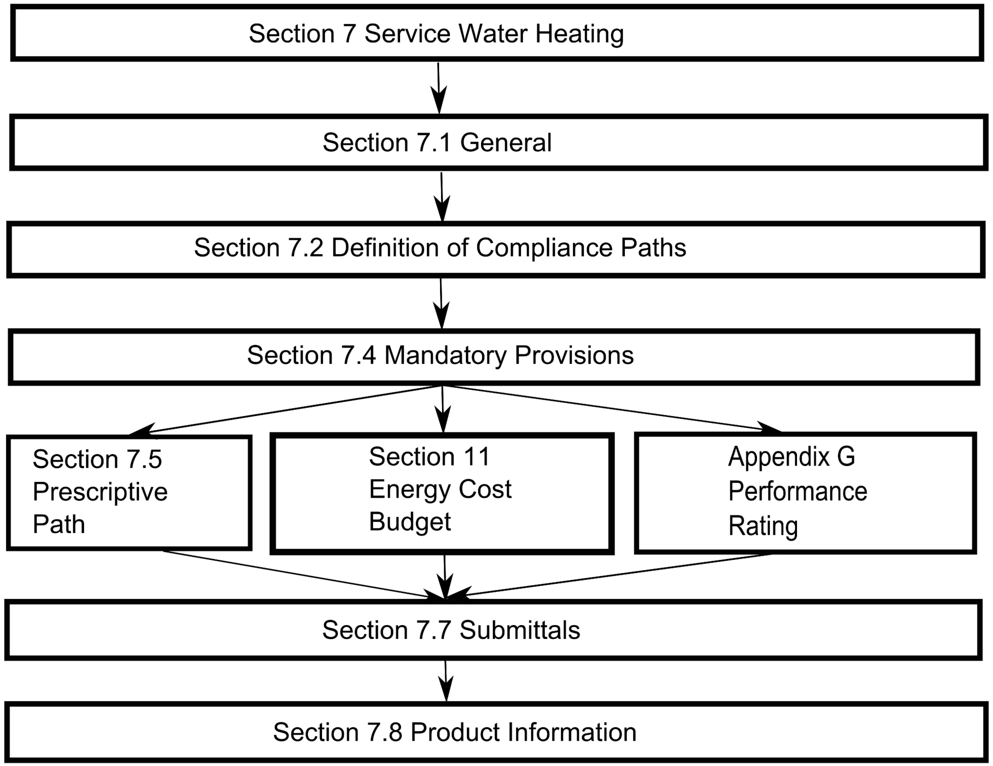
- Only
  - Gas-fired combi
  - Large gas-fired systems Et ≥ 90%

Service Water Heating in 90.1



<u>11 Energy Cost Budget Method</u>:
- Simulation Program
  - like DOE-2 or BLAST
  - tested to ASHRAE Standard 140
    - except Section 7
- service water-heating system type in budget building design shall be identical to proposed design

Service Water Heating in 90.1



<u>Appendix G Performance Rating Method</u>:

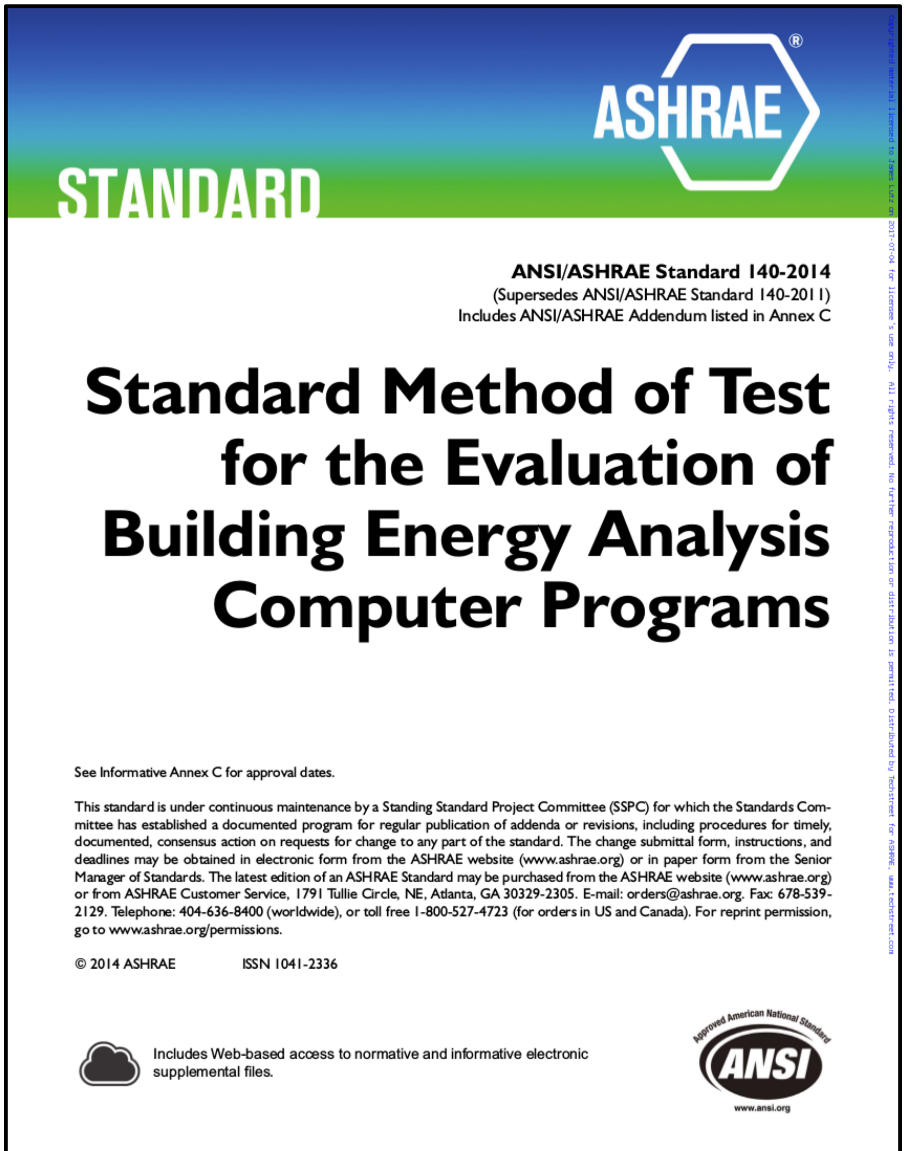
- Simulation Program
  - like DOE-2 or BLAST
  - tested to ASHRAE Standard 140
    - except Section 7
- Service water-heating energy consumption calculated from
  - volume of service water heating required
  - entering makeup water temperatures
  - leaving service water-heating temperatures.

Service water loads and use same for both proposed design and baseline building design

- except when:
  - reduced by water conservation measures that reduce amount of service water required
  - energy consumption can be reduced by
    - reducing required temperature of service mixed water (chemical sanitizers),
    - by increasing temperature (????), or
    - by increasing temperature of the entering makeup water (heat recovery).
  - Service water heating use reduced by reducing the hot fraction of mixed water to achieve required operational temperature (drain water heat recovery)
- Such reduction shall be demonstrated by calculations.

ASHRAE Standard 140

Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programs


STANDARD

ASHRAE

ANSI/ASHRAE Standard 140-2014
(Supersedes ANSI/ASHRAE Standard 140-2011)
Includes ANSI/ASHRAE Addendum listed in Annex C

Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programs

See Informative Annex C for approval dates.

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Includes Web-based access to normative and informative electronic supplemental files.

Approved American National Standard ANSI www.ansi.org

1. PURPOSE
This standard specifies test procedures for evaluating the technical capabilities and ranges of applicability of computer programs that calculate the thermal performance of buildings and their HVAC systems.

2. SCOPE
These standard test procedures apply to building energy computer programs that calculate the thermal performance of a building and its mechanical systems. While these standard test procedures cannot test all algorithms within a building energy computer program, they can be used to indicate major flaws or limitations in capabilities.

ASHRAE Standard 140

Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programs

Developed to identify and diagnose differences in predictions from whole-building energy simulation software caused by

- algorithmic differences,
- modeling limitations,
- faulty coding,
- input errors, or
- inadequate documentation.

Tests software

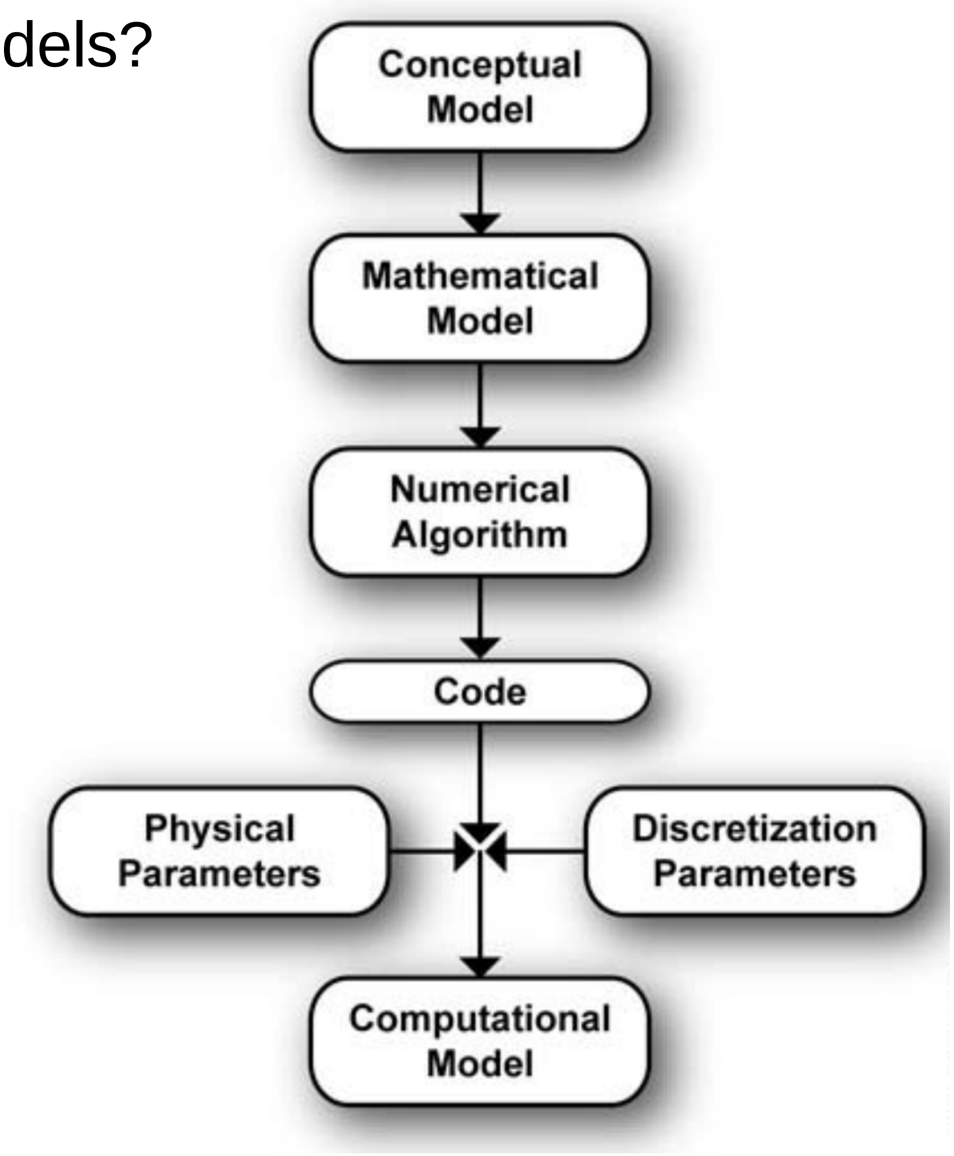
- over a broad range of parametric interactions and
- for a number of different output types,
- minimizes concealed of algorithmic differences hidden by compensating errors

Mechanical systems covered

- space-cooling
- space-heating
- are quasi-steady state models that use performance curves
- **no** waters heaters
- **no** hot water distribution system

Verification and Validation

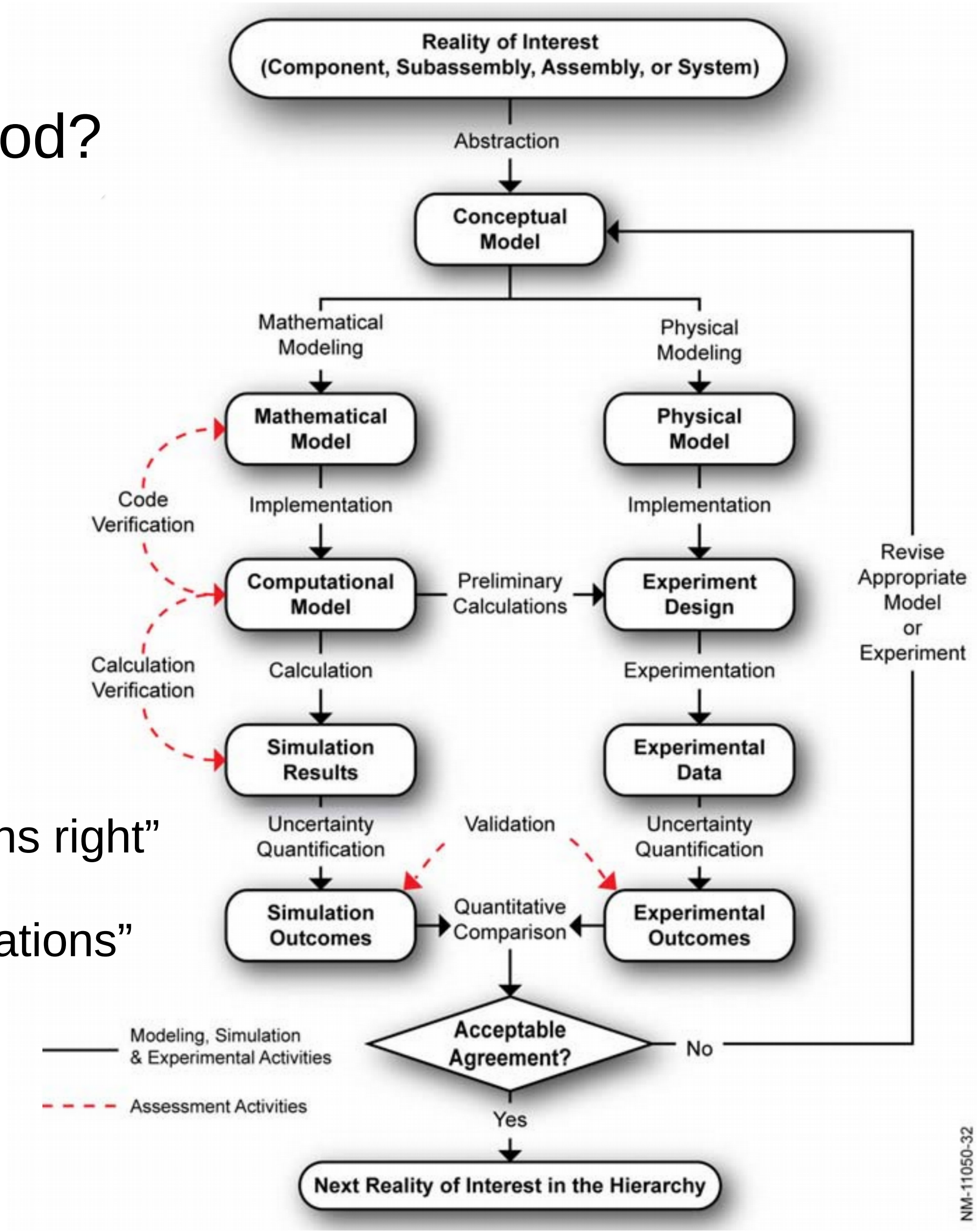
What are models?



source: ASME PTC 60/V&V 10

Verification and Validation

How do we know
our models are good?



"Verification is solving the equations right"

"Validation is solving the right equations"
(Boehm 1981)

source: ASME PTC 60/V&V 10

Verification and Validation

Technique	Advantages	Disadvantages
Empirical Validation Test of model and solution process	• Approximate truth standard within experimental accuracy • Any level of complexity	• Experimental uncertainties: • Instrument calibration, spatial/temporal discretization • Instrumentation can alter building operation • Imperfect knowledge/specification of the experimental object (building) being simulated • High quality, detailed measurements are expensive and time consuming • Only a limited number of test conditions are practical
Analytical Verification Test of solution process	• No input uncertainty • Exact mathematical or secondary mathematical truth standard for the given model • Inexpensive	• No test of model validity • Limited to highly constrained cases for which analytical or quasi-analytical solutions can be developed*
Comparative Testing Relative test of model and solution process	• No input uncertainty • Any level of complexity • Many diagnostic comparisons possible • Inexpensive and quick	• No absolute truth standard (only statistically based acceptance ranges are possible)

* Use of verified numerical solutions can extend the analytical verification approach to more realistic cases.

source: ASHRAE Standard 140

Parting Thoughts

- Easier to test water heaters and plumbing systems in a lab than to test buildings in a lab.
- Building energy simulationists have been thinking about this for decades
- Building energy simulationists want to model hot water systems
- Caution: calibration tests are not validation tests
- other?