SPECIAL NOTE

This American National Standard (ANS) is a national voluntary consensus standard developed under the auspices of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). *Consensus* is defined by the American National Standards Institute (ANSI), of which ASHRAE is a member and which has approved this standard as an ANS, as "substantial agreement reached by directly and materially affected interest categories. This signifies the concurrence of more than a simple majority, but not necessarily unanimity. Consensus requires that all views and objections be considered, and that an effort be made toward their resolution." Compliance with this standard is voluntary until and unless a legal jurisdiction makes compliance mandatory through legislation.

ASHRAE obtains consensus through participation of its national and international members, associated societies, and public review.

ASHRAE Standards are prepared by a Project Committee appointed specifically for the purpose of writing the Standard. The Project Committee Chair and Vice-Chair must be members of ASHRAE; while other committee members may or may not be ASHRAE members, all must be technically qualified in the subject area of the Standard. Every effort is made to balance the concerned interests on all Project Committees.

The Assistant Director of Technology for Standards and Special Projects of ASHRAE should be contacted for:

a. interpretation of the contents of this Standard,
b. participation in the next review of the Standard,
c. offering constructive criticism for improving the Standard, or
d. permission to reprint portions of the Standard.

DISCLAIMER

ASHRAE uses its best efforts to promulgate Standards and Guidelines for the benefit of the public in light of available information and accepted industry practices. However, ASHRAE does not guarantee, certify, or assure the safety or performance of any products, components, or systems tested, installed, or operated in accordance with ASHRAE's Standards or Guidelines or that any tests conducted under its Standards or Guidelines will be nonhazardous or free from risk.

ASHRAE INDUSTRIAL ADVERTISING POLICY ON STANDARDS

ASHRAE Standards and Guidelines are established to assist industry and the public by offering a uniform method of testing for rating purposes, by suggesting safe practices in designing and installing equipment, by providing proper definitions of this equipment, and by providing other information that may serve to guide the industry. The creation of ASHRAE Standards and Guidelines is determined by the need for them, and conformance to them is completely voluntary.

In referring to this Standard or Guideline and in marking of equipment and in advertising, no claim shall be made, either stated or implied, that the product has been approved by ASHRAE.

CONTENTS

ANSI/ASHRAE Standard 140-2007
Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programs

SECTION **PAGE**

NOTE

When addenda, interpretations, or errata to this standard have been approved, they can be downloaded free of charge from the ASHRAE Web site at http://www.ashrae.org.

1791 Tullie Circle NE
Atlanta, GA 30329
www.ashrae.org

(This foreword is not part of the standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

FOREWORD

This Standard Method of Test can be used for identifying and diagnosing predictive differences from whole building energy simulation software that may possibly be caused by algorithmic differences, modeling limitations, input differences, or coding errors. The current set of tests included herein consists of

- *comparative tests that focus on building thermal envelope and fabric loads and mechanical equipment performance*

and

- *analytical verification tests that focus on mechanical equipment performance.*

These tests are part of an overall validation methodology described in Annex B18.

This procedure tests software over a broad range of parametric interactions and for a number of different output types, thus minimizing the concealment of algorithmic differences by compensating errors. Different building energy simulation programs, representing different degrees of modeling complexity, can be tested. However, some of the tests may be incompatible with some building energy simulation programs.

The tests are a subset of all the possible tests that could occur. A large amount of effort has gone into establishing a sequence of tests that examine many of the thermal models relevant to simulating the energy performance of a building and its mechanical equipment. However, because building energy simulation software operates in an immense parameter space, it is not practical to test every combination of parameters over every possible range of function.

The tests consist of a series of carefully described test case building plans and mechanical equipment specifications. Output values for the cases are compared and used in conjunction with diagnostic logic to determine the sources of predictive differences. For the building thermal envelope and fabric load cases of Section 5.2, the "basic" cases (Sections 5.2.1 and 5.2.2) test the ability of the programs to model such combined effects as thermal mass, direct solar gain windows, window-shading devices, internally generated heat, infiltration, sunspaces, and deadband and setback thermostat control. The "in-depth" cases (Section 5.2.3) facilitate diagnosis by allowing excitation of specific heat transfer mechanisms. The space-cooling equipment cases of Section 5.3 test the ability of programs to model the performance of unitary space-cooling equipment using manufacturer design data presented as empirically derived performance maps. In the steady-state analytical verification cases of Sections 5.3.1 and 5.3.2, which utilize a typical range of performance data, the following parameters are varied: sensible internal gains, latent internal gains, zone thermostat setpoint (entering dry-bulb temperature), and outdoor dry-bulb temperature. Parametric variations isolate the effects of the parameters singly and in various combinations and isolate the influence of part-loading of equipment, varying sensible heat ratio, "dry" coil (no latent load) versus "wet" coil (with dehumidification) operation, and operation at typical Air-Conditioning and Refrigeration Institute (ARI) rating conditions. Quasi-analytical solution results are presented for the test cases in this section. The comparative test cases of Sections 5.3.3 and 5.3.4 utilize an expanded range of performance data, an outside air mixing system and hourly varying weather data and internal gains. These cases cannot be solved analytically. In these cases the following parameters are varied: sensible internal gains, latent internal gains, infiltration rate, outside air fraction, thermostat setpoints, and economizer control settings. Through analysis of results, the influence of part loading of equipment, ODB sensitivity, and "dry" coil (no latent load) versus "wet" coil (with dehumidification) operation can also be isolated. These cases help to scale the significance of simulation results disagreements in a realistic context, which is less obvious in the steady-state analytical verification cases of Sections 5.3.1 and 5.3.2. The space heating equipment cases of Section 5.4 test the ability of programs to model the performance of residential fuel-fired furnaces. These tests are divided into two tiers. The Tier 1 cases (Sections 5.4.1 and 5.4.2—Analytical Verification Tests) employ simplified boundary conditions and test the basic functionality of furnace models. Boundary conditions that are more realistic are used in the Tier 2 cases (Section 5.4.3—Comparative Tests), where specific aspects of furnace models are examined. The full set of space heating test cases is designed to test the implementation of specific algorithms for modeling the following aspects of furnace performance: furnace steady-state efficiency, furnace part-load ratio, furnace fuel consumption, circulating fan operation, and draft fan operation. These cases also test the effects of thermostat setback and undersized capacity.

For consistent numbering of test cases within the standard, case numbers used for the mechanical equipment tests in Sections 5.3 and 5.4 have been changed from the numbering used in the original research reports where the test specifications were developed. For example, in Section 5.3.1, Case CE100 was named Case E100 in the original research.

The tests have a variety of uses, including:

a. *comparing the predictions from other building energy programs to the example results provided in the informative Annexes B8 and B16 and/or to other results that were generated using this SMOT;*
b. *checking a program against a previous version of itself after internal code modifications to ensure that only the intended changes actually resulted;*
c. *checking a program against itself after a single algorithmic change to understand the sensitivity between algorithms; and*
d. *diagnosing the algorithmic sources and other sources of prediction differences (diagnostic logic flow diagrams are included in the informative Annex B9).*

Regarding the comparative test results of Annex B8 and selected parts of Annex B16, the building energy simulation