MODELING NOTES FOR ASHRAE STANDARD 140

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INTRODUCTION
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This document shall include supplemental information about the ASHRAE Standard 140 tests performed. One S140outNotes document shall be provided for each set of tests (e.g., one for the building thermal and fabric load tests of Section 7.2; one for the space cooling equipment analytical verification tests of Section 9.2; etc.) The types of information listed below shall be provided in this document, each in a separate section:

a. Software information
b. Alternative modeling methods
c. Equivalent modeling methods
d. Nonspecified inputs
e. Omitted test cases and results
f. Changes made to source code for the purpose of running the tests, where such changes are not available in publicly released versions of the software
g. Anomalous results.

Notes in this document shall be limited to the topics shown above. Notes must be factual and objective and shall only refer to the software being tested. Notes shall not refer to any other software program.

INFORMATIVE NOTE: Text at the start of each section describes the content of the section for the reader and provides instructions for supplying the content. Sample notes are provided in a separate document (S140outNotes_Examples.TXT).

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A. SOFTWARE INFORMATION
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CONTENT: This section shall include reference information for the software - the vendor, name, and version of the software, plus operating system and computer hardware requirements.

INSTRUCTIONS: Information for items 1 through 7 below shall be provided. Information for Item 8 shall be permitted but is not required.

1. SOFTWARE VENDOR: Thermal Energy System Specialists, LLC and Transsolar Energietechnik GmbH
2. SOFTWARE NAME: TRNSYS
3. SOFTWARE VERSION (unique software version identifier): 18.06.0002
4. OPERATING SYSTEM REQUIREMENTS: Windows 10, Windows 11
5. APPROX HARD DISK SPACE REQUIRED FOR INSTALLATION: Maximum = 415 MB; Minimum (to run input files) = 51 MB
6. MINIMUM RAM REQUIRED FOR SOFTWARE OPERATION: 128 MB
7. MINIMUM DISPLAY MONITOR REQUIREMENTS: VGA with 600x800 resolution and 256 colors
8. OTHER HARDWARE OR SOFTWARE-RELATED REQUIREMENTS: None

INFORMATIVE NOTE: Item 8 can be used to supply additional relevant information.

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B. REPORT BLOCK FOR ALTERNATIVE MODELING METHODS
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CONTENT: If the software being tested provides alternative modeling methods or algorithms for performing the tests, this section shall describe modeling methods used for the tests.

INSTRUCTIONS: If alternative modeling methods are applicable, a separate note for each alternative modeling method or algorithm situation shall be provided. The standard format shown below and a separate number and title for each note shall be applied. If alternative modeling methods are not applicable, specify "NONE" in place of the information below.

NOTE 1 – Building Geometry

1.1 Describe the Effect Being Simulated:

1.2 Optional Settings or Modeling Capabilities:
Manual
Mixed
3D Data

1.2.1 Manual:
Physical Meaning: The manual geometry mode allows the user to manually enter the wall surface area. Thus, the user has to provide the necessary
orientation information for the software's radiation processor.

1.2.2 Mixed:
Physical Meaning: The mixed geometry mode allows 3D data and manually entered wall surface area data.

1.2.3 3D Data
Physical Meaning: The 3D Data geometry mode requires the use of the plugin to create the building envelope. The advantage of using the 3D Data Geometry mode is that it allows the use of the automatic radiation processing for the different surface orientations of the building. It also allows for the ability to use the detailed beam, diffuse, and longwave radiation mode. Furthermore, the detailed radiation modes allow other capabilities including the implementation of emissivity in the longwave radiation mode.

1.3 Setting or Capability Used:
3D Data

NOTE 2 – Wall Conduction

2.1 Describe the Effect Being Simulated:
Wall conduction

2.2 Optional Settings or Modeling Capabilities:
"Massive layer"

"Massless layer"

2.2.1 Massive layer:
Physical Meaning: takes into account the thermal capacity of the material

2.2.2 Massless layer:
Physical Meaning: uses a resistive only conduction calculation for this layer.

2.3 Setting or Capability Used:
Massless layer

NOTE 3 - Surface Convective Heat Transfer Coefficients

3.1 Describe the Effect Being Simulated:
Convective Heat Transfer Coefficients

3.2 Optional Settings or Modeling Capabilities:
Userdefined
Internal Calculation

3.2.1 Userdefined
Physical Meaning: As a default, the software package has userdefined constant convective heat transfer coefficients for interior surfaces, 11 kJ / h m² K, and for exterior surfaces, 64 kJ / h m² K. The software also allows the user to make this value an input into the Type56 Multizone building component, so a transient value may be used from another component or an equation with a wind velocity correlation. For values less than 0.001 kJ / h m² K, the documentation exclaims the following from the software documentation, "05-MultizoneBuilding.pdf": "For wall types with a known boundary temperature, the convective heat transfer coefficient can be set to a very small value (less than 0.001 kJ/h m² K) to force the surface temperature of the wall to be equal to the boundary temperature. The use of a very small value can be confusing but was kept for backwards compatibility reasons."

3.2.1.1 Userdefined for exterior surface
Physical Meaning: A userdefined value was implemented for exterior. According to the developer of the TRNSYS Building Component, the radiative part of the heat transfer coefficient is 4.63 W/m² K. Thus, a value of 24.67 W/m² K (88.812 kJ/h m² K) was used for the exterior convective heat transfer coefficient as recommended in section 5.3.1.8 since the program does not have automatic calculation of exterior heat transfer coefficients.

3.2.2 Internal Calculation
Physical Meaning: It is possible to choose internal calculation for any surface within a zone if desired for the interior surface. The user has to select whether the wall is a floor a ceiling or vertical to fit the appropriate heat transfer mechanism.

3.3 Setting or Capability Used:
Internal calculation for interior surfaces
Userdefined for exterior surfaces

NOTE 4 - Ground Coupling

4.1 Describe the Effect Being Simulated:
Ground Coupling

4.2 Optional Settings or Modeling Capabilities:
Userdefined Constant Temperature
Input Temperature

4.2.1 Userdefined Constant Temperature
The user can define a constant value for the back side temperature for the back side of the floor temperature (ground temperature).

4.2.2 Input Temperature
Physical Meaning: An input temperature may also be implemented for the back side temperature of the floor (ground temperature). As an input to the TRNSYS Building component, another component's ground temperature output can provide the input to this ground temperature. There is a simple ground temperature component in the TRNSYS standard library, but that still will not provide enough accuracy with for the building to earth heat transfer. There is also a slab on grade component in TRNSYS that will calculate the ground temperature based on the work that was completed for the IEA Annex 34/43 as well as additional ground coupling components in the add-on TESS Component Libraries.

4.3 Setting or Capability Used:
Input temperature: Since the floor is decoupled thermally from the ground a constant temperature equal to the given deep ground temperature of 10 °C is used.
(The ambient temperature output of the weather reader was implemented as the input to the back side of the floor.)

NOTE 5 - Temperature Control

5.1 Describe the Effect Being Simulated:
Temperature Control

5.2 Optional Settings or Modeling Capabilities:
Temperature Level Control
Energy Rate Control

5.2.1 Temperature Level Control
Physical Meaning: In temperature level control in the TRNSYS Building model calculates the air temperature based on the energy balance of the zone (infiltration, gains, ventilation, etc.) just as a real, physical building would perform.

A thermostat component would "watch" the zone temperature (the zone temperature output from the TRNSYS Building Component would be the monitoring temperature input to the thermostat component), and turn on or off the zone's conditioning equipment to send conditioned air to the zone.
Just as a real conditioned zone performs, the conditioning equipment would be on when the temperature is within the deadband of the setpoint temperature of the thermostat.

5.2.2 Energy Rate Control

Physical Meaning: The TRNSYS Building model can operate in energy rate control where the building model calculates and outputs the amount of sensible energy (removed for cooling the zone and added for heating) to maintain a user-defined setpoint temperature. Since the cases in the standard require implementation of part load ratios, it was determined to operate the TRNSYS building in energy rate control.

5.3 Setting or Capability Used:

Energy Rate Control

NOTE 6 - Infiltration

6.1 Describe the Effect Being Simulated:

Infiltration

6.2 Optional Settings or Modeling Capabilities:

Infiltration as a constant
Infiltration as an input

6.2.1 Infiltration as a constant

Physical Meaning: The TRNSYS building model allows the user to define a constant infiltration rate value in airchanges per hour (ACH) in the TRNSYS building application, TRNBuild.

6.2.2 Infiltration as an input

Physical Meaning: The TRNSYS building model allows the user to define the infiltration rate in in airchanges per hour (ACH) as an input to the building. Thus, an infiltration component or filtration schedule may be implemented to supply this building input for infiltration rate. For the cases in section 5.3.3 that had an infiltration schedule, a schedule was created as an external data file, and the Type9 data reader read the infiltration schedule into the simulation, and the TRNSYS building model used this input for the infiltration rate.

6.3 Setting or Capability Used:

Infiltration as a constant in cases for section 5.3.2; infiltration as an input for the cases in section 5.3.3

NOTE 7 - Gains

7.1 Describe the Effect Being Simulated:

Gains

7.2 Optional Settings or Modeling Capabilities:

Gains as a constant
Gains as an input
Predefined Gains in TRNSYS Building Application

7.2.1 Gains as a constant

Physical Meaning: The TRNSYS building model allows the user to define a constant gain value. The user has the option to specify the amount of radiative power, the amount of convective power, and an absolute humidity gain. The user also has the option to apply a scaling factor, so if the user specifies the convective and radiative powers as fractions, the user can apply the scaling factor appropriately.

7.2.2 Gains as an input

Physical Meaning: The TRNSYS building model allows the user to define the gains as inputs as an input to the building. Not only does the user have the option to create inputs for radiative power, the amount of convective power, and an absolute humidity gain, but the user also has the option to have the scaling factor for the gains be an input. For the cases in section 5.3.3 that had a gains schedule, a schedule was created as an external data file, and the Type9 data reader read the gain schedule into the simulation, and the TRNSYS building model used this input for the gains.

7.2.3 Predefined Gains in TRNSYS Building Application

Physical Meaning: The TRNSYS building application, TRNBuild, has predefined options for zone gains in addition to the user defined constant or input gains. The options are people gains with the activity level from the ISO 7730, computer gains with different computer size options, and an option for lighting gains.

7.3 Setting or Capability Used:

Gains as a constant in cases for section 5.3.2; gains as an input for the cases in section 5.3.3

NOTE 13 - Simulation time step

13.1 Describe the Effect Being Simulated:

Simulation time step

13.2 Optional Settings or Modeling Capabilities:

userdefined constant value

13.2.1 userdefined constant value

Physical Meaning: Simulation time step

13.3 Setting or Capability Used:

The simulation time step is 5 minutes: Time step = 1/12

NOTE 14 - Simulation convergence tolerances

14.1 Describe the Effect Being Simulated:
Convergence tolerances

14.2 Optional Settings or Modeling Capabilities:
Absolute Tolerances
Relative Tolerances

14.2.1 Absolute tolerances
Physical Meaning: Specifying an absolute tolerance indicates that TRNSYS should not converge until all connected outputs are changing by a value of TolA and all integration outputs are changing by a value of TolD

14.2.1 Relative tolerances
Physical Meaning: Specifying a relative tolerance indicates that TRNSYS should not move on to the next time step until all connected outputs are changing by less than (100 TolA) percent of their absolute value and all integrated outputs are changing by (100 TolD) percent of their absolute value.

14.3 Setting or Capability Used:
Relative Tolerances: 0.001 0.001

NOTE 15 - Integration

15.1 Describe the Effect Being Simulated:
Integration

15.2 Optional Settings or Modeling Capabilities:
Type24 Integrator Component
Type46 "Printegrator" Component

15.2.1 Type24 Integrator Component
Physical Meaning: Since TRNSYS simulates dynamically with inputs and outputs (i.e. mass flow rates, energy rates, etc.), and integrator component is required to quantify the rate over a specified time value. The TRNSYS Type24 Integrator Component integrates any specified output over any period of simulation time (i.e. a timestep, 1 hour, 1 month, or 1 year). The integrated values such as the load are necessary for the other values the simulation (such as part load ratio); therefore, the Type24 integrator component was used in the simulations.

15.2.2 Type 46 "Printegrator" Component
Physical Meaning: The TRNSYS Type46 "Printegrator" Component not only integrates any components' output over a user defined timeperiod, but it also "prints" the integrated value to a text output file.

15.3 Setting or Capability Used:
Type 24 Integrator Component

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C. REPORT BLOCK FOR EQUIVALENT MODELING METHODS

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CONTENT: This section shall describe equivalent modeling methods used to perform the tests. When the software does not model an effect exactly as stated in the standard or does not permit the input values required, equivalent modeling methods shall be permitted to perform the test.

INSTRUCTIONS: If equivalent modeling methods are applied, a separate note for each instance of equivalent modeling shall be provided. The standard format shown below and a separate number and title for each note shall be applied. If equivalent modeling methods are not applicable, specify "NONE" in place of the information below.

NOTE 1 - Preconditioning of Zone

1.1 Describe the Effect Being Simulated:
Preconditioning of Zone

1.2 Section(s) of the Standard where Relevant Inputs are Specified:
5.1.6

1.3 Equivalent Input(s) Used:
Zone initial values were set to the thermostat setpoint defined in the standard and a percent relative humidity of 50%.

1.4 Physical, Mathematical or Logical Justification of the Equivalent Input(s) – provide supporting calculations, if relevant:
The TRNSYS Building does not have preconditioning as defined in section 5.1.6 for the standard. There also does not exist an option to have the zone air conditions equal to the outdoor air conditions. However, for each zone in the TRNSYS the user can provide initial condition values for the zone temperature and percent relative humidity, so the initial zone temperature was set to the thermostat setpoint from the standard, and the initial zone percent relative humidity was left at the default of 50%.

NOTE 2 - Cooling Equipment Data File

2.1 Describe the Effect Being Simulated:
Cooling Equipment Data File

2.2 Section(s) of the Standard where Relevant Inputs are Specified:
5.3.1.10.3.4, 5.3.1.10.3.6

2.3 Equivalent Input(s) Used:
The external data file used in the simulations for section 5.3.2 was the net total plus the indoor fan power and net sensible

capacity plus the indoor fan power with the total device power (compressor, condenser fan, and indoor fan).

2.4 Physical, Mathematical or Logical Justification of the Equivalent Input(s) – provide supporting calculations, if relevant:

The external data file requirement for the mechanical system's air conditioner, Type144 Air Conditioner, is the total capacity, total sensible capacity, and the total power. The component does not require the default fan heat to be added to the total and sensible capacities. It does require that the actual fan heat be added to the total and sensible capacities. Thus, the data from Table 26a with the addition of the actual fan heat (230 Watts) to the net total and net sensible capacities was used for the simulations. The external data file for the Type144 Air Conditioner also requires the total power of the device, so the condenser fan power (108 Watts) and the indoor fan power (230 Watts) were added to the compressor power for the data file. The data was also manually extrapolated in a spreadsheet as that is not done automatically the software (only interpolation is done by the software).

NOTE 3 - Part Load Ratio

3.1 Describe the Effect Being Simulated:

Part Load Ratio

3.2 Section(s) of the Standard where Relevant Inputs are Specified:

5.3.1.10.4

3.3 Equivalent Input(s) Used:

TRNSYS Equation Block to Calculate Part Load Ratio

3.4 Physical, Mathematical or Logical Justification of the Equivalent Input(s) – provide supporting calculations, if relevant:

The TRNSYS building model and the Type144 air conditioner component for TRNSYS are intended to work in temperature level control iterating together with a thermostat. Since the intention of this standard is to use part load ratio to depict efficiency degradation, the TRNSYS building model operates in energy rate control to output the instantaneous sensible energy demand of the zone, and the Type144 air conditioner outputs the full load instantaneous sensible and full load instantaneous total energy. The quotient of the instantaneous sensible energy demand from the zone and the instantaneous full load sensible energy is used to obtain an instantaneous sensible PLR. The product of the instantaneous sensible PLR and the full load instantaneous total energy from the Type144 is the instantaneous total coil load. The Type24 Integrator component integrates the instantaneous total coil load and the instantaneous total full load. In another TRNSYS equation block, quotient of the integrated values is the part load ratio (PLR) as intended by the standard and is used in the other calculations for CDF and Runtime.

NOTE 4 – Compressor Power

4.1 Describe the Effect Being Simulated:
Compressor Power

4.2 Section(s) of the Standard where Relevant Inputs are Specified:
5.3.1.10.4

4.3 Equivalent Input(s) Used:
TRNSYS Equation Block with Runtime and Full Load Power

4.4 Physical, Mathematical or Logical Justification of the Equivalent Input(s) – provide supporting calculations, if relevant:
The compressor power for the simulation was obtained by the product of the equipment full load power (minus outdoor fan power and indoor fan power) from Type144 air conditioner and the equipment runtime. The equipment runtime is a function of the part load ratio (PLR) described in the previous section and the CDF described in section 5.3.1.10.4.1.

NOTE 5 – Indoor Fan Power

5.1 Describe the Effect Being Simulated:
Indoor Fan Power

5.2 Section(s) of the Standard where Relevant Inputs are Specified:
5.3.1.10.6

5.3 Equivalent Input(s) Used:
Runtime as a control signal for variable speed fan

5.4 Physical, Mathematical or Logical Justification of the Equivalent Input(s) – provide supporting calculations, if relevant:
The TRNSYS Type147 variable speed fan was used to cycle and deliver air to the zone. The fan cycled based on the runtime variable that was calculated in the TRNSYS equation (see previous note). The rated fan power was specified as a parameter for Type147 variable speed fan, so when the runtime variable from the TRNSYS equation block supplied the control signal, it cycled appropriately. Implementing the fan with this method also added the necessary sensible fan energy to the zone. The output of the fan, fan power, was integrated to quantify the amount of power that it consumed throughout the simulation.

NOTE 6 – Outdoor Fan Power

6.1 Describe the Effect Being Simulated:
Outdoor Fan Power

6.2 Section(s) of the Standard where Relevant Inputs are Specified:
5.3.1.10.6

6.3 Equivalent Input(s) Used:

Product of integrated full load fan power and Runtime

6.4 Physical, Mathematical or Logical Justification of the Equivalent Input(s) – provide supporting calculations, if relevant:

The full load outdoor fan power (108 Watts) was integrated in a TRNSYS Type24, and that integrated value is sent to a TRNSYS Equation block. In the equation the outdoor fan power is determined by the product of the integrated full load fan power and the Runtime value.

NOTE 7 – Total Power

7.1 Describe the Effect Being Simulated:

Total Power

7.2 Section(s) of the Standard where Relevant Inputs are Specified:

5.3.1.10.6

7.3 Equivalent Input(s) Used:

Sum of the integrated values

7.4 Physical, Mathematical or Logical Justification of the Equivalent Input(s) – provide supporting calculations, if relevant:

The total power of the system is determined by sum of the integrated values of the compressor power, indoor fan power, and outdoor fan power in a TRNSYS equation block.

NOTE 8 – Latent Energy Removal

8.1 Describe the Effect Being Simulated:

Latent energy removal

8.2 Section(s) of the Standard where Relevant Inputs are Specified:

5.3

8.3 Equivalent Input(s) Used:

The latent energy removal included as a negative gain to the space.

8.4 Physical, Mathematical or Logical Justification of the Equivalent Input(s) – provide supporting calculations, if relevant:

The instantaneous latent coil load was determined from the difference of the instantaneous total coil load(discussed in NOTE 3) and instantaneous sensible energy demand from the zone in a TRNSYS equation block. The TRNSYS Building model in energy rate control allows the user to specify a humidity setpoint for the zone similar to how a temperature setpoint is used in energy rate control; however, it is the intention of the standard for the software to calculate the amount of humidity for the zone. Using the flexibility of the TRNSYS building model, the instantaneous latent coil load determined from the equation block was sent back to the building model as a negative latent gain input. By implementing this method, the appropriate amount of latent energy is removed from the zone.

NOTE 9 – Zone Total and Zone Sensible Loads

9.1 Describe the Effect Being Simulated:
Zone Total and Zone Sensible Loads

9.2 Section(s) of the Standard where Relevant Inputs are Specified:
5.3

9.3 Equivalent Input(s) Used:
The total and sensible zone loads were calculated from the difference of the coil loads and the indoor fan power.

9.4 Physical, Mathematical or Logical Justification of the Equivalent Input(s) – provide supporting calculations, if relevant:
Since the instantaneous fan power was added directly to the zone, the total coil load and sensible coil load included this energy rate. After these values were integrated in a Type24 integrator component, a TRNSYS equation block calculated the zone total load from difference between the integrated total coil load and the integrated indoor fan power, and likewise, zone sensible load from difference between the integrated total coil load and the integrated indoor fan power.

NOTE 10 – Coefficient of Performance (COP)

10.1 Describe the Effect Being Simulated:
COP

10.2 Section(s) of the Standard where Relevant Inputs are Specified:
5.3.1.10.4

10.3 Equivalent Input(s) Used:
The COP was calculated from the quotient of zone total load and total power.

10.4 Physical, Mathematical or Logical Justification of the Equivalent Input(s) – provide supporting calculations, if relevant:
The COP was calculated in a TRNSYS equation block by the quotient of the integrated zone total load (the integrated total coil load minus the integrated fan power) and the integrated total power.

NOTE 11 – Economizer

11.1 Describe the Effect Being Simulated:
Economizer

11.2 Section(s) of the Standard where Relevant Inputs are Specified:
5.3.4.2

11.3 Equivalent Input(s) Used:
TRNSYS Equation Block

11.4 Physical, Mathematical or Logical Justification of the Equivalent Input(s) – provide supporting calculations, if relevant:

The cases with the economizer required the implementation of a TRNSYS equation block. The TRNSYS equation block has the ability to use any output from any component in the simulation with logical functions to create values of 1 or 0 ("on" or "off"). Thus, when comparing the outdoor temperature to the indoor temperature and comparing the indoor temperature to the setpoint, this was simply done in a TRNSYS equation block. When the signal for the economizer was "on", that would set the fraction of outdoor air to 100%.

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D. REPORT BLOCK FOR USE OF NON-SPECIFIED INPUTS

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CONTENT: This section shall describe nonspecified inputs used to perform the tests. Use of nonspecified inputs shall be permitted only for the following specified sections relating to the following topics:

* Alternative constant exterior surface coefficients in Sections 5.2.1.9.3, 5.2.3.1.4.3, 5.2.3.3.2, and 5.3.1.8
* Alternative constant interior surface coefficients in Sections 5.2.1.10.3, 5.2.3.1.4.4, 5.2.3.2.2, and 5.3.1.9
* Alternative constant interior solar distribution fractions in Sections 5.2.1.12, 5.2.2.1.2.2, 5.2.2.1.6.2, 5.2.2.1.7.2, 5.2.2.2.7.4, 5.2.3.9.3, 5.2.3.10.2, and 5.2.3.12.2
* Air density given at specific altitudes for the space-cooling and space- heating equipment cases in Sections 5.3.1.4.3, 5.3.3.4.3, and 5.4.1.4.3.

INSTRUCTIONS: If nonspecified inputs are applied, a separate note for each use of nonspecified inputs shall be provided. The standard format shown below and a separate number and title for each note shall be applied. If nonspecified inputs are not applied, specify "NONE" in place of the information below.

NONE

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E. REPORT BLOCK FOR OMITTED TEST CASES AND RESULTS

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CONTENT: This section shall describe test cases that were omitted and/or individual results of test cases that were omitted along with the reason for the omission.

INSTRUCTIONS: If test cases were omitted, a separate note to describe each type of omission shall be provided. The standard format shown below and a separate number and title for each note shall be applied. If there are no omitted test cases, specify "NONE" in place of the information below.

NONE

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F. REPORT BLOCK FOR CHANGES TO SOURCE CODE FOR THE PURPOSE OF RUNNING THE TESTS, WHERE SUCH CHANGES ARE NOT AVAILABLE IN PUBLICLY RELEASED VERSIONS OF THE SOFTWARE
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CONTENT: This section shall describe changes to software source code made to allow the software to run a test, where such changes are not available in a publicly released version of the software.

INFORMATIVE NOTE: This section addresses special situations where a change to source code is necessary to activate a feature or to permit inputs needed for a test when these features are not available in the publicly released version of the software.

INSTRUCTIONS: If changes to the source code for the purpose of running a test are applied, separate notes to describe each source code modification shall be provided. The standard format shown below and a separate number and title for each note shall be applied. If changes to source code are not applied, specify "NONE" in place of the information below.

NONE

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G. REPORT BLOCK FOR ANOMALOUS RESULTS
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CONTENT: Describing anomalous results shall be permitted but is not required. If anomalous test results are described, this section shall be used.

INSTRUCTIONS: If anomalous test results are described, each type of anomalous result shall be described in a separate note. The standard format shown below and a separate number and title for each note item shall be applied. If anomalous results are not discussed, it shall be permitted to specify "NONE" in place of the information below.

NONE