Formula 1

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Formula 2

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Formula 3

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Detailed Explanation

Annex D of ASHRAE Guideline 14-2014 is not a standalone standard but a critical validation protocol embedded within the broader framework for measurement-based calibration and simulation of energy conservation measures (ECMs). Its primary purpose is to mitigate modeling uncertainty in TES systems—such as chilled water tanks, ice storage, or molten salt accumulators—by prescribing systematic verification activities before and after model execution. The annex mandates documentation of boundary conditions (e.g., ambient temperature profiles, load schedules, chiller/thermal generator performance curves), identification of key model parameters subject to calibration (e.g., heat transfer coefficients, stratification effectiveness, pump efficiencies), and rigorous comparison of simulated versus measured time-series data (e.g., tank temperature profiles, return water temperatures, kWh consumption) using statistical metrics like CV(RMSE) and NMBE.

The validation process outlined in Annex D follows a hierarchical approach: first confirming model logic and syntax (conceptual validation), then verifying numerical solution stability and convergence (numerical validation), and finally assessing physical fidelity against empirical data (empirical validation). It requires establishing a 'baseline' simulation representing pre-ECM conditions, followed by sensitivity analysis to identify dominant parameters influencing TES performance—enabling focused calibration efforts. Crucially, Annex D distinguishes between model calibration (adjusting uncertain parameters to match observed data) and model validation (testing predictive capability on independent datasets not

used in calibration), both of which must be transparently reported.

In practice, Annex D supports engineers, energy modelers, and commissioning agents in defending the credibility of TES-related energy savings claims—especially for performance-based contracts, utility incentive programs, or LEED EAc3 compliance. Its checklist format includes mandatory sign-offs for data quality assessment (e.g., missing data handling, sensor uncertainty quantification), temporal resolution alignment (e.g., matching simulation timestep to measurement interval), and uncertainty propagation analysis. While not prescriptive about specific software tools, it implicitly assumes use of dynamic building energy simulation engines capable of modeling transient heat transfer, fluid flow, and control logic (e.g., EnergyPlus with TES objects, TRNSYS, or custom MATLAB/Simulink models).

Key Components

#	Component
1	Input Data Verification
2	Model Configuration Documentation
3	Empirical Validation Metrics (CV(RMSE), NMBE)

Applications

#	Application
1	Verifying chilled water storage model accuracy prior to industrial plant retrofit
2	Supporting M&V (Measurement and Verification) plans under IPMVP Option B or C
3	Enabling third-party review of TES simulation reports for utility rebate applications

Related Concepts

#	Concept
1	IPMVP Volume I (International Performance Measurement and Verification Protocol)

#	Concept
2	ASHRAE Standard 205P (Standard for Thermal Energy Storage Systems)
3	Dynamic Building Energy Simulation

Tags

> TES, model_validation, ASHRAE, energy_simulation, M_V