

ASHRAE Guideline 36: Best in Class HVAC Control Sequences



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Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

Learning Objectives

1. Explain the advantages of using standardized advanced sequences to designers, contractors, and owners
2. Recognize the ASHRAE research behind Guideline 36 sequences and how current research will be used for future enhancements
3. Learn how to specify Guideline 36 sequences in control system specifications
4. Learn more about upcoming commissioning tools for Guideline 36

Agenda

- Why standardize HVAC control sequences?
- ASHRAE Guideline 36
 - Goals
 - Current status
- Energy Performance Validation
- Implementing Guideline 36 SOOs
- Commissioning Guideline 36 SOOs
- Summary: why Guideline 36 is a win-win-win-win for all parties involved in buildings

About Steve Taylor

- Principal and Founder, Taylor Engineers
- Education
 - Stanford University, BS Physics, 1976
 - Stanford University, MS Mechanical Engineering, 1977
- ASHRAE
 - Fellow
 - Standard 62 Indoor Air Quality, >12 years, chair, current consultant
 - Standard 90.1 Energy Standard, Mechanical Subcommittee, >30 years, current voting member
 - Standard 55 Thermal Comfort, member
 - **Guideline 36 High Performance Sequences of Operation for HVAC Systems, founder, chair, current nonvoting member**
 - Guideline 16 Economizer Dampers, chair
 - Guideline 13 Specifying Building Automation Systems, chair
 - TC 4.3 Ventilation, chair
 - TC 1.4 Control Theory & Applications, chair
 - Distinguished Lecturer
- USGBC LEED
 - Indoor Environmental Quality TAG, vice chair
- UMC/IAPMO (California Mechanical Code)
 - Mechanical Technical Committee, member and ASHRAE Liaison

Issues with Current Practice

- We keep reinventing the wheel!
 - Same application, different sequences
 - Every building is a “one off”
- We don't keep up with codes!
 - Title 24, ASHRAE/IES Standard 90.1, ASHRAE Standard 62.1...
- We don't keep up with research
 - ASHRAE RP-980, 1455, 1515, 1547, 1587, 1747, 1711, etc. ...
- Poor alarms and diagnostics
 - No alarms or too many alarms!
 - No advanced diagnostics

Kiss Principle

K I S S

KEEP ~~I~~ SIMPLE, STUPID
INTERFACE

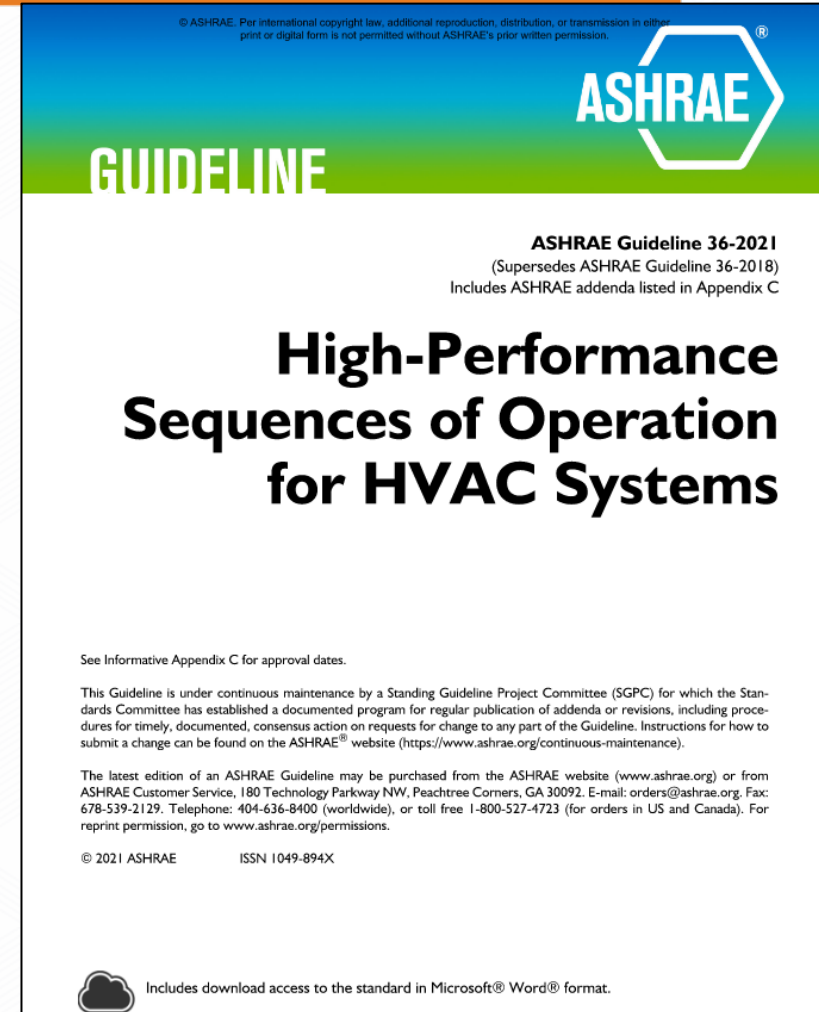
- Old paradigm:
 - Building engineers will disable things until the controls get down to their level of understanding
 - So, keep control sequences simple
- New paradigm:
 - We cannot afford KISS in modern world
 - Make the interface simple....
 - But make the engine high performing

The fix: ASHRAE Guideline 36

- The plan:
 - ASHRAE experts create and maintain advanced sequences
 - Manufacturers preprogram, test, and debug all the sequences for their dealers
 - Engineers simply spec: “Use ASHRAE Guideline 36 sequences”
 - Control contractors simply use the preprogrammed sequences
 - Commissioning agents use the functional performance tests (FPTs) (eventually) included with ASHRAE Guideline 36
 - Perhaps even forgo FPTs once they are comfortable that manufacturers have programmed them correctly
- It's OK if sequences are complex!
 - Sequences are proven by research and practice
 - Standardized so designers, controls subs, building engineers soon know them
 - Programmed only once per manufacturer and maintained/debugged by manufacturer

Guideline 36 Title, Purpose, and Scope (TPS)

- Title: *High-Performance Sequences of Operation for HVAC Systems*
- Purpose: Provide uniform sequences of operation for heating, ventilating, and air-conditioning (HVAC) systems that are intended to maximize HVAC system energy efficiency and performance, provide control stability, and allow real-time fault detection and diagnostics.
- Scope:
 - This guideline provides detailed sequences of operation for HVAC systems.
 - This guideline describes functional tests that, when performed, will confirm implementation of the sequences of operation.

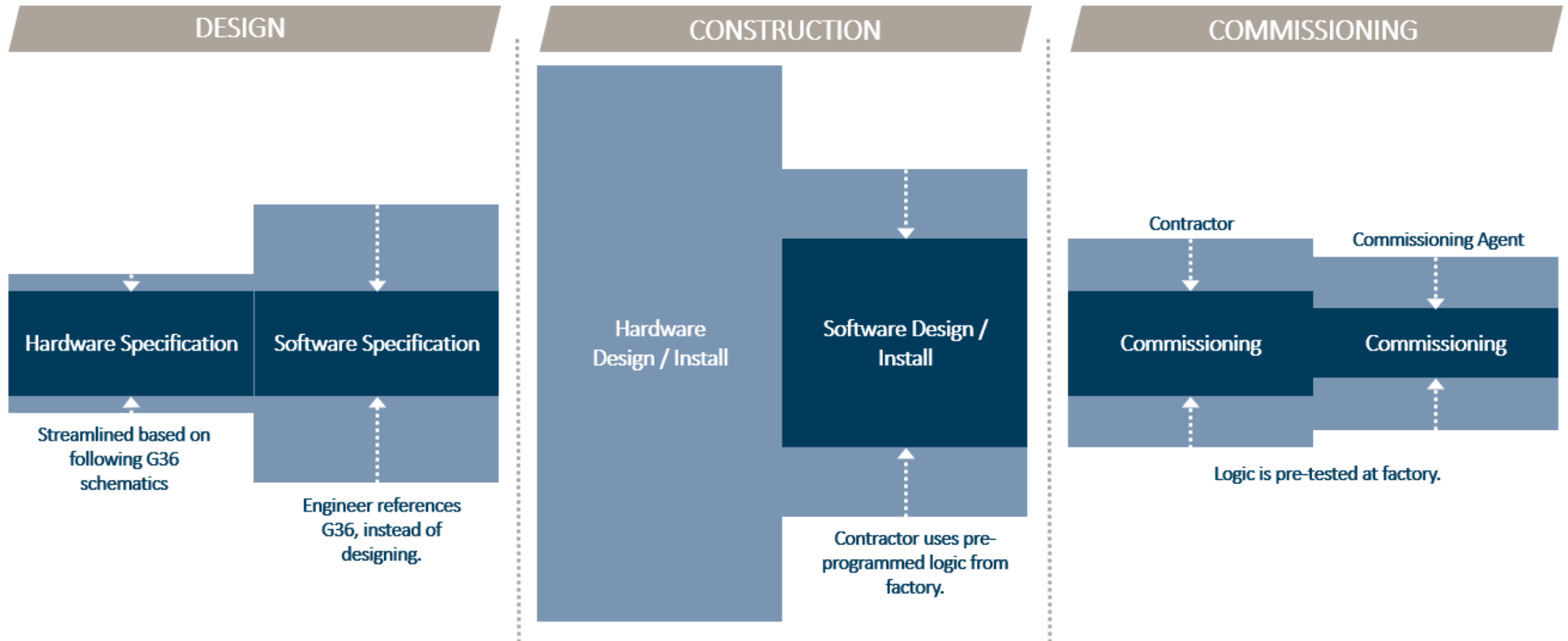


ASHRAE Guideline 36 Goals

- Reduce cost
 - Writing sequences, programming, and commissioning
- Reduce errors
 - Unambiguous sequences
 - Algorithms pretested and standardized
- Ensure relevant code and standard compliance
 - ASHRAE/IES Standard 90.1 and Title 24 (energy)
 - ASHRAE Standard 62.1 and Title 24 (ventilation)
 - ASHRAE Standard 55 (comfort)
- Improve energy efficiency and IAQ
 - Code compliance
 - Advanced, proven sequences based on research and field tests
- Improve reliability and ease of operation
 - Hierarchal alarms
 - Automatic fault detection and diagnostics
 - Consistent pretested and proven sequences of operations (SOOs)
 - Familiarization with standardization

ASHRAE Guideline 36 Value: Design thru Commissioning

● BUSINESS AS USUAL - LEVEL OF EFFORT ● G36 MODEL - LEVEL OF EFFORT



Guideline 36 Status

- First published June 2018
 - All VAV system variations
 - Single zone VAV
- 2021 version published August 2021
 - 23 addenda
- 2024 version scheduled to be published this summer
 - 26 addenda in process

Major Controls Manufacturers are Developing G36 Compliant Application Libraries (status thru 2021)

Manufacturer	Status of Application Libraries			Elements of Library Released							
				Sequence of Operation						FDD	Alarms
	Interest expressed	In Development	Released	MZ AHUs	SZ AHUs	DFDD	VAV Terminal Units	Dual duct terminal unit	Fan powered terminal unit	-	-
	✓	✓	↻	✓*	✓*	✓	✓*	—	✓	✓	✓
	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	✓	✓	↻	↻	↻	—	✓**	—	—		
	✓	✓	↻	✓	✓	✓	✓	✓	✓	✓	✓
	✓	✓	—	—	—	—	↻	—	—	—	—
	✓	✓	↻	✓	✓	—	✓	—	✓	✓	✓
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	✓	✓	↻	? →							

KEY

- ✓ Complete
- ↻ Partially Complete
- Not Started

*Third-party verified

** beta version

Based on available information

September 2021

As claimed by manufacturer

Contents

1 Purpose

2 Scope

3 Set Points, Design, and Field Determined

3.1 Information Provided by Design

3.2 Information Provided by (or in Conjunction with) the Testing, Adjusting, and Balancing Contractor

3.3 Information Provided by Control Contractor

4 List of Hardwired Points

5 Sequences of Operations

Informative Appendix A: Control Diagrams

Informative Appendix B: Abbreviations and Acronyms

Zone temperature set points, ventilation rates, CO₂ set points, terminal unit set points, economizer high limit type and climate zone, etc.

Maximum DP set points, minimum speeds, etc.

VAV box controllable minimum

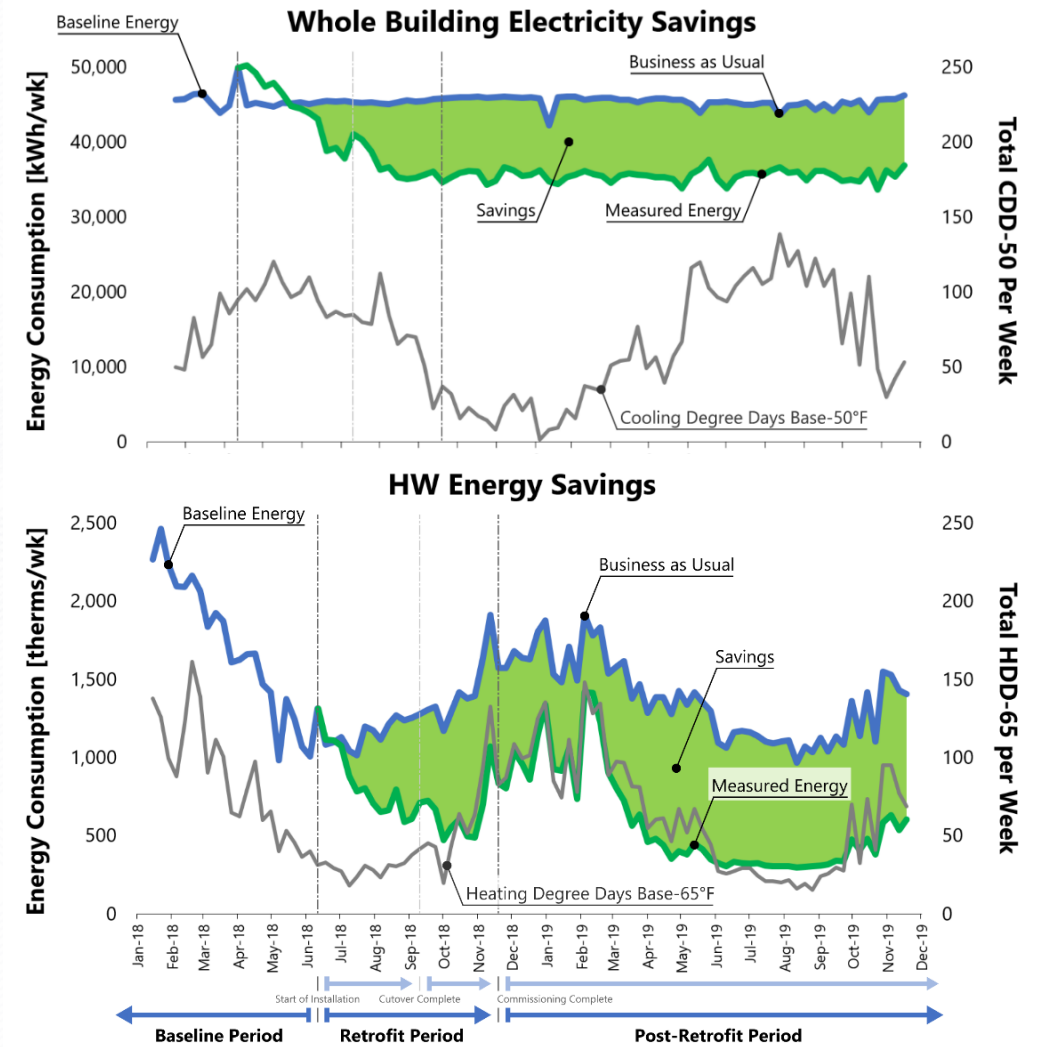
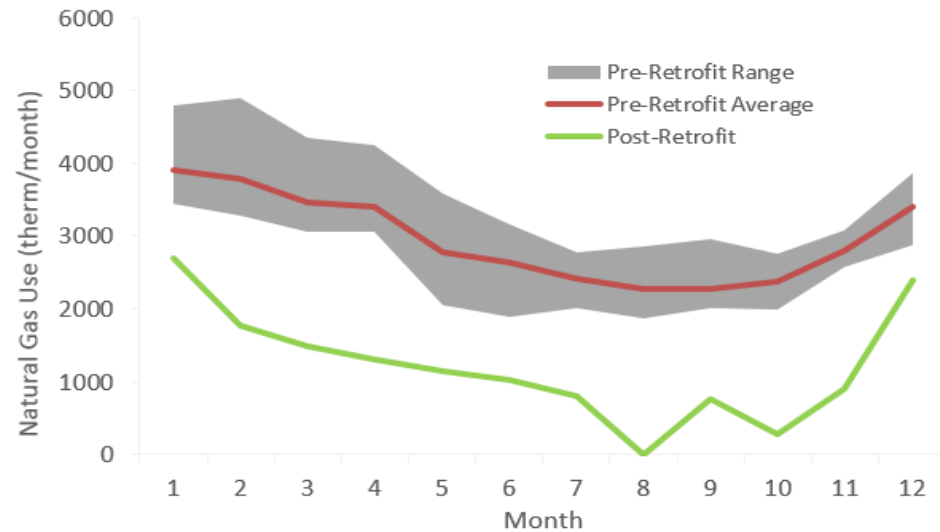
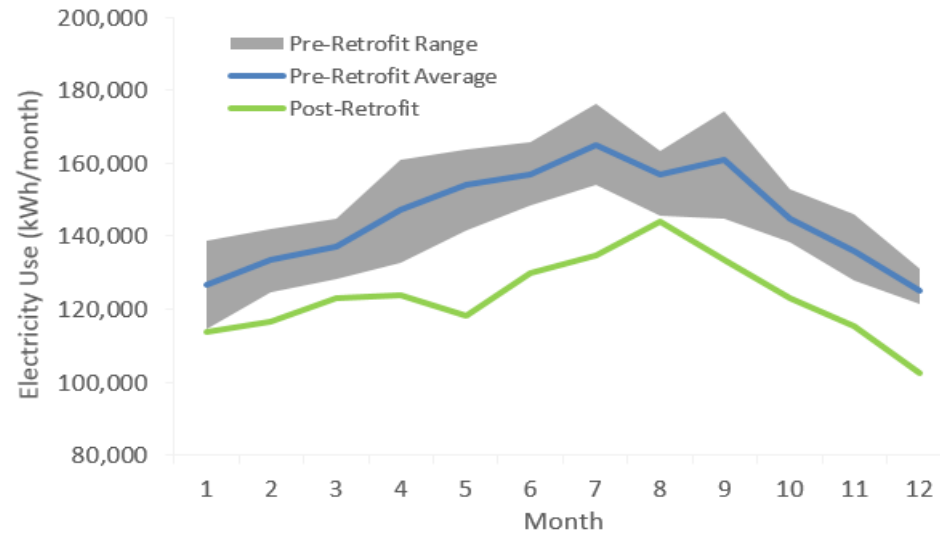
Sequences of Operation—to Date

5.1	General.....	5.12	Dual-Duct VAV Terminal Unit—Mixing Control with Inlet Airflow Sensors
5.2	Generic Ventilation Zones	5.13	Dual-Duct VAV Terminal Unit—Mixing Control with Discharge Airflow Sensor
5.3	Generic Thermal Zones	5.14	Dual-Duct VAV Terminal Unit—Cold-Duct Minimum Control
5.4	Zone Groups	5.15	Air-Handling Unit System Modes
5.5	VAV Terminal Unit—Cooling Only	5.16	Multiple-Zone VAV Air-Handling Unit
5.6	VAV Terminal Unit with Reheat.....	5.17	Dual-Fan Dual-Duct Heating VAV Air-Handling Unit
5.7	Parallel Fan-Powered Terminal Unit—Constant-Volume Fan	5.18	Single-Zone VAV Air-Handling Unit
5.8	Parallel Fan-Powered Terminal Unit—Variable-Volume Fan	5.19	General Constant Speed Exhaust Fan
5.9	Series Fan-Powered Terminal Unit—Constant-Volume Fan	5.20	Chilled Water Plant
5.10	Series Fan-Powered Terminal Unit—Variable-Volume Fan	5.21	Hot Water Plant.....
5.11	Dual-Duct VAV Terminal Unit—Snap-Acting Control.....	5.22	Fan Coil Unit.....

Added in 2021 version

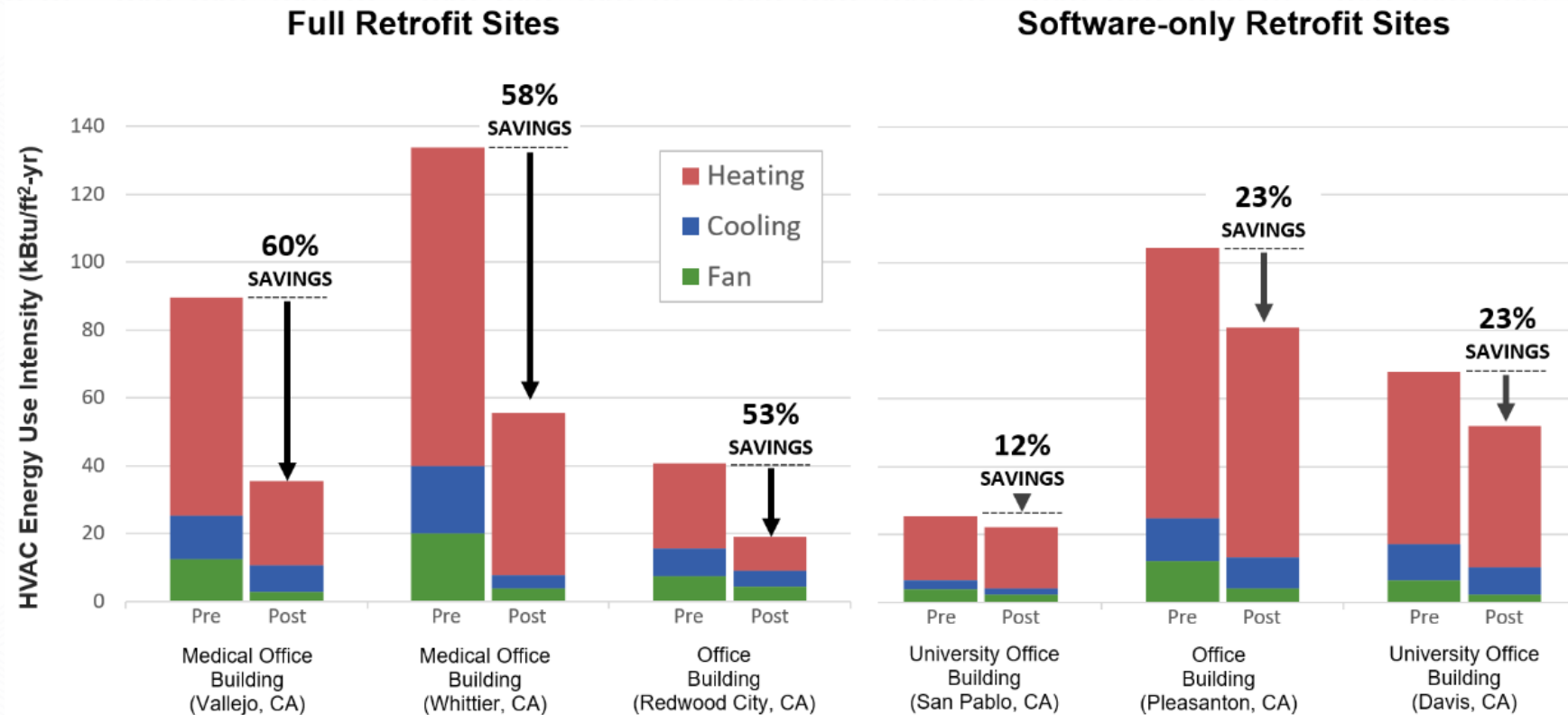
G36 Energy Performance Validation

ASHRAE Guideline 36 Demonstration Results

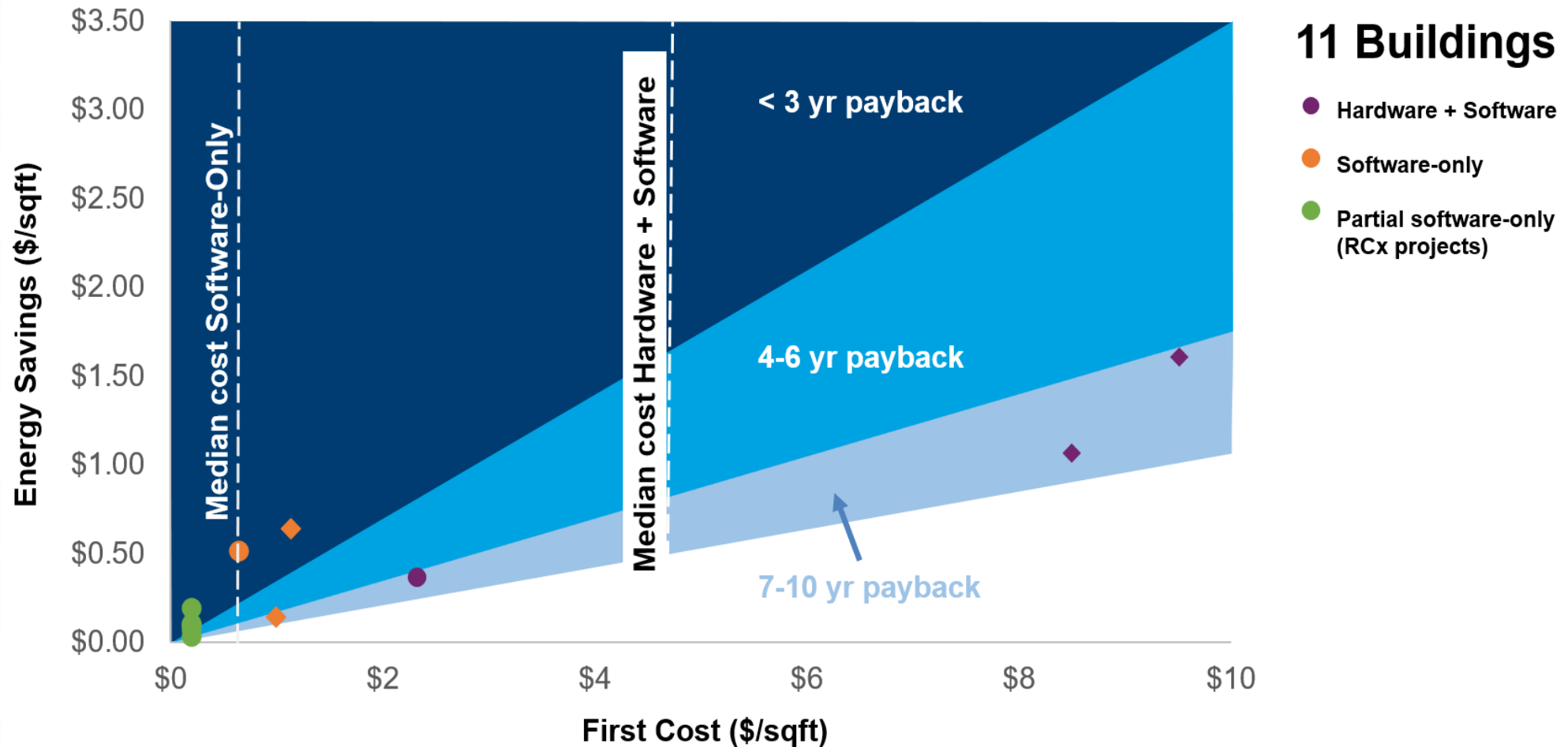


ASHRAE Guideline 36 Demonstration Results

- Full retrofits – all new control hardware and software
- Software-only – revisions only to control programming

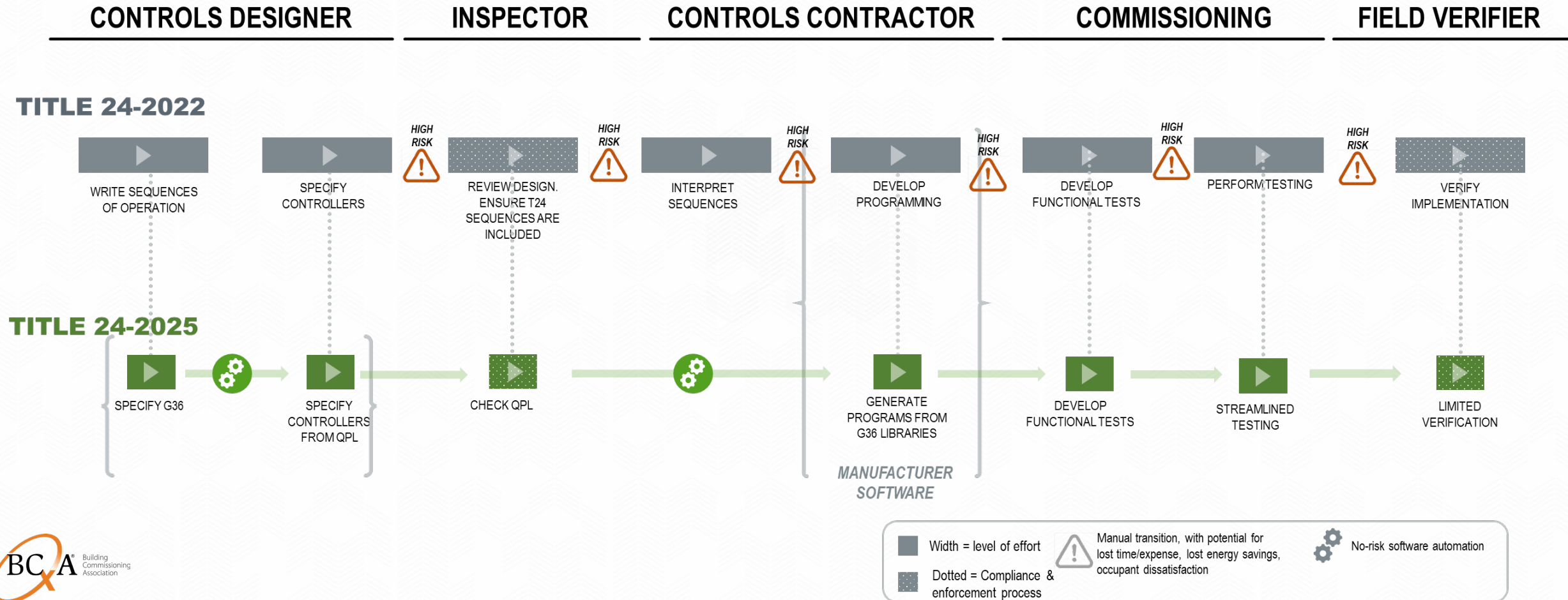


ASHRAE Guideline 36 Cost Effectiveness



Title 24-2025

2025 Standards will mandate Guideline 36 for applicable HVAC control requirements



Implementing Guideline 36

3 Ways Engineers Can Specify Guideline 36

1. Download Word version, cut and paste into specs, then edit per the instructions built into the guideline
 - Complex editing work by designer
 - Sequences must be kept up to date with ongoing addenda
 - Need to be clear what SOOs are custom vs. G36, e.g. **different fonts**
2. Specify G36 by section number, e.g.,

H. VAV Reheat boxes

 1. Fully comply with ASHRAE Guideline 36-2021 Section 5.6. except as otherwise noted below.
 - Section numbers through 3 digits will not change
 - Still need a complete as-built SOO (by contractor)
3. Simply say “Control sequences shall fully implement and be in accordance with ASHRAE Guideline 36”
 - Still need a complete as-built SOO (by contractor)

Also include this in your BAS specs:

2.1 Primary BAS Manufacturer

- A. To qualify for this project, the primary BAS manufacturer shall agree to fully program and test all ASHRAE Guideline 36 sequences that are referenced herein for their dealers bidding this project at no direct cost to these dealers. The cost of Guideline 36 programming and testing shall not be a direct cost to this project.

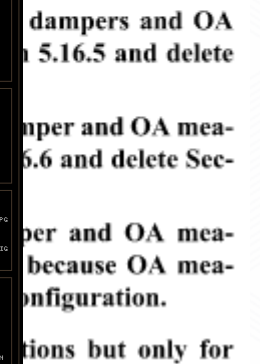
Implementation Challenges

- Complex / unfamiliar concepts
- Difficult to edit
- Programming: interpretation / translation

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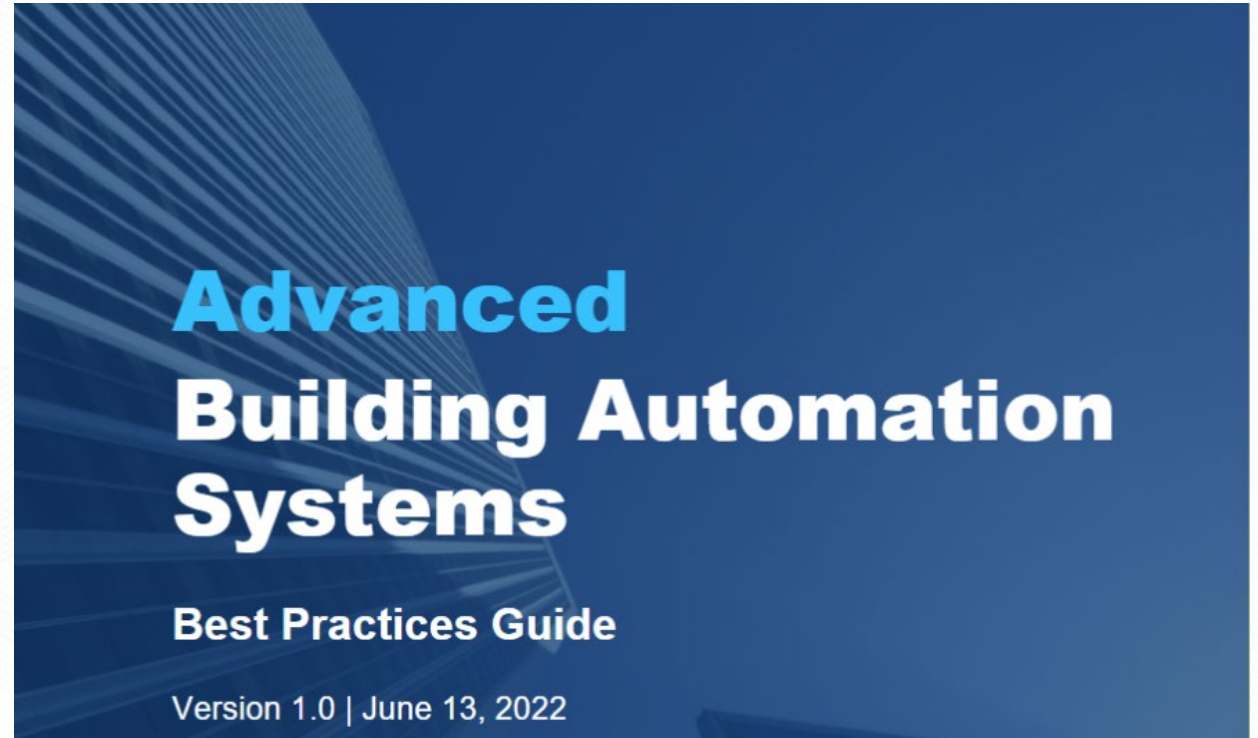
- Do the minimum outdoor air and economizer functions use separate dedicated dampers or a single common damper?
- Is outdoor air volume measured by DP ΔP or an air-flow measurement station (AFMS)?

- **For AHUs with separate dedicated dampers and OA measurement by ΔP , use Section 5.16.4 and delete Sec-**



...Solution: Advanced BAS Best Practices Guide

- Free!!
- One stop resource
 - Based on Guideline 36
 - Key sequences explained
 - Other important advice
 - Troubleshooting guide



https://tayloreng.egnyte.com/dl/phXTDfFQb8/2022-06-13_BAS_Best_Practices_Guide_v1.0.pdf_

...Solution: G36 Sequence Selection Software

Pick from Menus:

Unit of measurement	Inch-Pound
Cooling	Chilled Water
Ventilation	Title 24
Air Handling System	MZVAV
Pressure Control	Barometric
OA Damper Configuration	Single OA Damp
OA Measurement	AFMS
Terminal Types	☐ VAV Cooling-only ☐ VAV Reheat ☐ Parallel FPB Constant ☐ Parallel FPB Variable ☐ Series FPB Constant ☐ Series FPB Variable ☐ DD VAV Snap-acting ☐ DD VAV Mixing / Inlet ☐ DD VAV Mixing / Disch

Auto-generated Output:

Sequences of
Operation

Functional
Performance Test
Scripts

Control Schematics

Programming and
Graphics Files

OpenBuildingControls project v1.0 released April

2023: <https://ctrl-flow.lbl.gov>

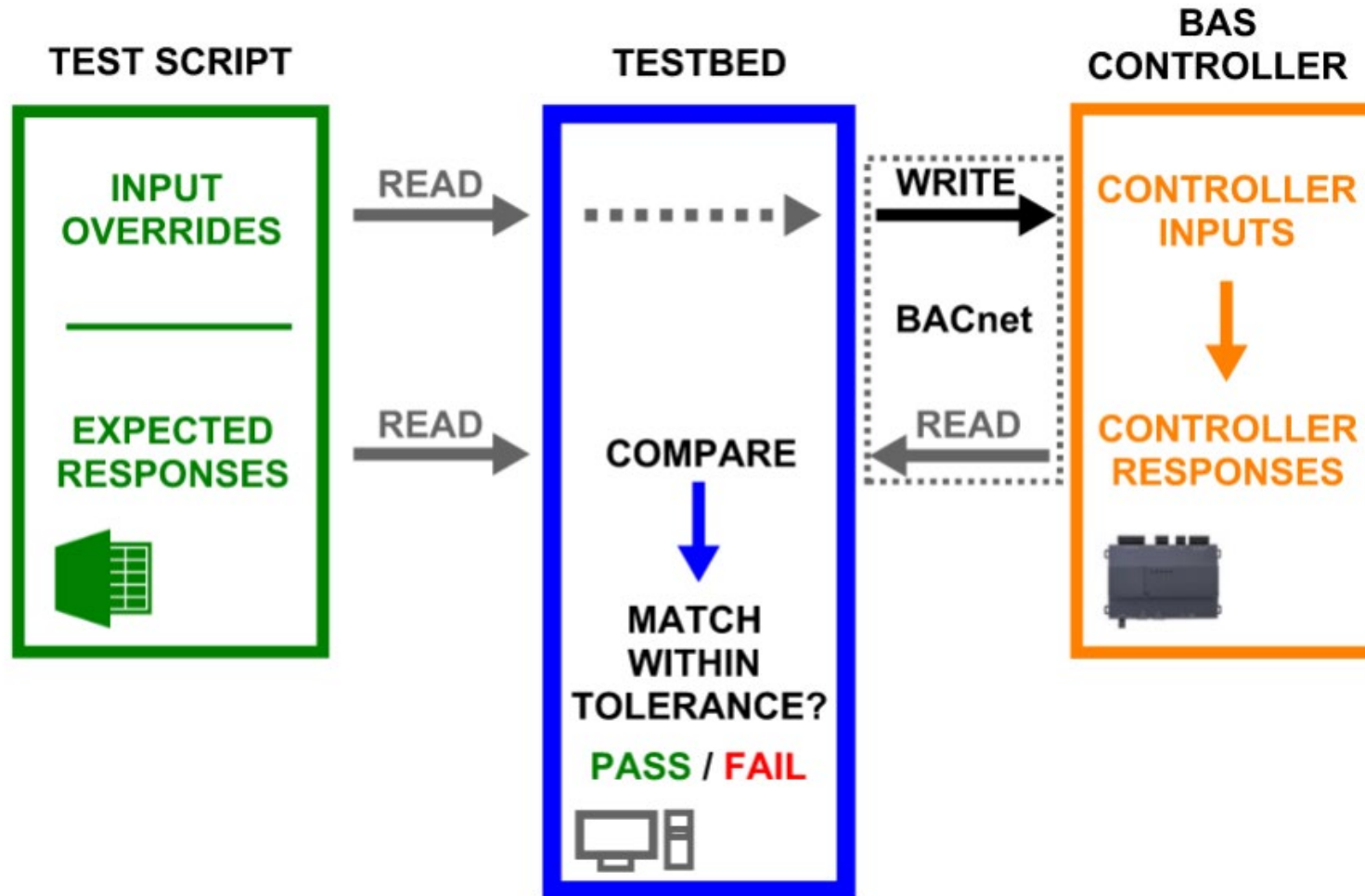
Challenges with Guideline 36: Implementation...

- Manufacturer's G36 programming libraries
 - Really complete or just marketing claim?
 - Do they actually meet G36 verbatim or just "equivalent"?
 - Have they been pretested and debugged by manufacturer?

...Solution: G36 Validation – Automated testing

- Goals
 - Level playing field and clear target
 - Independent validation for users
 - California Title 24 requirement for certified G36 programming libraries
- Automated, objective testing focused on factory libraries
- Bench-scale testing focused on programming only
 - Does not address HVAC equipment, point mapping, calibration, tuning, etc
- Status:
 - Pilot demonstration completed
 - CalNEXT funding for method of test (MOT) due 2026
- MOT could become ASHRAE Standard or independent certification (e.g., BTL)

G36 Validation – Automated testing



G36 Validation – Human-based functional testing

- Functional Performance Tests (FPTs) included in scope of G36 but not yet developed
- Originally to be developed by RP-1746 in 2015
 - Never really started due to contractor issue, then cancelled
- Replaced by ASHRAE RTAR-1966
 - Approved Dec 2023 for Work Statement development
 - Editable test scripts
 - Ongoing debates on software platform and style
 - Organized, modular for software streamlining (e.g., ctrl-flow)
 - Contractor selection weighted heavily on Cx experience
 - Completion 2025 or 2026
- In the meantime, CxPs need to develop their own FPTs
 - But at least you just have to do it once...

G36 Validation – Human-based functional testing

	A	B	C	D	E	F
1	Test Sequence for Multiple Zone VAV AHU	TRAINING VIDEO FOR USING THIS FORM: CLICK HERE			Open Table of Contents	
2	Please be sure to indicate the DATE, TIME, and PASS/FAIL status of the test in each case.					Reveal Hidden Rows
3	Technician Name:				BAS Spec	
4	Tested Equipment Tag(s):	AH-1			Test Template	MZ_VAV_AC
5	Last Test Completed at:					
6	Step #	Test	Expected Response	Result	Comments	Pass?
199	D. Standard Supply Air Temperature Setpoint Reset					
224	2	Override zone cooling PID loop outputs to 96%	Date: Insert Date & Time			Inc.
3	Technician Name:				BAS Spec	
4	Tested Equipment Tag(s):	VAV-RH-x-xx			Test Template	VAV RH
5	Last Test Completed at:					
6	Step #	Test	Expected Response	Result	Comments	Pass?
7	A. Occupied Operation					
52	ii. Cooling Mode					
53	3	Override the cooling PID loop output to 50%.	Date: Insert Date & Time		MANDATORY SCREENSHOT. USE SEPARATE DIRECTORY. PHOTO NAME IF NOT CLEAR:	Inc.
54		Time:				
55		VAV-RH-x-xx goes into occupied cooling mode (Y/N):				
56		Expected active airflow setpoint (CFM):		Auto-calc		
57		Actual active airflow setpoint (CFM):				
58		Actual active airflow setpoint matches expected (Y/N):				
59		Damper modulates to meet the active setpoint (Y/N):				
60		Damper position at the end of the test (%; do not wait for damper loop to stabilize):				
61		HW valve remains open in cooling mode since the DAT is below the 50°F minimum setpoint (Y/N):				
62		No cooling SAT reset requests are active since the cooling loop is <95% and zone temp < cooling setpoint (Y/N):				
63						
64	Retest		Insert Row	Add/Go To Graphic Sheet		
65	4	Override the discharge air temperature feedback to 50.5°F.	Date: Insert Date & Time		MANDATORY SCREENSHOT. USE SEPARATE DIRECTORY. PHOTO NAME IF NOT CLEAR:	Inc.
66		Time:				
67		HW valve shuts since the discharge air temperature is above the 50°F minimum setpoint (Y/N):				
68		Cooling SAT reset request is suppressed for 30sec (0.1°F×5min/°F) to allow the zone time to reach setpoint (Y/N):				
69		3 cooling SAT reset requests are active after 30s since the zone temperature > cooling setpoint + 5°F (Y/N):				
70						
71		Override the occupied cooling setpoint to 74.9°F.				
72						
73						
74		Override the zone temperature feedback to 80°F (5.1°F above the new zone cooling setpoint).				
75	Retest		Insert Row	Add/Go To Graphic Sheet		
76	5	Release the override on the discharge air temperature feedback.	Date: Insert Date & Time			Inc.
77		Time:				
78		2 cooling SAT reset requests are active since the zone temperature > cooling setpoint + 3°F (Y/N):				
79		Override the cooling PID loop output to 96%.				
80						
81		Override the zone temperature feedback to 78°F (3.1°F above the new zone cooling setpoint).				
82						
83	Retest		Insert Row	Add/Go To Graphic Sheet		

What's next?

- 26 addenda in the works for 2024 version
 - Laboratory VAV controls
 - Staged fan arrays and outdoor air dampers/AFMS
 - Energy recovery integration
 - Wildfire mode switch
 - Pandemic mode switch
 - Humidity control (including Standard 62.1 limits)
 - Many other enhancements and bug fixes
- RP-1865 SOOs for dedicated outdoor air systems (DOAS)
 - Stalled due to COVID
 - Complete later this year
 - Will add hydronic zonal logic at the same time, e.g. radiant, ACBs

Conclusions

- ASHRAE Guideline 36 merges two competing goals:
 - Plug and play
 - Advanced sequences and diagnostics for maximum performance
- Desired implementation
 - Engineers no longer write sequences
 - Sequences all preprogrammed and debugged by control system manufacturer
 - A total of 8 manufacturers have already done most popular apps!
 - Controls contractors no longer program sequences
 - Commissioning agents no longer test all sequences
- Everyone wins
 - Lower first costs for entire design/construction team
 - Lower maintenance costs and easier to maintain
 - Lower energy costs and improved performance



Questions?

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