Addendum y to

ASHRAE Guideline 36-2018

Public Review Draft

Proposed Addendum y to Guideline 36-2018, High-Performance Sequences of Operation for HVAC Systems

Second Public Review (April 2021)

(Draft shows Proposed Independent Substantive Changes to Previous Public Review Draft)

This draft has been recommended for public review by the responsible project committee. To submit a comment on this proposed standard, go to the ASHRAE website at www.ashrae.org/standards-research--technology/public-review-drafts and access the online comment database. The draft is subject to modification until it is approved for publication by the Board of Directors and ANSI. Until this time, the current edition of the standard (as modified by any published addenda on the ASHRAE website) remains in effect. The current edition of any standard may be purchased from the ASHRAE Online Store at www.ashrae.org/bookstore or by calling 404-636-8400 or 1-800-727-4723 (for orders in the U.S. or Canada).

This standard is under continuous maintenance. To propose a change to the current standard, use the change submittal form available on the ASHRAE website, www.ashrae.org.

ASHRAE, 180 Technology Parkway, Peachtree Corners GA 30092

(This foreword is not part of this guideline. It is merely informative and does not contain requirements necessary for conformance to the guideline.)

FOREWORD

This ~~addendum includes the HW plant sequences and associated logic variables and hardwired control points developed as part of ASHRAE Research Project 1711: Advanced Sequences of Operation for HVAC Systems – Phase II Central Plants and Hydronic Systems. Typos and minor language clarity issues identified since final publication of the RP-1711 sequences on December 31, 2019 have been cleaned up in this version.~~ is the second public review of addendum y addressing control sequences for Hot Water Plants and includes only substantive changes to the first public review draft. Rationale for each change is shown directly before the change.

~~Cross-references herein refer to content from Addendum r. Approval of this addendum is therefore predicated on approval of Addendum r.~~

Note: This public review draft makes proposed independent substantive changes to the previous public review draft. These changes ~~In this addendum, changes to the current guideline~~ are indicated in the text by underlining (for additions) and strikethrough (for deletions) unless the instructions specifically mention some other means of indicating the changes. Only these changes are open for review and comment at this time. Additional material is provided for context only and is not open for comment except as it relates to the proposed substantive changes.

Addendum y to Guideline 36-2018

**This addendum version assumes Addendum x adoption.*

Revise Section 3.1.8.4 as follows to clarify that QbX is not limited to condensing boilers and is the output capacity.

~~Retain the following parameter for plants with non-condensing boilers. Delete otherwise.~~

a. QbX, design output capacity of Boiler X, in KBtu/h.

Add Section 3.1.8.5 to include variables for the number of pumps for clarity. Renumber the rest of this section accordingly.

3.1.8.5. Headered Pump Design Quantities

Retain the following parameters if primary hot water pumps are headered.

a. N-PHWP, the number of primary hot water pumps that operate at design conditions

Retain the following parameters if secondary hot water pumps are headered.

b. N-SHWP, the number of secondary hot water pumps that operate at design conditions

Revise Section 4.11.1. to no longer list firing rate as a required point; sequences use calculated load for staging instead since firing rate is not always available.

4.11.1. Boilers

Required?	Description	Type	Device
R	Boiler enable	DO	Connect to boiler enable contact; typ. each boiler
R	HW supply temperature setpoint	AO	AI to boiler control panels or AI through boiler network interfaces.
Optional point for monitoring boiler firing rate.			
~~R~~O	Boiler firing rate	AI	Firing rate from boiler controller (may be via network connection rather than hardwired). Use gas valve position if firing rate is not known. Typ. each boiler.

Revise Section 4.11.3. to clarify that minimum flow bypass is not required for boilers that do not have a minimum flow rate such as high mass boilers.

4.11.3. Primary HW Loop

Required?	Description	Type	Device
HW flow required for primary-only plants; the flow meter must be located on the plant side of the HW minimum flow bypass where provided. Optional for variable primary-variable secondary plants. Not required nor recommended for constant primary-variable secondary plants.			
A	HW supply or return flow	AI	Flow meter
HW bypass valve is required for variable flow primary-only plants with boilers with non-zero minimum flow. Delete otherwise.			
A	HW Min flow bypass valve	AO	Modulating valve sized for minimum flow of one boiler

Delete Section 5.21.3.7 since noncondensing boilers are not staged on minimum firing rate.

~~**Retain the following clause for hybrid plants. Delete otherwise.**~~

~~5.21.3.7. Non-condensing boilers in hybrid boiler plants are staged in part based on the capacity output of operating non-condensing boilers alone, $Q_{Non\text{-}Cond}$. $Q_{Non\text{-}Cond}$ is calculated as the sum of boiler firing rate times design capacity, QbX, for all operating non-condensing boilers.~~

~~*The non-condensing boiler primary loop in hybrid boiler plants typically does not have a flow meter, so capacity output is estimated based on firing rate and design capacity.*~~

Modify Section 5.21.3.9.f to be more conservative when staging boilers on to ensure they do not end up cycling off; cycling losses are much larger than the efficiency improvement of running condensing boilers at part load.

f. Stage up if any of the following is true:

1. **Availability Condition:** The equipment necessary to operate the current stage are unavailable. The availability condition is not subject to the minimum stage runtime requirement. Or

2. **Efficiency Condition:** Both of the following are true:

5. $Q_{required}$ exceeds ~~150~~200% of $B\text{-}STAGE_{MIN}$ of the next available stage for 10 minutes

iii. Hot water flowrate exceeds the minimum flow setpoint of the next available stage (see 5.21.8).

3. Failsafe Condition: HW supply temperature is 10°F < setpoint for 15 minutes.

g. Stage down if all of the following are true:

1. Either:

i. $Q_{required}$ falls below 110% of $B\text{-}STAGE_{MIN}$ of the current stage for 5 minutes; or

ii. The minimum flow bypass valve, if provided, is greater than 0% open for 5 minutes.

2. The failsafe stage up condition is not true.

3. $Q_{required}$ is less than 80% of the design capacity, QbX, of the boilers in the next available lower stage for 5 minutes.

Condensing boilers are generally more efficient at low load since the ratio of heat transfer surface area to thermal mass flowrate is maximized, increasing flue gas condensation. Staging on boilers at low load therefore maximizes plant efficiency. However, the energy penalty from cycling losses due to staging on lag equipment prematurely, only to have them cycle off, may more than offset the part load efficiency gains.

Staging is delayed until the current stage output exceeds the minimum output of the next stage by ~~50~~100% to avoid boiler short cycling following stage up, which dramatically decreases plant efficiency. The default stage up~~ing~~ threshold for the efficiency condition is set ~~intentionally high~~ to ensure sufficient load to prevent boilers from short cycling and to create an adequate hysteresis to prevent unnecessary boiler staging, but the optimal threshold will depend in part on the boiler turndown. The designer should consider adjusting this threshold based on plant attributes: higher for boilers with more turndown, lower for boilers with less turndown.

Modify Section instructions for S~~s~~ections 5.21.3.10. and 5.21.3.11 which are not used for hybrid plants. Hybrid plants are covered under Clauses 5.21.3.12 through 5.21.3.17.

Retain the following two clauses for plants with only condensing or non-condensing boilers. Delete the following two clauses for hybrid plants.

~~5.21.3.11.~~5.21.3.10. Whenever a lag boiler is enabled:

Revise Section 5.21.6.4 and 5.21.7.3 to reference a variable for the number of pumps, which has been added as a parameter in Section 3.

5.21.6.4. HW pumps shall be staged as a function of the ratio of current hot water flow, $FLOW_P$, to design flow, $PHWF_{design}$, and the number of pumps, N-PHWP, that operate at design conditions. Pumps are assumed to be equally sized.

$$\text{HWFR} = \frac{FLOW_P}{PHWF_{design}}$$

5.21.7.3. Secondary HW pumps shall be staged as a function of SHWFR, the ratio of current hot water flow, $FLOW_S$, to design flow, and the number of pumps, N-SHWP, that operate at design conditions. Pumps are assumed to be equally sized.

$$\text{SHWFR} = \frac{FLOW_S}{SHWF_{design}}$$

5.21.8.

5.21.9.

~~5.21.10.~~

Revise Sections 5.21.11.4.b and 5.21.11.6, revising variable name from $HWFlow_{B-X}$ to $HWStatus_{B-X}$.

~~5.21.10.~~

5.21.11. Automatic Fault Detection and Diagnostics

The Automatic Fault Detection and Diagnostics (AFDD) routines for hot water plants continually assess plant performance by comparing the values of BAS inputs and outputs to a subset of potential fault conditions. The subset of potential fault conditions that is assessed at any point depends on the Operating State of the plant, as determined by the positions of the isolation valves and statuses of pumps. Time delays are applied to the evaluation and reporting of fault conditions, to suppress false alarms. Fault conditions that pass these filters are reported to the building operator as alarms along with a series of possible causes.
These equations assume that the plant is equipped with isolation valves, as well as a pump status monitoring. If any of these components are not present, the associated tests, and variables should be omitted from the programming.
Note that these faults rely on reasonably accurate measurement of water temperature. Extra precision sensors installed in thermowells with thermal paste are recommended for best accuracy.

5.21.11.1. AFDD conditions are evaluated continuously for the plant.

5.21.11.2. The Operating State (OS) of the plant shall be defined by the commanded positions of the valves and status feedback from the pumps in accordance with the following table. For hybrid plants, determine the Operating State for each primary loop.

The Operating State is distinct from and should not be confused with the hot water plant stage.
OS#1 – OS#3 represent normal operation during which a fault may nevertheless occur, if so determined by the fault condition tests below.

Operating State	Boiler Isolation Valve or Dedicated Primary HW Pump Status	PHW Pump Status (if primary-only) or SHW Pump Status (if primary-secondary)
#1: Disabled	All Closed/Off	All Off
#2: One boiler enabled	One Open/On, All Others Closed/Off	Any On
#3: More than one boiler enabled	Any Open/On	Any On

5.21.11.3. The following points must be available to the AFDD routines for the hot water plant:

Retain the following two variables for primary-secondary plants and primary-only plants where pump speed is controlled to maintain differential pressure. Delete otherwise.

a. DP = Hot water loop differential pressure (each loop, where applicable)

b. DPSP = Hot water loop differential pressure setpoint (each loop, where applicable)

Retain the following variable if there is a flow meter in the primary loop. Delete otherwise.

c. $FLOW_P$ = Primary hot water flow (each primary loop, where applicable)

Retain the following variable if there is a flow meter in the secondary loop. Delete otherwise.

d. $FLOW_S$ = Secondary hot water flow (each secondary loop, where applicable)

Retain the following two variables for primary-only plants with a minimum flow bypass valve. Delete otherwise.

e. MFBPV = Hot water minimum flow bypass valve command; 0% ≤ MFBPV ≤ 100%

f. HW-MinFlowSP = Effective minimum hot water flow setpoint (equal to MinFlowRatio multiplied by the sum of HW-MinFlowX of operating boilers)

Retain the following variable for primary-secondary plants where pump speed is controlled to maintain differential pressure. Delete otherwise.

g. $Speed_{HWP}$ = Secondary hot water pump speed command; 0% ≤ SpeedHWP ≤ 100%

Retain the following variable for primary-only plants where pump speed is controlled to maintain differential pressure. Delete otherwise.

h. $Speed_{HWP}$ = Hot water pump speed command; 0% ≤ SpeedHWP ≤ 100%

i. $Status_{PHWP}$ = Lead primary hot water pump status (each primary loop, where applicable)

Retain the following variable for primary-secondary plants. Delete otherwise.

j. $Status_{SHWP}$ = Lead secondary hot water pump status (each secondary loop, where applicable)

k. HWST = Common hot water supply temperature

l. HWSTSP = Hot water supply temperature setpoint

m. HWRT = Average boiler entering water temperature (each loop)

Retain the following variable for plants headered primary pumps. Delete otherwise.

n. $HWISO_{B-x}$ = B-x hot water isolation valve commanded position (each boiler)

Retain the following variable for plants where system gauge pressure is monitored. Delete otherwise.

o. P_{GAUGE} = Hot water system gauge pressure

5.21.11.4. The following values must be continuously calculated by the AFDD routines:

a. 5-minute rolling averages with 1-minute sampling time of the following point values; operator shall have the ability to adjust the averaging window and sampling period for each point independently

1. $HWST_{AVG}$ = rolling average of the common hot water supply temperature (each primary loop, where applicable)

2. $HWRT_{AVG}$ = rolling average of the average boiler entering water return temperature.

Retain the following variable for plants where system gauge pressure is monitored. Delete otherwise.

3. $P_{GAUGE,AVG}$ = rolling average of hot water system gauge pressure

b. $HWFlowStatus_{B\text{-}X}$ (each boiler)

Retain the following clause for plants with headered primary pumps. Delete otherwise.

1. For plants with headered primary hot water pumps: 1 if $HWISO_{B\text{-}X}$ = open, 0 if $HWISO_{B\text{-}X}$ = closed

Retain the following clause for plants with dedicated primary pumps. Delete otherwise.

2. For plants with dedicated primary hot water pumps: 1 if $Status_{PHWP}$ = on, 0 if $Status_{PHWP}$ = off

5.21.11.6. The following are potential Fault Conditions that can be evaluated by the AFDD routines. If the equation statement is true, then the specified fault condition exists. The Fault Conditions to be evaluated at any given time will depend on the Operating State of the hot water plant.

Edit the table below. Remove fault conditions that do not apply.

Retain the following fault condition for plants with any hot water pumps controlled to maintain differential pressure. Delete otherwise. Duplicate the following fault condition for each differential pressure sensor.			
FC#1	**Equation**	$DP_{AVG} > \varepsilon_{DSP}$ and $Status_{HWP}$ = Off	**Applies to OS #1**
	Description	Differential pressure is too high with the hot water pumps off	
	Possible Diagnosis	DP sensor error	

<table>
<tr><td colspan="4">Retain the following fault condition if there is a flow meter in the primary loop. Delete otherwise. Duplicate the following fault condition for each primary loop with a flow meter.</td></tr>
<tr><td rowspan="3">FC#2</td><td>Equation</td><td>$FLOW_{P, AVG} > \varepsilon_{FM}$
and
$Status_{PHWP} = Off$</td><td rowspan="3">Applies to OS #1</td></tr>
<tr><td>Description</td><td>Primary hot water flow is too high with the hot water pumps off</td></tr>
<tr><td>Possible Diagnosis</td><td>Flow meter error</td></tr>
<tr><td colspan="4">Retain the following fault condition for primary-secondary plants with a flow meter in the secondary loop. Delete otherwise. Duplicate the following fault condition for each secondary loop flow meter.</td></tr>
<tr><td rowspan="3">FC#3</td><td>Equation</td><td>$FLOW_{S, AVG} > \varepsilon_{FM}$
and
$Status_{SHWP} = Off$</td><td rowspan="3">Applies to OS #1</td></tr>
<tr><td>Description</td><td>Secondary hot water flow is too high with the associated hot water pumps off</td></tr>
<tr><td>Possible Diagnosis</td><td>Flow meter error</td></tr>
<tr><td colspan="4">Retain the following fault condition for primary-secondary plants and primary-only plants where pump speed is controlled to maintain differential pressure. Delete otherwise. Duplicate the following fault condition for each differential pressure sensor and/or each secondary loop where pump speed is controlled to maintain differential pressure.</td></tr>
<tr><td rowspan="3">FC#4</td><td>Equation</td><td>$DP_{AVG} < DPSP - \varepsilon_{DP}$
and
$Speed_{HWP} \geq 99\% - \varepsilon_{VFDSPD}$</td><td rowspan="3">Applies to OS #2, #3</td></tr>
<tr><td>Description</td><td>Hot water loop differential pressure is too low with hot water pump(s) at full speed.</td></tr>
<tr><td>Possible Diagnosis</td><td>Problem with VFD
Mechanical problem with pump(s)
Pump(s) are undersized
Differential pressure setpoint is too high
HWST is too low
Primary flow is higher than the design flow of the operating boilers</td></tr>
<tr><td colspan="4">Retain the following fault condition for primary-only plants with a minimum flow bypass valve. Delete otherwise.</td></tr>
<tr><td rowspan="3">FC#5</td><td>Equation</td><td>$FLOW_{P, AVG} < HW\text{-}MinFlowSp - \varepsilon_{FM}$
and
$MFBPV \geq 99\% - \varepsilon_{MFBPV}$</td><td rowspan="3">Applies to OS #2, #3</td></tr>
<tr><td>Description</td><td>Primary hot water flow is too low with the minimum flow bypass valve fully open.</td></tr>
<tr><td>Possible Diagnosis</td><td>Problem with minimum flow bypass valve
Problem with boiler isolation valves
Minimum loop differential pressure setpoint too low</td></tr>
<tr><td colspan="4">For hybrid plants, duplicate the following fault condition for each primary loop.</td></tr>
</table>

FC#6	**Equation**	$HWST_{AVG} + \varepsilon_{HWT} < HWSTSP$	**Applies to OS #2, #3**
	Description	Hot water supply temperature is too low.	
	Possible Diagnosis	Mechanical problem with boilers Primary flow is higher than the design flow of the operating boilers Deviation between the internal boiler hot water supply temperature sensor and the plant hot water supply temperature is too high (i.e. boiler sensor is out of calibration).	
Retain the following fault condition for plants where system gauge pressure is monitored. Delete otherwise.			
FC#7	**Equation**	$P_{GAUGE,\ AVG} < 0.9 * ETPreChargePress$	**Applies to OS #1 – #3**
	Description	Hot water system gauge pressure is too low	
	Possible Diagnosis	Possible hot water system leak	
Retain the following fault condition for plants with a condensing boiler. Delete otherwise.			
FC#8	**Equation**	$HWRT_{AVG} - \varepsilon_{HWT} > CondTemp$	**Applies to OS #2, #3**
	Description	Hot water return temperature is too high for condensing to occur.	
	Possible Diagnosis	Hot water supply temperature setpoint is too high. Hot water load is too low. High bypass flow is raising the entering water temperature. Hot water coils are not designed for condensing at current loads.	
Retain the following fault condition for plants with a non-condensing boiler. Delete otherwise.			
FC#9	**Equation**	$HWRT_{AVG} + \varepsilon_{HWT} < CondTemp$	**Applies to OS #2, #3**
	Description	Hot water return temperature is too low. Condensing is likely to occur.	
	Possible Diagnosis	Hot water supply temperature setpoint is too low.	
Retain the following fault condition if any boiler has a network interface and the plant has a common hot water supply temperature sensor at the discharge of the boiler(s). Delete otherwise. For hybrid plants, duplicate the following fault condition for each primary loop.			
FC#10	**Equation**	$\lvert (\sum(HW\text{-}FlowStatus_{B\text{-}X} * HWST_{B\text{-}X}) / \sum HW\text{-}FlowStatus_{B\text{-}X}) - HWST_{AVG} \rvert > \varepsilon_{HWT}$	**Applies to OS #2**
	Description	Deviation between the active boiler hot water supply temperature and the common hot water supply temperature is too high.	
	Possible Diagnosis	A hot water supply temperature sensor is out of calibration	
Retain the following fault condition if any boiler has a network interface and the plant has a common hot water return temperature sensor at the inlet of the boiler(s). Delete otherwise. For hybrid plants, duplicate the following two fault condition for each primary loop.			
FC#11	**Equation**	$\lvert (\sum(HW\text{-}FlowStatus_{B\text{-}X} * HWRT_{B\text{-}X}) / \sum HW\text{-}FlowStatus_{B\text{-}X}) - HWRT_{AVG} \rvert > \varepsilon_{HWT}$	**Applies to OS**

	Description	Deviation between the active boiler hot water return temperature and the common boiler entering water temperature is too high.	**#2**
	Possible Diagnosis	A hot water return temperature sensor is out of calibration	
FC#12	**Equation**	$\Delta OS > \Delta OS_{MAX}$	**Applies to OS #1 – #3**
	Description	Too many changes in Operating State	
	Possible Diagnosis	Unstable control due to poorly tuned loop or mechanical problem	
FC#13	**Equation**	$\Delta StartsCH\text{-}x > \Delta BStart_{MAX}$	**Applies to OS #2, #3**
	Description	Too many boiler starts	
	Possible Diagnosis	Boiler is cycling due to load loads Boiler is oversized and/or has insufficient turndown. Boiler stage-up threshold may be set too low.	
FC#14	**Equation**	$\Delta Stage > \Delta Stage_{MAX}$	**Applies to OS #1 – #3**
	Description	Too many stage changes	
	Possible Diagnosis	Staging thresholds and/or delays need to be adjusted	

5. FC#8: Hot water return temperature is too high for condensing to occur

6. FC#9: Hot water return temperature is too low. Condensing is likely to occur

7. FC#12: Too many changes in Operating State

8. FC#13: Too many boiler starts

9. FC#14: Too many stage changes

5.21.11.8. For each boiler, the operator shall be able to suppress the alarm for any Fault Condition.

5.21.11.9. Evaluation of Fault Conditions shall be suspended under the following conditions:

a. When no pumps are operating.

b. When all equipment associated with a fault condition in maintenance mode.

c. For a period of StageDelay minutes following a change in plant stage.

5.21.11.10. Fault Conditions that are not applicable to the current Operating State shall not be evaluated.

5.21.11.11. A Fault Condition that evaluates as true must do so continuously for AlarmDelay minutes before it is reported to the operator.

5.21.11.12. Test Mode shall temporarily set StageDelay and AlarmDelay to 0 minutes for a period of TestModeDelay minutes to allow instant testing of the AFDD system and to ensure normal fault detection occurs after testing is complete.

~~5.21.11.13.~~ When a Fault Condition is reported to the operator, it shall be a Level 3 alarm and shall include the description of the fault and the list of possible diagnoses from the table in 5.21.11.6.

5.21.11.13.