ADDENDA

ASHRAE Addendum r to
ASHRAE Guideline 36-2018

High Performance Sequences of Operation for HVAC Systems

Approved by ASHRAE on February 24, 2021.

This addendum was approved by a Standing Guideline Project Committee (SGPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the guideline. Instructions for how to submit a change can be found on the ASHRAE® website (https://www.ashrae.org/continuous-maintenance).

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b. participation in the next review of the Guideline,
c. offering constructive criticism for improving the Guideline, or
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FOREWORD

Addendum r includes the lead/lag and lead/standby equipment rotation sequences developed as part of ASHRAE Research Project 1711: Advanced Sequences of Operation for HVAC Systems—Phase II Central Plants and Hydronic Systems.

Note: 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.

Addendum r to Guideline 36-2018

(IP and SI Units)
Revise Section 5.1.15 as follows:

5.1.15 Equipment Staging and Rotation

~~*Sequences for automatic lead/lag equipment staging and rotation will be added in a later version of Guideline 36.*~~

5.1.15.1 Parallel equipment shall be lead/lag or lead/standby rotated to maintain even wear.

5.1.15.2 Two runtime points shall be defined for each equipment:

a. Lifetime Runtime: The cumulative runtime of the equipment since equipment start-up. This point shall not be readily resettable by operators.

Lifetime Runtime should be stored to a software point on the control system server so the recorded value is not lost due to controller reset, loss of power, programming file update, etc.

b. Staging Runtime: An operator resettable runtime point that stores cumulative runtime since the last operator reset.

Staging Runtime provides a resettable runtime counter, which allows for reset of the staging runtime hours used for lead/lag or lead/standby rotation between maintenance intervals or equipment replacement while maintaining a separate log of the Lifetime Runtime. If runtime were not resettable, and logic relied only on Lifetime Runtime for determining staging lead/lag position, newly added equipment could run for years as the lead equipment before swapping rotation positions with older equipment per the logic below.

5.1.15.3 Lead/lag equipment: Unless otherwise noted, identical parallel staged equipment (such as CHW pumps and cooling towers) shall be lead/lag alternated when more than one is off or more than one is on so that the equipment with the most operating hours as determined by Staging Runtime is made the last stage equipment and the one with the least number of hours is made the lead stage equipment.

*This strategy effectively makes it such that equipment are **not** "hot swapped", e.g., a pump would **not** be started and another stopped during operation just for runtime equalization.*
For example, assume there are two equipment and only one is on, but the operating equipment has exceeded the run hours of the disabled equipment. The equipment will not rotate positions until either a stage up or down occurs. If the plant stages up, then both equipment will be on and lead/lag position will switch; when the plant next stages down, the former lead equipment with more run hours will then turn off.
Expanding further, for a plant with three equipment, if all three are off or all are on, the staging order will simply be based on run hours from lowest to highest. If two equipment are on, the one with more hours will be set to be stage 2 while the other is set to stage 1; this may be the reverse of the operating order when the equipment were started. If two of the equipment are off, the one with the more hours will be set to be stage 3 while the other is set to stage 2; this may be the reverse of the operating order when the equipment were stopped.
Example with three pumps:
1. P-1 (1000 hours), 2 (950 hours), and 3 (900 hours) are all off. Staging logic makes lead/lag order: 3, 2, 1.
2. P-3 starts. Logic does not change its order since it is on by itself.
3. P-3 runs for 51 hours. Since it is on and others off, the lead/lag order does not change. It can run this way indefinitely and the order does not change.
4. There is then a stage-up command. P-2 (the next in lead/lag order) is started. So, both P-2 and P-3 are on. P-3 now has more run hours than P-2. So, the Lead/lag order changes to: 2, 3, 1.
5. These two pumps run another 51 hours. Run times are P-1 (1000 hours), P-2 (1001), and P-3 (1002). No changes are made to lead/lag order because P-1 is off alone.
6. There is a stage down command. P-2 is now lead so it stays on. P-3 is shut off. The order for the two off pumps is now adjusted because P-1 has fewest run hours. Lead/lag order is now: 2, 1, 3.
7. P-2 runs for 100 more hours. It now has the longest runtime, but order does not change since it is on alone. Order is still 2, 1, 3.
8. There is a stage down or plant-off command. P-2 shuts off. Run times are P-1 (1000 hours), P-2 (1101), and P-3 (1002). Since all are off, order is switched to: 1, 3, 2.

5.1.15.4 Lead/standby equipment:

a. Unless equipment runs continuously, parallel equipment that are 100% redundant shall be lead/standby alternated when more than one of the equipment is off so that the equipment with the most operating hours as determined by Staging Runtime is made the last stage equipment and the one with the least number of hours is made the earlier stage equipment.

For example, assuming there are three equipment, if all three are off, the staging order will be based on run hours from lowest to highest.

b. If equipment runs continuously, lead/standby positions shall switch at an adjustable day of the week and time (e.g., every Tuesday at 10:00 am) based on Staging Runtime; standby equipment shall first be started and proven on before former lead equipment is changed to standby and shut off.

Retain the following clause for plants with variable speed fans or pumps. Delete otherwise.

1. Variable speed fans and pumps shall have a deceleration rate of 1 Hz/second or slower set in BAS logic when disabled to prevent nuisance trips of operating equipment (e.g., chillers).

5.1.15.5 Exceptions to Lead/lag and Lead/standby rotation

a. Operators with appropriate access level shall be able to manually command staging order via software points, but not overriding the In-Alarm or Hand-Operation logic in the following subsections.

1. Staging order changes initiated via operator override shall be instituted as part of normal staging events.

2. Staging order shall remain overridden until released by operators.

b. Faulted Equipment:

1. A faulted equipment is any equipment commanded to run that is either not running or unable to perform its required duty. If an operating equipment has any fault condition described subsequently, a Level 2 alarm shall be generated, and a response shall be triggered as defined below.

i. Fans and Pumps

(a)

(b) ~~In Alarm. If the lead device has a fault condition or has been manually switched off, a Level 2 alarm shall be generated and the device shall be set to the last-stage position in the staging order until the alarm is reset by an operator. A device in alarm can only automatically move up in the staging order if another device goes into alarm.~~

(c) ~~This sequence does not lock out a device that is in alarm. It moves all devices in alarm to the end of the rotation sequence such that they will be the last devices called to run. The sequence will only call for these devices in alarm if all of the devices not in alarm are already enabled and there is a call for a stage-up. A device in alarm will respond if called to run only if it is capable of doing so (e.g., not locked out on internal safety, locked out on a hand-OFF-auto (HOA) switch at the starter, or otherwise disabled). It is important to note that this staging does not override the devices internal safeties, so it will not damage equipment.~~

(d) ~~Note that some alarm conditions could be triggered when the underlying equipment is fully operable. For example, a status point not matching the ON/OFF command could be triggered by a faulty status signal. The same is TRUE for a supervised HOA at a control panel; the operator might have been testing the equipment and simply forgot to turn the HOA back to AUTO.~~

(e) ~~Alarm conditions include the following:~~

(f) ~~Variable-speed fans~~
(g) Status point not matching its on/off point for 3 seconds after a time delay of 15 seconds while the ~~device~~ equipment is commanded on

~~i. Current scope of these sequences only include variable-speed fans. Pumps, chillers, and boilers are currently beyond the scope of Guideline 36. They will be incorporated into this logic as a part of RP-1711, which addresses sequences for central heating and cooling plants.~~

ii. Chillers

(a) Safety shutdown alarm condition either through network or hardwired alarm contact, or
(b) Chiller is manually shut off as indicated by the status of the Local/Auto switch from chiller gateway, or
(c) Chiller status remains off 5 minutes after command to start (note: this condition only applies when a chiller first starts, i.e., once status is proven, then status is no longer used as a fault condition because status will come and go if chiller cycles on low load), or

Retain the following sentence for plants with parallel chillers and CHW isolation valve position feedback. Delete otherwise.

(d) CHW isolation valve feedback indicates valve is not open 90 seconds after valve is commanded open, or

Retain the following sentence for plants with series chillers and CHW isolation valve position feedback. Delete otherwise.

(e) CHW isolation valve feedback indicates valve is not closed 90 seconds after valve is commanded closed, or

Retain the following sentence for chillers with CW isolation valve position feedback. Delete otherwise.

(f) CW isolation valve feedback indicates valve is not open 90 seconds after valve is commanded open, or
(g) For 10 minutes, chilled water return temperature has been at least 3°C (5°F) above the CHWST setpoint, and delta-T across the chiller, as determined based on the difference between chilled water return temperature and chilled water supply temperature measured at the chiller (i.e., not common CHWST), has been less than 2°C (3°F).

iii. Boilers

(a) Safety shutdown alarm condition either through network or hardwired alarm contact, or

Retain the following sentence for boilers with HW isolation valve position feedback. Delete otherwise.

(b) HW isolation valve feedback indicates valve is not open 90 seconds after valve is commanded open, or

(c) If boiler leaving water temperature remains 8.3°C (15°F) below setpoint for 15 minutes and delta-T across the boiler, as determined based on the difference between hot water supply temperature and hot water return temperature measured at the boiler (i.e., not common HWST), has been less than 6°C (10°F).

iv. Cooling Towers

(a) Tower fan has failed as defined above, or

Retain the following sentence for cooling towers with inlet isolation valve position feedback. Delete otherwise.

(b) Inlet end switch indicates valve is not open 90 seconds after valve is commanded open, or

Retain the following sentence for cooling towers with outlet isolation valve position feedback. Delete otherwise.

(c) Outlet end switch indicates valve is not open 90 seconds after valve is commanded open.

2. Upon identification of a fault condition:

i. For fans, pumps, and cooling towers:

(a) The next commanded off equipment in the staging order, Equipment "B," shall be commanded on while alarming Equipment "A" remains commanded on.

(b) If Equipment "B" fails to prove status (i.e., it also goes into alarm), it shall remain commanded on, and the preceding step shall be repeated until the quantity of equipment called for by the current stage has proven on, or there are no more available equipment.

(c) Set alarming equipment to the last positions in the lead/lag or lead/standby staging order sequenced reverse chronologically (i.e., the equipment that alarmed most recently is sent to last position).

(d) Staging order of non-alarming equipment shall follow the even wear logic. Equipment in alarm can only automatically move up on the staging order if another equipment goes into alarm.

(e) Equipment in alarm shall run if so called for by the lead/lag or lead/standby staging order and present stage.

Both this and the subsequent chiller and boiler sequence do not lock out equipment that are in alarm. Instead, they move all equipment in alarm to the end of the rotation sequence such that they will be the last equipment called to run. The sequences will only call for the equipment in alarm if all of the equipment not in alarm are already enabled and there is a call for a stage-up. Equipment in alarm will respond if called to run only if it can do so (e.g., not locked out on internal safety, locked out on an HOA switch at the starter, or otherwise disabled). It is important to note that this staging does not override the equipment's internal safeties so it will not damage equipment.

Note some alarm conditions could be triggered when the underlying equipment is fully operable. For example, a status point not matching the on/off command could be triggered by a faulty status signal. The same is true for a supervised HOA at a control panel: the operator might have been testing the equipment and simply forgot to turn the HOA back to AUTO.

Example: For a set of (4) lead/lag equipment, the current staging order is Equipment A, B, C, then D. The current stage requires two of the equipment, so A and B are running. Then A goes into alarm. C is then commanded on and starts with no alarm. Since the required quantity of equipment has proven on (2), A is moved to the end of staging order since it is in alarm and disabled. The staging order is now B, C, D, A. Equipment B and C are running with no alarms.

Then the staging logic calls for a third equipment. D is commanded on but goes into alarm. Then A is commanded on. Since D entered an alarm state after A and all equipment are commanded on, D is set to last in the lead/lag staging order. The staging order is now B, C, A, D, and all equipment remain enabled since (3) are called but only (2) are running without alarms.

ii. For chillers and boilers:

(a) The next commanded off equipment in the staging order, Equipment "B", shall be commanded on while alarming Equipment "A" is commanded off and set to the last position in the lead/lag staging order.
(b) If Equipment B fails to prove status (i.e., it also goes into alarm), repeat the preceding step until the quantity of equipment called for by the lead/lag logic have proven on or until all equipment has been tried.
(c) If all equipment has been tried and the quantity of non-alarming equipment is less than called for, then the most recently alarmed equipment will remain commanded on.
(d) Staging order of non-alarming equipment shall follow the even wear logic. Equipment in alarm can only automatically move up in the staging order if another equipment goes into alarm.
(e) Equipment in alarm shall run if so called for by the lead/lag staging order and present stage.

The sequence for chillers and boilers differs from that used for pumps and cooling towers in that the alarming equipment does not remain commanded on until the next equipment proves

status. The pump and tower logic mitigates the risk of lost loads and/or chain reaction trips of chillers and boilers by still taking advantage of any capacity the alarming equipment may provide until the lag equipment proves. This approach does not however typically work for chillers and boilers because bringing on the lag equipment while still commanding the alarming equipment to run may prevent a successful startup of the lag equipment. For example, in a parallel variable primary chilled water plant under low load conditions, starting a lag chiller while keeping the alarming chiller enabled may cause both chillers to trip on either low chilled water flow or low condenser water flow unless the minimum chilled water flow setpoint is changed to maintain minimum chilled water flow and condenser water pumps are staged to maintain minimum condenser flow through both chillers.

Example: For a set of (4) lead/lag equipment, the current staging order is Equipment A, B, C, then D. The current stage requires two equipment, so A and B are running. Then A goes into alarm. A is then commanded off at the same time as C is commanded on. If C then goes into alarm, it is commanded off at the same time that D is commanded on. If D then goes into alarm, it remains commanded on since all equipment has been tried. If B (the last equipment not in alarm) also goes into alarm, then it remains commanded on (as the last alarming equipment with no non-alarming equipment available). At this point, all equipment are in alarm and only B and D will remain commanded on until an equipment comes out of alarm. The staging order is B, D, A, C. Note that staging up/down is disabled in this condition per 5.2.4.13 and 5.3.3.9.

c. Hand Operation. If an ~~device~~ equipment is on-in-hand (e.g., via an HOA switch or local control of VFD), the ~~device~~ equipment shall be set to the lead ~~device~~equipment, and a Level 4 alarm shall be generated. The ~~device~~ equipment will remain as lead until ~~the alarm is reset by the operator~~placed back into Auto. Hand operation is determined by the following:

Any condition in which ~~a device~~ equipment appears to continue to run after being commanded OFF is considered a case of hand operation; in practice, this condition may arise due to other circumstances (e.g., a bad current transducer).

1. ~~Variable-speed fans~~ Fans and Pumps

   i. Status point not matching its on/off point for 15 seconds after a time delay of 60 seconds when~~while~~ the ~~device~~ equipment is commanded off

Logic for hand operation of chillers, boilers, and cooling towers is not provided because sequences cannot stably respond to overrides by operators in all possible scenarios. For example, if a chiller is turned on in hand in a variable primary system with only one other chiller currently running, the control system would need to react by opening the isolation valves of the chiller placed in hand and either (1) immediately shutting down the former lead chiller or (2) changing the minimum chilled water flow setpoint, opening isolation valves, and possibly staging on condenser water pumps and cooling towers. Chillers, boilers, and cooling towers should only be placed in hand by changing the staging sequence manually via the control system interface; they cannot be safely or stably operated in hand at the chiller/boiler/tower controllers.
~~Current scope of these sequences only include variable-speed fans. Pumps, chillers, and boilers are currently beyond the scope of Guideline 36. They will be incorporated into this logic as a part of RP-1711, which addresses sequences for central heating and cooling plants.~~

Add Section 5.16.9.1as follows:

5.16.9 Relief Fan Control

Relief fans are enabled and disabled with their associated supply fans, but all relief fans that are running and serve a common volume of space run at the same speed. All operating relief fans that serve a common/shared air volume shall be controlled as if they were one system, running at the same speed and using the same control loop, even if they are associated with different AHUs.
This prevents relief fans from fighting each other, which can lead to flow reversal or space pressurization problems.
The appropriate boundaries between relief systems, establishing which relief fans run together, will need to be determined by the engineer based on building geometry.

5.16.9.1 Relief fans shall be lead/lag alternated per Paragraph 5.1.15.3.

Renumber following paragraphs as required.

POLICY STATEMENT DEFINING ASHRAE'S CONCERN FOR THE ENVIRONMENTAL IMPACT OF ITS ACTIVITIES

ASHRAE is concerned with the impact of its members' activities on both the indoor and outdoor environment. ASHRAE's members will strive to minimize any possible deleterious effect on the indoor and outdoor environment of the systems and components in their responsibility while maximizing the beneficial effects these systems provide, consistent with accepted Standards and the practical state of the art.

ASHRAE's short-range goal is to ensure that the systems and components within its scope do not impact the indoor and outdoor environment to a greater extent than specified by the Standards and Guidelines as established by itself and other responsible bodies.

As an ongoing goal, ASHRAE will, through its Standards Committee and extensive Technical Committee structure, continue to generate up-to-date Standards and Guidelines where appropriate and adopt, recommend, and promote those new and revised Standards developed by other responsible organizations.

Through its *Handbook*, appropriate chapters will contain up-to-date Standards and design considerations as the material is systematically revised.

ASHRAE will take the lead with respect to dissemination of environmental information of its primary interest and will seek out and disseminate information from other responsible organizations that is pertinent, as guides to updating Standards and Guidelines.

The effects of the design and selection of equipment and systems will be considered within the scope of the system's intended use and expected misuse. The disposal of hazardous materials, if any, will also be considered.

ASHRAE's primary concern for environmental impact will be at the site where equipment within ASHRAE's scope operates. However, energy source selection and the possible environmental impact due to the energy source and energy transportation will be considered where possible. Recommendations concerning energy source selection should be made by its members.

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