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ASHRAE® Guideline 36

High-Performance Sequences of Operation

ASHRAE® Guideline 36, *High-Performance Sequences of Operation for HVAC Systems*, provides uniform sequences of operation that are intended to maximize energy efficiency and performance, and allow for real-time fault detection and diagnostics.

This *Engineers Newsletter* reviews the purpose and benefits of this guideline and explains some of its unique concepts, including Trim-and-Respond, automatic fault detection, hierarchical alarm suppression, and commissioning overrides.

Purpose of Guideline 36

The stated purpose of ASHRAE Guideline 36 is "to provide uniform sequences of operation for HVAC systems that are intended to maximize energy efficiency and performance, provide control stability, and allow for real-time fault detection and diagnostics."[1]

The foreword in the published guideline suggests it provides the following benefits:

- Reduced engineering time, by engineers adapting these standard sequences rather than developing their own
- Reduced programming and commissioning time for contractors
- Reduced energy consumption, by ensuring control sequences comply with ASHRAE Standard 90.1 (and California's Title 24), while minimizing the dependency on proper implementation and commissioning
- Improved indoor air quality, by ensuring control sequences comply with ASHRAE Standard 62.1 (and Title 24)
- Reduced system downtime, by automatically detecting and diagnosing system faults and notifying operators
- Improved communication between specifiers, contractors, and operators by using a common set of terms

Guideline 36 is **not** a standard, and there currently is no process in place to certify compliance with this guideline. In fact, Section 5.1.1 (see following excerpt) emphasizes that the sequences are intended to be performance-based, not prescriptive. That is, use of different logic that results in the same functional performance is acceptable.

> *5.1.1 These sequences are intended to be performance based. Implementations that provide the same functional result using different underlying detailed logic will be acceptable.*
>
> *The intention of these sequences is to specify the functional result of the programming logic. While all sequences are described using specific programming logic as a way to clearly document the resulting functionality, implementations using alternative logic that result in the same functional performance are acceptable.*

Current and Future Scope

Guideline 36 is under continuous maintenance. Therefore, expect the sequences to be adjusted, augmented, and possibly replaced over time.

The initial version of the guideline, published in 2018, included control sequences for only multiple-zone and single-zone VAV air-handling systems, which use chilled-water and hot-water coils. However, the committee's intent is to add sequences for other types of HVAC systems in the future. For example, in November 2020, two proposed addenda were issued for public review and comment; they included sequences of operation for both chilled-water and hot-water plants.[2,3]

In addition, functional performance tests are also being developed. The goal of these automated tests is to verify that a specific controller meets the functional result (provides similar performance) of the sequences in the guideline.

Sequences of Operation

The core of Guideline 36 is the sequences of operation for various types of HVAC equipment, as well as for coordinating system-level control. Each configuration includes a written sequence of operation, various levels of alarms, overrides for commissioning, and a process for generating the system-level "requests" used by the Trim-and-Respond reset logic (discussed later in this EN). In addition, a list of hardwired points and a sample control diagram are included.

As mentioned, in its initial version, the guideline addresses only multiple-zone and single-zone VAV air-handling systems.

VAV terminal units. The guideline includes sequences for the following configurations of VAV terminal units:

- VAV terminal unit (cooling-only, no heat)
- VAV terminal unit with a reheat coil
- Parallel fan-powered VAV terminal unit with a constant-speed fan
- Parallel fan-powered VAV terminal unit with a variable-speed fan
- Series fan-powered VAV terminal unit with a constant-speed fan
- Series fan-powered VAV terminal unit with a variable-speed fan
- Dual-duct VAV terminal unit using snap-acting control
- Dual-duct VAV terminal unit using mixing control with inlet airflow sensors
- Dual-duct VAV terminal unit using mixing control with a discharge airflow sensor
- Dual-duct VAV terminal unit using cold-duct minimum control

Air-handling units. The guideline also includes sequences for the following configurations of air-handling units:

- Multiple-zone VAV air-handling unit
- Heating VAV air-handling unit for a dual-fan, dual-duct VAV system
- Single-zone VAV air-handling unit

The control logic for air-handling units is a bit more complicated due to the wide range of variations. Therefore, the guideline includes multiple snippets of sequence text, allowing the specifying engineer to select the appropriate one (and delete the rest) to match the specific AHU configuration. For example, there are several snippets of sequence text related to building pressure control, depending on whether the AHU includes a relief fan, return fan, or neither.

In addition, the AHU sequences include logic to dynamically reset the supply duct static pressure and supply-air temperature setpoints, using a concept called Trim-and-Respond.

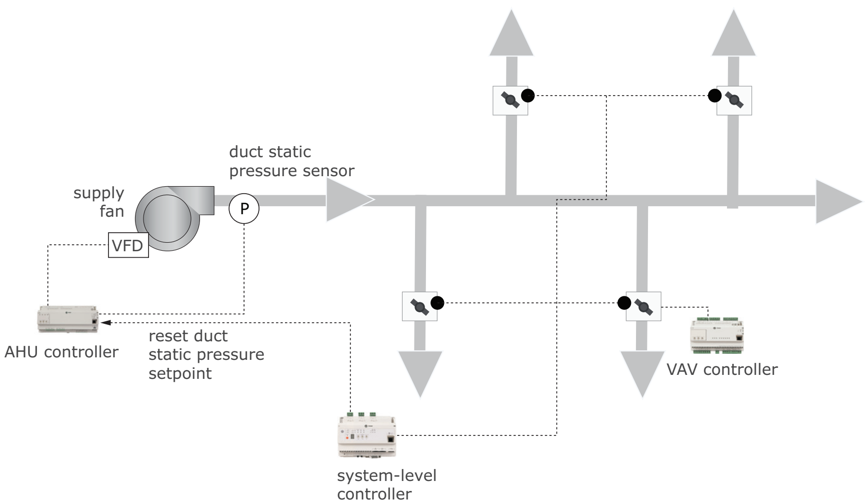
Trim-and-Respond

Trim-and-Respond is control logic used to reset a setpoint (such as pressure or temperature), or other variable, in response to requests from several input sources. In Guideline 36, Trim-and-Respond is the method suggested for resetting the duct static pressure and supply-air temperature setpoints in a multiple-zone VAV system, as well as the chilled-water and hot-water supply temperature setpoints in a central plant.[1,4]

A properly-functioning Trim-and-Respond control loop tries to balance energy efficiency with comfort. If comfort is being maintained, the control loop will adjust ("trim") the setpoint at a fixed rate to reduce energy use, until feedback from a downstream equipment-level controller generates a "request" indicating that comfort is no longer being maintained. When the total number of requests (R) rises above the Ignored Requests Threshold (I), the control loop will then "respond" by re-adjusting the setpoint until comfort is again achieved. This cycle repeats over and over.

To demonstrate this concept, consider the multiple-zone VAV system depicted in Figure 1. As the need for cooling or heating in a zone changes, the damper inside the VAV box modulates to vary the airflow supplied to that zone. This causes the pressure inside the supply ductwork to change, so the supply fan in the central air-handling unit modulates to maintain the static pressure in this ductwork at a certain setpoint. To minimize fan energy use, this duct static pressure setpoint is dynamically reset based on the position of the VAV dampers.

Figure 1. Resetting duct static pressure setpoint in a multiple-zone VAV system



First, each VAV unit controller generates “requests” based on the position of its airflow-modulation damper:

- If the VAV damper is < 95 percent open, the controller sends 0 requests
- If the VAV damper is > 95 percent open, it sends 1 request until the damper position is < 85 percent open
- If the VAV damper is > 95 percent open for longer than 1 minute **and** the measured airflow is < 70 percent of its current airflow setpoint, the controller sends 2 requests
- If the VAV damper is > 95 percent open for longer than 1 minute **and** the measured airflow is < 50 percent of its setpoint, it sends 3 requests

An Importance-Multiplier can be applied to ensure that requests from more important zones are weighted higher and less likely to be ignored.

Then, the system-level controller sums these “requests” and adjusts the duct static pressure setpoint using the Trim-and-Respond logic. For the following example, the “trim” amount is 0.04 in. H_2O (SP_{trim}), the “respond” amount is 0.06 in. H_2O (SP_{res}), and the setpoint is prevented from rising any higher than 2.0 in. H_2O (SP_{max}) or any lower than 0.70 in. H_2O (SP_{min}).

In the example depicted in Figure 2, the VAV system starts at 8:00 AM, and the supply fan is initially controlled to maintain a duct static pressure setpoint (SP_0) of 1.0 in. H_2O. Following a 10-minute Startup Time Delay (T_d), at 8:10 AM the duct state pressure optimization (reset) sequence begins and the system controller sums the requests (R) from the VAV controllers every 2 minutes (Run Frequency, T):

- At 8:12 AM, there is a total of one request (R = 1) from the VAV controllers. Since R is not higher than the Ignored Requests Threshold (I = 2), the duct static pressure setpoint is reduced by 0.04 in. H_2O (SP_{trim}), and the new setpoint of 0.96 in. H_2O is communicated to the air-handling unit for controlling the capacity of the central supply fan.
- At 8:14 AM, there are a total of two requests (R = 2). Since R ≤ I, the setpoint is again reduced by 0.04 in. H_2O to 0.92 in. H_2O.
- At 8:16 AM, there are three requests (R = 3). Since R > I, the setpoint is now increased by 0.06 in. H_2O [(R – I) × SP_{res} = (3 – 2) × 0.06], and the new setpoint is 0.98 in. H_2O.
- At 8:18 AM, there are four requests (R = 4). Since R > I, the setpoint is increased by 0.12 in. H_2O [(4 – 2) × 0.06] to 1.10 in. H_2O.
- At 8:20 AM, there are a total of six requests (R = 6). Since R > I, the algorithm wants to increase the setpoint by 0.24 in. H_2O [(6 – 2) × 0.06], but instead the amount of reset is limited such that the setpoint is only increased by 0.15 in. H_2O ($SP_{res\text{-}max}$) to 1.25 in. H_2O.
- At 8:22 AM, there are three requests (R = 3). Since R > I, the setpoint is increased by 0.06 in. H_2O [(3 – 2) × 0.06] to 1.31 in. H_2O.
- At 8:24 AM, there are zero requests (R = 0). Since R ≤ I, the setpoint is reduced by 0.04 in. H_2O (SP_{trim}) to 1.27 in. H_2O.

In this application, the Trim-and-Respond control logic seeks to gradually lower the duct static pressure setpoint—thus reducing fan energy—while responding more rapidly to any increase in demand from the VAV boxes—thus ensuring occupant comfort.

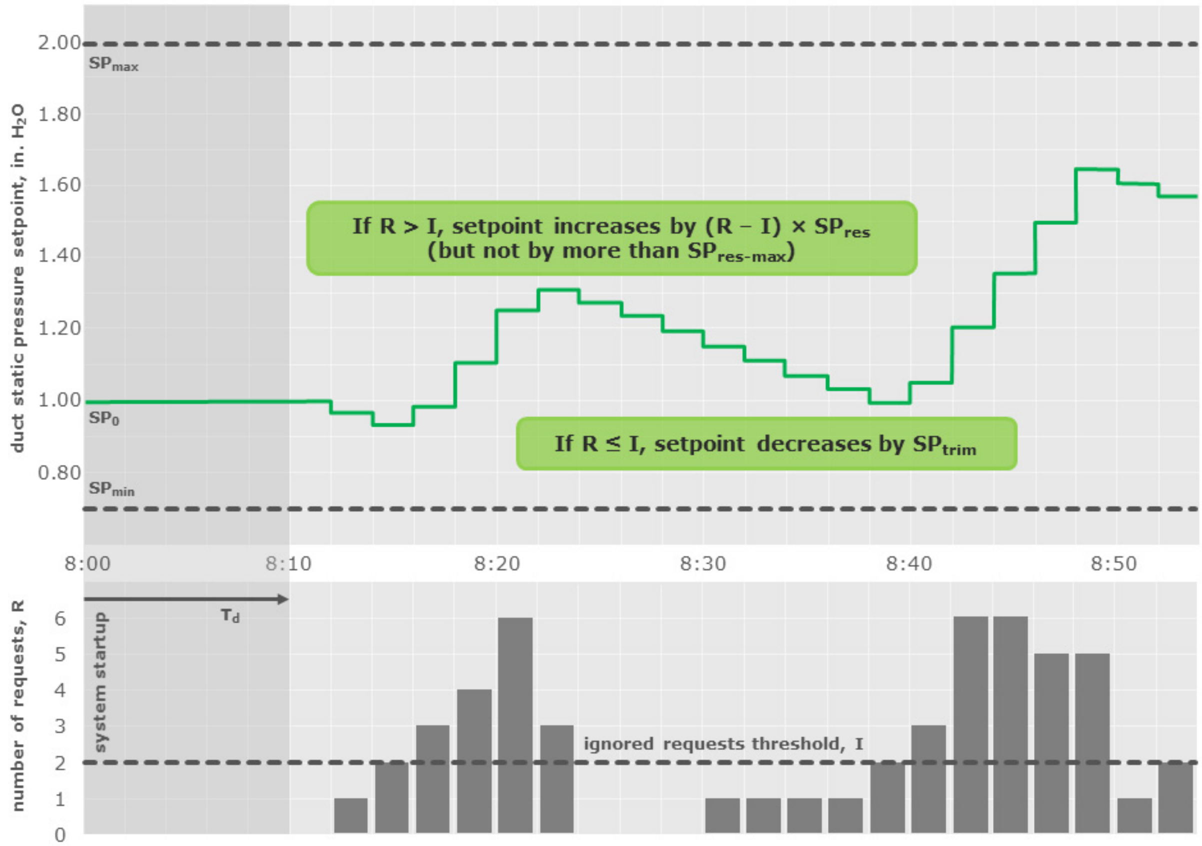
Note: “Trimming” does not always mean that the value of a setpoint is decreased; rather it adjusts the setpoint to a more energy-efficient value. For example, when used for resetting the cooling supply-air temperature (SAT) setpoint in a multiple-zone VAV system, trimming involves raising the SAT setpoint (warmer) to reduce cooling energy use, while responding involves lowering the SAT setpoint (cooler).

Guideline 36 also suggests a method for keeping a running total of requests generated by each zone over time, then notifying the building operator if a zone is excessively impacting the reset logic. In the example above, a “rogue” zone could cause the static pressure setpoint to increase to, and remain at, its maximum limit (SP_{max}), thus preventing any fan energy savings.

In general, Trim-and-Respond provides the following advantages:

- Tends to be more stable and easier to tune than a proportional-integral-derivative (PID) control loop
- Offers the ability to trim slowly and respond quickly
- Allows weighting the importance of individual zones
- Easily identifies “rogue” zones

Figure 2. Example of Trim-and-Respond for duct static pressure reset



Automatic Fault Detection

Automatic fault detection and diagnostics (AFDD) is a method for detecting operational problems in an HVAC system. The initial version of Guideline 36 includes rules for fault detection in VAV air-handling units only. This logic is expected to reside in the equipment-level controller and generate alarms when potential issues arise.

Table 1 describes one of the fault conditions suggested by the guideline. If the current supply duct static pressure (DSP) is less than the duct static pressure setpoint—minus an error threshold to account for sensory inaccuracy—**and** the current supply fan speed is 99 percent or higher, this suggests a potential problem (fault) with the system. In this case, even with the supply fan operating at full speed, it is not capable of reaching the desired duct static pressure setpoint.

This could indicate a problem with the fan's variable-frequency drive (VFD), a mechanical problem with fan itself, or that the fan has been undersized. Alternatively, it could indicate that the air-handling unit's current supply-air temperature (SAT) setpoint is too warm for the current cooling demand of the zones it serves.

Table 1. Example fault condition for a multiple-zone VAV air-handling unit

Equations	Duct static pressure < duct static pressure setpoint – DSP error threshold **AND** Fan VFD speed ≥ 99 percent – VFD speed error threshold
Description	Duct static pressure too low with fan at full speed
Possible diagnosis	• Problem with VFD • Mechanical problem with fan • Fan undersized • SAT setpoint too high (too much zone demand)

Hierarchical Alarm Suppression

In addition to defining alarms for various components of the HVAC system, Guideline 36 also includes a unique solution to suppress some alarms based on feedback from other equipment. The intent of hierarchical alarm suppression is to minimize nuisance alarms from a downstream ("load") component that result from the failure of an upstream ("source") component, thus reducing distractions for the building operator and hopefully making it easier to diagnose the root cause of the problem. It's based on the principle that if a fault occurs both at a "source" and a "load" component, the "load" fault is probably caused by the "source" fault, so the alarm for the "load" fault is suppressed while the alarm for the "source" fault is presented to the operator.

For the example in Figure 3, if the supply fan in a centralized VAV air-handling unit ("source") fails, the VAV terminal units ("loads") served by that air-handling unit will begin to generate alarms for low airflow, loss of space temperature control, high CO_2 concentration, and so on. The alarms from the VAV controllers ("low airflow" or "space too warm") will be suppressed so that the operator's attention can be focused on the alarm from the AHU controller ("loss of airflow").

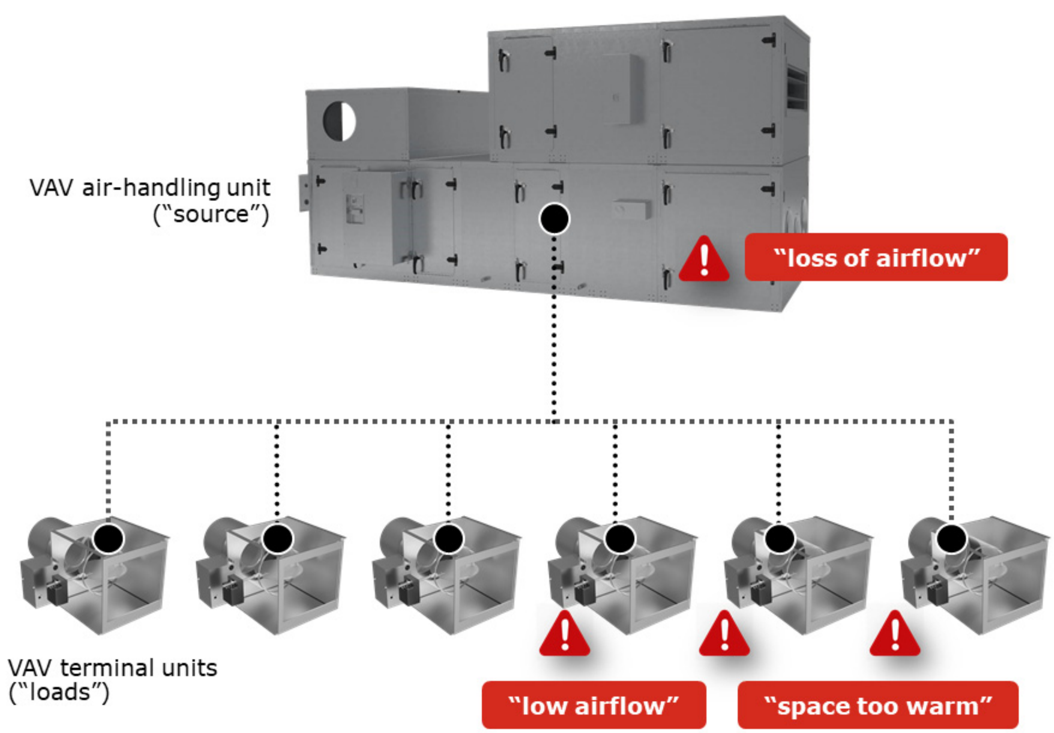
Commissioning Overrides

To aid in the process of commissioning or troubleshooting, Guideline 36 also states that points should be able to be overridden through the building automation system (BAS). For each equipment configuration, the guideline lists "software switches" that will override equipment operation.

As an example, for a VAV terminal unit with a reheat coil, the following overrides are suggested:

- Force zone airflow setpoint to zero
- Force zone airflow setpoint to maximum cooling airflow
- Force zone airflow setpoint to minimum airflow
- Force zone airflow setpoint to maximum heating airflow
- Force VAV damper fully closed or fully open
- Force heating valve closed (off)

Figure 3. Example of hierarchical alarm suppression



Summary

As mentioned, Guideline 36 is under continuous maintenance, so changes and additions will be made periodically via addenda. Sign up for the Guideline Project Committee (GPC) 36 "List Server" (www.ashrae.org/listserves) to receive e-mail notification when addenda are published.

In addition, the committee will be adding sequences for other types of HVAC systems in the future. Chilled-water plants and hot-water plants are likely the next to be added.

By John Murphy, Trane. To subscribe or view previous issues of the Engineers Newsletter visit trane.com. Send comments to ENL@trane.com.

References

[1] ASHRAE Guideline 36-2018, *High-Performance Sequences of Operation for HVAC Systems*. Atlanta: ASHRAE. 2018.

[2] ASHRAE. Proposed addendum X (chilled-water plants) to Guideline 36-2018, First Public Review Draft. November 2020.

[3] ASHRAE. Proposed addendum Y (hot-water plants) to Guideline 36-2018, First Public Review Draft. November 2020.

[4] ASHRAE. Addendum B to Guideline 36-2018. Atlanta: ASHRAE. August 2019.

Trane Controls and ASHRAE® Guideline 36

Trane controls have been developed to deliver ASHRAE Guideline 36 sequences and performance. Our pre-engineered Trim-and-Respond application includes the rules defined by Guideline 36, while allowing flexibility to modify or expand to meet any building or system need.

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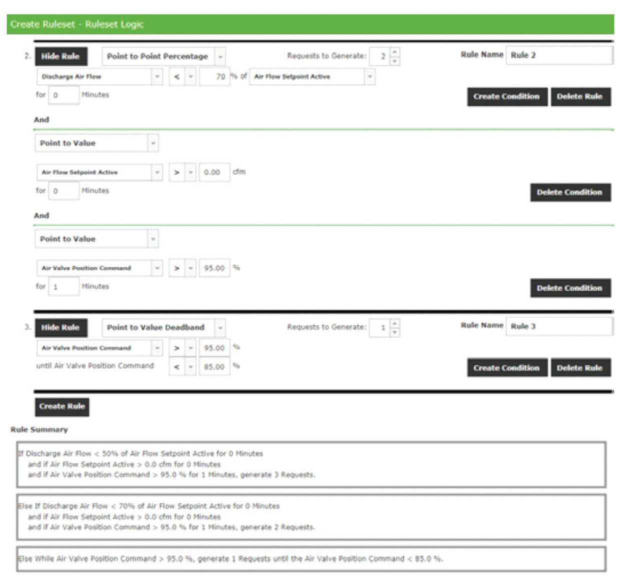

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MAY

ASHRAE Standard 62.1-2019. The 2019 version of ASHRAE Standard 62.1, *Ventilation for Acceptable Indoor Air Quality*, was published in late 2019. This ENL will overview the standard, discuss several key changes implemented in the 2019 version, explain the three allowed procedures for determining ventilation airflows (Ventilation Rate Procedure, IAQ Procedure, and Natural Ventilation Procedure), and walk through calculation steps using an example building.

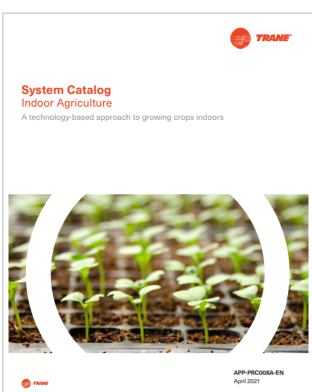
SEPTEMBER

Air Cleaning Devices for IEQ. A building's indoor environmental quality is key to maintaining safer, healthier, and more comfortable spaces for its occupants as we move forward in a post-pandemic future. This ENL will cover what Indoor Environmental Quality is, how to create resilient systems, and discuss air cleaning device testing in order to construct healthy and efficient spaces.

NOVEMBER

ASHRAE Standard 15. ASHRAE Standard 15, *Safety Standard for Refrigeration Systems*, focuses on the safe design, construction, installation, and operating of refrigerating systems. And the standard now includes requirements for systems with Class A2L (lower flammability) refrigerants. This ENL will overview the 2019 version of Standard 15 and explain how its requirements apply to various types of refrigerating systems, including packaged units, VRF systems, and water chillers.

Contact your local Trane office for more information or visit www.Trane.com/ENL.



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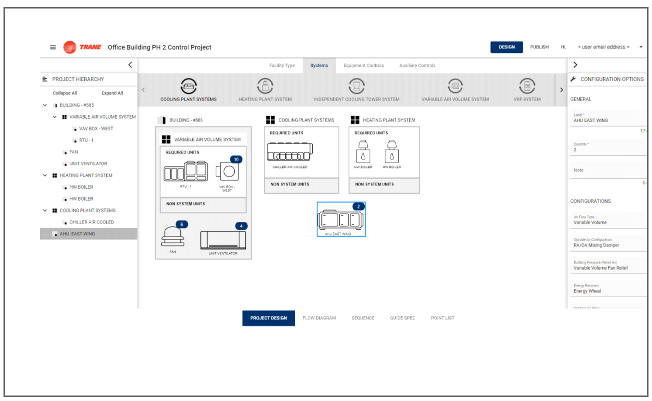

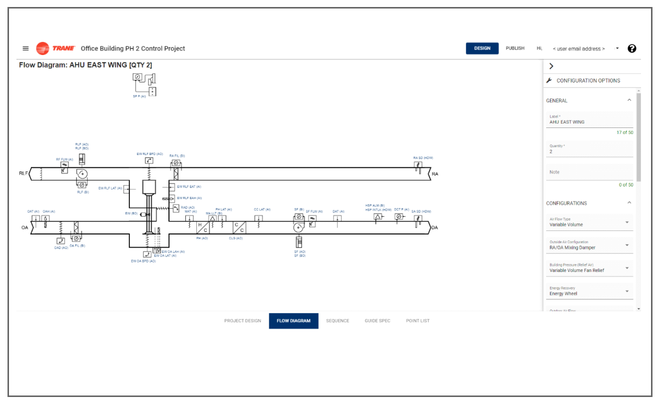

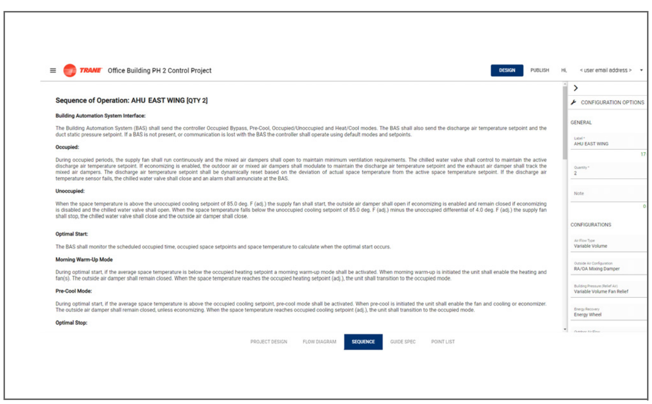

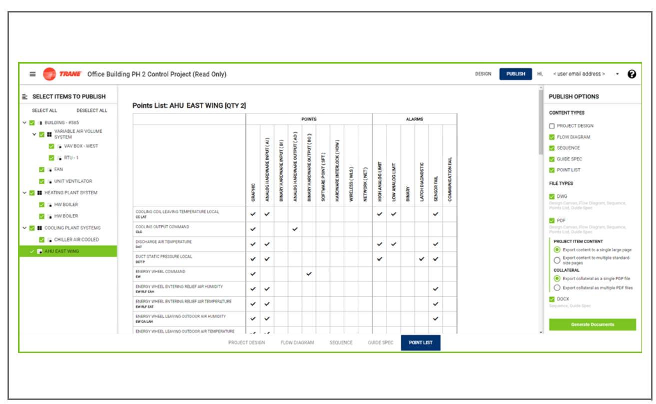

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