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EBTRON Insight

Understanding Hysteresis and Its Impact on HVAC Control Repeatability

Hysteresis in control dampers poses a significant challenge to achieving precise and repeatable airflow in HVAC systems. This phenomenon is a result of multiple mechanical and electrical imprecisions that, when combined, can result in significant position error. Therefore, relying solely on damper position or actuator feedback for airflow control is inadequate. These challenges can be mitigated by accurate, repeatable, and long-term stable airflow measurement devices regulating desired flow rates.

What is Hysteresis?
Hysteresis refers to a control damper's tendency to arrive at a different position when opening versus when closing in response to the same desired control position. For example, when the damper is closed, and the building enters occupancy mode and commands the outdoor air damper to a minimum position (e.g., 15%), the actual damper position is different than if the system was in economizer mode, and the dampers were at 100% and commanded to return to the minimum position. This results in the damper arriving at two different positions when intended to be in the same position (refer to Figure 1 below). Contributors to hysteresis in HVAC systems include:

Actuator mechanics: Internal Gear trains, springs, motor protections, torque, resolution and deadband, and other items may impact damper movement relative to the control signal.

Linkage interactions: Actuator clamp slippage or fit, alignment or number of connecting points in the linkage or crank arm, and forward or reverse slack in the linkage or crankarm can cause and amplify hysteresis.

Damper characteristics: Damper construction: internal pivots and linkages or gears, damper materials and thickness; size of dampers: number and lengths of blades, number of damper sections connected; Damper classification: pressure and leakage class, type of blade and jamb seals, and velocity of application can cause and amplify hysteresis.

Age degradation: loosening of fasteners or nuts in the linkage or actuator clamp, corrosion of the linkage or damper assembly, hardening or deterioration of seals, and other wear can cause and amplify hysteresis.

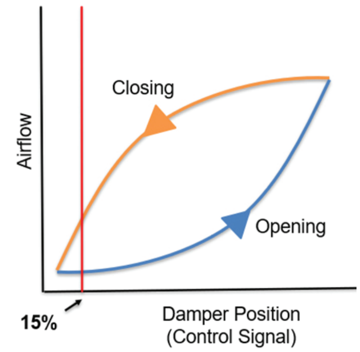

Figure 1

Example: Despite having the same control signal to the actuator, the damper ends up at different positions depending on direction of travel. This difference is caused by hysteresis, highlighting why relying solely on damper position is problematic. This phenomenon underscores the importance of precise airflow measurement solutions for consistent and reliable control.

Other documented impacts of Hysteresis in HVAC Systems

1. Challenges in Damper Modulation
According to the ASHRAE Fundamentals of HVAC Control Systems[1] (Section 3.4), achieving precise damper modulation is inherently difficult due to friction in low-leak seals, linkage play, and aging components. This results in higher torque requirements and reduced responsiveness to small signal changes.

2. Impact on Minimum OA Control
ASHRAE transaction papers[2,3] demonstrate both theoretically and experimentally that fixed damper positions fail to maintain consistent minimum outside air intake rates under variable flow conditions. They indicated that hysteresis exacerbates the inaccuracies of minimum OA control by fixed damper position, damper position reset strategies, and characterization of OA dampers, and that fixed damper position resulted in wasted fan energy.

3. Long-Term System Degradation
According to the ASHRAE Fundamentals of HVAC Control Systems[1] (Section 7.4), friction, binding dampers, aging linkages, corrosion, and other factors will prevent the damper from responding to small changes in controller output pressure.

Repeatability[2]: A Critical Metric
Hysteresis impacts control repeatability, which is essential for maintaining system stability and performance.

Nonlinear Relationships[3]: Small changes in damper position can cause disproportionately large airflow variations due to hysteresis.

Dynamic Errors: Calibration drift in sensors and actuators introduces further inaccuracies, which can only be mitigated through real-time airflow monitoring.

Airflow Measurement: The Key to Overcoming Hysteresis
Ideal control strategies are those based upon direct measurement of OA rates[4]. Since hysteresis cannot be eliminated, accurate airflow measurement compensates for these limitations. By measuring actual ventilation rates, systems can dynamically adjust to maintain compliance with indoor air quality (IAQ) standards.

EBTRON's thermal dispersion airflow measurement devices excel in this role by offering:

- **High accuracy:** Across all airflow rates, especially low turndown applications.
- **Long-term stability:** Minimizing recalibration needs through advanced technology.
- **Factory calibration:** Traceable to NIST standards, ensuring dependable performance.

These devices mitigate the errors caused by hysteresis and ensure that HVAC systems deliver consistent, reliable airflow control.

Conclusion
Hysteresis fundamentally limits the repeatability of HVAC systems that rely on damper position alone. However, integrating accurate airflow measurement technologies, such as EBTRON's solutions, bridges this gap. By doing so, systems achieve precise control, energy efficiency, and compliance with ASHRAE standards, ensuring both occupant comfort and operational reliability.

References

1. ASHRAE (2008). Fundamentals of HVAC Control Systems, Section 3.4, Section 7.4.

2. Drees, K.H., et al. (1992). Experimental Analysis of Measurement and Control Techniques of Outside Air Intake Rates in VAV Systems.

3. Janu, G., et al. (1995). Error Analysis of Measurement and Control Techniques of Outside Air Intake Rates in VAV Systems.

4. ASHRAE Research Project RP-980.