

Designing Beyond the Setpoint

How Performance Envelopes and Digital Platforms enable adaptive, efficient hydronic systems

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Consulting Engineers designing HVAC systems face increasing pressure to deliver lower energy consumption, reduced carbon impact, and long-term reliability. At the same time, system complexity has increased with the widespread adoption of digital controls, variable speed equipment, and integrated building systems.

Yet many hydronic plants are still designed and operated around a static operating setpoint.

This approach reflects an earlier era of constant speed equipment and stable loads. In modern buildings, conditions are continuously changing. Loads fluctuate, equipment performance shifts over time, and independent control loops interact in ways that are not always predictable.

The result is often instability: oscillation, setpoint hunting, excess energy use, and increased mechanical wear. These effects are typically mitigated through oversizing or added redundancy, approaches that increase both first cost and system complexity without addressing the root cause.

Performance Mapping and Operating Boundaries

Every mechanical asset whether a pump, heat exchanger, cooling tower, or chiller operates across a range of conditions defined by variables such as flow, head, efficiency, and power consumption. When the performance and relationships between these variables are digitally mapped, they form a **Performance Map**: a data driven representation of equipment behavior across its full operating range.

A **Performance Envelope** builds on this foundation by defining the validated operating region where equipment performs efficiently, reliably, and safely.

Rather than relying on a single design point, the Performance Envelope establishes a practical operating space that reflects real world conditions. It identifies where equipment should operate, not just where it can operate. This represents a fundamental shift from reactive control to guided operation within validated limits.

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Improving System Level Coordination

In conventional hydronic systems, multiple PID loops independently maintain pressure, temperature, and flow setpoints. Each loop reacts only after a deviation occurs and typically without awareness of system wide effects. As a result, one control action may inadvertently push another component outside its optimal range. The challenge is not the effectiveness of individual control loops, but the lack of coordination between them.

Performance Envelopes address this by introducing system level awareness through validated operating boundaries. As a result, control strategies can now guide equipment toward optimal regions while avoiding conditions that lead to inefficiency or instability. This reduces oscillation, improves interaction among plant components, and enables smoother response under varying load conditions.

Example of Pump Envelope



Design and Operational Benefits

Applying Performance Envelopes across design and operation provides several advantages:

- 1 Optimized System Design:** Systems can be designed based on actual operating ranges rather than conservative assumptions, reducing oversizing and improving capital efficiency.
- 2 Consistent Energy Performance:** Equipment operates within validated efficiency zones across a wide range of part load conditions, improving overall system performance.
- 3 Improved Reliability and Longevity:** By minimizing operation outside acceptable limits, mechanical stress and wear are reduced, extending equipment life.
- 4 Actionable Performance Insight:** Operating conditions can be continuously compared against defined envelopes, making deviations visible and enabling proactive intervention.
- 5 Improved Sustainability:** By minimizing operation outside acceptable limits, mechanical stress and wear are reduced, extending equipment life.

Scaling the Concept through a Digital Platform

While Performance Envelopes provide value at the equipment level, modern HVAC systems require coordination across entire plants and building portfolios. Engineers can now extend this concept by integrating performance maps and envelopes across multiple assets into a unified digital framework.

By combining real time data, predictive analytics, and edge-based optimization, such a digital platform enables coordinated optimization across pumps, heat exchangers, and other plant equipment. This would enable Engineers to implement adaptive control strategies that respond to changing loads while maintaining operation within validated boundaries. Such a platform would also enable continuous performance management with early detection of deviations and scalable deployment across systems and facilities.

Application in Practice

During design, Performance Envelopes can be used to evaluate multiple system configurations based on flow, head, redundancy, ambient temperature and load profiles. This enables identification of solutions that minimize installed power, lifecycle cost, and carbon impact without relying on rule of thumb methods.

In operation, system performance is continuously assessed against defined envelopes. When deviations occur, the system can respond through staging adjustments, control changes, or alerts, helping maintain alignment with design intent over time.

Static setpoints and reactive control can't keep pace with today's dynamic hydronic systems. Performance Envelopes define validated operating boundaries, and a digital platform coordinates operation across assets. The result is efficient, reliable, and sustainable performance, without added complexity.

About the Author:

Pratik Sharma is a Leadership Board Executive at Armstrong Fluid Technology. He is responsible for shaping the digital strategy, overseeing platform innovation, and cultivating partnerships to enhance ecosystem engagement and customer experience.



Learn more about how Performance Envelope concepts are being applied in hydronic system design and operation through real world engineering practice.