White Paper Series

Pneumatic to Digital: Open System Conversions

The Business Case for Conversion

Air Today, Digital Tomorrow

Venerable pneumatic systems have been around for decades. However, increased energy and labor costs provide plenty of incentive to consider upgrading to a more efficient system. A (partial or full) conversion from a pneumatic system to a digital BAS (Building Automation System) will give you these long-term benefits:

- More information (actionable data) for intelligent building management.
- Lower energy costs through greater operating efficiency.
- Lower maintenance costs through less need for calibration and service of equipment.
- Higher income potential through better environment control, which results in improved tenant retention and increased lease rates.

These points are explored further in the sections that follow.

Actionable Data

To manage something effectively, you need data. Intelligent decisions are dependent on getting adequate information about the real-world situations inside a building. Are all your system devices and schedules functioning properly at all times? How do you really know?

Pneumatic systems, unfortunately, provide little or no data to a building owner. That dearth of data means underperforming subsystems continue wasting energy, impending breakdowns aren't noticed until it is too late, and maintenance is reduced to chasing fires instead of proactive prevention.

Digital BAS systems, on the other hand, are all about data. They automatically adjust parameters and correct conditions that would require tedious manual labor on pneumatic systems. Digital systems also provide real-time and trended data for reports and graphs that allow for easy analysis and intelligent decision-making.

Energy Costs

Energy savings flow from data. Digital's precise measurement and control of setpoints as well as numerous automated energy savings techniques squeeze maximum efficiency out of energy dollars. Digital features that are difficult or impossible for pneumatics to provide include the following:

- Flexible schedules—programmed schedules predict occupancy. Crude electro-mechanical timers might provide pneumatics systems with occupied/unoccupied schedules, but digital schedules are quickly customizable and easily take into account such things as holidays and Daylight Saving Time.
- Motion detection—motion sensors verify whether or not occupants really are in office spaces during the predicted scheduled times. If no motion is detected within a set time, action is taken, such as changing the setpoints to reduce the energy usage. For some applications, Adaptive Occupancy Scheduling can even "learn" a schedule automatically by sensing motion.
- DCV (Demand Control Ventilation)—motion sensors determine whether-or-not at least one person is in a particular space, but the ventilation needs of one person are very different from the needs of one hundred people. CO_2 sensors measure the gas that people breathe out. By measuring the levels of CO_2, DCV sequences in a BAS estimate the actual occupancy and required (healthy) levels of ventilation and then adjust the ventilation accordingly. Since ventilation levels in buildings are designed for "worst-case" occupancy, reducing ventilation levels down to actual need (often much lower than the designed levels) can greatly reduce the need for conditioning fresh air and thereby reduce energy costs.
- Optimum start—the time required for a building to warm-up or cool-down in the spring and fall is less than the equivalent time in winter and summer. Tracking the actual time as the outside conditions change and adjusting the pre-occupancy system start time accordingly (starting no earlier or later than necessary) optimizes occupant comfort while saving energy.

- Monitoring and optimization of system setpoints—as conditions change, the optimum setpoints for supply air or water temperature, duct pressure, and other system parameters also change. Digital systems can easily calculate optimal values for multiple setpoints to minimize energy use while still maintaining occupant comfort.

Maintenance Costs

Pneumatic sensors and thermostats need calibration periodically to maintain reasonable accuracy (but typically infrequently performed in practice). Air compressors and air dryers need careful maintenance to avoid contaminating the lines with oil, and replacement costs for those items are high.

On the other hand, after installation, digital systems usually provide set-and-forget, self-maintaining, accurate control for long periods of time.

Income Potential

Pneumatic systems rarely complain. If something goes wrong, such as a damper getting stuck, a pneumatic system stays silent. The feedback loop is the tenant complaining that a room is too hot. Unhappy tenants tend to make building owners unhappy as well. Furthermore, in the time it takes tenants and owners to become alert to issues, operational efficiencies are being lost. Thus, less comfort may also be a symptom of increased energy costs.

Digital systems, on the other hand, continuously monitor what is happening. If a damper gets stuck, the system will notice that conditions aren't responding as they should, and an alarm can be sent to the owner. A repair could be in the works before the tenant even notices something is wrong. The result will be less griping from tenants as well as decreased operating costs.

The improved indoor environmental quality will make tenants happier with the building. Besides more comfort, knowledge of increased energy efficiency may also compel sustainability-aware tenants to stay longer and pay more premium prices for the privilege of being in a "greener" building.

The Mechanics of Conversion

Implementation Options

New commercial building construction almost always has digital controls. However, it's so much easier to install conduit, wires, and valves when a building is only half-finished than when walls and ceilings and HVAC equipment have already been in place for decades. Under these real-world conditions, digital conversions can range from moderately to very expensive, depending on how much "digitization" is performed:

- The most costly option initially is to rip out all the old pneumatic equipment and install new digital equivalents. This process can be time-consuming, and parts of the HVAC system may need to be shut down for periods of the retrofit, creating inconvenience for the building's occupants. This does, however, result in a highly energy-efficient, pure digital system.

- A less disruptive and possibly more cost-effective option is to replace only the parts of the particular system that make the most sense and to leave the parts that can still perform adequately in place. (New "brains" to control the old "guts.") This results in a pneumatic and digital hybrid, which can still be quite efficient (in a way analogous to the fuel efficiency of hybrid cars that combine the best of electric and gasoline technologies).

Applying new digital controls to old air handlers and roof top units is usually quite feasible and cost-effective (although it may require adding electrical conduit and replacing valves). But what about ripping out old pneumatic actuators and thermostats from dozens or even hundreds of Variable Air Volume (VAV) boxes, and then running conduit as well as 24 VAC and networking wiring to all of the digital replacements? Labor costs rise as the number of VAV boxes goes up since retrofitting VAV boxes is more expensive than installing new ones in new construction.

Going all digital is expensive to implement although it provides great savings in the long run. Going digital with just the "low-hanging fruit" of central operations doesn't capitalize on all of digital's capabilities for precision monitoring and controlling of an entire HVAC system, but it is often the most feasible option. The "fruitful" middle ground may involve leaving all the pneumatic damper actuators (which are usually very durable and reliable) in place. This option can give the building owner much of the same control as a full BAS but softens the financial blow of converting to a BAS. Areas of labor and material savings include:

- Minimal conduit and wiring needed to take control of valves and dampers.
- Much less 24 VAC power (fewer/smaller transformers) needed for a hybrid system than a pure digital system.
- No need for expensive purchase and installation of all new valves and damper motors.

Communication Challenges

In a hybrid system, how do analog air pressures and binary electrical pulses talk with each other? To convert apples to oranges, transducers serve as communication intermediaries between these completely different entities.

For a pneumatic system to talk to a digital system, a P-E (pressure to voltage) or P-I (pressure to current) transducer is used. Some, for example, can take a typical 3–15 psi signal from pneumatic devices (such as thermostats, transmitters, and receiver-controllers) and convert it to an analog electronic signal (e.g., 2–10 VDC or 4–20 mA). Thus, a standard pressure signal can translate into a standard analog electronic signal that serves as an input to a digital BAS, allowing the BAS to monitor the pneumatic operation.

But communication isn't just a one way street since the BAS needs to control the pneumatic operation. Some transducers, for example, can convert an analog voltage (E) or current (I) signal from a BAS into a linear pneumatic pressure

(P) output signal for accurate positioning of damper and valve actuators used in HVAC systems. The analog signal might be 2–10 VDC, and the transducer provides a linear 3–15 psi output signal to pneumatic devices.

When an electrical device just needs to be simply switched on or off based on a particular pressure, a proportional signal may be unnecessary and a simpler pneumatic-electric relay might do the job. Pneumatic-electric relays, for example, are ideal for applications such as starting fan coil unit fans, exhaust fans, and direct control of electric duct heaters.

Another solution to help "hybridize" and integrate pneumatic and digital control systems is to use wireless thermostats. Wireless pneumatic thermostats can replace existing pneumatic thermostats with wireless-capable devices that greatly expands the monitor and control capabilities of a pneumatic system. And since thousands of feet of pneumatic tubing do not have to be torn out and replaced with electrical wiring, the time and labor cost required for installation of wireless two-way communicating thermostats is a fraction of retrofitting with traditional electrically wired thermostats.

Maintaining "Openness"

Nothing lasts forever. When the time does come for a building's antiquated pneumatic system to be (fully or partially) retired and replaced, various controls manufacturers have the proprietary or open-protocol lines of digital BAS products for maximizing HVAC control.

As a communications protocol, air was never proprietary, and pneumatics was HVAC's original "open system," in which one manufacturer's device could be replaced by that of another manufacturer's. Such future-proofed flexibility can persist in a digital path by selecting a vendor that provides an open-protocol system (BACnet, in particular). Then if the original vendor provides unsatisfactory service or goes out of business, another vendor can be chosen to take its place for servicing that existing BACnet BAS system. (If a proprietary digital system is installed, on the other hand, and the original vendor disappears, future servicing is much more challenging and expensive, especially if it involves replacing much of the system yet again.)

Case Studies

Want to learn about how others have handled the pneumatic-to-digital conversion? Check out these case studies for different needs and solutions.

Success Stories: Royal Saudi Naval Force Headquarters, **http://www.bacnetinternational.net/success/stories.php?sid=43**.

Making pneumatic thermostats energy efficient, **http://powerelectronics.com/alternative-energy/making-pneumatic-thermostats-energy-efficient**.

About KMC Controls

For more than 40 years, KMC designed and manufactured control system hardware and software for flexible building automation. KMC remains the only privately held U.S. manufacturer to offer a complete line of components and digital automation systems. Learn more at www.kmccontrols.com or follow KMC on your favorite social media: