Compressed air is second only to electricity in importance as an industrial energy source, and there is hardly a factory that functions without it. For many industrial applications pneumatics is the preferred drive technology, thanks to advantages such as overload resistance, long life, economy, ease of assembly, reliability, and safety.

Because pneumatic equipment generally operates trouble-free, users tend to take it for granted and typically do not look for problems or inefficiencies. This may be why air leaks are often not taken seriously. After all, wasting compressed air is usually harmless to the environment.

The uncomfortable truth is compressed air is the most expensive energy available in production facilities. Manufacturers and machine builders are often surprised to learn that compressed air can cost up to $0.30/1,000 scf. In fact, studies show 79% of the costs for pneumatic systems are for electrical energy, with only 6% for maintenance and 15% for capital investment. Consequently, air leaks are often underestimated as a waste of energy and money. Leaks also degrade machine performance because actuators produce less force, run slower, and are less responsive.

Given today’s competitive landscape, smart companies are constantly looking for new methods to improve equipment efficiency as well as eliminate waste. Therefore, it makes sense to pay attention to the proper use of compressed air. One technique gaining ground is to monitor air consumption, as it is a good indicator of the health of pneumatic systems.

SYSTEM MONITORING

A common way to prevent waste is to regularly search for compressed-air leaks. Formal leak-detection programs usually involve complete, manual inspections of all air lines several times per year. Regular inspections find new leaks and also confirm that tagged leaks from past inspections have been repaired. Technicians typically diagnose pneumatic leaks by listening for hissing air, periodically inspecting tubes, and tightening fittings.

One disadvantage of leak-detection programs is that depending on inspection frequency, leaks can go undetected for a long time. Also, inspections are usually time consuming and may be problematic in noisy industrial environments. Inspectors often miss small leaks, which prevents repairs in the early stages before leakage becomes a major problem.
Many experts now recommend installing a network of flow sensors to continuously track compressed-air use. It is more efficient and cost effective than manual inspections and detects costly increases in air consumption caused by malfunctions and leaks.

The good news: The latest flow sensors are specifically designed to monitor pneumatic circuits for inefficiencies and leakage — and they are available at attractive prices.

MODERN SENSORS

Flow sensors, properly sized and installed at important locations within an air-distribution system, highlight deviations, send messages, and activate alarms when flow exceeds tolerance thresholds. Technicians can easily pinpoint leaks, failures, and other problems, and take immediate action to fix them. In addition, flow sensors in production facilities can track air consumption of pneumatic systems — even down to specific components — and help calculate true operating costs.

Advances in sensor technology have only recently made all this possible. Until now, most flow sensors only provided real-time flow data over a relatively narrow operating range. There were also a lot of restrictions on where they could be installed. Flow measurement is, unlike pressure measurement, rather complex. Normally, sensors are quite sensitive to upstream flow conditions, so installation plays a critical role in measurement accuracy. Units often had to be located in laminar-flow regions — for instance, away from tees and elbows — and this made widespread use on industrial equipment impractical.

In contrast, newer sensors contain features such as special inlet tubes or filter cartridges that stabilize flow. Thus, users do not face installation restrictions or require specific knowledge about the incoming flow. And a bypass-measurement system gives accurate readings over a wider flow range than was previously possible. The sensors quickly install most anywhere and even temporary setups are now practical.

Sensors cut operating costs

Probably the most important factor in deciding to invest in a compressed-air flow-monitoring system is whether or not it makes financial sense. So a cost-benefit analysis helps justify the purchase price and installation costs of flow sensors. The following example, typical of industrial pneumatic systems, demonstrates the cost of even small leaks.

A system operating at 87-psi (6-bar) pressure has several leaks. Taken together they measure 0.157 in. (4 mm) in diameter and cause an air loss of 21.9 scfm (621 lpm). Operating this system around the clock for 50 weeks/yr — based on compressed air at $0.30/1,000 scf — means the leaks cost over $3,312 annually. Assuming the application requires only one flow sensor, and technicians immediately detect and repair the leaks, the sensor pays for itself in just a few weeks.

SYSTEM SETUP

Flow sensors can be used throughout an entire air system, though the number of sensors and exact location depend on customer requirements. Typically, some sensors should be integrated at important points of the air-distribution system. These monitor flow to groups of machines. Any increase in air consumption would at least indicate a problem exists and note the general area of concern.

Other users are more interested in monitoring flow to a single machine or individual subsystem. In these cases, sensors quickly narrow the source of any increase in air consumption.

Finally, a single actuator is sometimes crucial to the manufacturing process or operating an entire assembly line. In such cases, it is a good idea to mount a sensor that will closely moni-
tor just that component.

A general rule of thumb is to install at least one flow sensor in the main supply line on every machine with an average-size pneumatic system. It tracks air consumption over the long term and easily identifies sudden increases in demand.

The sensors deliver analog or digital signals to any standard PLC or controller. And while currently hardwired, wireless data transmission can be expected within the next few years.

Determining acceptable deviations in normal operations and where to set alarm thresholds strongly depends on the application and the user's experience. But customer-selected thresholds are not only for alarms. Trigger signals are often used to start and control manufacturing processes. And on retrofits, feedback signals can lead to higher machine speeds.

Sensor data can also be used in predictive-maintenance programs. Early recognition of an increase in air consumption is a useful indicator that repairs are needed or equipment must be replaced.

Some manufacturers have started to mount flow sensors at critical locations within their plants and display the data on a central terminal in the maintenance department. For example, one OEM displays air consumption in different plant sections and highlights areas of higher air consumption in red. Armed with this knowledge, the maintenance staff quickly responds when and where it is needed.

DETERMINING FLOW RANGE

Before adding flow sensors to a line, engineers must determine the required measuring range. Choosing sensors for normal pneumatic applications is usually straightforward. But selection gets more complicated in low-flow applications. In such cases, it helps to calculate the required flow-measurement range. One way to estimate the flow range is from the orifice-flow equation:

\[ C = 0.154 \frac{d^2}{P} \]

where \( d \) = orifice diameter, mm \(^2\); \( P \) = pressure differential across the orifice, bar; and \( C \) = flow, liter/sec.

The equation is a simplified approximation for supercritical conditions and is

State-of-the-art flow sensors

Some sensor and fluid-power manufacturers have introduced products suited for use in industrial air systems. Festo, for instance, has developed a series of flow sensors that measure from 50 ml/min to 5,000 lpm specifically tailored for monitoring pneumatic circuits.

The newest units include the SFE1 and MS6-SFE that measure flows to 200 and 5,000 lpm, respectively. Both supply real-time absolute flow data, as well as measure and record cumulative air consumption of components and systems. The sensors can also send an output signal to the controller or activate an alarm if consumption surpasses user-set thresholds.

Users can program parameters such as threshold values, window comparators, and hysteresis, and the sensors permit in-depth analysis of pneumatic-system operations. Data are transmitted via digital signals and 0 to 10 V or 4 to 20-mA analog outputs. Both products have optional 2× pnp or 2× npn interfaces.

The flow sensors have no mounting restrictions because sensing is based on the anemometry measuring principle. A bypass system generates laminar flow inside the flow sensor and eliminates the need for special accessories to condition flow and ensure accuracy.

The devices require normal filtration of incoming air (DIN air quality 5.4.3) because the sensor element is a small electronic chip. Most installations need 40-μm particle filters, though low-flow applications (<10 lpm) require 5-μm filters.

The compact, IP65-rated units are suited for most industrial environments. And because the sensors have no moving parts, they tend to have long working lives. Applications include in-plant leakage detection, product leak testing, and flow monitoring during workpiece feeding. The devices are especially helpful in environments where airflow varies widely over time and must be closely monitored.
valid for small differential pressures and orifices.
As an example, an automotive supplier needs compressed air to clean a crankshaft borehole and possibly use airflow to also gage hole size. The goal is to ensure the crankshaft borehole diameter $d = 4 \pm 0.3$ mm. Selecting pressure is the first step. A one-bar pressure differential is a good compromise between ensuring sufficient flow to clean the hole and, at the same time, minimizing air consumption.

This results in the following $C$ values based on the above equation:

- $C = 147.8$ lpm at $d = 4.0$ mm
- $C = 170.8$ lpm at $d = 4.3$ mm
- $C = 126.5$ lpm at $d = 3.7$ mm

Results show significant differences in airflow, so the manufacturer can use flow sensors to determine borehole diameter and monitor consumption. In this example, an appropriate sensor should have a measuring range up to about 200 lpm.

Continuously evaluating airflow and consumption provides useful diagnostic information and helps determine whether a pneumatic system or subsystem operates efficiently. Flow sensors can highlight problem areas and quickly detect malfunctions.

Users who want to reduce production costs and system downtime should consider using flow sensors as an efficient and inexpensive diagnostic tool. They are a much better alternative than a futile search for leaks or adding compressors.

MAKE CONTACT
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