White Paper

Flow sensors are key to analyze, optimize and maintain the air consumption of a pneumatic application

Flow sensors ensure product and process quality and avoid downtime by continuous monitoring of flow and air consumption

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Introduction

Wasting compressed air is usually harmless to the environment. This may be the reason why air leaks are often not taken seriously. The fact is compressed air is the most expensive energy available in a production facility. Consequently, air leaks are often-times an underestimated waste of energy and a waste of money. In today's highly competitive markets, manufacturing companies and machine builders may be surprised to learn that costs for compressed air can range up to $ 0.30 per 1000 scf. Wasted compressed air may be harmless to the environment, but it is not harmless to the bottom line. When cost is an issue, it is absolutely essential to recognize when compressed air is exhausting into the atmosphere.

The importance of compressed air

Second only to electricity, compressed air is the most important energy carrier in industry. There is hardly a factory that can function without compressed air. For many industrial applications, pneumatic drives are the preferred drive technology. Pneumatic drive technology is often selected due to its advantageous characteristics including overload resistance, extraordinary service life, economy, ease of assembly, reliability, cost factors and safety aspects.

All these advantages might suggest that the pneumatic applications don't require any monitoring technology for operation. But after looking at Figure 1, one may agree that this suggestion should be reconsidered in view of the fact that 79% of the costs for compressed air are for electrical energy costs; 6% are for maintenance; and 15 % are for capital investment. Therefore, it makes sense to pay special attention to the proper usage of compressed air. Assuming that the compressors, the distribution system, and the pneumatic drives are all properly sized, steps must be taken to avoid the unfavorable use of compressed air or air losses caused by leaks.

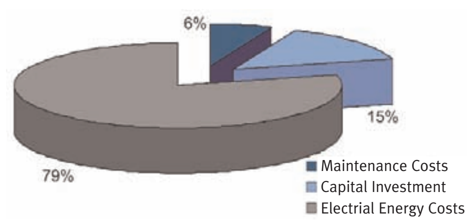


Figure 1:
Costs to operate compressed air systems (Source: ISI 2000)

Flow sensors ensure product and process quality and avoid downtime by continuous monitoring of flow and air consumption

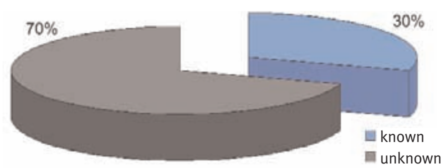
If not accidentally detected, a common way to prevent the waste of compressed air is to search for leaks on a regular basis, for example by a leak detection program. This usually involves a complete inspection of all air lines several times a year. Regular inspections ensure that new leaks are found and also confirm that tagged leaks from past inspections have been repaired. In this type of program, leaks are typically diagnosed in pneumatic systems by listening for the sound of hissing air and by periodically inspecting tubes and tightening fittings which might be susceptible to loosening. The disadvantage of a leak detection program is that these inspections are usually time consuming and may be difficult to perform in a noisy industrial environment.

Another big disadvantage of such leakage detection programs is that they often miss small leaks. This prevents maintenance or repairs from being done in the early stages of leakage before any problems occur. Also, depending on the interval of time between inspections, leaks can go undetected for a long time causing decreased efficiency of the machine and increased energy costs.

In order to continuously monitor the usage of compressed air and detect a costly increase of air consumption, the use of flow sensors is highly recommended as it is much more efficient and cost-effective.

Flow sensors constantly monitor the air consumption at important locations within the air distribution system or directly on the machine. They highlight deviations and can be used to create alarm messages when certain tolerance thresholds are exceeded. When a threshold of air consumption is violated, an alarm is activated. The problem area can be easily located and action can be taken to resolve the problem immediately. In addition, the use of flow sensors in the production facility can be used to identify the costs for air consumption and loss.

Do you know how much compressed air is consumed in your facility?



Have you achieved reductions in compressed air consumption?

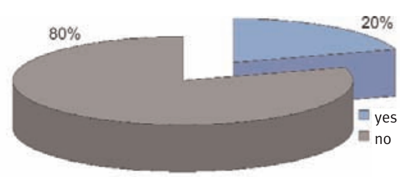


Figure 2:
Results of a customer survey by Festo

Do the cost savings provided by flow sensors justify the purchase and installation costs? The following example of how leakage affects the pneumatic system will help answer this question.

A system using a pressure rate of 87 psi [6 bar] with several leaks which have taken together 0.12 inch [3 mm] in diameter will cause an air loss of 23.5 scf per minute [666 l/min]. Operating this system over the course of 50 weeks a year (24 hours a day; 7days a week), based on costs for compressed air of $0.30 per 1,000 scf, these small leaks can cost over $3,500.00 per year. Assuming that by using one flow sensor for this application, the leaks are detected and repaired immediately, the purchase of the sensor pays for itself in just a few weeks.

Flow sensors make the air consumption transparent
Festo Corporation is now able to offer flow sensors in a measuring range from 50 ml/min up to 5000 l/min [1.76 to 176.6 scfm]. The existing flow sensor family SFE3/SFET with flow ranges up to 50 l/min [1.76 scfm] is now complete with two new flow sensors up to 200 l/min [7.1 scfm] (SFE1) and 5000 l/min (MS6-SFE), see Figure 3. Both sensors have embedded functionalities to identify the cumulative air consumption. Free programmability of the output signals (threshold values, window comparator, and hysteresis), including analog output signals - either current or voltage - allow the user in-depth analysis of their pneumatic system. The sensors use the anemometry measuring principle. A wide flow range is provided using a bypass system for measurement. The sensors, with their clear, bright displays, are easy to operate with no accessories required for the adjustment of the flow conditions. Since the sensors do not have any moving parts, the lifetime of the contact monitoring units are significantly increased.

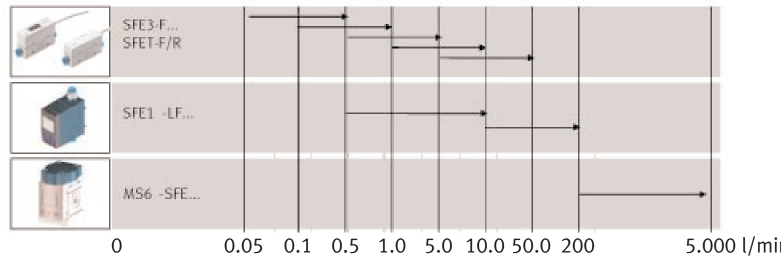


Figure 3: The measuring ranges of SFE3/SFET, SFE1 and MS6-SFE

The principle of the cumulative air consumption
The Festo flow sensors SFE1 and MS6-SFE have an operating mode which shows the cumulative air consumption. Using this functionality, the flow sensor works as an air consumption meter. The sensors also have the functionality to monitor an air consumption value which can be selected by the user responsible for the application. When this value is exceeded, a digital output impulse is sent out. This function makes it possible to measure and record air consumption. This is especially helpful in environments where volume is used over a period of time and needs to be monitored.

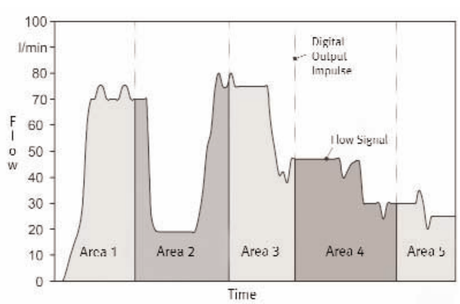


Figure 4:
Graphical representation of the generation of digital output signals, areas 1 to 5 are all of the same size

The Anemometrie Principle
An anemometer consists of one heating element, which is placed at the medium setting and kept at a constant temperature. In case of a fluid flow (gas or liquid), the heating element will be cooled by the fluid due to convective heat loss. A regulator ensures that the temperature of the heater remains constant. Therefore, when there is heat loss, it provides more power to the heater to keep the heating element at the constant temperature. The power used to keep the heating element at the constant temperature is used as an indicator for fluid velocity. This principle is also known as the Heat-Loss-Principle.

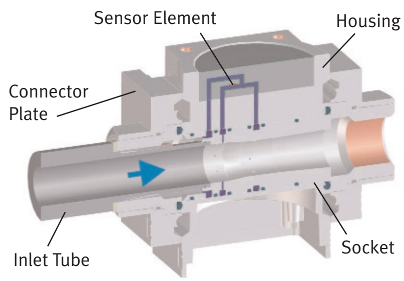


Figure 5:
Cross section of the MS6 flow sensor

Here, the anemometer is not placed in the main channel, but in a bypass channel. Within the main channel, a Venturi effect generates a pressure difference which forces a well defined proportion of the flow through the bypass. The flow in the bypass is equivalent to the flow in the main channel. The measured value is independent of the pressure level, which makes this flow measurement principle ideal for a variety of measurement tasks. If necessary, even small flow rates can be measured. The flow sensors are capable of measuring the air consumption of a specific pneumatic drive or of a larger production area, allowing for a multiplicity of applications with one single measuring device.

SFE1
The design of the flow sensor SFE1 is similar to the design and operation concept of the tried-and-trusted SDE1 pressure sensor. The measurement range reaches from 0.5 to 200 l/min [0.018 to 7.06 scfm] with 2 types. The large, illuminated LCD display allows for easy reading of the current flow data. The display can be rotated 270º to read the meter from a variety of orientations. The SFE1 family supplies absolute flow data or cumulative air consumption. Set-up of threshold values and convenient switching-point adjustments can be done via the display screen. The robust and compact design (protection class IP65) and its wide variety of mounting options makes the SFE1 suitable for applications in nearly every industrial environment. Sample applications are leakage detection in production; leak testing end products, and flow monitoring during workpiece feeding.

MS6-SFE
The MS6-SFE, with the same design as the well known MS6 service units, has a measurement range of 200 to 5000 l/min [7.6 to 176.6 scfm] and covers a wide spectrum of applications. The operating concept is identical to the SFE1. The MS6-SFE offers complete flow and air consumption data, along with convenient switching point adjustment. All data is easy to read on a large backlit LCD and is also able to be transmitted via a digital and an analog output. Thanks to the compact design and its IP65 rating, the MS6-SFE can fit anywhere.

Both products, SFE1 and MS6-SFE, have optional 2x PNP or 2x NPN interfaces and an analog output of 0 to 10 V or 4 to 20mA. These highly flexible and freely combinable options offer a multitude of application possibilities. Preferred applications of the MS6-SFE are consumption control of systems, consumption of records, cost center allocation for costs of compressed air, and leakage monitoring of pneumatic systems.

How to install a flow sensor?
Until now, flow sensors which can be operated in a stand-alone mode or be combined with service units have not been available on the market. The new approach from Festo Corporation enables users to equip new or existing pneumatic systems. Even the temporary installation of flow sensors is easily possible. The determination of air consumption of pneumatic applications or parts of pneumatic systems is also a possibility. The measurement of flow is, contrary to the measurement of pressure, quite complex. Normally, the installation conditions are a decisive factor for the correct measurement of flow.

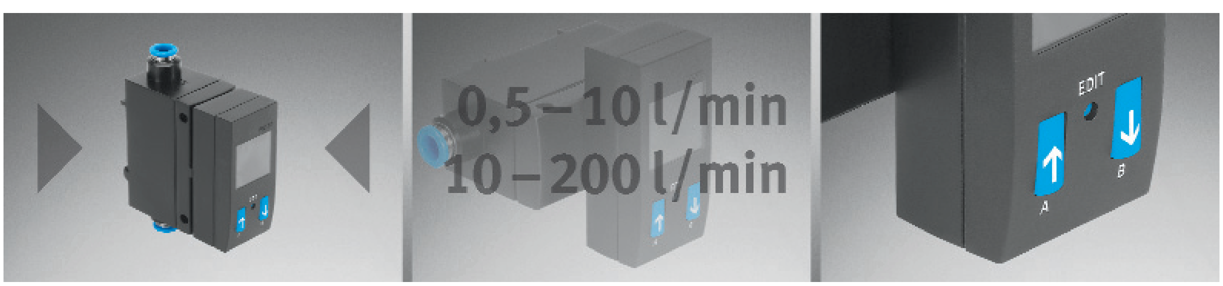
By using the Festo flow sensors, the user does not necessarily need specific knowledge about the incoming flow. The SFE1 contains an integrated flow stabilizing inlet. Therefore, no special incoming flow or installation conditions have to be met. When using the MS6-SFE, incorrect measurement results are averted by using an inlet tube which is connected to the sensor. In the case where the MS6-SFE is used as a module of the service unit MS6, a filter cartridge acts as a flow stabilizer and ensures the correct flow by requiring a minimum amount of space. These two alternatives allow for universal usage with a very short installation time.

Determination of the flow range
Flow sensors can be used throughout the entire air system. In some cases, the sensors may be integrated at important points of the air distribution system. In other cases, the sensors may be attached to individual subsystems. They may also be attached to single actuators if those actuators need to be monitored very closely because they are crucial for the operation of an assembly line or if they are responsible for the final product. By monitoring just that source, any increase in air consumption can clearly be pinpointed to the specific individual component.

Before a flow sensor can be integrated into a line, the sensor and the measuring range needs to be determined. The selection of a sensor for normal pneumatic applications is usually easy. But how can flow sensors be selected when only very small air flows are used? Applying the C-value as an indicator is useful. The formula for the C-value, which is shown in Figure 8, is often used to calculate the required measurement range of the air flow.

$$c = 0{,}154 \times d^2 \left[\frac{l}{s \times bar} \right]$$

Figure 8: c-value Formula



An example from an automotive supplier might help clarify this approach. The requirement is to measure the diameter of a borehole at a crank shaft. The only information we have is that the diameter (d) of the hole should be 4 mm [0.16 inch], with a deviation of approximately +/- 0.3 mm [0.11 inch]. In the first step, the pressure is selected.

Two different aspects influence the decision on which sensor to use. On one hand, the user requires a reduction in air consumption. On the other hand, the borehole is supposed to be cleaned during the measurement. Consequently, a pressure difference of approximately 1 bar is selected which results in the c-values shown in the table below:

C-value at d= 4,0 mm [0.16 inch]
147,8 l/min [5.2 scfm]

C-value at d= 4,3 mm [0.17 inch]
170,8 l/min [6 scfm]

C-value at d= 3,7 mm [0.145 inch]
126,5 l/min [4.45 scfm]

As the results show, the difference of the air flow is significant. For this reason, a flow sensor should be used to determine the borehole diameter. In this example, the most appropriate sensor to choose would be the sensor SFE1 with a measuring range up to 200 l/min [7.1 scfm].

Summary
Continuous evaluations of flow and air consumption in a compressed air system can provide useful diagnostic information and determine whether a pneumatic system or subsystem is operating efficiently. Flow sensors can easily take over this task by monitoring flow and air consumption, pinpointing problem areas, and detecting any occurring malfunctions in good time.

In conclusion, compressed air system users who want to reduce the cost of production and - at the same time - increase system availability should consider using flow sensors as an efficient and inexpensive diagnostic tool. This is a much better alternative than a futile search for leaks and/or adding additional compressor capacity.

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