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WHITEPAPER

COMPRESSED AIR CONSUMPTION MEASUREMENT AND LEAKAGE DETECTION – USING SAVINGS POTENTIALS

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TABLE OF CONTENTS

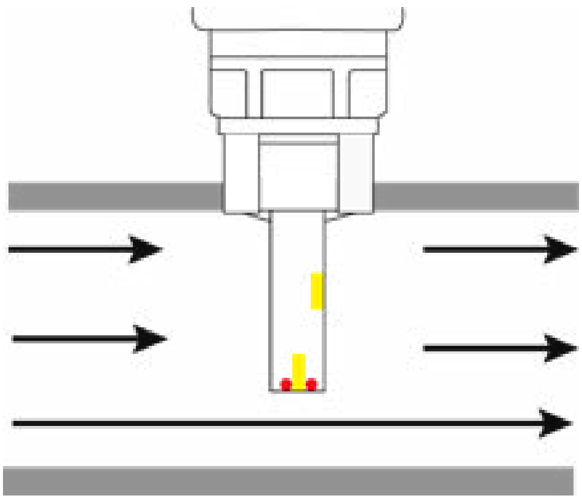
1 INTRODUCTION

There is usually complete transparency about the consumption of electricity, water or gas in every company. Even leaks, for example in water supply networks, are usually visible to everyone and can therefore be quickly eliminated. Compressed air, on the other hand, often is lost as waste unnoticeably due to leaks in the consumption network, even at weekends when the compressor is permanently in operation or when it is not needed for production. The amount of energy required to generate compressed air is enormous, since electricity costs account for around 70 to 80 percent of the total costs of a compressed air system.

Even with smaller systems, costs of 10,000 to 20,000 euros per year can quickly arise. It should therefore come as no surprise to anyone that compressed air is one of the most expensive forms of energy in industry. This is reason enough to pay more attention to this topic, if only with regard to possible savings in compressed air and electricity costs. In the following, various solutions for flow measurement are presented, which open up potentials for an optimal design of compressed air lines and a sustainable reduction of consumption. In addition, it will be shown how leaks in compressed air networks can be traced very easily and specifically so that they can be eliminated quickly, sometimes resulting in considerable savings in energy costs.

2 OPERATING PRINCIPLE OF FLOW SENSORS

Flowmeters from ipf electronic work according to the proven calorimetric measuring principle. The flow sensors, which have been tested many times in practice, have a measuring sensor that integrates two temperature sensors (yellow elements in the figure) and is installed in the mass flow of the medium. The temperature sensor integrated in the sensor tip is heated from the inside to a constant excess temperature by means of heating elements (red element in the figure). The second sensor in the sensor tip measures the temperature of the medium flowing past. This results in a temperature difference between the two sensors. This difference is the smaller, the higher the flow velocity of the medium is. The reason for this is the cooling effect on the heated sensor by the mass flow. Neither the pressure nor the temperature of the medium has any influence on the measuring results with the described measuring principle. Therefore, the flow meters or consumption meters can be used at different pressures and temperatures without further compensation. The flowmeters from ipf electronic measure the current flow rate e.g. in m^3/h or l/min as well as the consumption in m^3 or l.



Operating principle of flow sensors
▮ : Temperature sensor
●: Heating element
all figures: ipf electronic

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3 FLOW METERS (AIRFLOW SENSORS)

Leaks in consumption networks occur more frequently than is generally known. Therefore, the installation of airflow sensors for continuous compressed air consumption measurements is recommended in principle, in order to identify deviating high consumption levels at an early stage and, in addition, to be able to generally better recognize where is potential for savings in the use of compressed air. Depending on the area of application and also the installation situation on site, there are various solutions available for the continuous consumption measurement of compressed air: Puncture sensors, devices with integrated assembly line and compact solutions with rectifier.

Possible applications of different airflow sensors, e.g. on machines or in the immediate vicinity of the compressor.

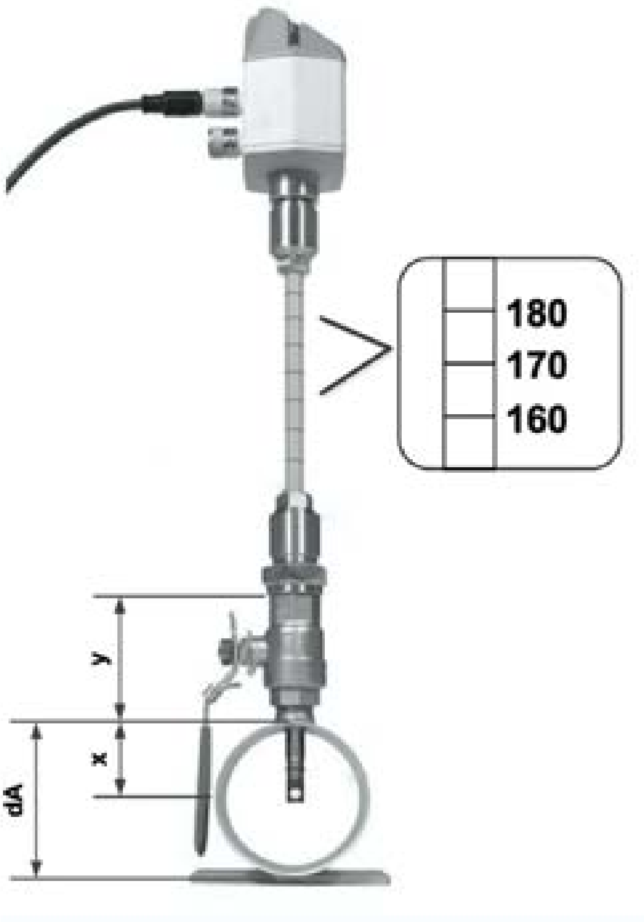
3.1 INSERTION SENSORS

So-called insertion sensors are suitable as an entry solution for continuous measurement of compressed air consumption due to their easy installation and handling. The programmable devices with TFT display can be installed under pressure, i.e. with the compressor running, via a ball valve and record the measured variables flow rate, consumption and speed.

Flow sensor **SL870020**. The blue arrows on the sensor housing mark the flow direction for mounting the device.

Since the calorimetric measuring principle (principle of thermal mass flow measurement) is very sensitive to flow disturbances, the sensor must be installed centrally in a straight piece of pipe (the measuring tip is located in the middle of the pipe cross section, the following figure shows the calculation of the installation depth) at a location with undisturbed flow. An undisturbed flow is achieved by a sufficiently long pipe section before the sensor (inlet section) and after the sensor (outlet section). The inlet and outlet sections must therefore have no edges, seams, bends or similar disturbing points.

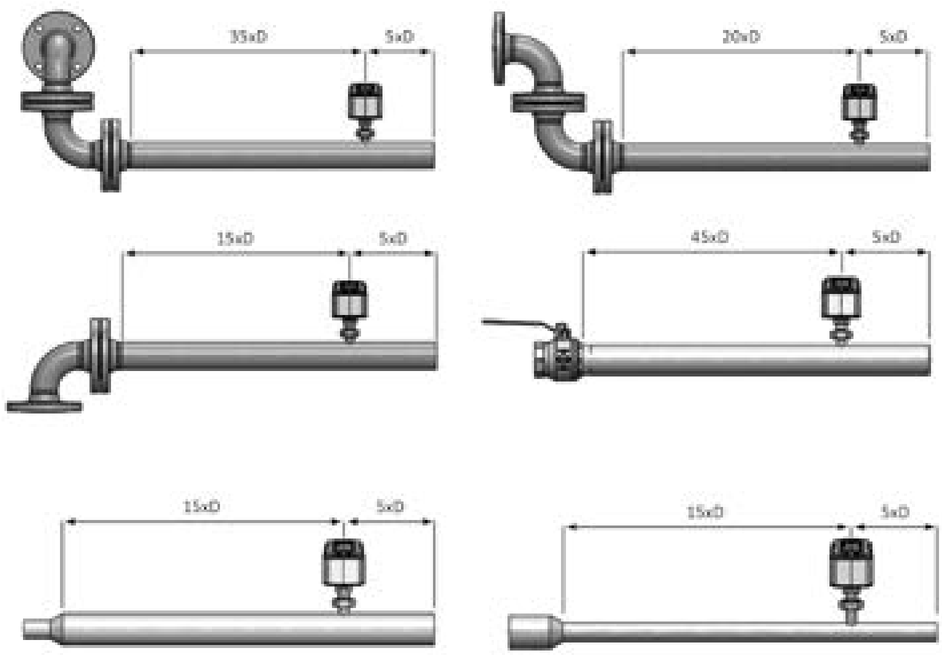
If there are flow obstacles in front of the measuring section, a minimum length of the inlet section must be maintained, depending on the type of obstacle, in order to obtain reliable measuring results, as the following two figures on page 6 illustrate. For example, the minimum length of the inlet section with a small bend (bend < 90°) in front of the measuring section must be 12 times the pipe diameter (12 x D), whereas the minimum length of the outlet section is 5 x D and basically always remains unchanged if there is no flow obstacle in this area. The programmable insertion sensors from ipf electronic provide high accuracy even in the lower measuring range and can therefore be used for leakage measurements. Furthermore, the devices are equipped with a RS 485 Modbus RTU interface for the connection e.g. to energy management systems, to the building control system, to a PLC, a SCADA system, etc.



Calculation of the installation depth: installation depth = x + y. dA = pipe outside diameter, x = dA / 2

Flow obstruction in front of the measuring section	Minimum length (inlet section)	Minimum length (discharge section)
Low curvature (arc < 90°)	12 x D	5 x D
Reduction (tube narrows to the measuring section) Expansion (tube expands to the measuring section) 90° bend or T-piece	15 x D	5 x D
2 bends á 90° in one plane	20 x D	
2 bends á 90° 3-dimensional change of direction	35 x D	5 x D
Shut-off valve	45 x D	5 x D

Table of inlet and outlet sections in case of flow obstacles in front of the measuring section



The illustrations show the minimum lengths of the inlet sections to be observed for various flow obstacles in front of the measuring section.

3.2 FLOW SENSORS WITH INTEGRATED INLET SECTION

Flow sensors with integrated assembly section were designed for easy integration into existing pipelines. Various solutions for pipe sizes from R 1/4“ to R 2“ are available. Since the mode of operation of these sensors is identical to the insertion sensors, the minimum lengths for the inlet and outlet sections as shown in the figure on page 6 must also be observed during installation. When calculating these lengths, the integrated assembly section (inlet and outlet) must also be taken into account.

Programmable flow sensor SL900020 with integrated mounting bracket for R 1/2“ pipe connection.

As with the insertion sensors, these flow sensors are adjusted by means of two capacitive keys on the TFT display. A Modbus RTU interface for data transmission is also available. Further special features of both device series are a freely scalable analog output (4...20mA) and a galvanically isolated pulse output. A software allows further settings to be made, service data to be read out and sensor diagnosis to be carried out. The compressed air consumption measuring devices (insertion sensors and devices with integrated assembly line) are designed for an operating pressure of 16bar. The accuracy is ± 1.5 % of the measured value and ± 0.3 % of the final value.

3.3 FLOW SENSORS WITH RECTIFIER

In a number of applications, e.g. inside machines, in the immediate vicinity of a plant or behind a maintenance unit, the integration of the flow sensors described under 3.1 and 3.2 is difficult or even impossible, since e.g. the mounting space for such devices is insufficient due to the limited space available. In addition, in such cases the necessary installation space for the inlet and outlet sections is often missing, which means that the required minimum lengths for the sections cannot be maintained. The extremely compact solutions with flow straighteners are suitable for such applications.

The devices with connection thread G 1/2“ to 2“ do not require an inlet and outlet section to calm the media flow (laminar flow), since the rectifier (measuring block made of aluminum) always ensures an optimal flow to the integrated sensor elements, completely independent of the respective installation situation. Excluded is the flow sensor of the series with measuring block for the 1/4“ connection, which has no rectifier.

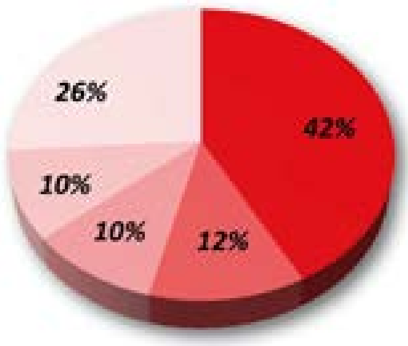
Flow sensor **SL920021** with integrated rectifier for space-saving installation e.g. on machines or behind maintenance units.

The flow sensors designed for an operating pressure of up to 16 bar record the measured variables flow rate, speed and consumption, whereby the display can simultaneously show the current consumption as well as the total consumption. The devices with connection thread G 1/2“ to 2“ are also suitable for air flow measurements within hose lines. In addition, the series offers specific devices that can measure system pressure in addition to compressed air consumption.

Flow sensors are a sensible investment in any case, since continuous consumption measurement in combination with suitable measures can usually lead to lower compressed air consumption and thus noticeable energy cost savings. If, however, conspicuously deviating high consumption levels are measured in a compressed air network, it is recommended that leaks be specifically identified as a possible cause and thus quickly eliminated.

4 LEAKAGE DETECTION

As already mentioned in the introduction, however, the waste of compressed air due to leaks in consumption networks often remains unnoticed. If at all, the sound of air escaping from a pipe due to a leak can only be detected by hearing. However, such indications are usually not registered at all simply because of the loud ambient noise in industrial plants. As the diagram shows, finding and eliminating leaks offers the greatest potential for savings.



Savings potential in compressed air generation.
42%: Identification and elimination of leaks.
12%: Design of the pneumatic system including a multi-pressure pipe network.
10%: heat recovery. 10%: Compressors with variable motor speed.
26%: other measures.

The waste of compressed air as a valuable resource becomes even clearer when one considers concrete figures on the possible annual costs that can arise from a leak. For example, if a compressed air network is in operation around the clock and the average cost is 1.9 cents per standard cubic meter (Nm3), then a leakage size of 3mm at 3 bar system pressure will result in costs of around 3,250 euros per year. The same leakage already causes costs of around 5,600 euros per year at 6bar pressure and around 7,300 euros per year at 8bar. And these are the energy costs alone that have to be spent on a compressor to compensate for the pressure loss in a line.

COSTS PER YEAR						
	LEAKAGE SIZE - DIAMETER(mm)					
PRESSURE	0.5mm	1.0mm	1.5mm	2.0mm	2.5mm	3.0mm
3bar	90€	361€	812€	1,444€	2,256€	3,248€
4bar	113€	451€	1,015€	1,805€	2,820€	4,061€
5bar	135€	541€	1,218€	2,166€	3,384€	4,873€
6bar	158€	632€	1,421€	2,527€	3,948€	5,685€
7bar	180€	722€	1,624€	2,888€	4,512€	6,497€
8bar	203€	812€	1,827€	3,248€	5,076€	7,309€

Annual costs due to leaks based on compressed air costs of 1.9 ct/Nm3 with permanent compressor operation (24h/365 days)

By using flow sensors as described in chapter 3, already disproportionately high consumptions can be detected, which indicate leakages. In order to avoid the high costs caused by such leaks at an early stage, they should be eliminated very quickly. However, this requires their targeted location.

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4.1 LEAKAGE DETECTOR WITH INTEGRATED CAMERA

The **UY000001** leak detector was developed primarily for this task and can also be used on gas and steam lines and vacuum systems. The handheld device with USB interface integrates, among other things, a microphone, a camera with a color display and a laser pointer (laser class 2) in order to obtain an optical orientation for the targeted location point during the leak detection. Further equipment of the **UY000001** includes headphones, a sound funnel and a shotgun. A software for data import via USB stick to a PC completes the solution. A gooseneck microphone and a parabolic mirror microphone are also optionally available. The possibilities offered by these features and accessories for practical use are described in more detail in the following chapters.

The leakage detector integrates, among other things, a microphone and a camera with a color display. In addition, there are headphones, a sound funnel and a shotgun.

4.1.1 GENERAL DESCRIPTION OF FUNCTIONS

When compressed air escapes from leaks in pipeline systems (e.g. due to leaking screw connections, corrosion, etc.), noises are generated in the ultrasonic range. If the leak detector is directed via the camera and with the support of the laser pointer as target bearing for a more precise localization to an area where a leak is suspected, the device bundles the ultrasonic waves of the escaping compressed air with the help of the sound funnel (quantification distance: 1- 6m) and records them via the microphone. Due to the recording in the ultrasonic range, other, potentially disturbing ambient noise is largely not recorded by the device.

The leakage detector converts the ultrasonic waves into audible frequencies and transmits them to the headphones, which also block out any disturbing noises in the immediate vicinity. In addition, the detected emission level is shown in the device display. In the standard setting, the device is in an auto mode, which simplifies the handling considerably, as the sensitivity is automatically regulated in different gradations within 10db to 100db, depending on the size of the leakage. In order to influence the acoustic behavior of the device during a specific leakage search, the sensitivity levels can alternatively be adjusted manually, thereby increasing or decreasing the valid value range accordingly.

The following sensitivity levels are available:

0-60db: highest sensitivity for small leakages and without noise
10-70db: small leakages
20-80db: medium leakages
30-90db: large leakages
40-100db: very large leakages, many interfering noises (heavy-duty application)

The handheld solution thus enables the user to locate even the smallest leaks, which are barely perceptible to the ear and are also not visible or detectable from a distance of several meters. The color display shows the compressed air loss in l/min. If the costs per liter or per cubic metre of compressed air were previously stored in the unit, the savings potential through leakage elimination can also be read off in the display in a freely selectable currency. If required, the shotgun (quantification distance: 0- 0.2m) can be used as an accessory to locate the smallest leaks with pinpoint accuracy in the smallest spaces.

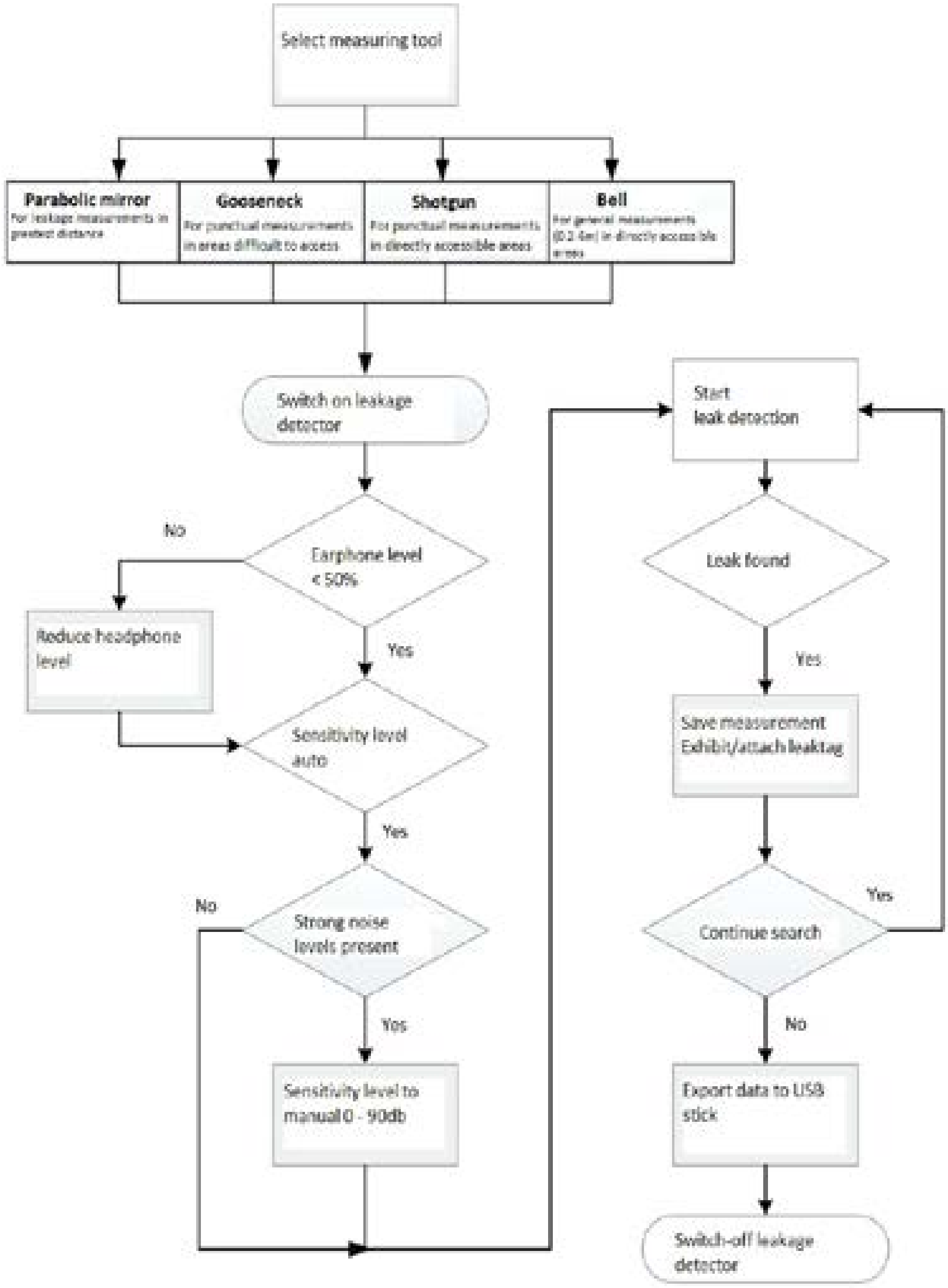
A gooseneck microphone and a parabolic mirror microphone are also optionally available. While the gooseneck version (quantification distance: 0- 0.05m) allows a targeted location of leaks in places that are difficult to access while at the same time suppressing background noise, the parabolic mirror system, which already integrates camera and laser pointer, can be used for leak detection from large distances (3 to a maximum of 12 meters). The figure on page 12 illustrates the procedure or individual steps for measurements during leak detection in connection with the previous versions.

4.1.2 DOCUMENTATION AND DATA PROCESSING

If a leak has been found, the integrated camera can be used to take a picture of the leak location including all data collected on the leak and shown on the display as documentation and provide additional information. The following data can be stored on the internal SD card of the device in addition to the image of the leakage location:

- Date / Time of recording
- Company name / department / name of leakage location
- Size of leakage in liters/min (unit adjustable)
- Costs of leakage per year e.g. in Euro (currency freely selectable)
- Comment

It is also possible to attach a so-called „Leak Tag“ in paper form directly at the leakage location with all the important information as on-site documentation, but also as a note, e.g. for maintenance purposes.



Procedure for leakage detection

An image of the leakage location with all collected data and additional information can be stored in the device for documentation purposes and then transferred to a PC with a USB stick for further processing.

After being saved on site, all data and information recorded on the leak detector is available for further processing on a PC. The transfer from the device to a PC takes place via USB stick. A software for the leakage detector now enables, among other things, the easy creation of detailed reports according to ISO 50001 for the implementation of a systematic environmental management or for further environmental audits. All reports can be created separately for individual departments as well as for the entire company, whereby the totals at the end of a report provide a very good overview of the total leakage management quantity (in l/min) as well as the annual total leakage costs (e.g. in €).

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