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WHITEPAPER

COMPRESSED AIR CONSUMPTION MEASUREMENT AND LEAK DETECTION – EXPLOITING POTENTIAL SAVINGS

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TABLE OF CONTENTS

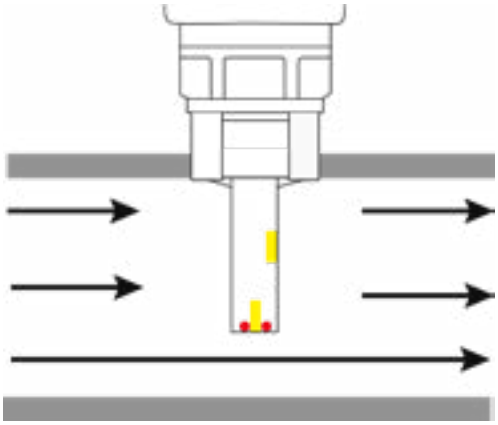
1 INTRODUCTION

There is usually complete transparency in every company via the consumption of electricity, water or gas. Even leaks in water pipe networks, for example, are usually visible to everyone and can therefore be eliminated quickly. Compressed air, on the other hand, often escapes unnoticed due to leaks in the
network often goes unnoticed, with compressors running continuously even at weekends or even when it is not needed straight away for production. The amount of energy required to generate compressed air is enormous, as electricity costs account for around 70 to 80 percent of the total costs of a compressed air system.

Even smaller systems can quickly incur costs of 10,000 to 20,000 euros per year. It may therefore come as no surprise to anyone that compressed air is one of the most expensive forms of energy in industry. Reason enough to take a closer look at this topic, if only in terms of possible savings in compressed air and electricity costs. Various solutions for flow measurement are presented below, which open up potential for the optimal design of compressed air lines and a sustainable reduction in consumption. In addition, it will be shown how leaks in compressed air networks can be detected very easily and specifically so that they can be eliminated quickly, sometimes resulting in considerable energy cost savings.

2 FUNCTIONALITY OF FLOW SENSORS

Flow meters from ipf electronic work according to the proven calorimetric measuring principle. The flow sensors, which have been tried and tested many times in practice, are via a
measuring probe that integrates two temperature sensors (yellow elements in the illustration) and is installed in the mass flow of the medium. The temperature sensor integrated in the probe tip is heated from the inside to a constant excess temperature with the help of heating elements (red element in the illustration). The second sensor in the probe measures the temperature of the medium flowing past. This results in a temperature difference between the measured values of both sensors as a delta. As the passing medium cools the heated sensor, it must be heated again in order to keep the previously determined delta between the measured temperature values of the sensors constant. The additional heating energy required for this is proportional to the flow velocity of the medium. Neither the pressure nor the temperature of the medium have any influence on the measurement results with the measuring principle described. Therefore, the flow meters or consumption meters can be used without any problems at different pressures and temperatures without further compensation. The flow meters from ipf electronic measure the current flow rate e.g. in m³/h or l/min as well as the consumption in m³ or



Functionality of flow sensors
■ : Temperature sensor
● : Heating element
All pictures: ipf electronic

3 FUNCTIONALITY OF FLOW SENSORS

Leaks in consumption networks occur more frequently than is generally known. It is therefore generally advisable to install air flow sensors for continuous compressed air consumption measurements in order to identify deviatingly high consumption at an early stage and also to be able to better recognize where there is potential for savings in the use of compressed air. Depending on the area of application and the installation situation on site, various solutions are available for the continuous measurement of compressed air consumption: Insertion sensors, devices with an integrated mounting section and compact solutions with a rectifier.

Possible areas of application for various air flow sensors, e.g. on machines or in the immediate vicinity of the compressor.

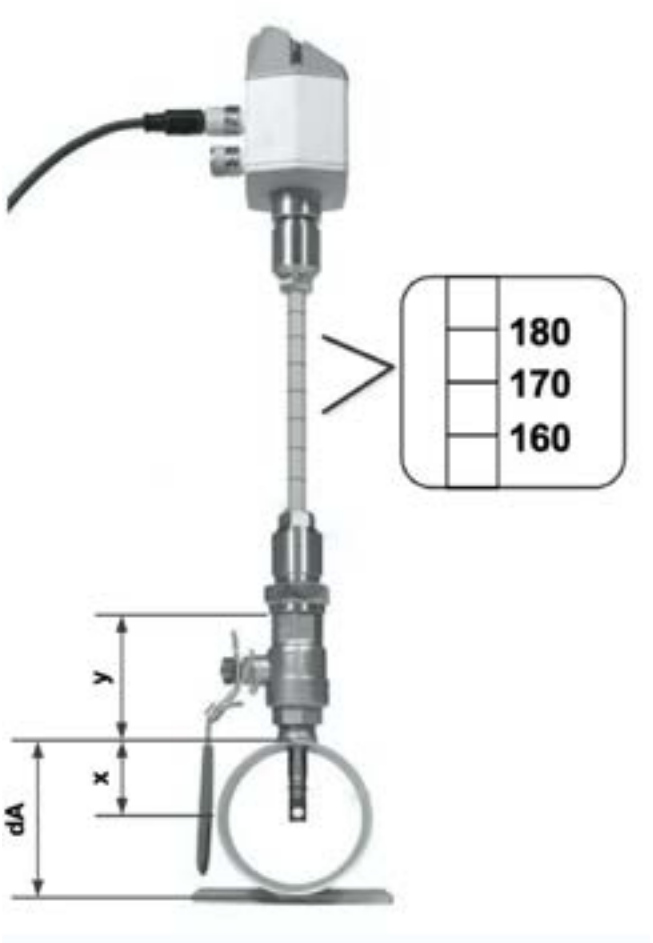
3.1 PUNCTURE SENSORS

So-called puncture sensors are an ideal entry-level solution for continuous compressed air consumption measurement due to their ease of 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 of flow rate, consumption and speed.

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

As 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 pipe section (the test prod is located in the middle of the pipe cross-section, the following figure shows the calculation of the installation depth) at a point with an undisturbed flow pattern. An undisturbed flow pattern is achieved by a sufficiently long pipe section upstream of the sensor (inlet section) and downstream of the sensor (outlet section). The inlet and outlet sections must therefore not have any edges, seams, bends or similar interference points.

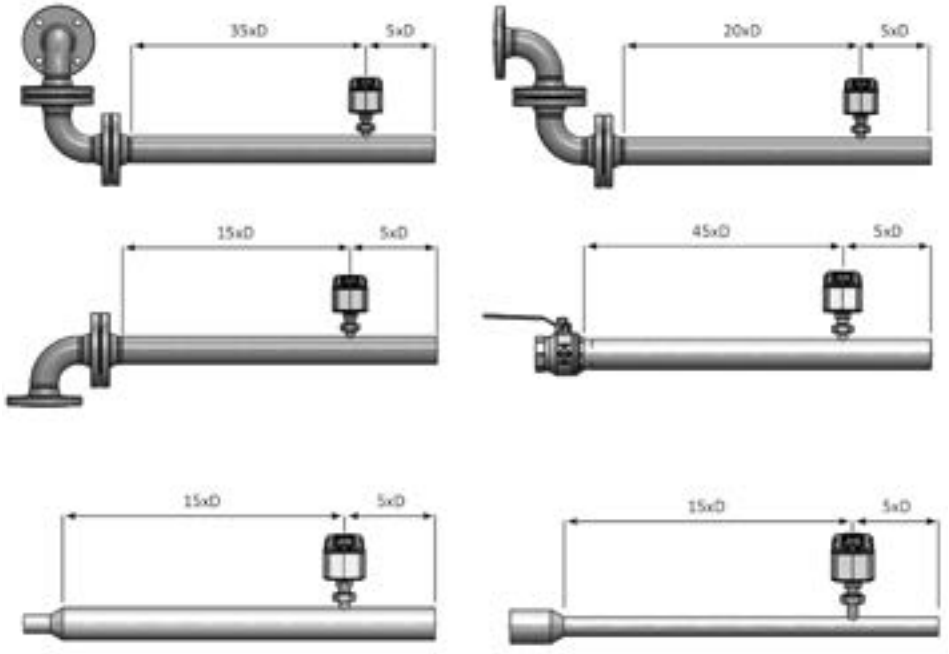
If there are flow obstacles in front of the measuring section, a minimum length of the inlet section must be observed depending on the type of obstacle in order to obtain reliable measurement results, as the following two figures on page 6 illustrate. For example, the minimum length of the inlet section must be 12 times the pipe diameter (12 x D) for a slight bend (bend < 90°) upstream of the measuring section, while 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 deliver high accuracy even in the lower measuring range and can therefore be used for leakage measurements. The devices also have an RS 485 Modbus RTU interface for connection e.g. to energy management systems, building management systems, a PLC (programmable logic controller), a SCADA system, etc.



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

Flow obstacle in front of the measuring section	Minimum lenght (run-in distance)	Minimum length (run-out distance)
Low curvature (arc < 90°)	12 x D	5 x D
Reduction (pipe narrows towards the measuring section) Expansion (pipe expands towards 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 for flow obstacles upstream of the measuring section



The figures show the minimum lengths of the run-in distances that must be observed for various flow obstacles upstream of the measuring section.

3.2 FLOW SENSORS WITH INTEGRATED MOUNTING SECTION

Flow sensors with an integrated mounting section have been designed for easy integration into existing pipes. Various solutions are available for pipe sizes from R 1/4“ to R 2“. As the function of these sensors is identical to the insertion sensors, the minimum lengths for the inlet and outlet sections shown in the illustration on page 6 must also be observed during installation. When calculating these lengths, the integrated mounting section (run-in and run-out) must also be taken into account.

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

As with the penetration sensors, the setting of these flow sensors is made via two capacitive buttons on the TFT display. A Modbus RTU interface for data transmission is also available. Other features of both device series include a freely scalable analog output (4...20mA) and a galvanically isolated pulse output. Further settings can also be made via software, and service data can be read out and sensor diagnostics carried out. The compressed air consumption measuring devices (insertion sensors and devices with integrated mounting section) 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 systems or behind a maintenance unit, it is difficult or even impossible to integrate the flow sensors described in 3.1 and 3.2, as, for example, the installation space for such devices is insufficient due to the limited space available. In addition, in such cases there is often a lack of installation space for the inlet and outlet sections, which means that the minimum lengths required 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), as the rectifier (measuring block made of aluminum) always ensures an optimum flow to the integrated sensor elements, regardless of the respective installation situation. The only exception is the flow sensor in the series with measuring block for the 1/4“ connection, which does not have a 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 of flow rate, speed and consumption, while the display can simultaneously show the current consumption as well as the total consumption. The devices with connection threads G 1/2“ to 2“ are also suitable for air flow measurements within hose lines. The series also offers specific devices that can measure system pressure in addition to compressed air consumption.

Flow sensors are always a sensible investment, as continuous consumption measurement in combination with suitable measures can usually lead to lower compressed air consumption and therefore noticeable energy cost savings. However, if conspicuously high consumption levels are measured in a compressed air network, it is advisable to specifically identify leaks as a possible cause and thus eliminate them quickly.

4 LEAK DETECTION

As already mentioned in the introduction, however, the waste of compressed air due to leaks in consumption networks often goes unnoticed. If at all, the sound of air escaping from a line as a result of a leak can only be detected via the ear. However, such signs are usually not even registered due to the loud ambient noise in industrial plants. Detecting and eliminating leaks offers the greatest potential for savings, as the diagram shows.

Savings potential in compressed air generation:
42%: Identification and elimination of leaks
12%: Design of the pneumatic system including a multi-pressure line 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 if you look at the concrete figures for the potential annual costs that can arise from a leak. If, for example, a compressed air network is in operation around the clock and an average cost of 1.9 cents per standard cubic meter (Nm3) is assumed, then a leakage of 3 mm at a system pressure of 3 bar already results in costs of around 3,250 euros per year. The same leakage at 6 bar pressure already causes costs of around 5,600 euros and at 8 bar around 7,300 euros per year. And these are the energy costs alone that have to be incurred for a compressor to compensate for the pressure loss in a line.

Costs per year						
	Leakage size - diameter (mm)					
Print	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 leakages 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, disproportionately high consumption can already be detected, indicating leaks. In order to avoid the resulting high costs at an early stage, such leaks should be eliminated very quickly. However, this requires their targeted localization.

4.1 LEAK DETECTORS IN THREE VERSIONS

The **UY000001**, **UY000002** and **UY000003** leak detectors were developed primarily for this task and can also be used on gas, steam and vacuum systems as well as steam traps, seals and connections. The solutions are available as case sets (**UYKS0001** for **UY000001** and **UY000002** as well as **UYKS0002** for **UY000003**) with complete accessories (e.g. headphones, acoustic horn, straightening tube) as well as PC software with a reporting tool in accordance with ISO 50001. The possibilities offered by these solutions in practice are described in more detail in the following chapters.

Pinpoint leaks in compressed air networks and save considerable costs

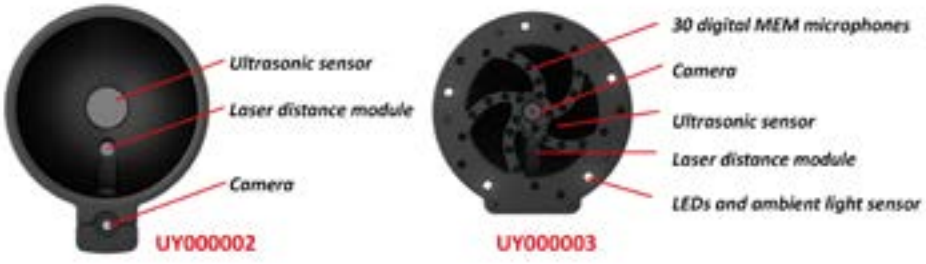
4.1.1 GENERAL FUNCTIONAL DESCRIPTION OF THE LEAK DETECTORS

Compressed air escaping from a leak generates ultrasonic waves. If one of the devices is pointed at an area with a suspected leak using the integrated camera and color display, these waves are bundled using a sound funnel, recorded via a microphone, converted into audible frequencies and transmitted to headphones. Due to the recording in the ultrasonic range, other potentially disturbing ambient noises (production conditions) are largely not detected by the device and are therefore suppressed. If corresponding values have previously been stored in the device, the costs per leak can also be determined. All leak detectors enable the detection of even the smallest leaks from 0.1 l/min, even from greater distances.

4.1.2 KEY FEATURES OF THE DEVICES AND OTHER ACCESSORIES

The **UY000001** is the basic model in ipf electronic's range of leak detectors. 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) to provide optical orientation for the targeted location during leak detection. The **UY000001** is also equipped with headphones, a sound funnel and a directional tube.

The **UY000002** has the same features as the **UY000001**, but is additionally equipped with a laser distance measurement (laser class 2), which works on the principle of time-of-flight measurement. With this additional function, the distance from the measuring location to the leakage point can be determined exactly, making it easier to localize the leakage with accuracy. The distance value determined is automatically transferred to the device together with other information (e.g. a photo of the leakage point, the size of the leakage, the loss of compressed air and the monetary losses caused by this, if the corresponding costs have been stored beforehand).



Equipment of the switching funnels of the **UY000002** (left) and **UY000003**.

Compared to the **UY000001** and **UY000002**, the **UY000003** enables particularly convenient leak detection, as this solution is able to clearly visualize a leak on the display. The **UY000003** has an UltraCam and 30 digital MEMS microphones in the sound funnel for precise leak detection and color display of the leakage location. Leak detection in darker environments is also particularly supported by five additional LEDs in the sound funnel.

Leaks are shown in color on the **UY000003** display, making them even easier to identify.

In order to be able to influence the acoustic behavior of the devices during a specific leak detection, the sensitivity levels can be adjusted manually, thereby increasing or decreasing the valid value range accordingly.

The following sensitivity levels are available for this:

0-60db:	Highest sensitivity for small leaks and without background noise
10-70db:	small leaks
20-80db:	medium sized leaks
30-90db:	large leaks
40-100db:	very large leaks, lots of background noise (heavy-duty application)

The handheld solutions thus enable users to locate even the smallest leaks that are barely perceptible to the ear and also undetectable or invisible from a distance of several meters.

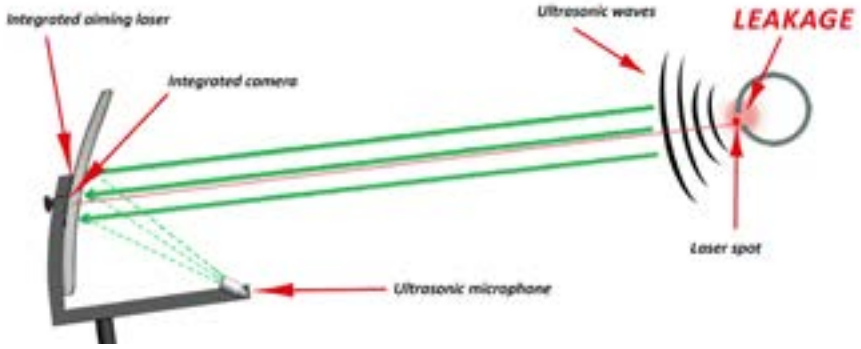
ADVANTAGES AND HIGHLIGHTS	UYKS0001	UYKS0002
Leak detection on: Compressed air, gas, steam, vacuum systems, steam traps, seals, connections, etc.	✓	✓
Leakage detection (L/min) and savings potential (€/year)	✓	✓
During ongoing production: Interference is suppressed, sensitivity is automatically adjusted	✓	✓
Detection of the smallest defects even at great distances (from 0.1L/min)	✓	✓
Laser pointer as an optical orientation aid incl. distance measurement	✓	✓
Integrated display to show all relevant information	✓	✓
Documentation via image recordings and measure details	✓	✓
Leak tags for marking the leak location	✓	✓
Data transmission from handheld device to PC via USB stick	✓	✓
PC software with integrated **reporting tool in accordance with ISO 50001**	✓	✓
Long battery life (up to 7 h)	✓	✓
Visual representation of the leakage on the display	✗	✓
5 LEDs and ambient light sensor for illumination in dark environments	✗	✓
30 digital MEMS microphones (MEMS = microelectromechanical systems)	✗	✓

Advantages and highlights of the **UY000002** (case set **UYKS0001**) and **UY000003** (case set **UYKS0002**)

For the **UY000001** and **UY000002**, a gooseneck and a parabolic mirror are also available as options. While the gooseneck with a length of 600mm (**VY000020**) or 1500mm (**VY000021**) enables pinpoint detection of leaks in hard-to-reach places while simultaneously suppressing background noise, the **VY000024** parabolic mirror, which already integrates a camera and laser distance measurement, can be used for leak detection from large distances (3 to a maximum of 12 meters).

Gooseneck for the **UY000001** and **UY000002.**

Parabolic mirror for leak detection from long distances.



How the parabolic reflector works.

4.1.3 DOCUMENTATION AND DATA PROCESSING

If a leak is found, an image of the leakage location can be taken via the integrated camera, including all the data collected on the leakage and shown on the display, as documentation and with additional information.
The following data can be saved on the device‘s internal SD card, among other things:

/ Date / time of recording
/ Company name / department / description of leakage location
/ Size of leakage in liters/min (unit adjustable)
/ Cost of leakage per year, e.g. in euros (currency freely selectable)
/ Comment

The leakage detectors enable, among other things, the simple creation of detailed reports in accordance with ISO 50001 for the version of systematic environmental management.

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

After saving on site, all data and information recorded on the leak detector is available for further processing on a PC. A USB stick is used to transfer the data from the device to a PC. Software for the leak detector now makes it easy to create detailed reports in accordance with ISO 50001 for the implementation of systematic environmental management or, for example, for further environmental audits. All reports can be created separately for individual departments as well as for the entire company, with the totals at the end of a report providing a good overview via the total leakage volume (in l/min) and the total annual leakage costs (e.g. in €).

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