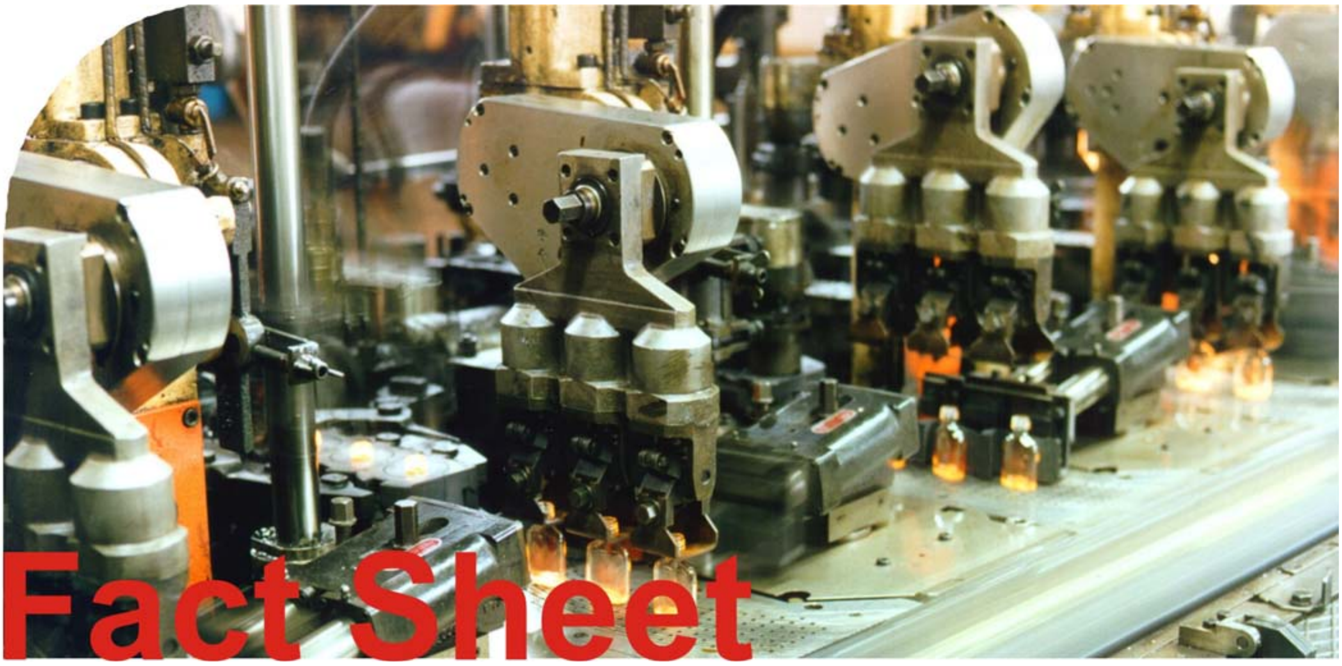

Measurement Technology

In the field of compressed air, measuring pressure provides the data basis for rating the correct pressure head of pressure differences in the distribution system as well as for controlling and regulating the compressors. Before a compressed air system is dimensioned or optimised, the volume flow should be measured. If especially high compressed air quality is required, the relevant measurements provide the basis to ensure compressed air quality as well as to optimise compressed air processing.

Pressure measurement or differential-pressure measurement

Measuring pressure under flow conditions is mainly done to control and regulate compressors or compressor systems as well as to assess compressed air systems.

Differential-pressure measurement is used in addition to monitor the functional performance and economic efficiency of the air processing systems such as filters.

Membrane pressure switch

In many of the compressors and compressor systems used today, membrane pressure switches record the pressure and pass on the data measured in the form of an electrical switch signal.

Please note:

- the ageing of the mechanical components impairs the repeatability.
- Membrane pressure switches require a high differential gap before they react and need a lot of room.

Contact manometer

Up until the 1990s, it was considered state-of-the-art to use mechanical contact manometers for differential-pressure measurements, e. g. to monitor filters or to control compressor systems.

Please note:

- in order to achieve sufficient resolution, the optimal measuring range should be close to the operating range.
- Electrical connections result in mediocre repeatability and complicated adjustments of max. four usable contacts.

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Electronic pressure sensor

The compressors of modern compressor systems should be controlled based on the pressure measurements of electronic pressure sensors which convert the pressure values into analogue signals.

Please note:

- pressure sensors with an output signal of 4 to 20 mA help to avoid cable breaks.
- If the maximum of the measuring range is close to the range of parameters to be controlled, a higher resolution should be aimed at.
- These very robust and reliable systems are characterised by their high repeatability as much as their compact construction.

Measuring the volume flow rate

Measuring the volume flow rate is used to detect the capacity of compressors both with regard to the total air consumption of a plant as well as with a view to individual air consumption of local production facilities.

It must be taken into account that the volume flow data of compressors and air consumers refer to the operational environment, but that the measurement is made in the system conducting the pressure. It is therefore necessary to convert the measured data to the operational environment.

In order to obtain an absolutely exact result, not only the volume flow rate, the temperature and the pressure of the compressed air, but also the atmospheric pressure, the atmospheric temperature and the humidity of the inlet air have to be determined (see Fig. 1). This is indispensable for performance testing compressors.

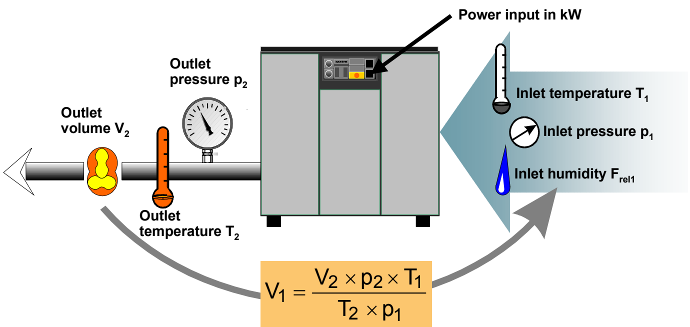


Fig. 1: Measuring the inlet volume flow rate

Volume flow rate measurements for in-plant accounting or planning a compressor system do not justify the cost of parallel measurements of the ambient temperature, humidity and atmospheric pressure.

However, a backward projection should be made based on average pressure and temperature conditions at the installation site.

Temperature and pressure compensation

Pressure and temperature are rarely constant in a compressed air system. Therefore when measuring air consumption, the pressure and temperature should be determined as well as the volume flow rate, so that a correct backward projection of the measured operating state can be made based on the ambient conditions (see gas equation, Fig. 1). This is essential for an accurate measurement.

Without temperature and pressure compensation

If a volume flow rate measurement is made without parallel pressure and temperature measurement and without backward projection of these factors to the relaxed state, it is only possible to determine the volume flow at actual temperature and pressure conditions. Otherwise pressure and temperature fluctuations occurring during the measurement result in errors when projecting backwards to the ambient state.

Direct measurement of the volume or mass flow rate

Measuring the dynamic pressure makes it possible to determine the volume flow rate with a high degree of accuracy. A venturi nozzle can be used or alternatively a dynamic pressure sensor (see Fig. 2).

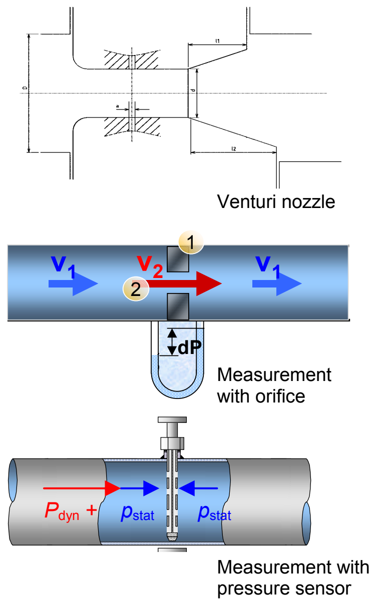


Fig. 2: Measuring dynamic pressure

Please note:

- In order to reach sufficient resolution, the optimum measurement range should be close to the operating range.
- Electrical connections result in mediocre repetitive accuracy and complicated adjustments of the max. four usable contacts.
- The correct lengths of the inlet and outflow zones are important as is the insertion of the measuring device into the distribution system and the exact geometrical data of the pipe.
- Attention!: contamination hazard.
- If the flow rate falls below 10 per cent of the maximum measured value, this results in lower measurement accuracy.

Volumetric measurement

Volumetric measurements are highly accurate measurements which are used, e. g. to determine the capacity of compressors. The most important measuring devices are rotary displacement gas meters and turbine gas meters. Whereas the rotary displacement gas meter should be applied in a measurement range from 10 to 90 % of its max. volumetric flow rate, the turbine gas meter is very accurate in the lower measurement range as well.

Please note:

- these measurement devices are complex mechanical components requiring intensive monitoring.
- Not overload-proof (danger in depressurised compressed air system).

Calorimetric measurement

So-called hot-wire anemometers can measure the volume flow rate as a function of the mass flow rate in a compressed air pipe by relating the heat removed to the volumetric flow rate (see Fig. 3).

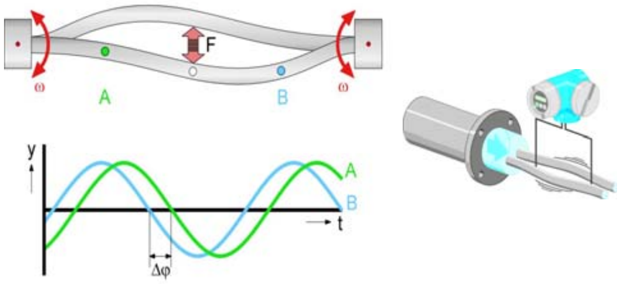
Fig. 3: Calorimetric volume flow rate measurement

Please note:

- Without temperature and pressure compensation, deviations from the design point in temperature, humidity and pressure fluctuations have a strong influence on the result.

Coriolis mass flow rate measurement

Is based on exploiting the controlled generation of the coriolis force. These forces occur where translatory (straight) and rotary (rotating) movements overlap. The magnitude of the forces depends on the masses moved and their velocity and thus on the mass flow rate (see Fig. 4).



ω = Angular velocityt
F = Coriolis force
$\Delta\varphi$ = Phase shift
A, B = Sensors
y = Amplitude
t = Time

Fig. 4: Coriolis mass flow measurement

Others

In addition to the classical methods of measuring volume flow rate, there are several new measurement systems available today.

Karman Vortex Street

The volume flow rate measurement is based on the Karman vortex street (see Fig. 5).

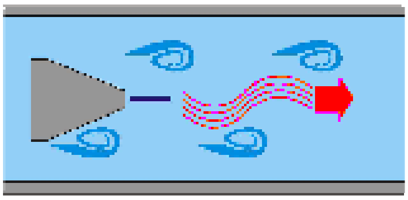


Fig. 5: Karman vortex street

An exactly defined body fixed in a compressed air system generates a vortex and thus vibrations which can be recorded. They vary analogue to the changes in the volume stream shed from the diverting body.

This test set-up has similar features to dynamic pressure measurement systems

Please note:

- Vibrations caused by the pipeline construction can influence the measurement result.

Ultrasonic measurement

Ultrasonic measurement devices such as those common in gas and water engineering, have not yet been widely used in compressed air systems (see Fig. 6).

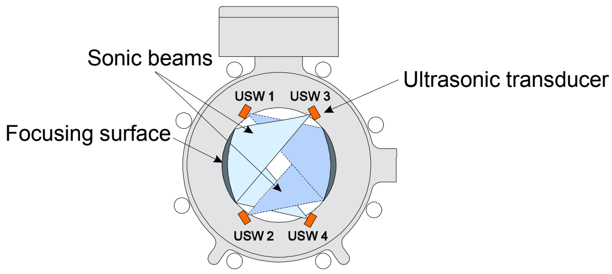


Fig. 6: Ultrasonic flow measurement

Indirect measurements

Whereas the direct measurements already described can be applied centrally and locally to measure the air consumption in companies and to determine the performance data of compressors, indirect measurements with the aid of the compressors serve to determine air consumption values and characteristics of complete compressed air systems.

Digitally recording the load time of compressors

Discontinuously regulated compressors are connected to a data logger which records the full load, no-load and downtime of the compressors (see Fig. 7).

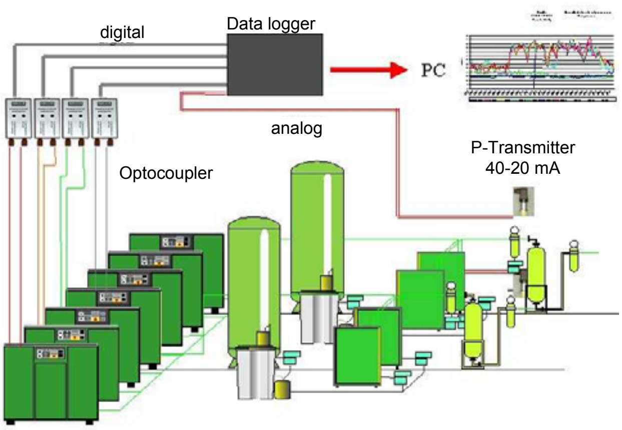


Fig. 7: Digital load time recording

After these data have been entered into a computer, the capacities of the individual compressors and the total air consumption value of the plant can be simulated.

Please note:

- One advantage of this indirect measurement method compared to direct measurements is that it not only provides information on air consumption values but also data on the efficiency and running performance of the compressors.
- Easy to set up.
- Min. measurement phase 1 sec to include consumption peaks.

Other methods

Simple air consumption measurement or load measurements of compressors can also be determined by reading the counter for load operating hours and measuring the time needed to drain the boiler.

Please note:

- Very personnel-intensive and rather vague.

Measuring leaks using pressure measurements

Using a pressure sensor which can be easily integrated into the compressed air system the pressure can be measured and recorded over a longer period of time at short intervals. In order to do so, the system does not have to be separated, a coupler or a one inch connection are sufficient.

The pressure curves are subsequently processed using a mathematical method so that the contractor knows exactly how high the share of leaks and how large the load capacity share (in per cent) is for each individual measurement point. This is done by calculating the pressure losses and their gradients, which result in a perfect curve using a mathematical algorithm. The perfect curve is then compared with the actually measured curves (see Fig. 8).

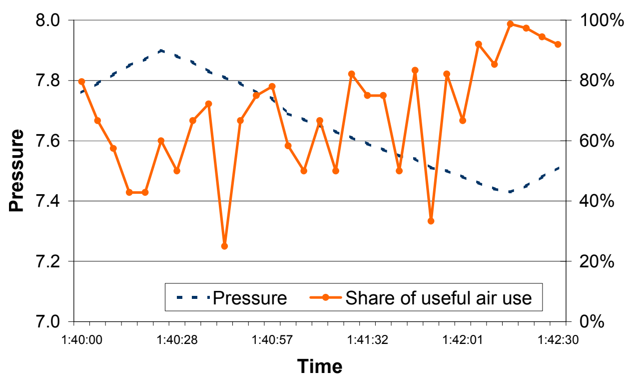


Fig. 8: Leckage measuring during plant operation

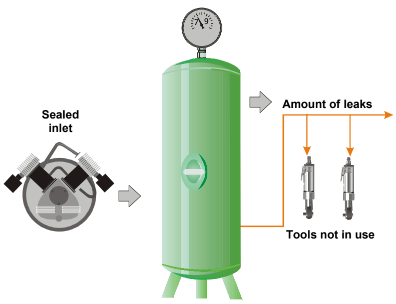
The results are the relative shares of the load capacity or the leaks at each point in time. If the flow rates or compressor. Operating times are recorded at the same time, the relative values can be converted into absolute losses.

Please note:

- The advantage of the method is that it is possible to calculate the leaks during operation. It is therefore particularly suitable for plants operating in continuous production.

Measuring leaks by draining compressed air receiver

A simplified leak measurement is also possible via the air receiver. The pressure here is increased to the maximum required in the system and the time it takes for a pressure drop of 1 to 2 bar due to leaks is measured (see Fig. 9).



$$\dot{V}_L = \frac{V_B \times (p_A - p_E)}{t}$$

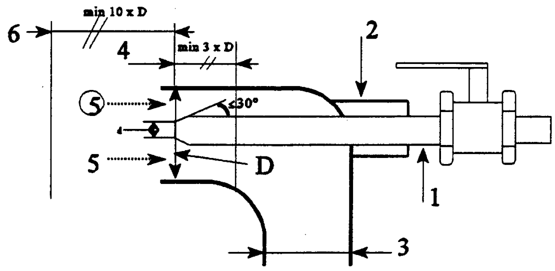
$\dot{V}_L$ = Amount of leaks
V_B = Receiver volume
p_A = Receiver initial pressure
p_E = Receiver final pressure
t = Measuring time

Fig. 9: Measuring leaks by draining compressed air receiver

Air quality measurements under ISO 8573

The manner of taking samples is particularly important for exact air quality measurements.

If there is a turbulent stream in a compressed air pipe and especially if boundary flows are present, the sample must be taken at a point at which it can be ensured that it contains a representative and utilisable mix of all the components of the compressed air. This can only be guaranteed with a so-called isokinetic sample (see Fig. 10).



1. Sampling probe in main pipe
2. Adjustable socket to fix probe
3. Compressed air pipe cross section "D"
4. Screw-in depth min. „3 x D"
5 Direction of flow
6. Min. length of inlet zone = 10 x D

Fig. 10: Isokinetic sampling

For the individual groups of contaminants, e. g.

- ISO 8573-2: Oil aerosol content
- ISO 8573-3: Water content
- ISO 8573-4: Particle content
- ISO 8575-5: Oil vapour and hydrocarbon content
- ISO 8573-6: Gaseous contaminants
- ISO 8573-7: Microbiological contaminants

the measuring systems described in each of the norms should be introduced downstream of the sampling point.

The air qualities are classified under ISO 8573-1.

The "Druckluft Schweiz" campaign (efficient compressed air in Switzerland) motivates and supports the operators of compressed air systems in Switzerland in implementing measures to increase the energy efficiency of compressed air supply. The campaign is led by the Fraunhofer Institute for Systems and Innovation Research and sponsored by the Swiss Federal Office of Energy and the "Electricity Saving Fund" of ewz, the electricity company of the city of Zurich. It is part of the "EnergieSchweiz" Programme. Co-sponsors are the following companies from the compressed air sector: Airtag, Atlas Copco, Donaldson, Dopag, Kaeser, Oetiker, Prematic, Servatechnik, Vektor.

Further information can be found at www.druckluft.ch

This information sheet was compiled as part of the "Druckluft effizient" campaign, which was conducted in Germany between 2001 and 2004. The campaign was carried out by the German Energy Agency (dena), the Fraunhofer Institute for Systems and Innovation Research (Fraunhofer ISI, project management) and the German Engineering Federation (VDMA) with the support of the Federal Ministry of Economics (BMWi) and industrial enterprises (http://www.druckluft-effizient.de/kontakt/partner/industrie.php).

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