APPLICATION NOTE

LEAK MANAGEMENT

OF COMPRESSED AIR SYSTEMS USING ULTRASOUND

STEFFEN MOECK

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CONTENTS

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Foreword

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Intelligent leak management

Reducing energy consumption has a lot of social and political interest as a way of achieving current energy and climate targets. With the implementation of the 2015 EU Energy Efficiency Directive at the latest, companies of a particular size and above are obligated to carry out energy audits or to become certified to standards such as DIN EN ISO 50001 and EMAS.
Compressed air production is an expensive process due to the low level of efficiency, and compressed air losses as a result of leaks provide a lot of potential for increasing energy efficiency. State-of-the-art broadband ultrasound testing technology is an important tool that helps companies to achieve their targets. Smartphone-based devices guide service engineers throughout the entire testing procedure: from regular leak detection and the automatic evaluation of leaks in l/min right through to documentation.

Steffen Moeck

Section 1

Leaks in compressed air systems

Compressed air is used as a source of energy in a lot of industrial sectors. This is due not least to the fact that compressed air is relatively easy to produce and transmit, but the provision of compressed air often involves considerable losses.

Increased efficiency with ultrasound technology

Why locate leaks?

In compressed air systems, a large proportion of the used energy is lost due to areas in the system that are not leak-tight (leaks). The leaks typically occur on couplings, valves, screw connections and flange connections, as well as on damaged hoses or corroded pipelines. The compressors need to be able to compensate for the permanent pressure loss in order to ensure the provision of compressed air. This in turn leads to an increase in operating costs, as the compressors consume more energy and the machine parts wear at a faster rate.

Energy savings & efficiency increases

At 80%, it is the energy costs that make up the largest share of the compressors' life-cycle costs. Measures designed to prevent compressed air losses therefore make a significant contribution to energy savings and efficiency increases. Ultrasound testing technology is used in practical applications for the location of leaks. The air escaping from leaking points create turbulence and therefore ultrasound. The maximum ultrasound is emitted in the direct vicinity of the leak. Ultrasound also disperses with a high degree of directionality. Broadband analysis methods based on flow-acoustics methods are used for the classification and assessment of the total leakage loss.

30% loss

- The production of compressed air accounts for around 10% of global industrial energy consumption
- No system is completely leak-tight – the average loss is around 30%

From detection to report

1

Detection

- Start up the broadband ultrasound testing device and select an accessory
- Visual display of the environment by means of broadband level and spectrogram in the frequency range of 20 to 100 kHz
- Detection possible even in loud industrial environments

2

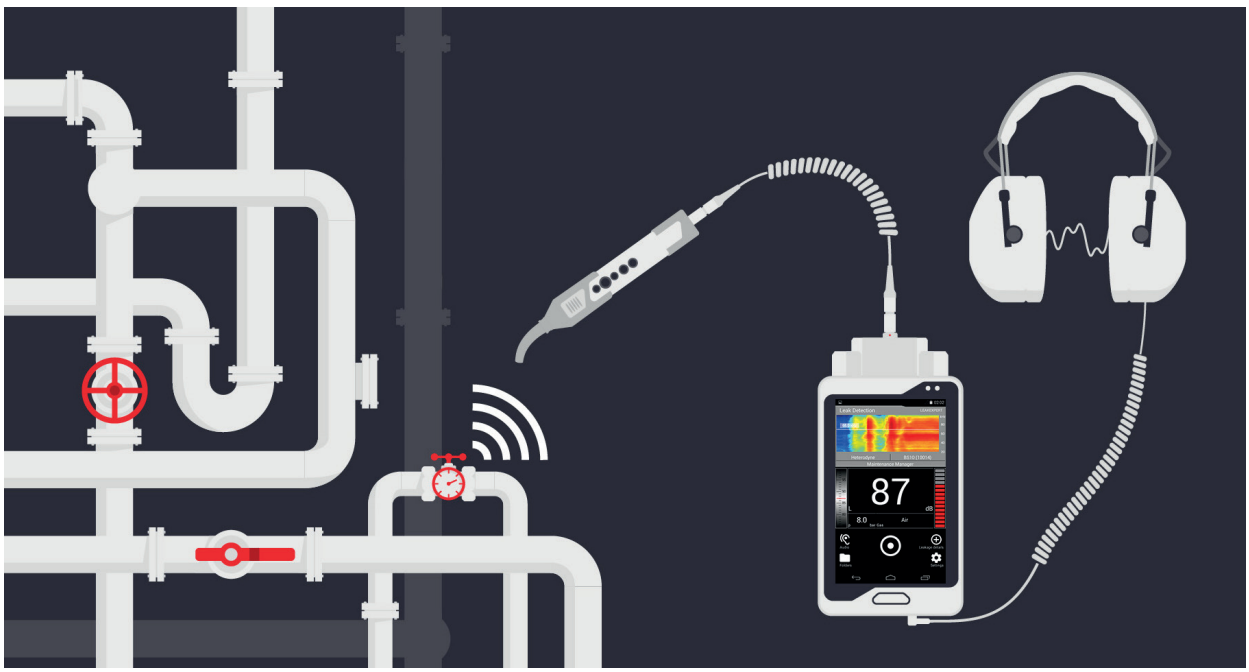
Evaluation

- Observe the defined testing procedures!
- Search for the maximum sound level and initiate leak evaluation at the touch of a button
- Prioritisation of service measures via leak classification (classes 1-5) and leak evluation (in l/min)

3

Documentation

- Add location information
- Add photos, voice memos and comments
- Track the repair status
- Save the documentation as a CSV, PDF or ZIP file in accordance with DIN EN ISO 50001 in just a few clicks



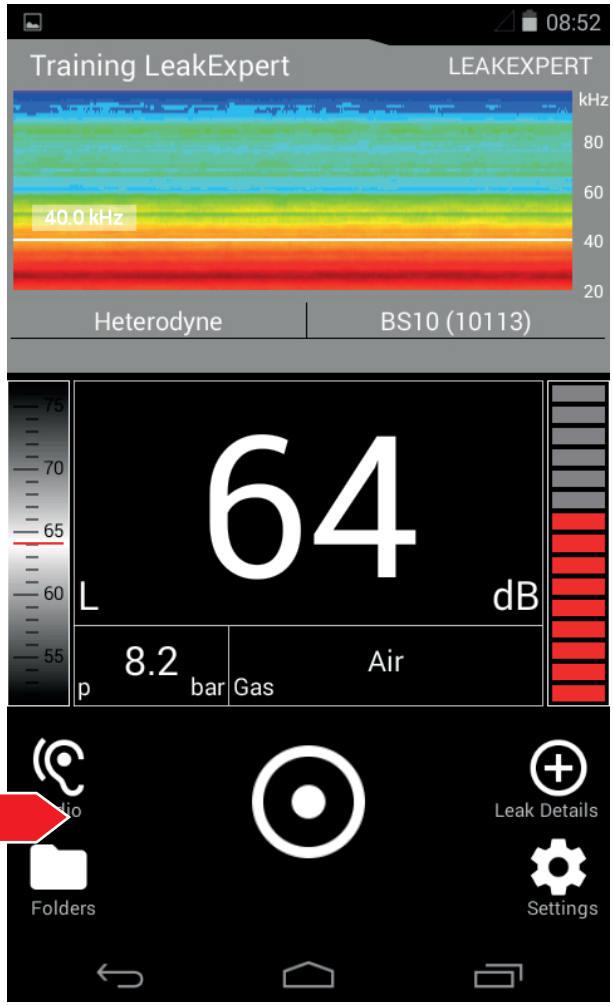
Section 2

Detection

New broadband sensors with sensitive ultrasound microphones make it easier to detect leaks in challenging loud environments. The spectrogram on the display immediately shows the user whether there is any interfering ultrasound and if so, which frequency range it falls into. The user can use the touchscreen to move the audible carrier frequency out of the range of the interfering ultrasound signals.

Leak detection in loud industrial environments

One of the major challenges in the detection of leaks is the high level of noise from machines and systems that is often found in industrial environments. The noise level is present not only in the audible range (audible frequencies up to 16 kHz), but also in the lower ultrasound spectrum in the form of an interference signal (frequency range between 20 and 40 kHz, see spectrogram example 1). The established testing technology works in a narrowband around 40 kHz, which can make it difficult to reliably locate any leaks.

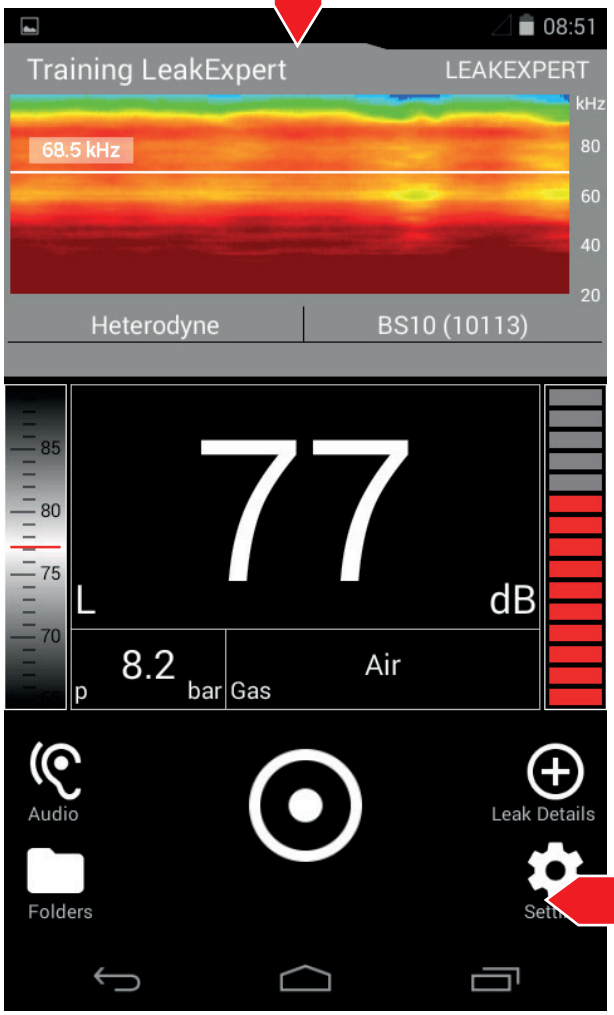


SPECTROGRAM 1
Typical ultrasound environment in a steel factory with ultrasound emissions from the machinery in a frequency range up to approximately 40 kHz.

Level display and spectrogram

On the one hand the intensity of the ultrasonic signals is represented by the levels. For the detected broadband ultrasonic signals in the frequency range between 20 and 100 kHz different broadband levels are calculated, e.g. instantaneous level $L_{(t)}$ or equivalent continuous sound level L_{eq}. Based on the equivalent continuous sound level L_{eq}, the system pressure and the gas type, the leakage losses are calculated in l / min.
On the other hand in the spectrogram the spectral information over time are displayed. The intensity of the ultrasonic signals is represented by the color coding. The color coding can be adapted to individual needs.

Suppressing interference signals

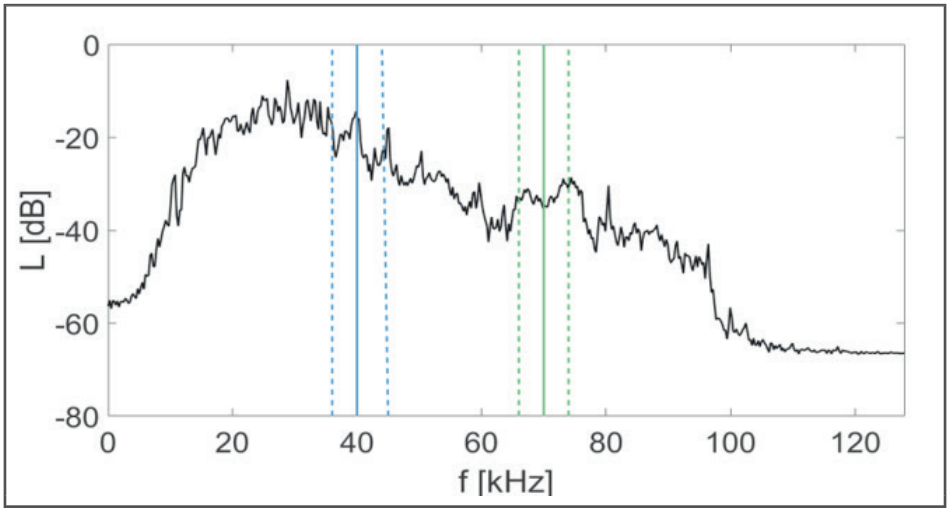


In order to eliminate interference signals during leak detection, the SONAPHONE makes use of one of the benefits of compressed air systems, namely the fact that the generated ultrasound disperses over a large frequency band. The SONAPHONE broadband testing device records the ultrasound signals up to 100 kHz, which is significantly higher than the interference level (see spectrogram example 2). As the information is shown on the device display in the form of a spectrogram, it is easy to distinguish between leaks and interference sources.

SPECTROGRAM 2
Leak on the compressed air line in the same steel factory. The leak was detected above the background noise from the machinery in the production area.

Listening in a narrowband of between 20 ... 100 kHz

In addition to the visual display, leaks can also be located via headphones using the transformed audible signal. When "narrowband listening" to the 40 kHz signal, some leaks may not be registered when scanning the compressed air system due to the close proximity of the interference level and the leak signal.
The use of the heterodyne listening method within the broadband range means that the SONAPHONE is also able to reliably detect leaks using acoustic methods. For acoustic leak location, the desired narrowband can be set to a carrier frequency of 70 kHz, for example. When a leak is located, a signal will be emitted in the audible range exclusively for this narrowband (see example). Leaks can therefore be easily located using the headphones.



Adjusting the carrier frequency from 40 to 70 kHz in order to suppress the interference noise in the audible signal.

"Whereas only one sound can be heard with standard ultrasound testing devices, broadband ultrasound testing technology opens up an entire symphony of flows and airborne sound".

— Prof. Dr. Peter Holstein (Strategic Development, SONOTEC GmbH)

Section 3

Evaluation

Once a leak has been detected, the measurement is then initiated by the service engineer. The leakage loss is calculated and evaluated automatically based on the broadband level and the system pressure.

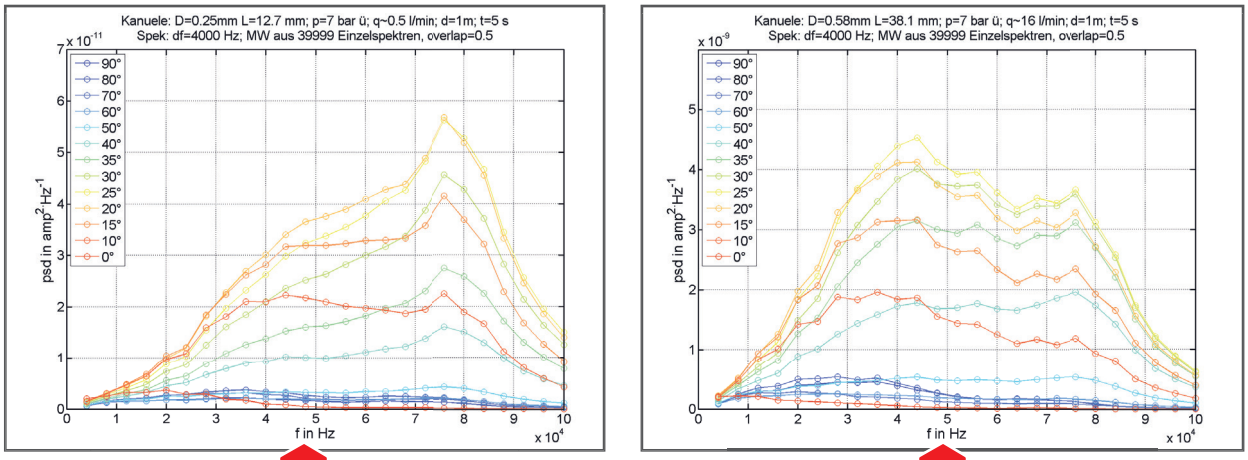
Defined testing procedures for evaluation

Complying with the defined testing procedures is a fundamental part of ensuring that leaks are evaluated with a high level of reliability. The first step involves using a large acoustic horn from further away in order to carry out a rough search for leaking points within the compressed air system. Once an ultrasound source has been identified and isolated, a precise locator is used to locate and record the maximum sound level of the leak at a distance of 5 cm. The leak is then evaluated (l/min) and classified (1-5) using the special LeakExpert app.

The acoustic radiation is highly dependent on the size and shape of the leak, the surface properties of the material, the pressure differential, the escape flow velocity and escape flow profile, as well as the temperature. The measurement distance also plays an important role, as does the measurement angle. A reproducible quantification of the loss volume is therefore only possible when using defined testing procedures.

Classification of leaks

Leaks have a wide variety of spectral signatures. Depending on their characteristics, they can have a stochastic dispersion over the ultrasound range of 20 to 100 kHz. With a narrowband evaluation, e.g. at 40 kHz, there is a risk of incorrect evaluation due to the locally high level values (amplitudes) or signal breaks (see diagram). Quantitative evaluations based on a narrowband frequency may lead to incorrect results. It is therefore recommended that a leak be analysed and evaluated using the broadband level.



Spectral data from 2 exemplary circular leaks and their variation in different measuring angles and diameters
(left: D=0,25 mm, L=12,7 mm, q~0,5 Nl/min; right: D=0,58 mm, L=38,1 mm, q~16 Nl/min)

The digital SONAPHONE device not only makes the most of the benefits of broadband analysis. It also features a specially developed app for leak evaluation. The LeakExpert app guides the user through the testing process. Based on the equivalent continous sound level L_{eq}, the system pressure and the gas type, the individual leakage losses are determined in l / min. The objective here is to classify the leaks based on their size (classes 1-5) in order to establish and prioritise the necessary maintenance measures. The most significant savings potential can be achieved by repairing large leaks; in certain circumstances, it may not be economically viable to repair small leaks.

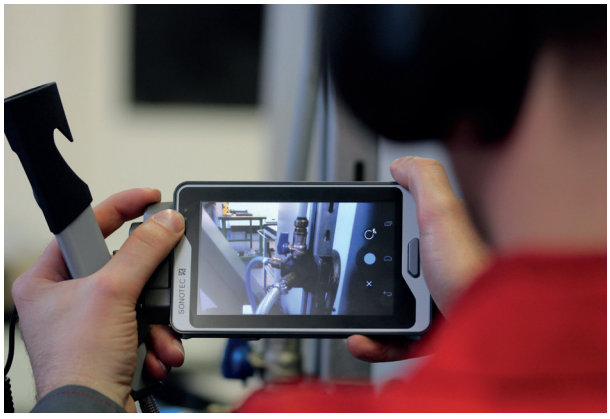
Section 4

Documentation

The digital testing device makes it quick and easy to create reports, which are then used as important decision-making tools for any follow-up measures, as well as for the verification of successful energy management. The documentation regarding the results can be created with a single click, providing the company management with all of the necessary information on leak location and energy loss, as well as photographic documentation and the priority level of the repair work. The systematisation of the leak detection and evaluation work means that the device also helps ensure significant time savings and cost reductions during servicing work.

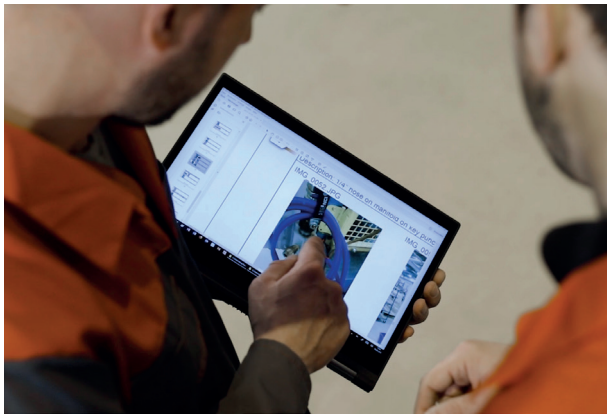
Add additional leak details

- Addition of location information
- Photos and voice memos
- Priority and repair status



Create reports

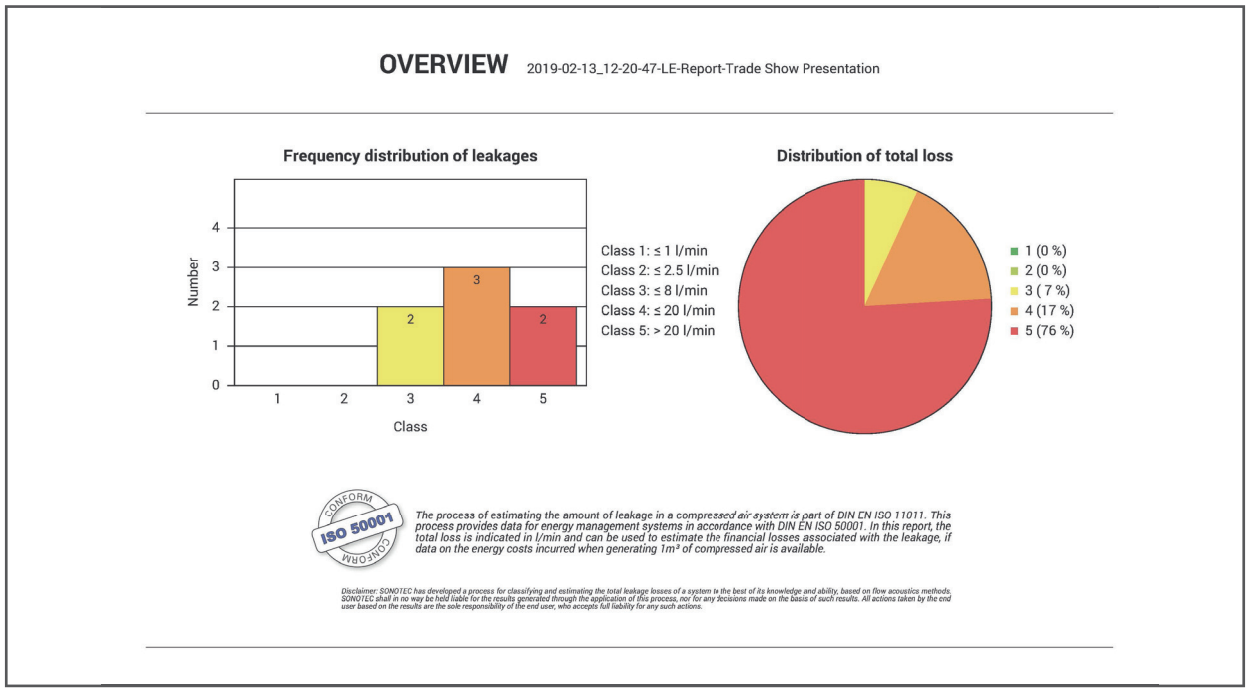
- Data in PDF, ZIP or CSV format
- ISO 50001-compliant
- Time-saving, comparable reports



Reports in accordance with ISO 50001

Companies with an energy management system in accordance with DIN EN ISO 50001 are obligated to record energy-related data and to use this information to develop energy management targets. Compressed air systems usually have high levels of energy consumption and offer a great deal of potential for the systematic and long-term improvement of energy-related performance.

Compressed air leaks are essentially unavoidable, but companies should nevertheless aim to create an optimal system condition and to maintain this by means of regular servicing work. Residual leakage losses of 10% are viewed as economically viable.



The report in the LeakExpert app meets the documentation requirements of DIN EN ISO 50001 and provides reliable information regarding the individual and total leakage loss that has been rectified in the compressed air system. As well as the ultrasound analysis, the SONAPHONE device can also be used to store additional relevant information such as photos and servicing notes. In addition to helping with servicing measures, the report is also used as verification of successful energy management as part of internal and external audits.