Acoustic Imaging Guidebook

An Informative Guide for the Use of Acoustic Imaging Cameras in Industrial Applications


Si2
SPL [dB]: 28.0
Leak size [l/min]: 0.1
Leak detected: Yes
Leak cost [EUR/yr]: 31
High
81

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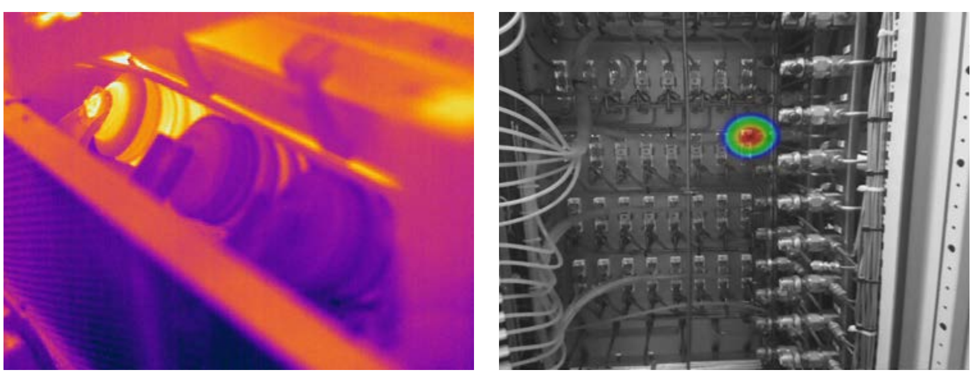
INTRODUCTION

In the past, humans heavily relied on their auditory senses to detect anomalies across various applications. Whether pinpointing gas leaks or identifying partial discharge (PD) in power grids, the human ear proved somewhat efficient, though not without limitations. One major challenge was the ambient noise that often masked the target sounds. Another was the difficulty in accurately identifying the origins of certain sounds.

Recognizing these limitations, and inspired by the ultrasonic echolocation abilities of bats, technological advancements led to the creation of directional ultrasonic microphones. These devices enabled users to focus on specific frequencies, to reduce interference, and accurately pinpoint sound origins through a scanning process. However, it wasn't entirely seamless. The process was time-intensive and demanded rigorous training and experience. Users had to interpret the heterodyned sounds through headphones and recognize the sounds created by leaks, mechanical faults, and various PD types amidst the remaining background noise.



Like thermal imaging (left), acoustic imaging (right) uses the wavelengths emitted by an object to locate and measure defects. Thermal imaging uses invisible light wavelengths, while acoustic imaging uses inaudible sound wavelengths.

The development of acoustic imaging cameras marked a significant improvement. These devices not only identify and visually present the location of leaks and PD on their screens but also intelligently differentiate these ultrasounds from other noise sources. Upon recognizing a sound as either a leak, mechanical issue, or PD, its built-in analysis evaluates the intensity type, and other factors, helping users prioritize the most critical issues.

While today's market offers numerous acoustic cameras, it's the tailored analytics that distinguishes FLIR Acoustic Imaging Cameras. FLIR's decision support empowers users, providing clarity on detected issues, their severity, and prioritizing solutions while lowering the requirement for training and experience.

This guidebook will cover the following topics:

- An introduction to the acoustic imaging camera and its functionality
- The benefits of using acoustic imaging for locating and measuring compressed air leaks, mechanical faults, and partial discharge
- Guidance on selecting the right acoustic imaging camera
- Step-by-step instructions for conducting acoustic imaging inspections.

Ultrasound cameras showing, from left to right: compressed air leak, mechanical fault, and partial discharge.

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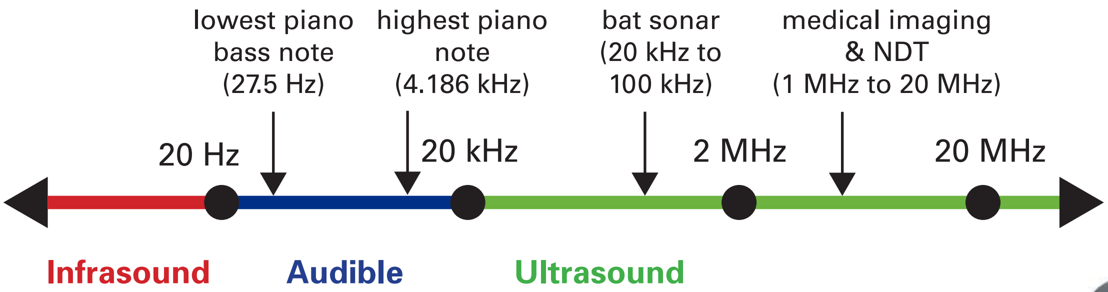
THE ACOUSTIC CAMERA AND HOW IT WORKS

An acoustic imaging camera—also known as an industrial ultrasound imaging camera—is a handheld device that visualizes audible sound and ultrasound sources.

What is ultrasound?
Ultrasound refers to sound waves travelling through the air at frequencies beyond the upper limit of human hearing, which is approximately 20 kHz for healthy young adults.

While not distinct in nature, ultrasounds are distinct from other sound waves in being inaudible to the human ear. The principles governing these waves are consistent across all frequency ranges. Devices harnessing ultrasound can operate within a spectrum starting from 2 kHz and extending to several GHz, hundreds of times greater than the limit of human hearing.



Approximate frequencies of common sounds.

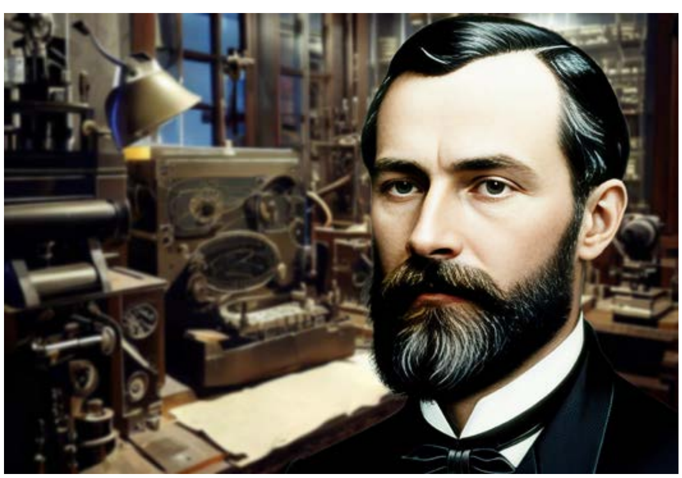
How does an acoustic imaging camera work?

An acoustic imaging camera uses audible and ultrasonic sound waves to detect, locate and measure problems in electrical, mechanical, compressed gas, and vacuum systems that are often not easily detected by traditional methods.

Acoustic imaging cameras use an array of microphones to triangulate the location of sound sources and create a sound visualization map. The loudest noise sources in the map are then superimposed on to a visual camera image.

The basic principle used by most acoustic imaging cameras is beamforming. Beamforming focuses on sound from a specific direction while reducing background noise from other directions. By using this technique, acoustic imaging cameras create a detailed acoustic portrait, allowing users to visualize ultrasonic data even in noisy environments.

Electronic noise filters and AI models are used to further eliminate background noise to provide a clear understanding of the location and size of a noise source, as well as to identify the kind of noise.



The German inventor and physicist Karl F. Braun demonstrated beamforming for the first time in 1905.

3

WHY USE ACOUSTIC IMAGING?

Recalling the evolution of thermal imaging, with the first commercial unit sold in 1965 by what would burgeon into FLIR, a parallel can be drawn with acoustic imaging. Both technologies serve to detect what's typically elusive to human senses, enabling proactive interventions before systems falter or fail.

Early detection of potential failures
Engineering professionals in utility, manufacturing, and oil & gas use acoustic imaging when they need to be guided to the precise source of sound or noise.

Examples of acoustic imaging camera applications range from analysing noise inside automobiles, aircraft, and trains to identifying leaks in compressed, air, gas, steam, and vacuum systems.

Additionally, acoustic imaging cameras can detect and pinpoint partial discharge conditions in components like insulators, transformers, switch gears, and high-voltage (HV) power lines.

Acoustic imaging finds leaks more accurately than traditional methods
FLIR Si-Series acoustic imaging cameras use machine learning to distinguish other characteristics of the sound pattern created by leaks from the background noise. It is the same way you distinguish between a harmonica and a bell playing the same note. Combining that with the ability to actually see the leak on a screen allows technicians to pinpoint leak locations almost instantly.

Modern thermal and acoustic imaging cameras are small, lightweight and easy to use.

When pressurized air escapes out into the atmosphere, finding it using any other method than ultrasound can be difficult. With an advanced ultrasonic system, it can be easy. Background noise can very effectively be filtered out, which means that a good ultrasonic solution like the FLIR Si-Series also works in noisy conditions.

Acoustic imaging pays for itself

The financial rationale for proactively addressing leaks and PD is straightforward: it proves to be a far more cost-effective and less disruptive approach to identify and address issues, strategically plan scheduled downtime, and undertake necessary repairs and replacements for insulators and electrical components.

FLIR leak detection acoustic imagers can calculate your energy savings while you're still in the field, so you can instantly see how soon you'll get a return on your investment. While a FLIR partial discharge acoustic imager employs artificial intelligence (AI) to evaluate the severity and type of partial discharge occurring. The AI component also distinguishes between various forms of partial discharge such as arcing, corona, and surface discharge. Each type has distinct characteristics and implications for the integrity of electrical systems.

FLIR Si2 leak detection acoustic imager in the field calculating leak size and cost of leak.

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USING ACOUSTIC IMAGING FOR INDUSTRIAL APPLICATIONS

Acoustic imaging cameras for industrial applications are powerful and non-invasive tools for monitoring and diagnosing the condition of electrical and mechanical installations and components. With an acoustic imaging camera, you can identify problems early, allowing them to be documented and corrected before becoming more serious and more costly to repair.

Uses of acoustic imaging:

Electrical faults
- Partial discharge
- Corona

Mechanical
- Rotating equipment
- Belts, bearings, and conveyors

Air and gas leaks
- Compressed air
- Steam systems
- Argon, helium, methane, CO_2, and more...

In this section, we explore several ways in which acoustic imaging cameras can be applied across various industrial contexts—specifically, their applications can be categorized into 'leak detection' (LD) and 'partial discharge' detection (PD). Let's delve deeper into these categories to understand their significance and application in industry settings.

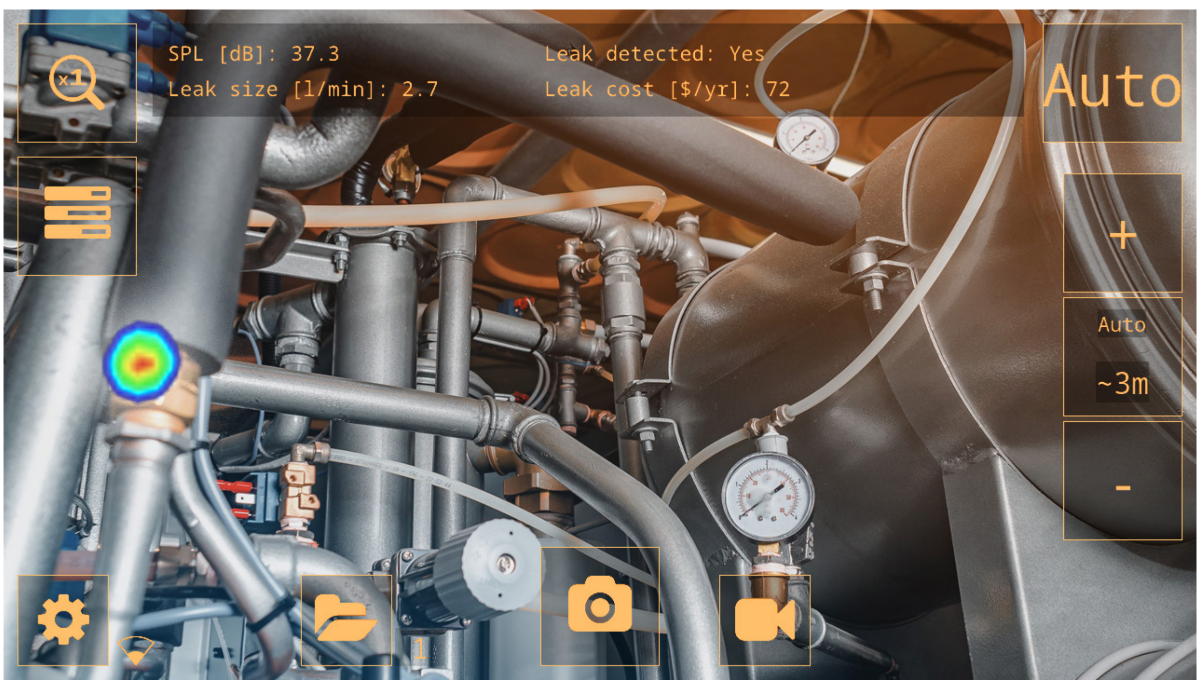
The FLIR Si2 camera detects, assesses, and measures electrical faults, mechanical issues, and air and gas leaks.

Find compressed air, vacuum, CO_2, and other gas leaks
High energy costs can have a huge impact on a company's bottom line, especially for manufacturers who rely on compressed air and vacuum systems or use gases such as carbon dioxide in their production process. When these systems leak—it's like money seeps out along with the air. So being able to see the system leaks, pinpoint the source, and even calculate the energy loss is a game changer.

The FLIR Si-Series are acoustic imaging cameras for leak detection: your perfect solution for locating pressurized leaks in compressed air systems, faults in vacuum systems, and speciality gas leaks. Whichever model in the Si-Series you choose, these lightweight, one-handed cameras can help you identify efficiency losses and potential failures up to 10 times faster than traditional methods, and with minimal training.

Examples of leaks in systems that can be detected with acoustic imaging:

- Compressed air leaks
- Compressed gas leaks including CO_2, helium, ammonia, hydrogen, methane, nitrogen, and argon
- Vessel testing such as shipping and other sealed container seal testing
- Steam leaks in building heating and power generation systems
- Vacuum systems

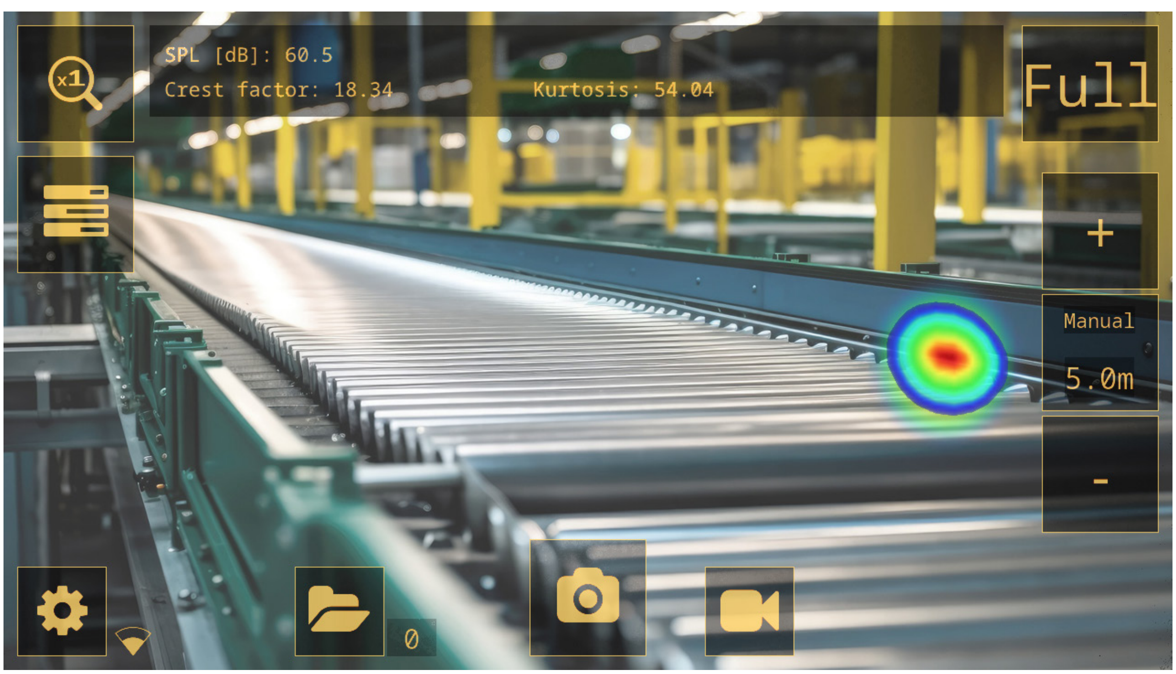


The FLIR Si2 camera detecting, locating, and calculating the size and cost of a leak.

Acoustic imaging for mechanical fault detection
Acoustic imaging for mechanical fault detection is an innovative technique that utilizes sound-based technology to detect, localize, and analyze faults in mechanical systems. This approach is particularly valuable for preventive maintenance and condition monitoring, as it allows for early detection of anomalies before they evolve into serious failures.

By pinpointing the exact location of faults, acoustic imaging reduces the need for extensive manual inspections and disassembly, saving time and labor costs. Additionally, early detection of faults helps prevent catastrophic failures, extending the lifespan of equipment and enhancing overall operational efficiency.

Examples of mechanical faults that can be detected with acoustic imaging:
Industrial Rotating Machinery, such as:
- Bearings
- Rollers
- Conveyors
- Pulleys
- Compressors
- Motors

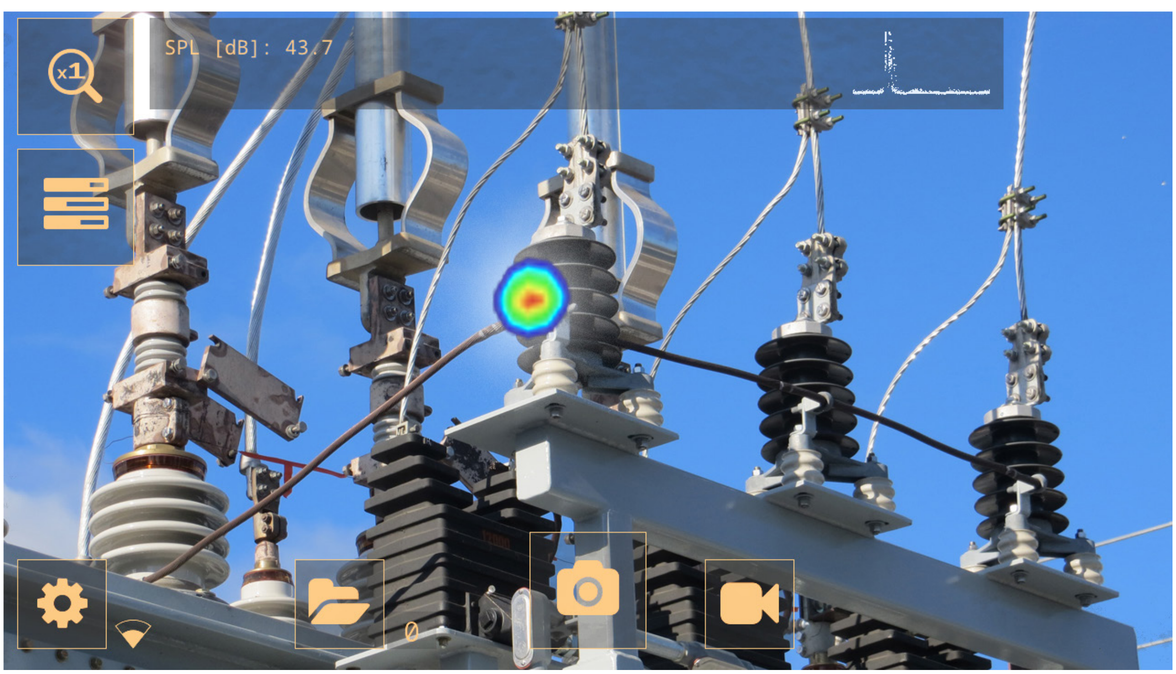


The FLIR Si2 camera detecting and locating a mechanical fault.

Keep your high-voltage equipment in peak condition
With high-voltage (HV) electrical equipment, partial discharge (PD) represents an invisible threat that can wreak havoc on critical infrastructure. If left undetected, PD—such as arcing, corona, and surface discharge—can run the risk of causing power interruptions, leading to emergency repairs. These repairs can amount to millions of dollars for remote locations and are many times more costly than planned repairs.

This non-invasive method allows for real-time monitoring, enabling maintenance teams to identify PD issues early, before they escalate into serious problems. By providing precise localization of PD activity, acoustic imaging reduces the need for extensive manual inspections and minimizes the risk of unplanned outages. This proactive approach not only ensures the reliability and safety of electrical infrastructure but also leads to substantial cost savings by preventing expensive emergency repairs and reducing operational downtime.

Examples of partial discharge that can be detected with acoustic imaging:
- Corona discharge on high-voltage power lines
- Surface discharge on insulators and bushings
- Internal discharge within transformers and switchgear
- Tracking and arcing in electrical connections
- PD in cable joints and terminations



The FLIR Si2 camera detecting and locating partial discharge.

5 CHOOSING THE RIGHT ACOUSTIC CAMERA

Six key requirements are important to evaluate when investigating a suitable acoustic imaging camera.

1. **Ergonomics**
2. **Workflow simplicity**
3. **Decision support**
4. **Dynamic performance**
5. **Software that works the way you do**
6. **Intelligent analytics**
7. **Tool usability**

1 ERGONOMICS

For safe operation of any handheld tool, it is imperative that scanning must be performed using one hand so that the other hand may be used to hold on to railings or be available to adjust safety equipment like hardhats or glasses. A free hand also ensures easy documentation via touchscreen to ensure accurate identification of targets and speedy reporting.

2 WORKFLOW SIMPLICITY

Most acoustic imaging camera users capture images to be transferred and stored to their company's servers for use in work order creation, training, and issue trending. Image transfer should be easy with automatic wireless upload of imagery to an online data portal. USB transfer should be available, but due to increasing recognition of cyberattack vulnerabilities, USB or SD card data transfer is becoming a high risk activity.

Data sharing within inspection teams and across the organization should also be supported, while tool fleet management provides supervisors the ability to locate underutilized tools or ensure equipment has been updated, which in return maximizes return on investment and helps to justify additional tool purchases or inspection program expansion.

Finally, getting data to a database of record is key to futureproofing the acoustic inspection program.

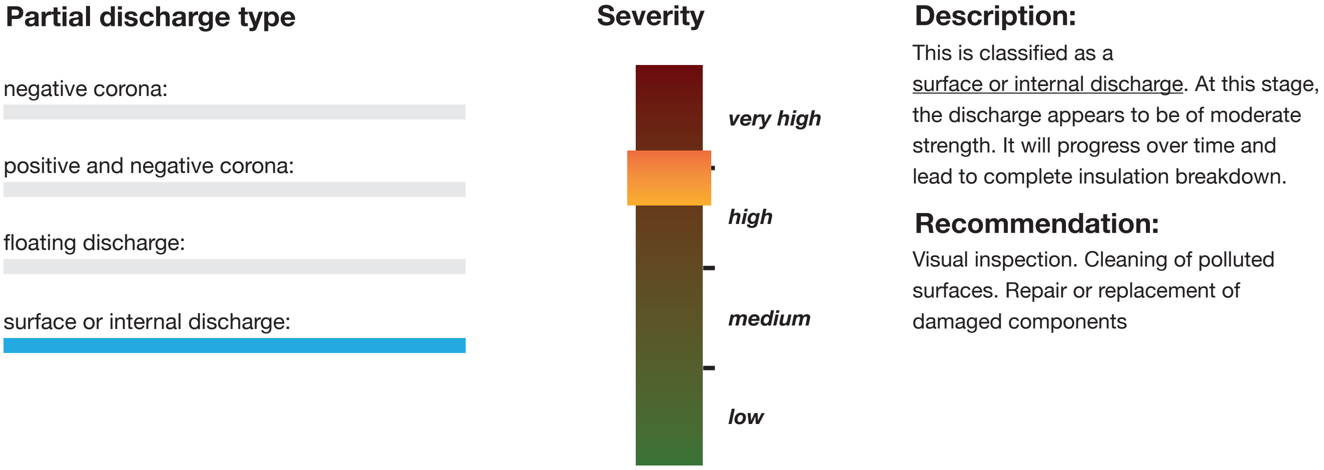
3 DECISION SUPPORT

In-tool and in-software decision support is critical to overcome gaps in user experience and training and enable new tool users to effectively improve plant productivity while reducing safety hazards.

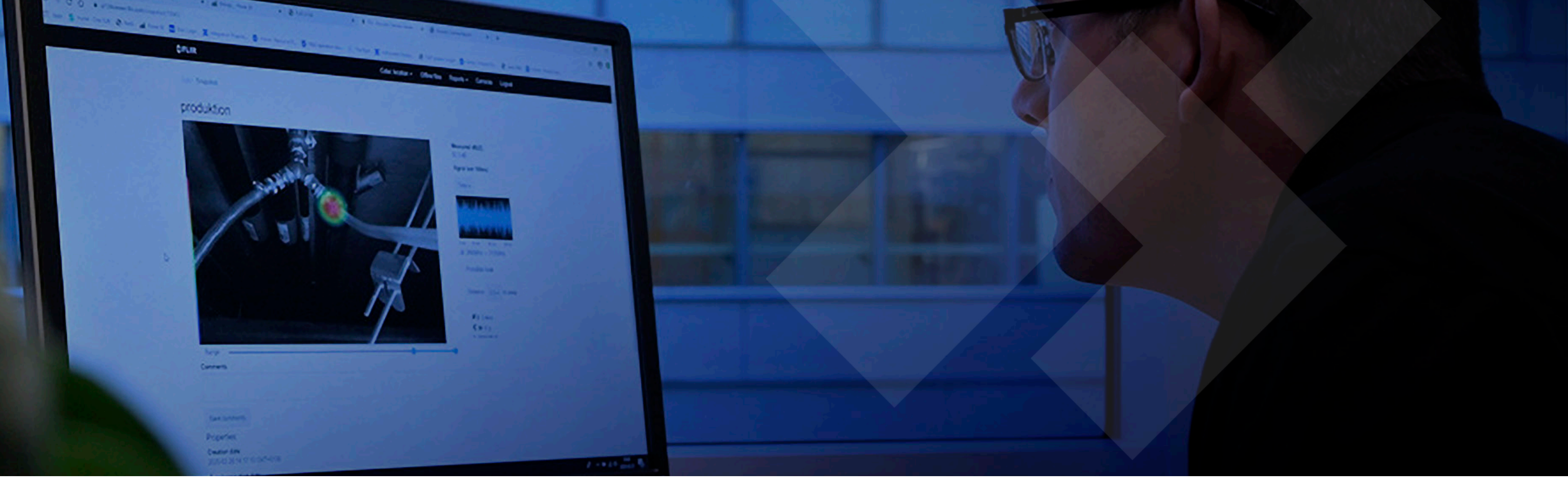
Quantification of compressed air and industrial gas leaks, including estimated leak cost, helps maintenance departments prioritize repairs and makes it easy for maintenance managers to point to the impact their team is having on a company's bottom line.

Providing mechanical noise analysis tools beyond loudness provides the ability of inspectors to determine if a bearing or other piece of rotating equipment is degrading over time.

Partial discharge issues can be difficult for new inspectors to diagnose with traditional techniques, leading to uncertainty or lack of action on corrective action. Acoustic imagers that not only locate partial discharge issues, but also classify as to type, assess the issue severity, and provide a clear course of corrective action remove that uncertainty and enable maintenance managers to make quick, effective decisions to reduce maintenance costs or even avoid catastrophic equipment failure.



PD decision support includes PD type & confidence along with PD Severity Assesment



4 DYNAMIC PERFORMANCE

Depending on the asset, component, or gas, small issues can sometimes be as critical as big issues. However, inspectors typically don't perform a large leak survey and then immediately walk the same path looking for small leaks: they want to see all the leaks in the same inspection at the same time.

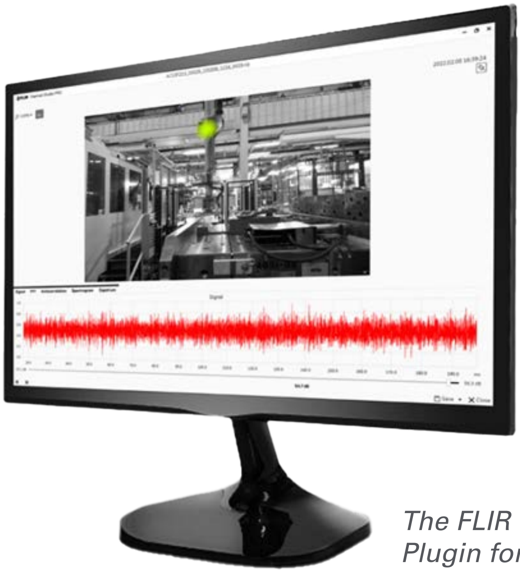
This is why it is important to be able to scan for both large and small leaks, mechanical noise, or partial discharge without changing modes, which interrupts and doubles inspection times.

5 SOFTWARE THAT WORKS THE WAY YOU DO

Software needs vary. Some users prefer as much as possible to be built into the tool, while others want analysis and reporting to be simple, without cost, and without computer installation. Still more need on-premises software that does not connect to any 3rd party cloud service provider due to restrictive IT policies.

Another factor may be the desire to combine your ultrasonic imaging and thermography inspection into one software package, one report, or perhaps even on the same page so you can directly compare an issue using two different inspection modalities.

Whatever your situation, it is important to choose a system that meets the right requirement for your business and is capable of growing with you as your predictive maintenance program matures.



The FLIR Si-Series Plugin for FLIR Thermal Studio

6 INTELLIGENT ANALYTICS

Legacy ultrasound technology detects issues through frequency tuning, but there is another, more effective technology that makes use of the advances that have recently taken place in computing power and machine learning. FLIR acoustic imaging cameras utilize machine learning to distinguish the characteristics of sound other than frequency in much the same way you can distinguish between the sounds created by two different musical instruments playing the same note (i.e., frequency). For the FLIR Si-Series it is easy to distinguish between an air leak and background machine noise because those two sources sound as different as a bell compared to a harmonica.

Furthermore, machine learning makes operation of the tool a great deal simpler for partial discharge analysis. Experts in ultrasound defect recognition have “tagged” the data, providing guidance on issue severity and appropriate corrective action. As a result, you get the benefit of their expert experience without undergoing days of training and hundreds of hours of practice. This is similar in many ways to the language translation apps on your smartphone which translate text for you without requiring you to spend years learning a new language.

7 TOOL USABILITY

Tool ruggedness, dust and moisture resistance, and ability to quickly swap out batteries are key components that differentiate a tool that is fit for purpose from one that isn’t.

Look for IP54 ingress protection rating for dust and moisture, drop testing ruggedness testing and intelligent batteries that are easily replaceable in the field.

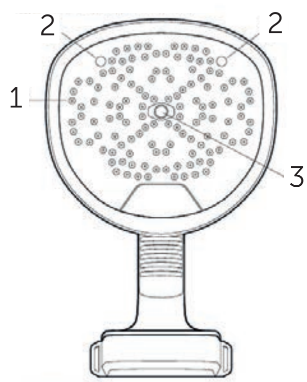
Si2 rechargeable battery

6

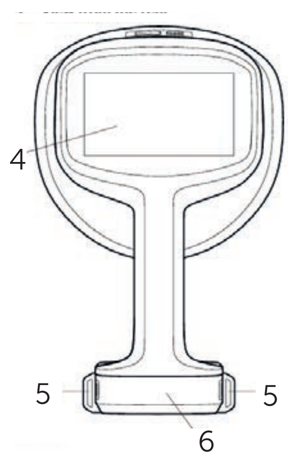
HOW TO CARRY OUT ACOUSTIC IMAGING INSPECTIONS

So, the acoustic imaging camera has been delivered and the inspecting can begin. But where do you start? In this section of the guidebook some acoustic imaging methods will be present in order to get you going.

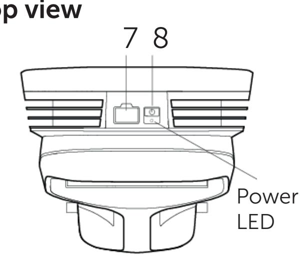
Front view



Rear view



Top view



General setup

Unbox and familiarize Take a few minutes to get to know your acoustic imaging camera.

Anatomy of the FLIR acoustic imaging camera

1. Microphone array: Detects sounds your ears can't hear in noisy environments.

2. LED lamps: Illuminate dimly lit areas with built-in LED lights.

3. Digital camera: Camera

4. LCD screen: The colour touchscreen interface is where you personalize preferences, save files, and make selections.

5. Neck strap attachment panels: Attach the provided neck strap for easier and safer handling.

6. Battery cover: Located at the back, towards the bottom. Your camera comes with a fully charged battery.

7. USB port: Use a USB-C connector to transfer images and videos to your computer.

8. On/Off button: Push and hold for 2 seconds to turn it on. To turn it off, push once and tap "OK" on the screen.

Camera setup

Initial setup

You can set up the camera to upload images to the FLIR Acoustic Camera Viewer. If automatic upload is enabled, your Si-Series camera will automatically send new snapshots and videos to your FLIR Acoustic Camera Viewer account. You can also upload files manually. In order to upload snapshots and videos, you must connect the camera to the internet and pair the camera with a FLIR Acoustic Camera Viewer account.

Mode selection

Choose the appropriate mode from the settings:

- Leak Detection: Detects pressurized gas leaks and vacuum leaks
- Partial Discharge: Detects electrical partial discharges
- Mechanical Faults: Identifies mechanical faults in bearings and other components

Filter settings

The camera's filters are like a fine-tuned radio, zeroing in on the sounds you care about and tuning out the background noise. Each filter narrows the frequency range, so you only see the interesting stuff on the screen. Say goodbye to distractions and hello to pinpoint precision!

- Automatic filter selection: The Auto filter is like having a personal assistant for your inspections. It automatically picks the perfect filter for whatever you're dealing with, cutting out industrial noise by considering the environment.

- Manual filter selection: In Mechanical mode, you select the filter manually. In the Leak detection and Partial Discharge modes, manual filter selection can be useful if there are significant noise disturbances in the environment. Keep in mind that the most suitable filter may depend not only on the source of interest, but also on the background noise.

Filters: fine-tune your inspections

- Auto: Automatically selects the best filter.
- Norm (10 kHz to 65 kHz): Removes very low and high frequency background noise in PD and Mechanical modes.
- High (20 kHz to 65 kHz): Filters most background noise, good detection range.
- Ultra (30 kHz to 130 kHz): Best for strong background noise conditions over short distances.
- Full (2 kHz to 130 kHz): Uses full range, intended for experienced users.

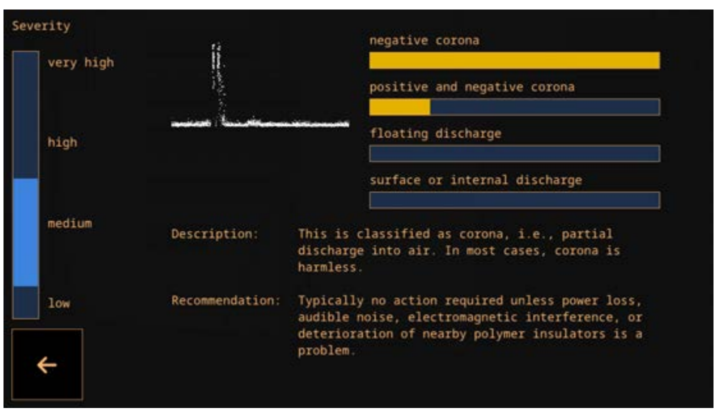
Performing the inspection

1. Scanning: Get ready to find those elusive faults with ease.

- Multi-source Mode: Use this mode to scan large areas quickly and identify multiple sound sources.
- Single-source Mode: Switch to this mode for detailed inspection of detected sound sources.
- Aim the camera at the target area (e.g., pressurized gas systems, electrical components, mechanical parts) and move smoothly across the target.

2. Capture data: Document your findings with just a tap.

- Snapshots: Tap the Capture button to take a snapshot of the current image and acoustic image.
- Videos: Tap the Record button to start recording and tap again to stop.
- Annotations: Add text annotation comment via touchscreen keyboard or QR code scan.



This image shows the results of a partial discharge inspection displayed by the camera after the analysis of a snapshot.

3. Review results: Analyze your data to pinpoint issues and their severity.

- Leak detection: The camera displays leak size and cost estimates.
- Partial discharge: The camera displays a Phase-Resolved Partial Discharge (PRPD) pattern, analysis results, and recommendation.
- Mechanical faults: The camera displays Sound Pressure Level (SPL), Crest factor, and Kurtosis. Compare these metrics with healthy components.

Results cheat sheet

Sound Pressure Level (SPL): Measures the strength of a sound. Higher SPL indicates potential faults.

Mechanical fault analysis results

- Crest factor: Ratio of peak amplitude to RMS value. Healthy bearings ≈ 5. Faults developing if ≥ 6.
- Kurtosis: Measures the distribution of sound signal samples. Healthy bearings ≈ 0. Faulty bearings ≥ 2.
- Fault condition: Qualitative assessment of mechanical faults

Partial discharge fault analysis results

- PRPD pattern: Phase-Resolved Partial Discharge pattern for identifying discharge activity.
- Types: Negative corona, Positive & Negative corona, Floating discharge, Surface/Internal discharge.
- Severity bar: Indicates the severity of detected partial discharge.
- Description: Type of partial discharge.
- Recommendation: Suggested actions based on severity.

Leak detection analysis results

- Leak detected: Indicates a detected leak
- Leak size: Estimated size of the detected leak.
- Leak cost: Estimated annual cost of the detected leak.

Reporting and analysis

Data management:

- **Option 1** Upload to FLIR Acoustic Camera Viewer: Connect the camera to the internet and pair it with your FLIR Acoustic Camera Viewer account. Upload snapshots and videos to the cloud service for further analysis and reporting.
- **Option 2** Export to USB Memory Stick: Use the supplied USB memory stick to transfer files. Insert the USB stick into the camera and follow the on-screen instructions to complete the transfer.

Using FLIR Acoustic Camera Viewer:

- Access: Log into your FLIR Acoustic Camera Viewer (acousticviewer.flir.com) account via a web browser on your computer or mobile device.
- Analyze: Use the Viewer to further analyze detected leaks, partial discharges, and mechanical faults. The Viewer allows for detailed evaluation and helps pinpoint the exact location of issues.
- Organize: Create folders to keep images and videos organized. Use annotations to add notes about findings, timing, or other useful information.

Using FLIR Thermal Studio:

- Import files: Open files (.nlz) that you have downloaded from the FLIR Acoustic Camera Viewer or imported from a USB memory stick.
- Analyze: View and analyze snapshots and videos. The software displays application-specific analysis results and allows for setting adjustments.
- Reporting: Use predefined acoustic reporting templates or create custom templates for generating detailed inspection reports.

***Si2-Pro** for partial discharge, pressurized leak, and mechanical fault detection and analysis*

***Si2-LD** for pressurized leak detection and mechanical fault detection and analysis*

***Si2-PD** for partial discharge detection and analysis*

***Si124-LD Plus** for compressed air leak detection and analysis*

YEAR 2 FULL PRODUCT WARRANTY*

YEAR 10 DETECTOR WARRANTY*

** After product registration on www.flir.com*

For technical or sales support, please visit:
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