FLYABILITY

The Last Guide to NDT (Non-Destructive Testing) You'll Ever Need!

- What is NDT?
- The 8 Best Types of NDT Methods
- How Drones are Increasing Savings and Safety in NDT?
- Find out in this in-depth guide

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NDT (NON-DESTRUCTIVE TESTING) REFERS TO AN ARRAY OF INSPECTION TECHNIQUES THAT ALLOW INSPECTORS TO COLLECT DATA ABOUT A MATERIAL WITHOUT DAMAGING IT.

NDT stands for Non-Destructive Testing. It refers to an array of inspection methods that allow inspectors to evaluate and collect data about a material, system, or component without permanently altering it.

NDT may also be called:

- **NDE**
  Non-destructive examination or evaluation
- **NDI**
  Non-destructive inspection

In the field, NDT is often used as an umbrella term to refer to non-destructive inspection methods, **inspection tools**, or even the entire field of non-destructive inspections.

For commercial application, the goal of NDT is to ensure that **critical infrastructure** is properly maintained in order to avoid catastrophic accidents.

While NDT methods are typically associated with industrial use cases, like inspecting weak points in a boiler used at an oil refinery, uses in medicine are actually some of the most common. For example, an expecting mother getting an ultrasound to check on the health of her baby would be considered an NDT use case, as would getting an X-ray or MRI to learn more about an injury.

But it's important to note that NDT does not necessarily require the use of special tools, or any tools at all.

For instance, when inspectors in industrial settings review the outside of a pressure vessel with their naked eye, that would fall under the NDT designation, since they are collecting data on the status of the boiler without damaging it. On the other hand, using a sophisticated tool like an ultrasonic sensor to look for defects in a certain material or asset would also be called NDT.

Regardless of the specific use case, the underlying commonality among all these examples is the collection of data in a non-intrusive manner.

Here is a table of contents to help you navigate all the information related to NDT contained within this article:

WHAT IS NDT - A CLOSER LOOK

We've already covered what NDT stands for and how the phrase is used in the field. Now let's dive in and look more closely at some of the details that govern the world of NDT.

DESTRUCTIVE VS. NON-DESTRUCTIVE TESTING

Before we go any further, we should clarify that there are some methods used to test materials that alter—or even damage and destroy—the materials tested.

The use of these methods is called Destructive Testing.

In Destructive Testing, a piece of the material might be scraped away for analysis or altered in some way onsite.

Here are some examples:

- **Macro Sectioning**
  Macro sectioning tests a small section of a welded material by polishing and etching it for examination.
- **Tensile Testing**
  Also called tension testing, this is a destructive testing technique that uses controlled tension applied to a sample material to see how it reacts. Tension could be applied to test certain loads or conditions, or to test a material's failure point.
- **3 Point Bend Testing**
  3 point bend testing examines the soundness and flexibility (or ductility) of a material by taking a sample of it, called a coupon, and bending it in three points to a specified angle.

NDT CODES AND STANDARDS

NDT techniques can be used for all kinds of inspections. But some of the most important types of NDT inspections are of assets like boilers and pressure vessels, which could be incredibly dangerous if not properly maintained.

Because proper maintenance of these assets is so important for the safety of those working nearby (or even at a distance, when it comes to nuclear power plants), most countries have laws requiring companies to adhere to specific inspection codes and standards when conducting inspections.

These standards and codes typically require inspections to be conducted periodically following specific guidelines. For the most assets that present the greatest risk, these inspections must be both conducted by a certified inspector and approved by a certified witness working for a formal inspection body.

Here are the most commonly followed organizations in the world for creating NDT standards and codes:

- **API** (American Petroleum Institute)
- **ASME** (American Society for Mechanical Engineers)
- **ASTM** (American Society for Testing and Materials)
- **ASNT** (American Society For Nondestructive Testing)
- **COFREND** (French Committee for Non-destructive Testing Studies)
- **CSA Group** (Canadian Standards Association)
- **CGSB** (Canadian General Standards Board)

WHY USE NDT

Here are the top reasons NDT is used by so many companies throughout the world:

- **Savings**
  The most obvious answer to this question is that NDT is more appealing than destructive testing because it allows the material or object being examined to survive the examination unharmed, thus saving money and resources.
- **Safety**
  NDT is also appealing because almost all NDT techniques (except radiographic testing) are harmless to people.
- **Efficiency**
  NDT methods allow for the thorough and relatively quick evaluation of assets, which can be crucial for ensuring continued safety and performance on a job site.
- **Accuracy**
  NDT methods have been proven accurate and predictable, both qualities you want when it comes to maintenance procedures meant to ensure the safety of personnel and the longevity of equipment.

"Nondestructive testing is the life blood of a well-run facility. NDT techniques and repeatable results depend on highly trained technicians with experience and integrity. Industrial NDT methods and interpretation of results are performed by certified professionals. Not only does the technician need to be certified in a specific NDT method, but they also need to know how to operate the equipment being used to gather data. Understanding equipment capabilities and limitations is the difference between making an accept or reject determination."

- Jason Acerbi,
General Manager at MFE Rentals,
"Your One Stop Inspection Source"

THE 8 MOST COMMON NDT METHODS

There are several techniques used in NDT for the collection of various types of data, each requiring its own kind of tools, training, and preparation.

Some of these techniques might allow for a complete volumetric inspection of an object, while others only allow for a surface inspection. In a similar way, some NDT methods will have varying degrees of success depending on the type of material they're used on, and some techniques—such as Magnetic Particle NDT, for example—will only work on specific materials (i.e., those that can be magnetized).

Here are the eight most commonly used NDT techniques:

- **Visual NDT (VT)**
- **Ultrasonic NDT (UT)**
- **Radiography NDT (RT)**
- **Eddy Current NDT (ET)**
- **Magnetic Particle NDT (MT)**
- **Acoustic Emission NDT (AE)**
- **Dye Penetrant NDT (PT)**
- **Leak Testing (LT)**

VISUAL TESTING (VT)

01

A visual inspection is an inspection of an asset made using only the naked eye.

This kind of inspection does not necessarily require any special equipment, but it does require special training so that the inspector knows what to look for as they visually review the asset.

Visual inspections have traditionally taken place with an inspector walking around or inside of an asset like a boiler, visually reviewing every single part of it.

But new Remote Visual Inspection (RVI) tools have been allowing inspectors to collect visual data without having to be physically present, changing the approach to how they conduct visual inspections. In fact, some RVI tools are so good that inspectors can rely almost entirely on the visual data they collect for the purposes of their inspection.

This guide covers details about visual inspections, the industries that use visual inspections, other types of inspection techniques that inspectors use, and also includes information on how drones can help with visual inspections.

Here is a table of contents to help you navigate the different topics we're covering here

WHAT IS THE GOAL OF A VISUAL INSPECTION?

Visual inspection is one of the oldest and most trusted ways to evaluate the condition of an asset as part of the overall maintenance process.

The goal of a visual inspection is to find anything that might be wrong with the asset which could require maintenance.

For example, if an inspector is conducting a visual inspection of the inside of an **industrial boiler**, they might be looking for:

- **Cracks or buckling in the welds that hold the boiler together**
- **Corrosion on the sides of the boiler**
- **Leaks or other issues with the integrity of the boiler's walls or floor**
- **Issues with any of the supporting equipment that helps make the boiler run**

The primary goal of finding these issues is to fix them before they get worse.

In commercial inspections like this, missing critical issues in an asset—like a crack in the side of a boiler, for example—could result in a serious accident. And that's why visual inspections of critical assets like boilers and pressure vessels are typically conducted only by licensed inspectors who operate according to very strict guidelines, usually mandated by law.

WHICH INDUSTRIES USE VISUAL INSPECTIONS?

Visual inspections are used in every industrial industry.

The reason for this is simple—reviewing an asset with the naked eye is one of the most simple and powerful ways to find flaws in it.

Here are just some of the sectors that use visual inspections as part of their regular maintenance processes:

- **Oil & Gas**
- **Power & Utilities**
- **Chemicals**
- **Mining**
- **Maritime**
- **Food & Beverage**

If the industry in question uses any kinds of large assets that require regular inspections, the go-to approach inspectors will take when starting their inspection is a visual inspection.

REMOTE VISUAL INSPECTION (RVI)

As we mentioned at the start of this article, visual inspections don’t have to be conducted in person.

As the quality of cameras and robotics continues to improve, inspectors are using RVI tools more and more to collect visual data remotely instead of in person.

Inspectors usually want to use RVI instead of conducting a visual inspection in person because the area that needs to be inspected is dangerous to enter or difficult to enter, or both.

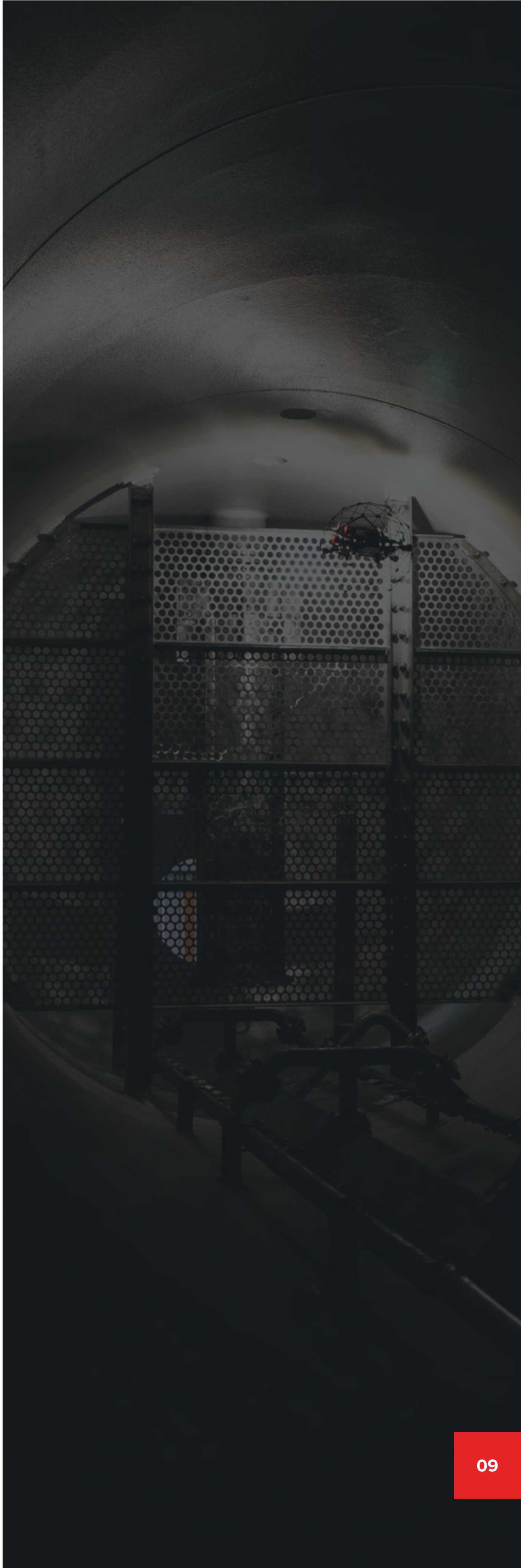
For example, walking into a mine shortly after a blast is so dangerous that it simply isn’t done. But a drone can be used to survey the area remotely, collecting visual data on its condition so that mining personnel can make a determination about whether it’s safe enough to enter.

In a less extreme example, inspecting a huge oil storage tank could be potentially dangerous because it requires climbing scaffolding erected dozens of feet in the air. But using a drone removes the potential danger of falling, allowing the inspector to remain at a safe distance while collecting the visual data they need for the inspection.

Here is how an inspector might use RVI in their workflow:

- **An inspector sends a drone into a boiler and collects all of the visual data they need to evaluate its current condition**
- **Once the visual data is collected, the inspector carefully reviews it, looking at all of the video footage to identify potential problem areas**

As you can see, the inspector is still conducting a visual inspection, but now the inspection is of data seen on a screen, not in person.



HOW DRONES CAN HELP WITH VISUAL INSPECTIONS

Drones aren't the only tool for conducting RVI.

Inspectors have experimented with dropping cameras into confined spaces on ropes, or attached to robotic crawlers.

But more and more inspectors have been turning to drone technology as a preferred RVI tool because it offers a high degree of control and a high degree of quality.

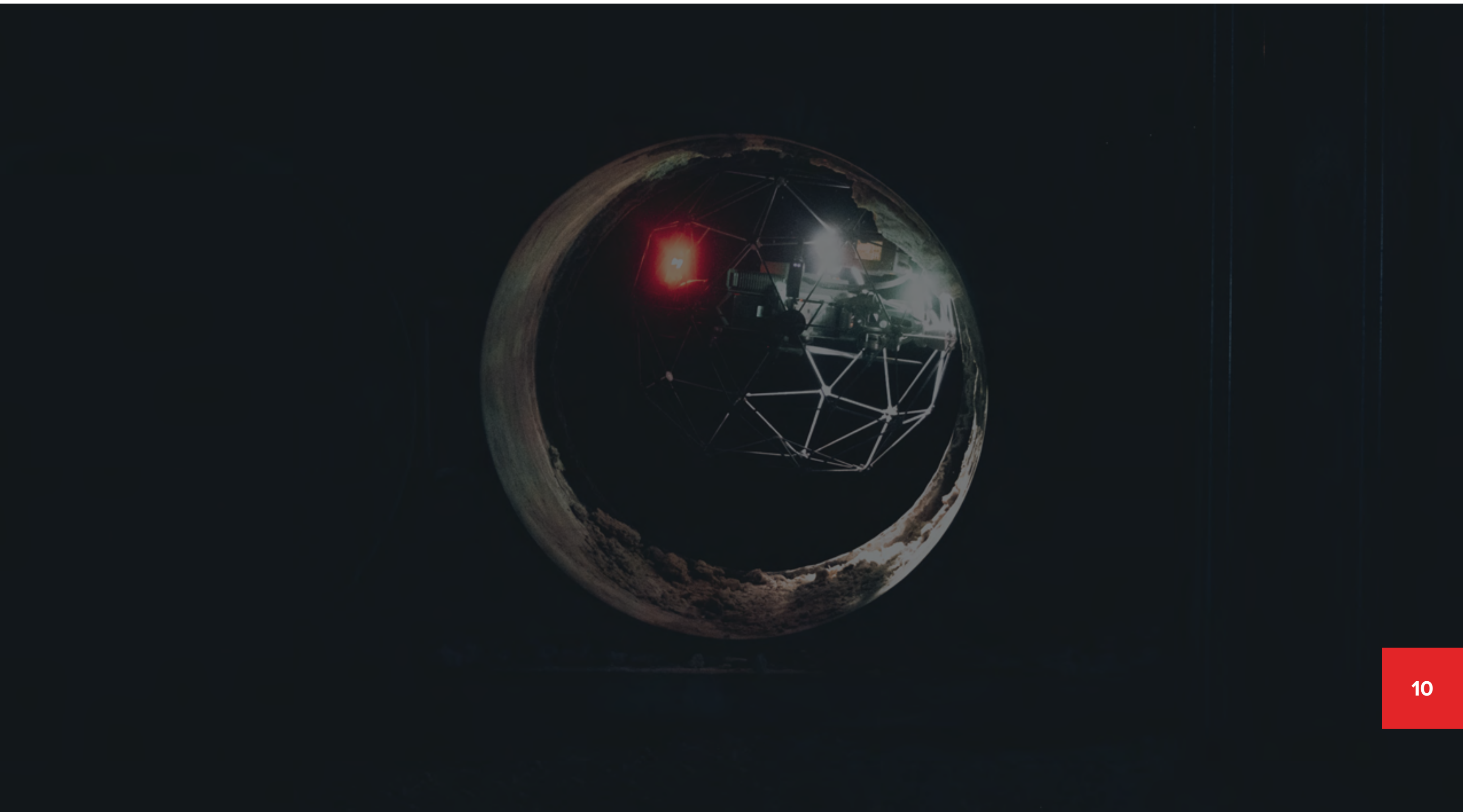
And drones like Flyability's **Elios 2** provide features like oblique lighting, which allows inspectors to visualize the depth of the surface they're inspecting so they can understand what they're looking at without having to be physically present.

Here are some of the primary benefits to using drones to collect data remotely for visual inspections:

- **Safety**
  Drones improve safety by removing the need for an inspector to enter a confined, potentially dangerous space in order to collect visual data.

- **Savings**
  Entering confined spaces to conduct a visual inspection often requires costly scaffolding and extended downtimes for the asset being inspected. A drone removes the need for scaffolding and greatly reduces the time needed for the inspection, resulting in significant savings.

- **High quality data**
  New inspection drones can collect high quality data, which can be archived and referred to in the future to determine the changes to an asset over time.



ULTRASONIC TESTING (UT)

02

Ultrasonic Testing is the use of sound waves to inspect the thickness of a material.

Ultrasonic Testing (UT) is also often called Ultrasonic Thickness Measurement (UTM). It is most commonly used on metal, because metal conducts sound waves in a manner that supports this kind of measurement.

This method is commonly used by inspectors as one of many Non-Destructive Testing (NDT) testing methods, allowing them to collect information about the condition of an asset without having to damage it.

Ultrasonic testing was first developed after the Titanic sank in 1912. Researchers wanted to identify ways that ships could find icebergs before they could see them, and they began testing sound waves for this purpose.

After these tests, UT was developed further during World War I as a way to find submarines.

It wasn't until 1928 that scientists started testing UT for industrial purposes, when a Soviet researcher named Sergei Sokolov found that soundwaves could be used to identify defects in metal materials. Over the next several decades the technique gained wide adoption, and since then it has become one of the more common NDT methods.

Here is a menu for this guide to UTM, in case you'd like to jump around:

WHAT IS ULTRASONIC TESTING?

To get more specific, ultrasonic testing uses high-frequency sound waves (typically 500kHz-20Mhz) to find defects in materials by measuring their thickness.

In ultrasonic testing, an inspector will use a probe or some other kind of transducer to send sound waves through the material they want to test. If there are no defects in the material, the sound waves will pass through it, but if the sound waves hit a defect they will bounce off of it, indicating its presence.

Inspectors can use the signal from the sound waves to create a 3-dimensional visualization of the material and determine the distances between different defects found within it.

Here are the primary benefits of using ultrasonic thickness measurements in inspections:

- **Results are immediate**
- **It doesn't require very much preparation**
- **It can detect defects both on the surface and beneath the surface of a material**
- **It can be done on a single side of a material (i.e., it can be performed even if you can't access the other side of the material)**
- **It can be automated**
- **Testing results can be shared fairly simply**

ULTRASONIC TESTING METHODS

There are three common testing methods used in ultrasonic thickness measurement:

- **Through transmission**
  Through transmission employs two transducers, each placed on opposite sides of the material being tested. One of the transducers creates a pulse and the other receives it. If there is a disruption in the pulse, inspectors will know a defect is present in the path between the two transducers.

- **Pulse echo**
  Pulse echo is more sensitive than through transmission. It is used to identify defects by measuring the time it takes amplitude signals to travel between different points or surfaces in a material.

- **Resonance**
  Resonance is similar to pulse echo, except that with resonance testing the regularity of transmission can be changed. Resonance testing is primarily used when only one side of a material can be accessed.

The Elios 2 is a drone created just for monitoring and inspections in confined spaces. Want to learn more about how it works? Watch a demo now.

WHERE IS ULTRASONIC TESTING USED?

The basic principle of ultrasonic testing is the use of sound to inspect a material's thickness at different points.

Ultrasonic thickness measurements can help inspectors find defects such as tiny cracks, gaps, corrosion, or other flaws in materials that are too minute to be seen by other NDT methods. It can also be used to find corrosion—if one area is thinner than another, that could be a sign that the area has been corroded, and may require maintenance.

In addition to metal, UT can also be used to test plastics, composites, and ceramics. It can also be used to test concrete but the findings may not be as reliable.

Here are some assets commonly tested using ultrasonic thickness measurement:

- **Flare stacks**
- **Wind turbines**
- **Large storage tanks**

Her are the industries that commonly use ultrasonic testing as part of their inspection procedures:

- **Aerospace**
- **Automotive**
- **Electronics & Battery**
- **Metals & Casting**
- **Oil and Gas**
- **Power Generation**
- **Railroad**

ULTRASONIC TESTING EQUIPMENT

Inspectors use several different types of ultrasonic testing equipment.

Some of this equipment is highly specialized, and may require the use of a technician trained in its use. Some companies hire third parties who are experts in the use of certain types of UT equipment, either to train internal team members on its use or to use the instruments and analyze their findings themselves.

That being said, even the most sophisticated UT equipment is usually easy to care and use, and highly reliable.

Here are the most common types of ultrasonic equipment that inspectors use:

- **Ultrasonic transducers and probes**
  Transducers are used in several types of ultrasonic thickness measurement, including weld testing and gauging thickness. Types include phased array, immersion, and contact transducers.

- **Flaw detectors**
  Field-tested portable ultrasonic testing solutions for fast, accurate inspections for internal product integrity, searching for defects, cracks, and other discontinuities. Flaw detectors are portable, powerful, and sensitive, allowing inspectors to penetrate materials at a considerable depth.

- **Thickness gauges**
  Ultrasonic thickness gauges are commonly used to inspect the thickness of various metals, including brass, steel, nickel, and lead, among others. Thickness gauges can be especially helpful for identifying corrosion.

- **Automated UT systems**
  Automated ultrasonic thickness systems are systems that can be put in place and collect ultrasonic readings without an inspector physically present, allowing data collection that can be useful for the longevity of an asset even when someone isn't there. These systems are commonly used to monitor pipes in the Oil and Gas industry.

DRONES AND ULTRASONIC TESTING

Drones are typically used for visual inspections—that is, to collect visual data reflecting the condition of an asset—but they're also starting to be used for UT.

Two big benefits to using a drone to collect ultrasonic thickness measurements instead of a person are safety and savings.

For safety, a drone can be used in scenarios that would require a person to work at height using a lift, catwalk, or scaffolding. Using the drone to collect UT data removes the need for a person to endanger themselves with this kind of work.

For savings, a drone can potentially collect UT data more quickly than a person, and also helps avoid the need for scaffolding, which can be costly and time-consuming to erect and take down, driving up costs through prolonged downtimes.

Ultrasonic testing by drone is still in its infancy. Right now, one of the only drone companies that offers it is Appelix. To perform UT by drone, the drone must apply a couplant to the surface that will be tested in order to optimize it for propagating soundwaves.

As drone technology progresses, we are sure to see more inspection drones offering ultrasonic testing.

RADIOGRAPHY TESTING (RT)

03

Radiography is the use of radiation to create images of things that can't be seen by the naked eye.

In the medical field, radiography is used to create images that reveal the condition inside the human body—so, images of things like bones, tissue, or internal organs.

In industrial settings, radiography is used to help inspectors detect flaws that might not be visible to the naked eye. In this guide we're going to look closely at how radiography is used in industrial settings. If you're looking for information on how radiography is used in medical settings, we recommend reading this article by the FDA.

Here is a menu to help you find the information you're looking for:

INDUSTRIAL RADIOGRAPHY

Industrial radiography (IR) is the use of radiation to inspect the integrity and structure of a material.

Both gamma rays and x-rays are used in industrial radiography. These two types of radiation can travel through many substances, allowing inspectors to conduct internal examinations for quality without having to do anything to the thing being examined.

Industrial radiography has two primary uses:

- **Manufacturers** use industrial radiography to look for defects inside materials they use.
- **Inspectors** use industrial radiography to look for defects in industrial assets, in order to ensure they are safe to use and comply with mandated inspection requirements.

Common industries that use radiography in manufacturing include automakers and airplane makers, who use radiographic testing to examine vehicle parts and plane parts.

Common industries that use radiography in inspections include any operation that uses boilers, welding, or pipes, including Oil and Gas and Power Generation.

NON-DESTRUCTIVE VS. DESTRUCTIVE TESTING

As a side note, inspection methods like radiography that allow inspectors to examine a material without changing it are called non-destructive testing methods for that very reason—they don't change or "destroy" the thing being tested.

In contrast to NDT methods, there are testing methods that require taking a sample of a substance or altering it in order to learn more about it. For example, if you want to find out whether there is lead in the paint used in a building, one easy method is to apply a chemical mix that will change colors when it encounters lead. This testing method permanently alters the paint, and would therefore be considered a destructive testing method.

A NOTE ON SAFETY IN INDUSTRIAL RADIOGRAPHY

The radiation used in industrial radiography comes from a radiation-producing machine or a radioactive materials source.

Industrial radiography can be a powerful method to determine the interior structure of a material, but it can also expose people to harm if it's not done properly.
Compared to other types of work with radiation, industrial radiographers experience the most accidents that involve radiation.

Given these dangers, strict processes are in place and required by law for industrial radiography. See the Careers and Salary section below to learn more.

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RADIOGRAPHIC TESTING - HOW DOES IT WORK?

Radiographic testing is the act of using radiation to test or inspect a material for inspection purposes.

Radiographic testing like this:

- **Line up radiation**
  An inspector points radiation (gamma rays or x-rays) at the object they want to inspect.
- **Line up detector**
  On the other side of the object, the inspector places a detector in line with the beam of radiation.
- **Take recordings**
  The detector takes recordings on the radiation passing through the object.
- **Analyze recordings**
  These recordings are then analyzed to determine the findings from the test.

As you can see, the benefit here is all in the analysis.

At a high level, what industrial radiographers look for when analyzing findings from the detector are places where less or more radiation was able to pass through the object.

Less radiation passing through means that the material is thick in those places, indicating that it's probably in good working order. More radiation passing through, on the other hand, could indicate that there is a crack or flaw in that area, causing the material to be thinner and thus allowing more radiation through.

The pictures produced from radiographic testing are called radiographs. These days, most cameras used for radiography record digital images, but they used to be recorded using film.

INDUSTRIAL RADIOGRAPHY EQUIPMENT

The two primary types of industrial radiography equipment use the two different types of radiation we've already discussed—x-rays and gamma rays.

GAMMA RAY EQUIPMENT

Industrial radiography equipment that uses gamma rays leverages radiation that comes from radioactive material contained within the equipment. This type of equipment is smaller than equipment that uses x-rays, making it useful inside smaller spaces.

Gamma ray radiographic testing equipment doesn't require electricity, but that also means it can't be turned off. The device will always be emitting some amount of radiation, and the only way to protect workers from this radiation is to enclose it inside a metal cover made for this purpose.

X-RAY EQUIPMENT

Industrial radiography equipment that uses x-rays is typically larger, so it's better suited to radiographic testing inside large spaces, such as those found in factories or warehouses.

These types of equipment run on electricity, and can be turned on and off, which means that it is safe to be around when it's off (i.e., no protective shield is required for these devices).

Given the potential dangers of radiation, the use, ownership, and transportation of radiography equipment requires a license in the U.S., and in several other parts of the world.

In the U.S., rules on licensing requirements are created and overseen by the U.S. Nuclear Regulatory Commission. Learn more here.

For asset inspections, industrial radiographers typically inspect large pieces of equipment like aboveground and underground pipelines, such as those used in the Oil and Gas industry, or other large machinery.

DRONES AND INDUSTRIAL RADIOGRAPHY

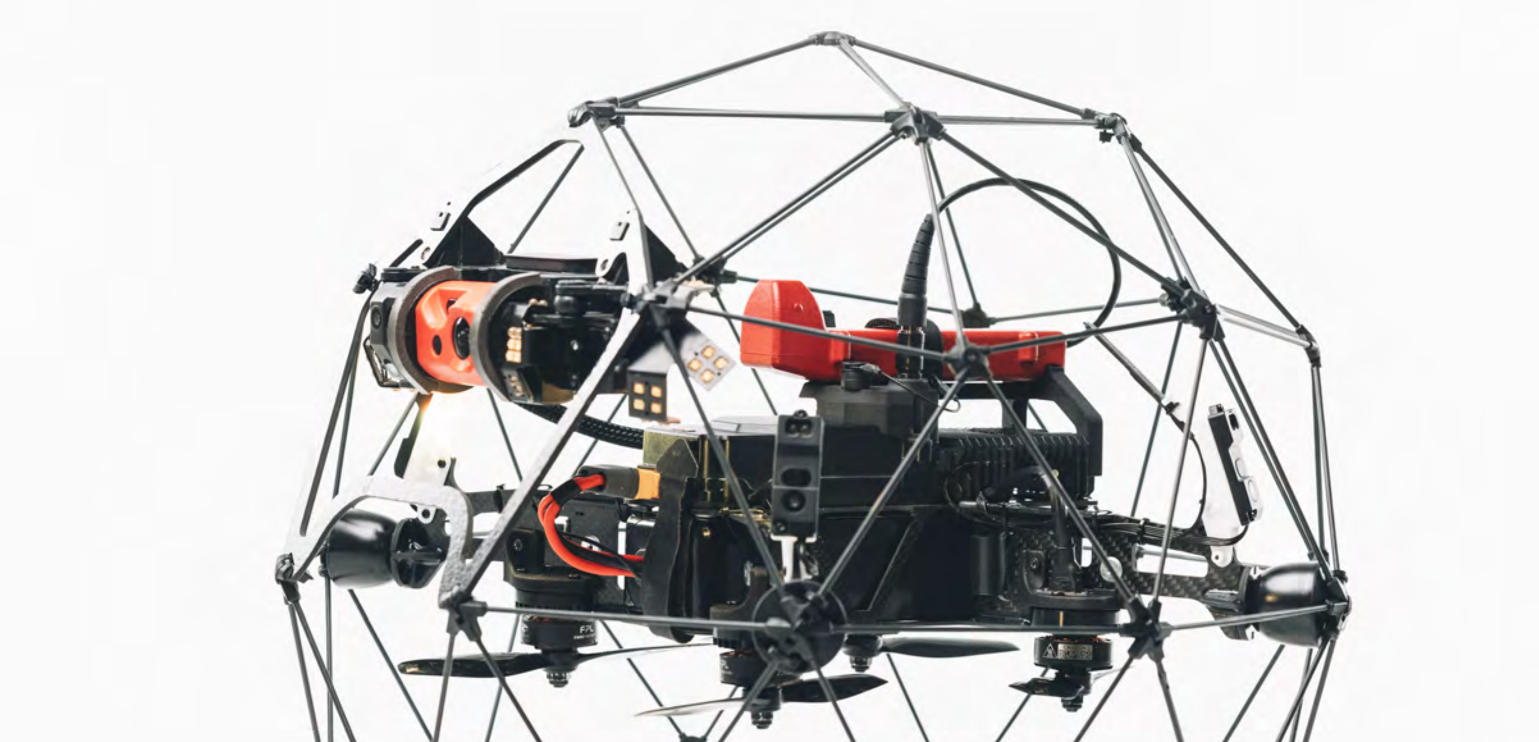
Drones are not commonly used in industrial radiography right now, but that could change over the next few years.

That being said, there is at least one drone made by a company called Pacific Imaging that is equipped with an x-ray imaging machine.

The drone is called DroneX and it is being used to inspect conductor sleeves on power lines.

Based on our research, the DroneX platform is already in use for powerline inspections, allowing inspectors to collect data about the condition of power lines without having to endanger themselves by climbing or standing in a bucket truck to conduct a manual inspection.

As drone technology continues to improve, we may see more and more drones equipped with x-ray imaging, pushing the boundaries of how industrial radiation can be performed.



EDDY CURRENT (ELECTROMAGNETIC) TESTING (ET)

Eddy current testing is the process of running electronic probes through the length of various types of tubes or along the surfaces of materials in order to find flaws in them.

An eddy current is a current that runs opposite to the current introduced by a probe into a conductive material.

Alternate terms:

- **Eddy-current testing (ETC)**
- **Electromagnetic testing (ET)**

In this guide, we will use these terms interchangeably.

Using eddy-current testing, inspectors can find very small defects that might not be visible to the naked eye.

The raw data gathered from eddy current testing probes must be processed using software made for this purpose and then analyzed by trained inspectors, who know how to identify defects in ETC results.

Eddy current testing is one of several electromagnetic testing methods used for non-destructive testing (NDT), which refers to tests performed for the purposes of inspections that do not damage the material being tested.

Here is a menu to help you navigate this guide:

WHAT IS EDDY CURRENT TESTING?

In an eddy current test, an inspector will run a probe through the length of a tube in order to identify tiny defects.

Here is how it works:

- **Probe**
  An inspector starts with a probe—for example, the single-element ETC probe, which uses an alternating current. The ETC probe consists of a coiled conductive piece of wire.

- **Magnetic field creation**
  When electrified, the probe will create an alternating magnetic field.

- **Introduce the field to the object**
  Once the field has been created, the inspector will introduce it to the object they want to inspect by moving it through the object.

- **Create eddy currents**
  When the magnetic field is introduced to the object or material, it will create currents running opposite to the currents in the probe. These currents are called eddy currents.

- **Collect data**
  Any defects present in the material will cause a change in these eddy currents, and inspectors collect this data after introducing the ETC probe into the tube.

- **Evaluate the data**
  After the data has been collected it needs to be analyzed so that defects in the object can be identified. Note that the inspector who collects the data may not always be the same inspector who analyzes it, since these two activities require different levels of training and certification.

HE HISTORY OF EDDY CURRENT TESTING

The eddy current phenomenon was first observed by researcher François Arago in 1824, but it is the inventor Léon Foucault who is actually credited with its discovery.

Foucault's discovery happened in 1855, and was based in part on research conducted by Michael Faraday, who discovered the principle of electromagnetic induction in 1831.

This principle describes the relationship between electric currents and magnetic fields, and was the result of Faraday observing that a magnetic field will pass through a conductive material in a manner that varies over time as an electric current flows through it.

Despite these early observations, it wasn't until 1879 that scientist David Hughes found a potential use for eddy currents. Hughes was able to demonstrate that the properties of a coiled, conductive wire changed when it came in contact with different kinds of conductive materials.

Eddy-current testing didn't come into mainstream use until World War II, when Professor Friedrich Förster of Germany began exploring its industrial applications.

After the war, Förster founded a company called the Foerster Group that manufactured instruments for eddy current testing, further developing the technology and expanding its potential uses.

Today, ETC is one of the most common NDT methods used by inspectors, with a well established track record for providing reliable data.

USE CASES, TYPES OF FLAWS, AND INDUSTRIES

Eddy current testing is most commonly used to inspect surfaces and tubes. It is an incredibly sensitive testing method, and can identify even very small flaws or cracks in a surface or just beneath it.

On surfaces, ETC can be done with both ferromagnetic and non-ferromagnetic materials.

In tubes, ETC can primarily only be done with non-ferromagnetic tubing.

Here are the types of flaws eddy current testing is generally used to find:

- **Cracks**
- **Corrosion**
- **Wear (in tubes, often due to erosion)**
- **Freezing-related damage (in tubes)**
- **Lack of fusion**
- **Pitting**
- **Wall loss / thickness loss**

The types of materials eddy current testing is commonly used to inspect include:

- **Bores**
  Bolt hole bores, bores for in-use tubes
- **Welds**
  Welded joints, nozzle welds, friction stir welds
- **Tubes**
  Steam generator tubing, metal tubing

Here are the industries where inspectors most commonly use ETC:

- **Aerospace**
- **Nuclear / Power Generation**
- **Manufacturing**
- **Oil & Gas**
- **Petrochemical**
- **Transportation**

EDDY CURRENT TESTING PROS AND CONS

ETC allows inspectors to find defects on the surface and subsurface level of an object easily and with a high degree of accuracy—but that's just one of the reasons inspectors commonly use it to look for defects in a material.

Here's a list of pros and cons for ETC:

Pros

- It is incredibly versatile in terms of accuracy and portability/ease of use).
- It's results are highly reliable, providing data of a high quality.
- It is highly sensitive, allowing inspectors to identify defects as small as .5mm.
- It is effective on surfaces that have paint or some other type of coating on them.
- It can be used on high-temperature and underwater surfaces.
- It provides immediate data.
- It takes a relatively short amount of preparation time to perform (i.e., not much pre-cleaning or couplant is needed).
- It can be automated for testing uniform parts, such as boiler tubes or wheels.

Cons

- It only works with a current.
- ECT current always runs parallel to the surface of a material, so a defect that doesn't come in direct contact with the current can't be detected—and this means that some defects may go undetected.
- It's not ideal for inspecting large areas.
- It's efficacy for different depths can vary.
- It can be subject to changes in magnetic permeability, which can make it hard to use it for inspecting parts of ferromagnetic materials.It's also non-conductive with ferromagnetic materials, as ECT equipment is subject to permeability changes on the welds.
- Interpreting signals correctly can be difficult, since it may require weeding out non-relevant data points.

EDDY CURRENT TESTING PROCEDURE

There are several different methods for conducting an eddy current test.

Here are some of the most common ones:

EDDY CURRENT ARRAY

Eddy current array testing uses an array of electrically charged coils to create a sensitivity profile made to identify defects in a material.
In this kind of testing, inspectors have to be careful to avoid mutual inductance between the individual coils.

HEAT EXCHANGER TESTING

Heat exchanger testing is one of the most popular uses for eddy currents.
In this type of testing, inspectors use eddy currents to find defects in metal tubes, providing immediate data after a single pass through with a probe.

LORENTZ FORCE ETC

Lorentz force eddy current testing is a newer NDT method that uses multiple DC magnets to try and overcome the skin effect (that is, a cancellation of a flow's current in the center of a conductor with a corresponding reinforcement in the skin).

In addition to the use of multiple magnets, the Lorentz force eddy-current testing uses relative motion to help inspectors conduct quick, accurate eddy current tests.

SURFACE ARRAY TESTING

Surface array testing is commonly used in the aerospace industry, where it can help measure conductivity as well as corrosion / wall thickness with a high degree of accuracy.
This type of testing is very versatile, and is capable of finding defects in places that are hard to access where other inspection methods may not work.

EDDY CURRENT TESTING EQUIPMENT

In eddy current testing there are two categories of equipment—probes and instruments and probes.

In general, probes collect the data and instruments convert that data into interpretable results.

Here is our list of ETC probes:

HANDHELD PROBES

Handheld probes are used in a variety of industries, and commonly come with interchangeable parts for the probe's tip and handle.

SURFACE ARRAY PROBES

Surface array probes are used in surface array testing, and commonly used to identify defects in surfaces that aren't flat.

TUBING ARRAY PROBES

These types of probes can commonly collect all the data an inspector needs in a single pass through a tube.

Here is our list of ETC instruments:

EDDY CURRENT TESTING HANDHELD INSTRUMENT

Handheld eddy current testing instruments give inspectors greater versatility in the field, providing them with a portable device for recording ETC data.

EDDY CURRENT TESTING INSTRUMENT

Larger eddy current testing instruments also help inspectors record ETC data. These instruments can come in both surface array and tubing configurations.

MODULAR EDDY CURRENT TESTING UNITS

A modular ETC unit is generally smaller, more portable instrument-only systems. These units are made only for use at power plants, where they're used to inspect condensers and steam generators.

EDDY CURRENT TESTING STANDARDS AND CODES

Leak testing is commonly used for code-based inspections.

Here are some of the more widely used leak testing codes and resources:

ASME (AMERICAN SOCIETY OF MECHANICAL ENGINEERS)

- A New Research Method for Corrosion Defect in Metal Pipeline by Using Pulsed Eddy Current
- An Engineer's Guide to Eddy Current Testing
- Analytical and Experimental Approaches for the Sizing of Fatigue Cracks in Inconel Welds by Eddy Current Examination
- Basic Characteristics of Eddy Current Testing Using Resonant Coupling
- Real-Time Eddy Current Imaging and Flaw Detection Under Tube Support Plate by Cylinder-Type Magnetic Camera
- Remote Field Eddy Current Testing Technology for Ferromagnetic Heat Exchanger Tubes

See a full list on the ASME website.

ASTM (AMERICAN SOCIETY FOR TESTING AND MATERIALS)

- ASTM E376-19: Standard Practice for Measuring Coating Thickness by Magnetic-Field or Eddy Current (Electromagnetic) Testing Methods
- ASTM E566-19: Standard Practice for Electromagnetic (Eddy Current/Magnetic Induction) Sorting of Ferrous Metals
- ASTM E690-15 (2020): Standard Practice for In Situ Electromagnetic (Eddy Current) Examination of Nonmagnetic Heat Exchanger Tubes
- ASTM E703-20: Standard Practice for Electromagnetic (Eddy Current) Sorting of Nonferrous Metals
- ASTM E1004-17: Standard Test Method for Determining Electrical Conductivity Using the Electromagnetic (Eddy Current) Method
- STP1151: Electromagnetic (Eddy Current) Testing
- ASTM E309-16: Standard Practice for Eddy Current Examination of Steel Tubular Products Using Magnetic Saturation
- ASTM E2884-17: Standard Guide for Eddy Current Testing of Electrically Conducting Materials Using Conformable Sensor Arrays
- ASTM E2934-14(2018): Standard Practice for Digital Imaging and Communication in Nondestructive Evaluation (DICONDE) for Eddy Current (EC) Test Methods
- ASTM E3052-16: Standard Practice for Examination of Carbon Steel Welds Using Eddy Current Array

See a full list on the ASTM website.

ISO (INTERNATIONAL ORGANIZATION FOR STANDARDIZATION)

- ISO 15549:2019 NON-DESTRUCTIVE TESTING — EDDY CURRENT TESTING — GENERAL PRINCIPLES
- ISO 12718:2019 NON-DESTRUCTIVE TESTING — EDDY CURRENT TESTING — VOCABULARY
- ISO 20669:2017 NON-DESTRUCTIVE TESTING — PULSED EDDY CURRENT TESTING OF FERROMAGNETIC METALLIC COMPONENTS
- ISO 17643:2015 NON-DESTRUCTIVE TESTING OF WELDS — EDDY CURRENT TESTING OF WELDS BY COMPLEX-PLANE ANALYSIS
- ISO 20339:2017 NON-DESTRUCTIVE TESTING — EQUIPMENT FOR EDDY CURRENT EXAMINATION — ARRAY PROBE CHARACTERISTICS AND VERIFICATION
- ISO 15548-1:2013 NON-DESTRUCTIVE TESTING — EQUIPMENT FOR EDDY CURRENT EXAMINATION — PART 1: INSTRUMENT CHARACTERISTICS AND VERIFICATION
- ISO 15548-2:2013 NON-DESTRUCTIVE TESTING — EQUIPMENT FOR EDDY CURRENT EXAMINATION — PART 2: PROBE CHARACTERISTICS AND VERIFICATION

See a full list on the ISO website.

MAGNETIC PARTICLE INSPECTION (MPI)

Magnetic particle inspection is an inspection method used to identify defects on the surface of ferromagnetic materials by running a magnetic current through it.

It can also be used to detect defects just beneath the surface of materials. The types of defects it can detect include cracks, pores, cold lap, and the lack of sidewall fusion in welds.

Alternative terms:

- **Magnetic particle inspection (MPI) is also commonly called magnetic particle testing (MT)**

In this guide, we will use the terms magnetic particle inspection and magnetic particle testing interchangeably, following the alternate terms listed above.

Magnetic particle inspections work by running a magnetic current through the material that is being inspected. When the current is interrupted by a defect magnetism spreads out from that point, indicating its presence and allowing inspectors to identify its location in the material.

Magnetic particle testing is one of the more commonly used non-destructive testing (NDT) methods because it is quick and relatively inexpensive.

However, it only works on materials that can be magnetized—called ferromagnetic materials—so its applications are somewhat limited. Some examples of ferromagnetic materials include steel, cobalt, iron, and nickel.

HOW DO MAGNETIC PARTICLE INSPECTIONS WORK??

To conduct a magnetic particle test, inspectors start by magnetizing the material they want to inspect.

If the magnetized object has no defects, the magnetic field will transfer throughout the material without any discontinuities or interruptions. But when the current encounters defects in the material it will be interrupted, causing it to spread out from that point and create what is called a flux leakage field where the defect is located.

Once the material is magnetized and defects have created these secondary flux leakage fields, inspectors spread magnetic particles over the surface. The particles will be drawn to the secondary field, gathering around it and making it visible to the naked eye.

The particles inspectors use are typically either black or coated with some kind of fluorescent dye to make them easier to see. These particles can be used in the form of powder or put into a liquid.

THE HISTORY OF MAGNETIC PARTICLE TESTING

1868 was the first recorded time that magnetism was used to check the integrity of a material.

At the time, it was used to test cannon barrels for defects by magnetizing the barrels and then following its length with a magnetic compass, looking for any signs of discontinuity in the magnetic current. When a discontinuity appeared—indicating the presence of a defect in the barrel—the compass needle would move, allowing people to identify the location of flaws that weren't visible to the naked eye.

Fifty years later in the 1920s inventor William Hoke found that he could use metallic shavings to form patterns on a magnetized ferromagnetic surface. These patterns would cluster around the location of defects on the surface, showing their location—just as magnetic particles are used to identify defects today.

In the 1930s, the railroad industry began using Hoke's findings to inspect its ferromagnetic materials—namely steel—and the method soon became a standard way to identify flaws in materials.

The principles of the tests used today remain fundamentally the same as when they were first developed. At the time, MPI were used to test steel materials by magnetizing them in order to produce lines of flux. If these lines were interrupted by a defect in the material it would become clear by the creation of a second magnetic field, or flux leakage field, at the point where the defect is located.

THE PROS AND CONS OF MAGNETIC PARTICLE INSPECTION

Magnetic Particle testing is quick and fairly inexpensive, but it does have some limitations.

Here's a list of pros and cons for MPI:

Pros

- It is very portable and quick
- Results of the test immediately visible on the surface of the material
- No strict pre-cleaning regiment is required and post-cleaning can also generally be avoided
- Generally inexpensive, and does not need a stringent pre-cleaning
- Sensitive—it can detect shallow/fine cracks in a surface
- Can detect both surface and near-surface indications.
- Easy to use, without a lot of training required
- Flexibility - it can be used with strangely shaped objects, even on surfaces that have other materials on them
- Can inspect parts with irregular shapes (external splines, crankshafts, connecting rods, etc.)

Cons

- Only ferromagnetic material can be tested with MPI
- Only surface and subsurface (to a depth of about 0.100" in most conditions) defects can be detected
- After the test is complete the material has to be demagnetized, which can pose challenges
- Inspectors must achieve an alignment between indications and magnetic flux
- Only small sections of a surface can be examined at one time
- Paint must be removed if it is thicker than about 0.005" for MPI to work

MAGNETIC PARTICLE INSPECTION TECHNIQUES

As we've covered above, inspectors can use either a powder or water suspension to conduct magnetic testing.

Using a powder is called Dry Magnetic Particle Testing (DMPT) and using water suspension is called Wet Magnetic Particle Testing (WMPT).

Inspectors can choose to use either fluorescent or non-fluorescent materials for both the power and the water suspension methods, allowing them to use an approach that will make defects most highly visible for the environment.

TWO-STEP OVERVIEW

Here is the basic two step process for how inspectors do both the wet and the dry methods of magnetic particle testing:

- **Magnetize the object**
  Run a magnetic current through the material. If defects are present they will create a secondary magnetic field, or flux leakage field.

- **Spread metal particles on the object**
  Spread metal particles over the material or object in the form of a powder or liquid. The secondary field(s) will attract these particles to the location of defects, allowing them to be made visible.

Although the basics of the process are fairly straightforward, there are several considerations to how each step is performed. These are covered in the next section of this guide, entitled Magnetization Considerations.

Some of the most common techniques for on-site magnetic testing include:

- **Electromagnetic yoke**
- **Current flow probes**
- **Permanent magnet**
- **Flexible coil**
- **Adjacent cable**

MAGNETIZATION CONSIDERATIONS

Here's an overview of the most common considerations inspectors make when conducting magnetic particle testing.

WAYS TO MAGNETIZE THE MATERIAL

There are several different techniques for magnetizing a material when conducting a magnetic particle inspection. Here are the five techniques most commonly used, which are also recognized by various standards bodies, including the ASME (American Society of Mechanical Engineers).

- **Longitudinal magnetization technique**
- **Multidirectional magnetization technique**
- **Yoke technique**
- **Prod technique**
- **Circular magnetization technique**

PERPENDICULAR APPLICATION

Magnetic lines of force should be applied perpendicularly to the direction of the electric current. The current can either be Direct Current (DC) or an alternating current (AC).

To conduct a thorough MPI, inspectors need to inspect a material twice. This is because the defect will only interrupt the magnetic flux (or line of force) if the flux is perpendicular to the defect. If the two aren't perpendicular then there won't be an interruption in the flow, and the defect won't be identified.

Therefore, inspectors must conduct their magnetic testing twice in order to ensure that they've gotten coverage—once in one direction, and once more in a direction perpendicular to the first direction.

DIRECT VS. INDIRECT MAGNETIZATION

Inspector can magnetize materials either by indirect or direct magnetization.

- **Direct magnetization** refers to passing an electric current directly through the material, creating a magnetic field in it.
- **Indirect magnetization** refers to creating a magnetic field in the material from an outside source instead of passing an electric current through it.

ELECTRICAL CURRENT CONSIDERATIONS

Inspectors use several types of electrical current when doing magnetic testing.

To choose the right current for a given inspection, inspectors must consider:

- **The object's shape**
- **The types of defects they are looking for**
- **The object's material**
- **How deeply the magnetic field needs to go into the object to achieve the goal of the inspection**

Here's a list of electrical currents and associated considerations for MT:

- **AC (Alternating Current)**
  AC is used to detect flaws on the surface of materials—not ideal for subsurface flaw detection because it can be subject to the "skin effect," in which the electrical current runs only along the surface and doesn't penetrate it.

- **DC (Direct Current)—full wave**
  Also called FWDC, full wave DC is used to identify flaws that are just underneath the surface of materials, since it can magnetize materials more deeply than AC. The depth of magnetic penetration for DC is dependent on the amount of current running through the material.

- **DC (Direct Current)—half wave**
  Also called pulsating DC or HWDC, half wave DC can achieve similar results as full wave DC but it can achieve deeper magnetic penetration.

MAGNETIC PARTICLE INSPECTION EQUIPMENT

There are several different types of magnetic particle inspection equipment that inspectors use in their work. In general, this equipment is used to create magnetic currents and fields for inspection purposes.

Here are some of the most common types of magnetic particle testing equipment:

MAGNETIC WET BENCHES

Magnetic benches allow inspectors to create circular and longitudinal magnetic field outputs for magnetic particle testing.

POWER PACKS / ELECTROMAGNETIC CURRENT GENERATORS

Power packs give inspectors a quick, easy way to generate a magnetic current for MPI.

MAGNETIC YOKES

Inspectors use magnetic yokes to generate a magnetic field for magnetic particle inspections.

ENCLOSURES, HOODS, AND CURTAINS

Enclosures, hoods, and curtains are used to sufficiently darken the magnetic particle inspection area to required levels.

DEMAGNETIZERS

Demagnetizers help inspectors remove residual magnetism after a magnetic particle inspection has been conducted.

Magnetic Particle Inspection Standards and Codes

For certain inspections inspectors are required by law to follow specific steps when conducting magnetic particle testing. In addition, the inspector conducting the inspection must be certified to do so by the relevant standards body.

Here are some of the internationally recognized standards for magnetic particle inspection:

ASTM (AMERICAN SOCIETY OF TESTING AND MATERIALS)

- ASTM E1444/E1444M: Standard Practice for Magnetic Particle Testing
- ASTM A 275/A 275M: Test Method for Magnetic Particle Examination of Steel Forgings
- ASTM A456: Specification for Magnetic Particle Inspection of Large Crankshaft Forgings
- ASTM E543: Practice Standard Specification for Evaluating Agencies that Performing Nondestructive Testing
- ASTM E 709: Guide for Magnetic Particle Testing Examination
- ASTM E 1316: Terminology for Nondestructive Examinations
- ASTM E 2297: Standard Guide for Use of UV-A and Visible Light Sources and Meters used in the Liquid Penetrant and Magnetic Particle Methods

ISO (INTERNATIONAL STANDARDS ORGANIZATION)

- ISO 3059: Non-destructive testing - Penetrant testing and magnetic particle testing - Viewing conditions
- ISO 9934-1: Non-destructive testing - Magnetic particle testing - Part 1: General principles
- ISO 9934-2: Non-destructive testing - Magnetic particle testing - Part 2: Detection media
- ISO 9934-3: Non-destructive testing - Magnetic particle testing - Part 3: Equipment
- ISO 10893-5: Non-destructive testing of steel tubes
- ISO 17638: Non-destructive testing of welds - Magnetic particle testing
- ISO 23278: Non-destructive testing of welds - Magnetic particle testing of welds - Acceptance levels

CEN (EUROPEAN COMMITTEE FOR STANDARDIZATION)

- EN 1290: Surface Crack Testing
- EN 1330-7: Non-destructive testing - Terminology - Part 7: Terms used in magnetic particle testing
- EN 1369: Founding - Magnetic particle inspection
- EN 10228-1: Non-destructive testing of steel forgings - Part 1: Magnetic particle inspection
- EN 10246-12: Non-destructive testing of steel tubes - Part 12: Magnetic particle inspection of seamless and welded ferromagnetic steel tubes for the detection of surface imperfections
- EN 10246-18: Non-destructive testing of steel tubes - Part 18: Magnetic particle inspection of the tube ends of seamless and welded ferromagnetic steel tubes for the detection of laminar imperfections

ACOUSTIC EMISSION TESTING (AE)

06

Acoustic emission testing is an inspection method that uses the release of ultrasonic stress waves to identify defects in materials. These ultrasonic waves are not introduced from an external source, as they are in ultrasonic testing, but rather originate from within the material being inspected.

Alternative terms:

- **Acoustic Emission Testing is also called Acoustic Emission (AE) or Acoustic Testing (AT)**

In this guide, we will use the three terms listed above interchangeably.

Acoustic emission testing is one of the most common and useful methods for non-destructive testing (i.e., testing that allows inspectors to collect data on materials without harming them). One of its main advantages for inspectors is that it allows inspectors to test a material or asset for defects for its entire load history without damaging it.

Historically, AE has been used only for inspecting and maintaining expensive structures due to the high costs associated with it. But new developments have helped lower the cost of AE equipment, and it is becoming more accessible for a host of inspection applications.

Here is a menu to help you navigate this guide:

HOW DOES ACOUSTIC EMISSION TESTING WORK?

In an acoustic emission test, an inspector records elastic ultrasonic waves traveling through the surface of a solid material using one or more sensors.

As an acoustic wave travels on or through the surface of an object any defect it encounters can change that wave, both in terms of its speed and in terms of its amplitude. And inspectors look for these changes to identify the presence of defects.

The range of ultrasound typically used for acoustic emission testing is 20 KiloHertZ (KHZ) and 1 MegaHertZ (MHZ). (One KiloHertZ is equal to one one thousand Hertz, or cycles per second; one MegaHertZ is equal to one million Hertz, or cycles per second).

Here are a few definitions of terms we'll use throughout this article:

- **Ultrasonic**
  The terms ultrasonic and ultrasound refer to sound waves that are so high humans can't hear them.
- **Acoustic emission**
  The term acoustic emission refers to the generation of transient waves during the rapid release of energy from localized sources within a material.

WHERE DO ACOUSTIC EMISSIONS COME FROM?

Acoustic emissions happen when a material is under stress, either from holding a heavy load or from extremes of temperature.

These emissions typically correspond with some kind of defect or damage being done to the structure emitting them—and this damage is what inspectors are looking for when they do an AE test.

Sources of acoustic emission can include:

- **Phase transformation**
- **Thermal stress**
- **Cool down cracking**
- **Melting**
- **Bond and/or fibre failure**

THE HISTORY OF ACOUSTIC EMISSION

Compared to other NDT methods like **magnetic particle testing** or **dye penetrant testing**, acoustic emission testing is relatively new.

It was first used in the early 1980s as a way for inspectors to test polymer matrix composites (PMCs).

The sensors used to record acoustic emissions use a piezoelectric material. Piezoelectricity is the production of electrical charges by the introduction of mechanical stress. Imagine setting using a crane to set a slab of granite on to the top of a bus.

The heavy granite will push down onto the bus, generating stress and electrical charges. And these charges are a type of piezoelectricity.

Piezoelectricity was first discovered in 1880, by two brothers named Pierre Curie and Paul-Jacques Curie. But it was not used for much of anything until the early 1920s, when an inventor named **Walter Cady** experimented with using piezoelectricity for stabilizing electronic oscillators.

Around sixty years later, researchers began testing piezoelectricity for identifying defects in polymer matrix composites. Today, the sensors used for acoustic emission testing are called piezoelectric acoustic wave sensors, because they apply an oscillating electric field in order to generate a mechanical wave.

Although AE is a promising NDT method it is still in its infancy, and will require years of research and development before it is a completely reliable, stand-alone inspection technique.

One interesting new application for AE is using it to detect earthquakes before they actually happen, but this application is also just in the early stage of development.

COMMON APPLICATIONS AND INDUSTRIES

Inspectors typically use AE to look for:

- **Corrosion -** on the surfaces of various types of materials
- **Coating removal -** of protective coatings put on materials
- **Faults/defects -** for monitoring welding and for other general flaw detection
- **Leaks -** in pipe systems or storage tanks
- **Partial discharges -** from components subject to high voltage

For fibre specifically, AE is commonly used to test for cracking, corrosion, delamination, and breakages.

Here are some of the most common applications for acoustic testing:

- **Airplane longevity estimation**
- **Bridge inspections (learn more about bridge inspections)**
- **Concrete corrosion monitoring**
- **Mine wall stability inspections**
- **Pressure vessel inspections (learn more about pressure vessel inspections)**
- **Structural integrity inspections**
- **Wind turbine inspections**

ACOUSTIC EMISSION TESTING VS. ULTRASONIC TESTING

Although both acoustic testing and ultrasonic testing use ultrasound they are distinct inspection methods.

In AE, inspectors "listen" for acoustic emissions from defects present in a material. AE is specifically useful for determining whether a structure is overloaded, and it's the only NDT method that can be used during manufacturing. It does not require any use of external energy (unlike ultrasonic testing), because the test material or structure itself releases the acoustic emission.

In ultrasonic testing, inspectors send ultrasonic waves through a structure of material from an external source. If the waves are interrupted, this indicates the presence of a defect at the point of interruption.

THE PROS AND CONS OF ACOUSTIC EMISSION TESTING

Acoustic testing is a popular NDT method because it can provide a direct measure of failure mechanisms in action—but that's just one of the reasons inspectors commonly use it to look for defects in a material.

Here's a list of pros and cons for AE:

Pros

- It gives you a direct measure of failure mechanisms
- It is highly sensitive
- It provides data immediately
- It is non-destructive to the material being tested
- It allows for a structure to be globally monitored
- It can be used in hazardous environments, including those that have high pressures, are irradiated, or have high temperatures
- It can be done remotely, and can detect defects in materials that might be hard to test using other NDT methods

Cons

One of the drawbacks to AE is that it's not always reliable, in part because it is still a relatively new NDT method.

Here are the main cons for acoustic testing as an NDT method:

- It's usefulness is generally limited to locating a defect, not describing it in detail—that is, commercial acoustic testing systems can only provide qualitative estimations for the extent of damage found
- It cannot detect defects that do not change over time (i.e., defects that don't move or grow)
- It can be slow to implement
- It can be hard to use - AE signals can be very weak, making noise reduction and signal discrimination crucial for accurate readings

HOW TO PERFORM AN ACOUSTIC EMISSION TEST

To use AE, inspectors start by thoroughly cleaning the surface of the object they want to inspect.

After cleaning, they will place AE sensors onto the structure or material that they want to inspect.

Sensors will need to be mounted on the structure with an appropriate couplant—that is, a medium to help the transmission of the acoustic signal. Adhesives or grease are commonly used for this purpose.

Once attached, the sensors will convert any stress waves present in the material into electrical signals so that they can be read by the inspector.

Inspectors feed data from the sensors to a monitor using shielded coaxial cables, displaying the information in the form of both readable results and raw data. Once the data is available, inspectors interpret it to identify where there is stress on the object they are inspecting, and look for the possible locations of defects caused by that stress.

Determinations for the amount of sensors an inspector will need for a given structure are made according to several factors, including:

- **The complexity of the material or structure**
- **The size of the structure**
- **The type of material being tested**

THE KAISER EFFECT

The Kaiser effect refers to the absence of acoustic emission in an object until the level of stress that was previously applied to it has been exceeded.

The effect was first discovered in 1950, when a researcher named Kaiser found that metals could "remember" the maximum amount of stress to which they had previously been subjected.

Due to the Kaiser effect, a structure could be under damaging stress that inspectors cannot identify using AE if that stress has not exceeded the prior amount of stress the structure has experienced.

ACOUSTIC WAVE DEVICES

Here are the types of devices used in acoustic emission testing.

TRANSDUCERS / SENSORS / STRAIN GAUGES

These devices collect raw acoustic emission data. They are also called:

- **Piezoelectric transducers**
- **Piezoelectric sensors**
- **Strain gauges**

The most common set of transducers for AE consists of two sets of **interdigital transducers**, which is a device made of two interlocking, comb-shaped arrays of metallic electrodes arranged like a zipper.

One of the transducers converts electric field energy into mechanical wave energy, and the other transducer converts the mechanical wave energy back into an electric field.

Here are some of the different types of AE sensors:

- **Thickness shear mode resonator**
  Measures metal deposition rates.

- **Displacement gauges**
  A strain gauge that converts the acoustic emission of displacement caused by stress on a structure into electronic readings.

- **Accelerator gauges**
  A strain gauge that converts the acoustic emission of velocity caused by stress on a structure into electronic readings.

- **Bulk acoustic wave device (BAW)**
  A machine that propagates waves through the substrate of a material or structure. surface wave devices

- **Surface acoustic wave sensor (SH-SAW)**
  A type of BAW device used to detect acoustic emissions on the surface of a material.

- **Surface transverse wave sensor (STW)**
  A type of BAW device used to detect acoustic emissions on the surface of a material.

LOW-NOISE PREAMPLIFIERS

A low-noise preamplifier amplifies the output from the sensors to make it readable for inspectors.

These devices, combined with the right training, allow inspectors to identify the location of defects in a material that might not be visible to the naked eye.

ACOUSTIC EMISSION TESTING STANDARDS AND CODES

Given how inexpensive and easy it is, acoustic emission testing is often used by inspectors for informational purposes—that is, for inspections that do not have to comply with a specific code or set of standards.

But acoustic testing is also commonly used for code-based inspections.

For these inspections, inspectors must follow specific steps in how they conduct the test, including the requirement that they follow a written procedure and that the person conducting the test is certified to do so by the relevant standards body.

Here are some of the more widely used acoustic testing codes:

ASME (AMERICAN SOCIETY OF MECHANICAL ENGINEERS)

- ASME Boiler and Pressure Vessel Code: Section XI, Division 1, Article IWA-2000, Examination and Inspection, (IWA-2234) Acoustic Emission Examination
- ASME Boiler and Pressure Vessel Code: Section XI, Division 1, Code Case N-471, Acoustic Emission for Successive Inspections
- ASME Boiler and Pressure Vessel Code: Section XI, Division 1, Code Case No. N-471, Acoustic Emission for successive inspections—Supplement 1 Guidance information for acoustic emission monitoring of pressure boundaries during operation
- ASME Boiler and Pressure Vessel Code: Section XI, Appendix, Acoustic Emission Monitoring of Nuclear Reactor Pressure Boundaries during Operation
- ASME RTP-1-1995: Standard Guide to Test Methods and Standards for Nondestructive Testing of Advanced Ceramics

ASTM (AMERICAN SOCIETY FOR TESTING AND MATERIALS)

- ASTM C 1175: Standard Guide to Test Methods and Standards for Nondestructive Testing of Advanced Ceramics
- ASTM E 543: Standard Specification for Agencies Performing Nondestructive Testing
- ASTM E 569: Standard Practice for Acoustic Emission Monitoring of Structures During Controlled Stimulation
- ASTM E 650: Standard Guide for Mounting Piezoelectric Acoustic Emission Sensors

- ASTM E 749: Standard Practice for Acoustic Emission Monitoring During Continuous Welding
- ASTM E 750: Standard Practice for Characterizing Acoustic Emission Instrumentation
- ASTM E 751: Standard Practice for Acoustic Emission Monitoring During Resistance Spot-Welding
- ASTM E 976: Standard Guide for Determining the Reproducibility of Acoustic Emission Sensor Response
- ASTM E 1065: Standard Guide for Evaluating Characteristics of Ultrasonic Search Units
- ASTM E 1067: Standard Practice for Acoustic Emission Examination of Fiberglass Reinforced Plastic Resin (FRP) Tanks/Vessels
- ASTM E 1106: Standard Test Method for Primary Calibration of Acoustic Emission Sensors
- ASTM E 1118: Standard Practice for Acoustic Emission Examination of Reinforced Thermosetting Resin Pipe (RTRP)
- ASTM E 1139: Standard Practice for Continuous Monitoring of Acoustic Emission from Metal Pressure Boundaries
- ASTM E 1211: Standard Practice for Leak Detection and Location Using Surface-Mounted Acoustic Emission Sensors
- ASTM E 1212: Standard Practice for Quality Management Systems for Nondestructive Testing Agencies
- ASTM E 1316: Standard Terminology for Nondestructive Examination
- ASTM E 1359: Standard Guide for Evaluating Capabilities of Nondestructive Testing Agencies
- ASTM E 1419: Standard Practice for Examination of Seamless, GasFilled, Pressure Vessels Using Acoustic Emission
- ASTM E 1495: Standard Guide for Acousto-Ultrasonic Assessment of Composites, Laminates, and Bonded Joints
- ASTM E 1544: Standard Practice for Construction of a Stepped Block and Its Use to Estimate Errors Produced by Speed-ofSound Measurement Systems for Use on Solids
- ASTM E 1736: Standard Practice for Acousto-Ultrasonic Assessment of Filament-Wound Pressure Vessels
- ASTM E 1781: Standard Practice for Secondary Calibration of Acoustic Emission Sensors
- ASTM E 1888 / E 1888 M: Standard Practice for Acoustic Emission Examination of Pressurized Containers Made of Fiberglass Reinforced Plastic with Balsa Wood Cores
- ASTM E 1930: Standard Practice for Examination of Liquid-Filled Atmospheric and Low-Pressure Metal Storage Tanks Using Acoustic Emission
- ASTM E 1932: Standard Guide for Acoustic Emission Examination of Small Parts
- ASTM E 2075 / E 2075M: Standard Practice for Verifying the Consistency of AESensor Response Using an Acrylic Rod

- ASTM E 2076 / E 2076 M: Standard Practice for Examination of Fiberglass Reinforced Plastic Fan Blades Using Acoustic Emission
- ASTM E 2191 / E 2191 M: Standard Practice Method for Examination of Gas-Filled Filament-Wound Composite Pressure Vessels Using Acoustic Emission
- ASTM E 2374: Standard Guide for Acoustic Emission System Performance Verification
- ASTM E 2478: Standard Practice for Determining Damage-Based Design Stress for Fiberglass Reinforced Plastic (FRP) Materials Using Acoustic Emission
- ASTM E 2533: Standard Guide for Nondestructive Testing of Polymer Matrix Composites Used in Aerospace Applications
- ASTM E 2598: Standard Practice for Acoustic Emission Examination of Cast Iron Yankee and Steam Heated Paper Dryers
- ASTM E 2661 / E 2661M: Standard Practice for Acoustic Emission Examination of Plate-like and Flat Panel Composite Structures Used in Aerospace Applications
- ASTM E 2863 / E 2863M: Standard Practice for Acoustic Emission Examination of Welded Steel Sphere Pressure Vessels Using Thermal Pressurization
- ASTM E 2907: Standard Practice for Examination of Paper Machine Rolls Using Acoustic Emission from Crack Face Rubbing
- ASTM F 914 / F 914 M: Standard Test Method for Acoustic Emission for Aerial Personnel Devices Without Supplemental Load Handling Attachments
- ASTM F 1430 / F 1430 M: Standard Test Method for Acoustic Emission Testing of Insulated and Non-Insulated Aerial Personnel Devices with Supplemental Load Handling Attachments
- ASTM F 1797: Standard Test Method for Acoustic Emission Testing of Insulated and Non-Insulated Digger Derricks
- ASTM F 2174: Standard Practice for Verifying Acoustic Emission Sensor Response
- ASTM E 2374: Standard Guide for Acoustic Emission System Performance Verification

CEN (EUROPEAN COMMITTEE FOR STANDARDIZATION)

- CEN EN 1071-3 2005: Advanced technical ceramics - Methods of test for ceramic coatings - Part 3: Determination of adhesion and other mechanical failure modes by a scratch test
- CEN EN 1330-1 1998: Non-destructive testing – Terminology – Part 1: List of general terms
- CEN EN 1330-2 1998: Non-destructive testing – Terminology – Part 2: Terms common to the non-destructive testing methods
- CEN EN 1330-9 2009: Non-destructive testing – Terminology – Part 9: Terms used in acoustic emission testing

- CEN EN 12817: 2010: LPG Equipment and accessories - Inspection and requalification of LPG tanks up to and including 13 m^3
- CEN EN 12819 2009: LPG equipment and accessories - Inspection and requalification of LPG tanks greater than 13 m^3
- CEN ISO/TR 13115 2011: Non-destructive testing - Methods for absolute calibration of acoustic emission transducers by the reciprocity technique (ISO/TR 13115:2011)
- CEN EN 13445-5 2009: Unfired pressure vessels - Part 5: Inspection and testing (Annex E)
- CEN EN 13477-1 2001: Non-destructive testing – Acoustic emission – Equipment characterization - Part 1: Equipment description
- CEN EN 13477-2 2010: Non-destructive testing – Acoustic emission – Equipment characterization - Part 2: Verification of operating characteristic
- CEN EN 13554 2011: Non-destructive testing – Acoustic emission – General principles
- CEN EN 13480-5 2012: Metallic industrial piping - Part 5: Inspection and testing
- CEN EN 14584 2013: Non-destructive testing - Acoustic emission - Examination of metallic pressure equipment during proof testing - Planar location of AE sources
- CEN EN 15495 2007: Non Destructive testing - Acoustic emission - Examination of metallic pressure equipment during proof testing - Zone location of AE sources
- CEN EN 15856 2010: Non-destructive testing - Acoustic emission - General principles of AE testing for the detection of corrosion within metallic surroundings filled with liquid
- CEN EN 15857 2010: Non-destructive testing - Acoustic emission - Testing of fibre-reinforced polymers - Specific methodology and general evaluation criteria
- CEN EN ISO 16148 2006: Gas cylinders - Refillable seamless steel gas cylinders - Acoustic emission testing (AT) for periodic inspection (ISO 16148:2006)
- CEN ISO/TR 25107 2006: Non-destructive testing - Guidelines for NDT training syllabuses (ISO/TR 25107:2006)
- CEN CR 13935 2000: Non-destructive testing - Generic NDE data format model

DYE PENETRANT TESTING (PT)

07

Dye penetrant is a dye used by inspectors in dye penetrant inspections, an inspection method in which inspectors apply a dye or liquid to a surface to identify defects in it.

Alternative terms:

- **Dye penetrant is also called liquid penetrant**
- **Dye penetrant testing is also called dye penetrant inspection (DPI), liquid penetrant inspection (LPI), liquid penetrant testing (LPT), or simply penetrant testing (PT)**

In this guide, we will use the terms dye penetrant and liquid penetrant interchangeably, following the alternate terms listed above.

Dye penetrant is one of the most commonly used inspection methods. It falls into the non-destructive testing category of inspection methods, because inspectors can use it without permanently altering or damaging the object they're inspecting.

Here is a menu to help you navigate this guide:

WHAT IS A DYE PENETRANT INSPECTION?

Inspectors use dye penetrant testing to look for cracks on the surface of assets and materials. After flowing the dye penetrant onto the surface they want to inspect, inspectors will then draw the liquid out using a chalk-like developer, and thus reveal any material defects that might be present on the surface.

The process relies on the principle of capillary action, which describes how fluids penetrate into cracks (or discontinuities) on the surface of a material.

Liquid penetrant testing is commonly used to inspect the surfaces of non-porous assets made out of ceramics, plastics, and metals, where inspectors will be looking at:

- **Welds**
- **Castings**
- **Forgings**
- **Plates**
- **Bars**
- **Pipes**

In these materials, inspectors will be using dye penetrant to look for defects like:

- **Leaks**
- **Joint flaws**
- **Fractures**
- **Porosity on the surface of the materials**
- **Cracks (cracks from fatigue, hairline cracks, or grinding and quenching cracks)**
- **Incomplete fusion**

Dye penetration inspections were first performed in the railroad industry in the early 20th century.

These early tests followed the oil and whiting method, in which a person first cleans a surface with an oil solvent and then applies chalk to the area (or another "whiting" material). The whiting would absorb oil from cracks present in the material, revealing their presence so that railroad personnel could identify and fix them.

Other industries began to adopt the method, eventually adding dye to make cracks more visible.

THE PROS AND CONS OF DYE PENETRANT INSPECTIONS

Penetrant testing is a popular NDT method for inspectors because it is inexpensive and fairly easy to learn how to do.

But those are just two of its benefits—here's a list of pros and cons for dye penetrant testing:

Pros

- Easy to perform, even with complicated surfaces/shapes
- Inexpensive—no expensive cameras or equipment are required to perform DPI
- Can be used to inspect large areas quickly
- Findings (i.e., defects identified by this method) can be seen visually on the surface of the materials and can show the dimensions of the defect
- Material flexibility—can be used on a variety of materials, including ferrous/non-ferrous, conductive/non-conductive, and magnetic/non-magnetic

Cons

- Limited findings—only detects cracks on the surface (or "open" to the surface)
- Porous materials can't be inspected with dye penetrant
- Dirty surfaces can't be inspected with dye penetrant—DP won't work on surfaces that contain paint, oil, dirt, rust, or any other similar kind of obstruction
- Direct access to the material is required
- There are several steps in the inspection process, each of which could impact the quality of the findings
- Cleaning is required both before and after the inspection (before to prepare the surface for the penetrant and after to clean the penetrant off the surface)
- Chemicals are involved—inspectors must follow protocol to handle and get rid of them, and these chemicals could produce hazardous or flammable fumes

HOW TO PERFORM A LIQUID PENETRANT TEST

In dye penetrant testing, inspectors generally follow these six steps:

1. CLEAN THE SURFACE

First, inspectors clean the surface they plan to test so that the surface is open and any defects it contains will be exposed, instead of remaining hidden underneath dirt or other foreign elements.

Cleaning processes inspectors commonly follow could include less invasive methods, like vapour degreasing, the use of solvents, or just wiping it with a wet rag, or more invasive methods, like grinding or wire brushing.

2. APPLY THE DYE PENETRANT

The penetrant that inspectors use is made just for this purpose, and it's typically sprayed or wiped onto the surface with a brush. After applying the penetrant, inspectors wait for a "dwell period" of five to twenty minutes to allow it to dry. (The right amount of time should be indicated on the label of the specific penetrant being used.)

3. REMOVE EXTRA PENETRANT AND APPLY REMOVER

Remove any excess penetrant with a dry rag.
After cleaning off extra penetrant, apply a remover to the surface and rub it dry with a fresh clean, dry rag.

4. APPLY DEVELOPER

After cleaning and removing the dye penetrant, apply a white developer to the surface. The developer will draw the penetrant from the flaws or cracks on the surface of the material and make them visible.

5. INSPECTION

At this point, cracks and other types of defects will be visible either to the naked eye or using white or ultraviolet light, depending on the type of penetrant that was used.

For visible dye penetrants, regular lighting conditions will allow defects to be visible. For fluorescent penetrants, U.V. lights at low ambient lighting will allow defects to be visible.
Now that the defects have been made visible, inspectors can conduct a visual inspection to identify any flaws that are present.

6. CLEAN THE SURFACE

After the inspection inspectors typically clean the surface that was inspected to return it to its original condition.

CHOOSING PENETRANTS, REMOVERS, AND DEVELOPERS

Inspectors have a few options to choose from for the penetrant, remover, and developer in the penetrant testing process.

Each of these options can be matched with any other (except for dry powder, which can't be used with color contrast penetrant) allowing inspectors to create their own combination to suit their needs.

Here are the different options for each step:

Penetrant options

- Color contrast
- Fluorescent
- Combination (both color contrast and fluorescent)

Remover options

- Solvent
- Post-emulsifiable remover
- Water-soluble
- Water-suspendable

Developer options

- Dry powder
- Aqueous
- Non-aqueous developer

Inspectors choose between each of these options based on factors like the type of surface they're inspecting, the size of the surface, and complexity of the surface.

DYE PENETRANT STANDARDS AND CODES

Given how inexpensive it is and how relatively easy it is to do, dye penetrant is often used by inspectors for informational purposes—that is, for inspections that do not have to comply with a specific code or set of standards.

But penetrant testing is also commonly used for code-based inspections.

For these inspections, inspectors must follow specific steps in how they conduct the test, including the requirement that they follow a written procedure and that the person conducting the test is certified to do so by the relevant standards body.

Here are some of the more widely used dye penetrant testing codes:

ASTM (AMERICAN SOCIETY OF TESTING AND MATERIALS)

- ASTM E 165: Standard Practice for Liquid Penetrant Examination for General Industry
- ASTM E 1417: Standard Practice for Liquid Penetrant Testing
- ASME BPVC, Section V, Article 6: Liquid Penetrant Examination
- ASME BPVC, Section V, Article 24: Standard Test Method for Liquid Penetrant Examination SE-165 (this standard is identical to ASTM E-165)

ISO (INTERNATIONAL STANDARDS ORGANIZATION)

- ISO 3452-1: Non-destructive testing - Penetrant testing - Part 1. General principles
- ISO 3452-2 : Non-destructive testing - Penetrant testing - Part 2: Testing of penetrant materials
- ISO 3452-3: Non-destructive testing - Penetrant testing - Part 3: Reference test blocks
- ISO 3452-4 : Non-destructive testing - Penetrant testing - Part 4: Equipment
- ISO 3452-5 : Non-destructive testing - Penetrant testing - Part 5: Penetrant testing at temperatures higher than 50
- ISO 3452-6 : Non-destructive testing - Penetrant testing - Part 6: Penetrant testing at temperatures lower than 10
- ISO 3059: Non-destructive testing - Penetrant testing and magnetic particle testing - Viewing conditions
- ISO 12706: Non-destructive testing - Penetrant testing - Vocabulary
- ISO 23277: Non-destructive testing of welds - Penetrant testing of welds - Acceptance levels

CEN (EUROPEAN COMMITTEE FOR STANDARDIZATION)

- EN 1371-1: Founding - Liquid penetrant inspection - Part 1: Sand, gravity die and low pressure die castings
- EN 1371-2: Founding - Liquid penetrant inspection - Part 2: Investment castings
- EN 10228-2: Non-destructive testing of steel forgings - Part 2: Penetrant testing
- EN 10246-11: Non-destructive testing of steel tubes - Part 11: Liquid penetrant testing of seamless and welded steel tubes for the detection of surface imperfections

Follow these links to read more about penetrant testing on the websites of internationally recognized standards organizations:

- American Society of Mechanical Engineers (ASME)
- American Society for Testing and Materials (ASTM)
- The National Board of Boiler and Pressure Vessel Inspectors (NBIC)
- International Standards Organization (ISO)

LEAK TESTING (LT)

08

Leak testing is a procedure that inspectors use to determine whether an object or system is functioning within a specific leak limit.

Leaks occur when there is a defect—a hole, crack, or some other kind of flaw—in an object, allowing whatever the liquid or gas it is holding to flow out. Leak testing uses pressure to find these defects so that they can be addressed as part of regular maintenance procedures.

In general, leak tests are performed on objects that are used to store or move liquids or gases.

Leak testing is one of the most commonly used inspection methods. It falls into the category of non-destructive testing (NDT) methods because inspectors can perform it without permanently altering or damaging the object they're inspecting.

Here is a menu to help you navigate this guide:

WHAT IS LEAK TESTING?

In leak testing, inspectors use pressure to identify the presence of defects in an object that are causing leaks.

When substances leak out of a container they flow from where the pressure is higher pressure to where it is lower. Leak testing leverages this phenomenon, using pressure to generate flow toward lower pressure—that is, the location of leaks—while carefully monitoring that flow.

The success of a leak test depends on the object that is being tested. Different types of materials and objects may respond differently to the high pressures typically used in leak testing to force a liquid or gas out of a defect, thus revealing its presence and location.

When leak testing materials, inspectors will be looking for defects like:

- **Cracks**
- **Holes**
- **Weak seals**
- **Other flaws or imperfections that may be allowing a gas or liquid to leak out of an object or system**

Here are the industries that commonly use leak testing as part of their maintenance processes:

- **Automotive**
- **Consumer goods**
- **Medical Devices**
- **Packaging**
- **Sealed Electronics**

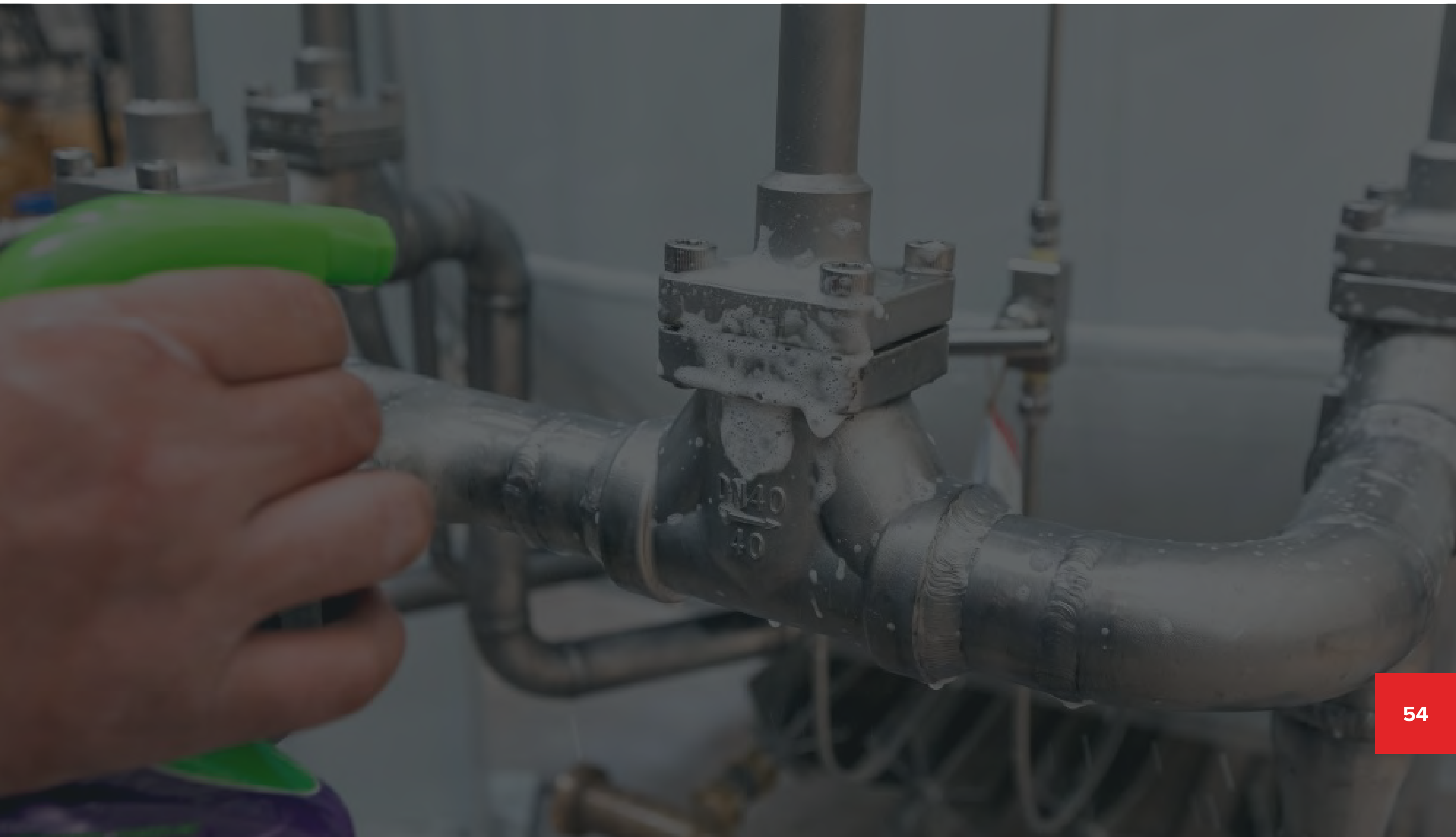
ADVANCES IN LEAK TESTING

Over the last several years, advancements in sensors, chips, valves, and other types of technology have helped make leak testing more sensitive and capable as an NDT method.

All of these advances have made leak testing faster and more accurate, and have in turn helped companies to improve the quality of their manufacturing processes and their overall output.

One of the biggest advances in leak testing has been the advent of the Internet of Things. Now, with an internet connection, inspectors can collect, monitor, and share leak testing data remotely, allowing them to get the information they need in a timely manner to ensure ideal maintenance.

This data can be evaluated not just by inspectors but also by manufacturing engineers, production managers, maintenance managers, and other stakeholders in the manufacturing process, allowing for improved, real-time insights into the conditions of the assets they're using.



LEAK TESTING METHODS

Here are some of the most common leak testing methods:

- **Burst**
  This method uses either a destructive or a non-destructive test that ramps pressure in order to find the point at which the device will break open (i.e., burst).

- **Chamber**
  This method is used to identify defects that are causing leaks in a sealed environment, like a device or package, that was not built with an opening to allow for the introduction of pressure for leak testing.

- **Pressure crack**
  This method is used to identify “weeping” in valves with a downstream sensor monitor.

- **Pressure / vacuum**
  This method uses the pressurization of a test object and a reference volume. If a leak is present, the difference between the two will decrease. (This process is fully automatic.)

- **Pressure decay**
  This method uses the pressure change of an object or system under positive pressure to identify defects that are causing leaks.

- **Vacuum decay**
  This method uses the pressure change of an object or system under negative pressure to identify defects that are causing leaks.

- **Occlusion**
  This method identifies obstructions in the flow path of a gas to identify defects that are causing leaks.

LEAK TESTING METHODS

Because leak testing requires inspectors to insert pressure into an object in order to identify leaks it has some unique considerations as an NDT method.

Here is an overview of things to keep in mind.

ACCEPTABLE LEAK RATE

It’s important for inspectors and maintenance personnel to know the acceptable leak rate for an object or system when performing leak testing.

Not all leaks require maintenance—some may just require further monitoring, or even no action at all. Different industries will typically have guidelines detailing acceptable leak rates for different products and substances.

MANUFACTURING CONSIDERATIONS

Before performing a leak test it’s important to consider the function for which a system, part, or object was originally made.

The target use case for a given object may require manufacturers to have created it in such a way that it will either retain or allow liquids to pass through it.

For example, a car part may be designed specifically so that gases can't escape from it, or an IV may be designed to keep liquids inside it.

MATERIAL CONSIDERATIONS

The substance that the object is made out of—its material—will impact a leak test, and should also be considered.

If a material is overly brittle or overly malleable, these qualities will directly relate to how the introduction of pressure will change the object, causing it to expand or change shape in some other way that should be considered when planning a leak test.

MEDIUM CONSIDERATIONS

The substance an object is made to hold must be considered when planning a leak test.

Different substances have different molecule sizes. When performing a leak test, it's important to know the size of defect that might be acceptable, and the size that would be big enough to allow a specific liquid or gas to escape.

A related consideration is pressure, because different substances will respond differently to different ranges of pressure. A pressure range that is too high could potentially damage the object being tested, while a pressure range that is too low may return inconclusive results.

LEAK TESTING EQUIPMENT

Here are some examples of the types of equipment that is commonly used in leak testing.

AIR LEAK TESTING DEVICES

Air leak testing devices have displays that show inspectors data from ongoing leak tests. These devices can be used for a variety of types of leak testing, including vacuum decay, pressure decay, burst, chamber, and others.

COMPACT PRESSURE DECAY LEAK TESTER

This kind of compact leak tester can be placed close to fixtures being used in leak testing, allowing inspectors to reduce the amount of connection volume needed for the test. This reduction in volume allows for a decrease in the time needed for the leak test and an increase in test sensitivity.

LARGE DISPLAY LEAK TESTER

Larger display leak testers like this one from Zaxis (called the 7i) have larger screens, greater internal capacity, larger test volumes, and allow for faster testing.

LEAK STANDARD

Inspectors use leak standards to define the parameters of their leak test by creating a simulated leak in the part under test, or to compare multiple leak systems with each other.

LEAK TESTING STANDARDS AND CODES

Leak testing is commonly used for code-based inspections.

Here are some of the more widely used leak testing codes:

ASME (AMERICAN SOCIETY OF MECHANICAL ENGINEERS)

- ASME B31.3: Pressure Testing and Leak Testing Requirements for Process Piping

ASTM (AMERICAN SOCIETY FOR TESTING AND MATERIALS)

- ASTM E432-91(2017)e1: Standard Guide for Selection of a Leak Testing Method
- ASTM E493 / E493M - 11(2017): Standard Practice for Leaks Using the Mass Spectrometer Leak Detector in the Inside-Out Testing Mode
- ASTM E499 / E499M - 11(2017): Standard Practice for Leaks Using the Mass Spectrometer Leak Detector in the Detector Probe Mode
- ASTM E1003 - 13(2018): Standard Practice for Hydrostatic Leak Testing
- ASTM A1047 / A1047M - 05(2019): Standard Test Method for Pneumatic Leak Testing of Tubing
- ASTM E1603/E1603M-11(2017) Standard Practice for Leakage Measurement Using the Mass Spectrometer Leak Detector or Residual Gas Analyzer in the Hood Mode
- ASTM F2164 - 21: Standard Practice for Field Leak Testing of Polyethylene (PE) and Crosslinked Polyethylene (PEX) Pressure Piping Systems Using Hydrostatic Pressure
- ASTM F2786 - 16(2021): Standard Practice for Field Leak Testing of Polyethylene (PE) Pressure Piping Systems Using Gaseous Testing Media Under Pressure (Pneumatic Leak Testing)
- ASTM E2930 - 13(2021): Standard Practice for Pressure Decay Leak Test Method
- ASTM WK76995: New Practice for Field Leak Testing of Polyamide-12 (PA12) Pressure Piping Systems Using Gaseous Testing Media Under Pressure (Pneumatic Leak Testing)

ISO (INTERNATIONAL ORGANIZATION FOR STANDARDIZATION)

- ISO 20484:2017(en): Non-destructive testing — Leak testing — Vocabulary
- ISO 20485:2017(en): Non-destructive testing — Leak testing — Tracer gas method
- ISO 20486:2017(en): Non-destructive testing — Leak testing — Calibration of reference leaks for gases
- ISO 27895:2009(en): Vacuum technology — Valves — Leak test

WHERE IS NON-DESTRUCTIVE TESTING USED?

Depending on how broadly you define NDT you could say that it's used in almost every industry in the world, since visual inspections (whether formalized or casual) take place in almost every workplace in some form or other.

That being said, there are specific industries that require NDT and have formalized processes for its use, as codified by those organizations we listed above like API and ASME.

These industries include:

- **Oil & Gas**
- **Power Generation**
- **Chemicals**
- **Mining**
- **Aerospace**
- **Automotive**
- **Maritime**

HOW DRONES CAN HELP WITH NDT

In the last several years drones equipped with cameras have become another tool commonly used in NDT for collecting visual data.

Due to limitations in the technology, for some time drones could only provide supplementary visual data for inspectors, but could not take the place of inspectors physically collecting visual data themselves.

However, as drone technology has improved, inspectors have been able to use drones more and more as RVI tools, in some instances completely replacing the need for them to collect visual data manually.

Here are two of the primary ways drones are helping with NDT these days:

SAFETY

By removing the need for inspectors to enter dangerous spaces in order to collect visual data drones are helping improve safety in the workplace.

For outdoor inspections of assets like power lines or towers, using a drone to collect visual data reduces the amount of time a person needs to physically be in the air on the tower or line.

For indoor inspections of assets like pressure vessels or boilers, using a drone like the **Elios 2** to collect visual data means the inspector does not have to enter a confined space to do so, again helping significantly reduce the exposure to risk.

SAVINGS

Drones can help companies improve their ROI in both indoor and outdoor scenarios, but savings are especially significant for indoor inspections.

Using a professional **indoor drone** instead of sending an inspector in to collect visual data manually means that companies save on not having to build and take down scaffolding, and can reduce **downtimes** associated with those requirements, in some cases by as much as one to two days.

WHAT'S NEXT FOR DRONES IN NDT?

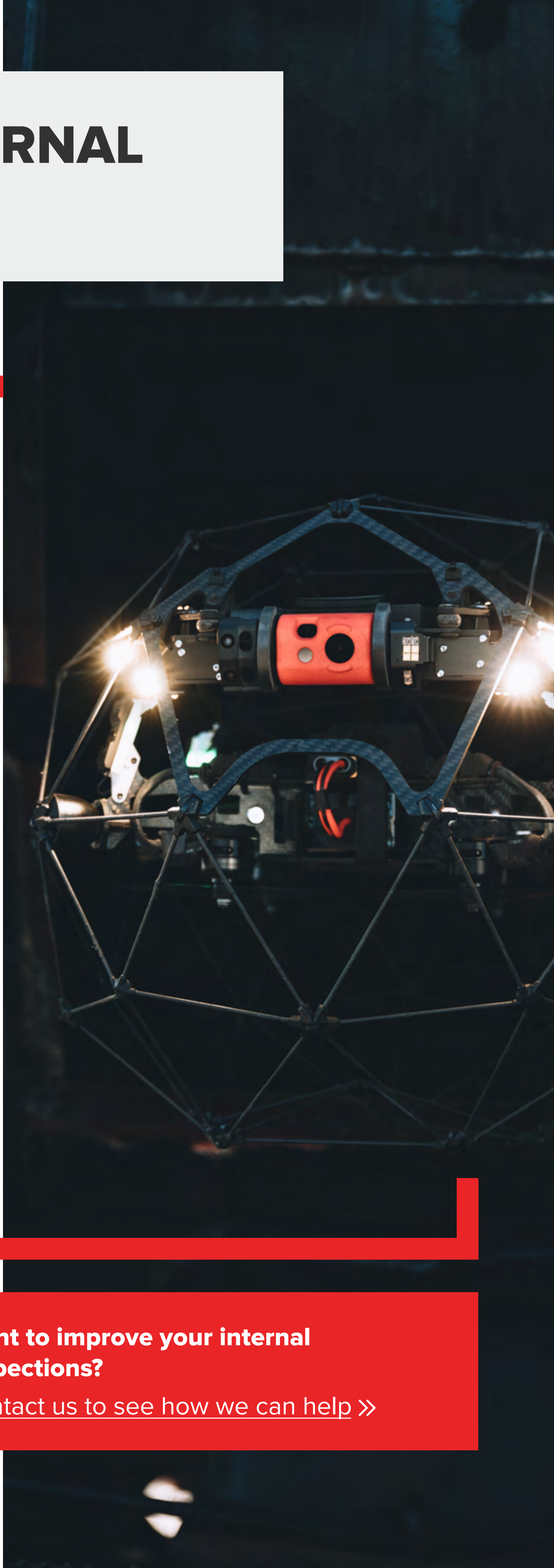
To date, the primary use case for drones in NDT has been for the collection of visual data.

But in the last few years, thermal sensors attached to drones have allowed inspectors to collect thermal data by drone, and as time passes it's likely that we'll see new sensors developed for drones to support even more NDT techniques.

IMPROVE YOUR INTERNAL INSPECTIONS

Any industry that requires visual data collection in confined spaces can realize these three benefits—safety, savings, and reduced downtimes—by using indoor drones in their internal inspections.

Flyability was the first company ever to create an indoor drone in a cage for internal inspections. Our Elios 2 is the premier indoor drone on the market, and can help you improve safety, cut costs, and significantly reduce downtimes for your internal inspections.



Want to improve your internal inspections?

Contact us to see how we can help »