

# CAT 1 Principles of Ultrasound



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# ASU Module 1-1 Training Overview

Ultrasound has been used for years for many different applications. From ultrasonic welding, mixing, motion detection, medical application like imaging & physical therapy just to name a few. The use of Ultrasound can all be tied back to one man who in 1901 demonstrated a direct conversion heterodyne receiver as a method for making continuous radiotelegraphy signals audible. His name was Reginald Aubrey Fessenden and he was born on October 6<sup>th</sup>, 1866 in East-Bolton, Quebec. He entered the Bishop College School in Port Hope, Quebec at the age of 14 years old where he was granted a mathematics mastership where he taught mathematics to younger and older students.

He created a process called Heterodyning which is a signal processing technique in which new frequencies are created by combining two frequencies. By shifting one frequency range into another, the new frequency goes through the process of modulation & demodulation. This process is used in a nonlinear signal processing device that combine the two frequencies to make two new frequencies. In the case of an Ultrasonic Detection Device the two frequencies are High and Low Frequencies. The unit will then filter out the Low Frequency and allows the High Frequency to stand alone. This process has been used in everything from Morse Code, Radio Receivers, Music synthesis to mixers and has been applied to Ultrasonic Detection Devices since the 1950's.

Ultrasonic detection equipment has become a trusted source for trending and troubleshooting over the last few decades. The ability now to run the sound waves through a sound analysis software has opened a new realm of things for the inspectors. No longer is Ultrasound simple a Go No Go test it can be used for determining Stray Voltage in a motor, Inner & Outer Race faults, Cage Faults, Ball Pass Faults, Corona, Track, Arcing, Loose connection, Delamination of Windings in a Transformer. These issues can be determined by simply look at the images of the sound wave. Each one will have a distinct image that shows the Harmonic Marks that tell us the Fault Frequency of those Harmonics. In addition, the use of a Time Series will show the harmonics and the Amplitude of the Sinusoidal Wave.

## Company Overview

IRISS is the global leader in Electrical Maintenance Safety Devices & Solutions (EMSD). We help our customers reduce downtime related costs & maximize efficiency by reducing inspection times. EMSD's warn you of potential equipment failures before they occur, maintain the energized compartment's closed, safe and guarded condition ensuring workers are never exposed to the dangers of Arc Flash or electrocution, & automate asset inspection data collection process driving more efficiency improvements. Our EMSD solutions reduce risk, minimize cost and maximize efficiency.

## Mission Statement:

At IRISS, we provide our customers unsurpassed quality at every touch point. We focus on what we do best by continuously improving infrared (IR) window technology, building reliable products, exceeding customer expectations, remaining a science-based R&D company, and protecting our polymer IR windows through Our Unconditional Lifetime Warranty.

IRISS industrial-grade IR windows facilitate safer, more efficient inspections of energized electrical equipment when compared to traditional crystal windows. Our award-winning, IR window designs feature a durable transparent polymer lens that allows visual, UV, and short/mid/longwave IR spectrum inspections. And...is available in custom shapes, sizes, and color to fit the needs of any application.

As solution providers, the team at IRISS brings a multitude of experience from world-class maintenance programs together to meet the individual needs of commercial, industrial, marine, power generation and government maintenance programs.

## Mission:

IRISS is a business born out of recognition of the need of the global condition-based maintenance industry to safely perform energized inspections on electrical assets. It is our mission to exceed client expectations by continuing to set the industry standard for products, services and support for the electrical maintenance market through innovative Electrical Maintenance Safety Devices (EMSDs) and solutions, that leverage our unique industry experience.

## Vision:

To become a driving force and the global leader in Electrical Maintenance Safety Devices (EMSDs) and training solutions.

## Values:

### Obsessed with Finding a Better Way:

We design and build quality into all products, services and operational systems. Our clients demand and deserve unsurpassed quality in every aspect of how we interface with them. It is our duty to not just meet their needs but to exceed their requirements on every project.

### Great just isn't Good Enough:

It is the daily responsibility of each and every IRISS employee to ensure that our commitment to excellence shows through in every aspect of the company, at all times, in every interaction with every customer both internal and external.

### Continuous Improvement:

We consistently leverage our personal, company and client experiences to continually innovate and improve our products, services and processes. We strive to serve as the industry leader in enabling safe electrical maintenance practices.

### Employee Involvement is Crucial:

IRISS is a team. As such we will value and support the unique skills and assets which every team member brings to the group. Above all, we demand that each team member consistently demonstrates respect for their team members. Our doors are open to men and women alike without discrimination and without regard to ethnic origin or personal beliefs.

### It's not about WHO is right, it's about WHAT is right:

IRISS only employs people with uncompromising integrity. Every IRISS team member will always act with the highest level of integrity when interacting with clients, peers and vendors. We must strive to earn the respect of our clients and our industry with unwavering integrity in a socially responsible manner, making a positive contribution not only to our clients, but to society.

## I.C.A.S.T. Course:

The I.C.A.S.T. course is one of the first steps in training that is available from IRISS. This course will stress the benefits of the different technologies and how they work in an integrated RCM Program. The course will offer help to the site in developing their program to insure the simplest collection of data. It is also the precursor course to Level 1 and should be taken prior to scheduling a Level 1 course as its focus is on insuring that the inspectors know what applications the equipment can be used for, how to operate the equipment, how to collect data, and how-to analysis the data in the software. This 20-hour course can be customized to focus on one application or all the applications. This course will also count toward the recommend number of hours of use recommended by ISO standards 13379, 17027, 18436-7, and 29821-1, that an inspector should've prior to taking a Level 1 Certification Course. This is important as the ASNT-TC-1A Level 1 Courses have generally been taught as a Theory class and they do not go as in-depth on the software and data collection process. The ISO Standards have changed this.

## Ultrasound Level 1 IRISS Qualification for Certification

**ISO Standard 18436 & ASNT SNT TC-1A**, Are standards for personnel Qualification and Certification in Nondestructive Testing.

ISO 18436-3:2012 Condition monitoring and diagnostics of machines -- Requirements for qualification and assessment of personnel -- Part 3: Requirements for training bodies and the training process.

ISO 18436-3:2012 defines the requirements for bodies operating training programs for personnel who perform machinery condition monitoring, identify machine faults, and recommend corrective action. Procedures for training of condition monitoring and diagnostics personnel are specified.

ISO 18436-6:2014 Condition monitoring and diagnostics of machines -- Requirements for qualification and assessment of personnel -- Part 6: Acoustic emission.

ISO 18436-6:2014 specifies the requirements for qualification and assessment of personnel who perform machinery condition monitoring and diagnostics using acoustic emission.

A certificate or declaration of conformity to ISO 18436-6:2014 will provide recognition of the qualifications and competence of individuals to perform acoustic emission measurements and analysis for machinery condition monitoring using acoustic emission equipment. This procedure may not apply to specialized equipment or other specific situations.

ISO 18436-6:2014 specifies a three-category classification program that is based on the technical areas delineated herein.

ISO 18436-8:2013 Condition monitoring and diagnostics of machines -- Requirements for qualification and assessment of personnel -- Part 8: Ultrasound.

ISO 18436-8:2013 specifies the requirements for qualification and assessment of personnel who perform machinery condition monitoring and diagnostics using ultrasound.

A certificate or declaration of conformity to ISO 18436-8:2013 provides recognition of the qualifications and competence of individuals to perform ultrasound measurements and analysis for machinery condition monitoring using ultrasound equipment. It is possible that this procedure is not applicable to specialized equipment or other specific situations.

ISO 18436-8:2013 specifies a three-category classification program that is based on the technical areas delineated herein, consistent with ISO 18436-1 and ISO 18436-3. (Source [www.iso.org/standard/50608.html](http://www.iso.org/standard/50608.html)).

Recommended Practice No. ANST SNT-TC-1A 2016 Personnel Qualification & Certification in Nondestructive Testing.

## 1.0 Scope

1.1 It is recognized that the effectiveness of nondestructive testing (NDT) applications depends upon the capabilities of the personnel who are responsible for, and performs, NDT. This recommended Practice has been prepared to establish guidelines for qualifications and certification of NDT personnel whose specific jobs require appropriate knowledge of the technical principles underlying the nondestructive tests they perform, witness, monitor, or evaluate.

1.2 This document provides guidelines for the establishment of qualification and certification program.

1.3 These guidelines have been developed by the American Society for Nondestructive Testing, Inc., to aid employers in recognizing the essential factors to be considered in qualifying personnel engaged in any of the NDT methods listed in Section 3.

1.4 It is recognized that these guidelines may not be appropriate for certain employers' circumstances and/or applications. In developing a written practice as required in Section 5, the employer should review the detailed recommendations presented herein and modify them, as necessary, to meet particular needs. Such modification may alter but shall not eliminate basic provisions of the program such as training, experience, testing and recertification. Supporting technical rationale for modification of detailed recommendation should be provided in an Annex to the written practice.

## 4.0 Levels of Qualification

4.1 There are three basic levels of qualification. The employer may subdivide these levels for situations where additional levels are deemed necessary for specific skills and responsibilities.

4.2 While in the process of being initially trained, qualified and certified, an individual should be considered a trainee. A trainee should work with certified individual. The trainee should not independently conduct, interpret, evaluate, or report the results of any NDT test.

4.3 The three basic levels of qualification are as follows:

4.3.1 NDT Level I. An NDT Level I individual should be qualified to properly perform specific calibrations, specific NDT, and specific evaluations for acceptance or rejection determination according to written instructions and to

record results. The NDT Level I should receive the necessary instruction and supervision from a certified NDT Level II or III individual.

4.3.2 NDT Level II. An NDT Level II individual should be qualified to set up and calibrate equipment and to interpret and evaluate results with respect to applicable codes, standards, and specifications. The NDT Level II should be thoroughly familiar with the scope and limitations of the methods for which qualified and should exercise assigned responsibility for on-the-job training and guidance of trainees and NDT Level 1 personnel. The NDT Level II should be able to organize and report the results of the NDT tests.

4.3.3 NDT Level III. An NDT Level III individual should be capable of developing, qualifying, and approving procedures, establishing and approving procedures, establishing and approving techniques, interpreting codes, standards, specifications, and procedures; and designating the particular NDT methods, techniques, and procedures to be used. The NDT Level III should be responsible for the NDT operations for which qualified and assigned and should be capable of interpreting and evaluating results in terms of existing codes, standards, and specifications. The NDT Level III should have sufficient practical background in applicable materials, fabrication, and product technology to establish techniques and to assist in the establishing acceptance criteria when none are otherwise available. The NDT Level III Should have general familiarity with other appropriate NDT methods, as demonstrated by an ASNT Level III Basic examination or other means. The NDT Level III, in the methods in which certified, should be capable of training and examining NDT Level I and II personnel for certification in those methods. (Source SNT-TC-1A 2016)

## Keys to a Successful Program

Being able to turn on an Ultrasound Unit does make someone an inspector any more than someone who goes through training but never uses the equipment makes them knowledgeable. The key to an ultrasound equipment is receiving proper training and time to use that equipment. This will help the Inspector gain more confidence in the equipment and themselves.

Understanding the physics of ultrasound is key factor to success of a program. If an inspector does not understand how the ultrasonic waves interact with different mediums or how they travel through said mediums they will struggle to acquire the proper signal, which can lead to misinterpretation of the sound waves and data collected.

It is just as important that the inspector have the physical capabilities to carry out the use of the equipment. This means they must be able to carry, operate, move around tight spaces, stand for hours at a time, can hear, can see, and comprehensive skill to analyzing all the information gathered. A great classroom test is to ask everyone to hold up their phones for everyone to see. If someone holds up a flip style phone, then they might not be comfortable using modern technology. This does not eliminate them from being able to perform the inspection it just means they may require more hands-on learning rather than lectured material or manuals.

The inspector must also have the knowledge of the safety hazards they should be concerned with while testing. Some examples are; Fork trucks, atmospheric conditions, electrical hazards, steam leaks, moving equipment, limited visibility, falls, slipping, foot holds, three points of contact, fire hazards, temperatures, and confined spaces to name a few.

Knowledge of the asset being tested is another key component to a successful ultrasound program. The inspector must know what type of motor they are testing so they know if it is a VFD controlled motor that would show stray voltage at the frequency its being driven at. This would also allow the inspector to pick out fault frequencies with the inner, or outer race, the bearing themselves or if there is a cage fault. On electrical systems, they would need to know the voltage of the asset being tested.

Inspectors must also know the techniques for properly testing so they can isolate anomalies from background noise. These techniques insure the inspector is actually locating the anomaly and not competing ultrasound. Over time as the inspector uses their equipment and software their experience will broaden, and they will feel more comfortable utilizing the equipment and software.

## Applications for Ultrasound

With so many applications that Ultrasound can be utilized for and its ease of use it has quickly become a mainstay of many programs throughout the World. It is also a great complimentary technology that can be used for confirmation of an issue, trouble shooting, or a sort tool for other technologies to be deployed. The ability to trend, compare, benchmark, and analyze like equipment allows for



expedited test results. With so many companies now using ultrasound as one of its Pd/M tools the science has improved greatly since it was first used for trouble shooting or pass-fail test results.

## Who can use Ultrasound?

No matter the type of facility the equipment is used in, the applications are the same. Even the equipment in different type of industry are similar it is just what they are used for that's different. For ultrasound testing we do not care if the electrical equipment is powering a conveyor or a mixer. We just need the voltage its driven at. In the case of motors RPM and number of bearings will help us confirm fault frequencies. In pressurized systems, we can use the decibels to determine annual cost avoidance of each induvial leak. So, it does matter if it's a Waste Water Treatment, Warehouse, Mine, or a Power Generation Station as Ultrasound is only looking for ultrasound anomalies and not the type of industry that's using it.

# ASU Module 1-2 Introduction to Sound Theory

Sound is one of the human senses that allows us to experience the World around us in sound waves. It can be the most amazing song or the loudest boom from a jet breaking the sound barrier. All of these sounds are translated by our ear and interpreted by our brain as something pleasant or pain full. In this chapter, we will discuss the makeup of a sound wave.

Ultrasound can be produced by frictional occurrence that are happening inside of an asset or occurring in atmosphere. Interior frictional occurrence can happen in motor, gear boxes, bearing housings, pistons, hydraulic rams, and fan housings. Exterior Frictional occurrences can happen on conveyor rolls, belts, belt splices, finger guards, chains, and sprockets to name a few.

Ultrasound can also be produced by turbulent occurrences that just like frictional occurrence can happen both internally and exteriorly. Internal occurrences such as vacuum leaks, valve leaks of all types of material, steam trap discharges, pump cavitation, and back pressure issues to name a few.

There are two other categories we need to understand as well. These categories fall under the antagonistic ultrasound anomalies categories. The first of these two antagonistic categories are man-made antagonistic ultrasound. The source of these man-made antagonistic ultrasound can be generated by ultrasonic motion detectors, ultrasonic pest repellents, bad ballast, control panel displays, and heat syncs to name a few things that will produce antagonistic ultrasound. The second category of antagonistic ultrasound is natural generated ultrasound. These happen often in nature from bats, to blades of grass rubbing together in a breeze, snowflakes, rain drop impacting on the ground, bug noises which sound electrical to even mice chirping.

It is critical that the inspector understand all the things that can produce ultrasound around them at any time they are using ultrasound. This course will teach the inspector how to properly use their equipment, its features, accessories, inspection techniques to minimize, isolate or eliminate these antagonistic ultrasound anomalies.

## What Is Ultrasound?

Animals such as bats & porpoises use ultrasound for finding prey and obstacles. Bats are a great example and the Brown Bat sound wave attached recorded in New York in the late summer. You can hear the frogs in the canal and the rustling of the grass under the feet of the researcher as he walks. You can even hear the shear wave in the unit from the researcher's voice. Then suddenly you hear a ticking sound start up. It last for a few seconds and you can even hear the signal returning to the Bat. When the researchers turned on their lights, they saw the Bat and it retreated from the area.

What we hear is part of the frequency admitted by the Bat as it navigates its way through the dark looking for a meal. This process is called Echolocation and scientist have applied this to everything from Sonars, Pulse Level Measurement Systems to Ultrasonic Light Switches. Check out more sounds of Bats on the USGS website. <https://www.werc.usgs.gov/OLDSitedata/bats/searchphasecall.html>

A mechanical wave is a local oscillation in medium and it transfers its energy through that medium. These waves can move over long distances and the oscillating medium itself does not move far from its incipient position as it is the mechanical wave that transport the energy through the medium. The energy propagates in the same direction as the wave travels through the medium. Mechanical waves can be produced only in medium which has an elastic or dense property. A mechanical wave must create an incipient energy input. Once this incipient energy takes place the wave will travel through that medium until it transfers all energy. In comparison, electromagnetic waves however need no medium, but can still travel through one. The following are the most common examples of a mechanical wave: seismic waves, and sound waves, and water waves.

## The Physics of Ultrasound

Ultrasound is a sound wave with a frequency higher than that of the upper audible limit of human hearing. Ultrasound is no different from audible sound in its physical properties, except it cannot be heard by human ear. From person to person this limit varies, and the normal range is approximately 20 kilohertz (20 kHz or 20,000 hertz) in young adults. Ultrasound devices operate with frequencies from 20 kHz up to several gigahertz.

Ultrasound is used in many different sciences as ultrasonic devices are used to detect objects, measure distances and detect anomalies. Ultrasound Imaging is often used in for medical application. To Power Ultrasound which can be used to bust up kidney

stones or reduce inflammation in joints during physical therapy.

In the Pulse Echo Ultrasound testing (Nondestructive Testing or NDT) of products & structures, ultrasound is used to detect invisible flaws in bridges, pipes or vessels walls to name a few applications. Power Ultrasound in the industrially setting can be used for cleaning, mixing, and to accelerate chemical processes.

In Airborne/Structure Borne Ultrasound the inspector uses the Ultrasonic Emission of the anomaly identify the source & condition of the asset. These anomalies have 2 primary sources of creation. Frictional events and Turbulent events. These sources help to identify quickly asset health. There is a 3<sup>rd</sup> source that can create competing Ultrasonic Anomalies when testing. This 3<sup>rd</sup> source is Manmade Ultrasonic Anomalies which can be generated by motion sensing light switches, electronic display panels, PA speakers, bad ballast, and flat panel monitors to name a few.

Ultrasonic Sound Waves are not capable of passing through solid objects like a low frequency sound wave can & as such will not penetrate through a second medium. We will explore this later in this section.

## The Theory of Sound

What exactly is sound? Sound is a vibration that travels through the air or another medium and can be heard when they reach with the human or animal's ear. Sound is a type of energy made by vibrations. When any object vibrates, it causes movement in the medium particles. These particles bump into the particles close to them, which makes them vibrate too causing them to bump into more medium particles. This movement, is called a sound waves.

## The Human Hearing Experience

The Human experience of hearing is not unique to just our species. All animals having hearing capabilities like we do, but many have different ranges than we can detect. The range of Human hearing is 20 Hz – 20 kHz, while our hearing is best suited for the 2,000 Hz to 5,000 Hz range. The Male voice can range from 85 – 180 Hz, and the Female voice can range from 165 – 255 Hz. Most speech falls below the bottom of the “voice frequency” band as defined above. That does not however mean that there will not be enough of the harmonic series present for the missing frequency to give the impression of the Human hearing experience. In the Telecommunication industry, the approximate range for the usable voice is 300 – 3400 Hz.

Over stimulation of the nerves is enough to cause acoustic trauma. Symptoms can range from migraines, dizziness to more serious issue like these ones reported in “Noise: Health Effects and Controls” (PDF). University of California, Berkeley. Archived from the original (PDF) on 2007-09-25. High frequency hearing is the first level to go. If you've ever heard a ringing in your ear this is the death tone of that frequency. You will not realize you have suffered damaged to your hearing until it starts too effect your lower frequency hearing range. Hearing loss often happens gradually, very seldom does hearing loss happen all at once.

## Intensity Level of Sounds

The amplitude of a sound wave of a given frequency and wavelength is a measure of its intensity. In other words, intensity is the amount or degree of strength of a sound in each area or volume. Sound can be gauged in decibels which is most commonly used in acoustics as a unit to measure the intensity of the pressure wave. The human hearing experience is said to have a large dynamic range. Since the human hearing experience is sensitive enough to hear all sounds, greatest noise levels are gauged more heavily into some measurements using frequency weighting. This is based of Steven's power Law which states the following;

Stevens's power law is a proposed relationship between the magnitude of a physical stimulus and its perceived intensity or strength. It is often considered to supersede the Weber–Fechner law on the basis that it describes a wider range of sensations, although critics argue that the validity of the law is contingent on the virtue of approaches to the measurement of perceived intensity that are employed in relevant experiments. In addition, a distinction has been made between local psychophysics, where stimuli are discriminated only with a certain probability, and global psychophysics, where the stimuli would be discriminated correctly with near certainty (Luce & Krumhansl, 1988). The Weber–Fechner law and methods described by L. L. Thurstone are generally applied in local psychophysics, whereas Stevens's methods are usually applied in global psychophysics.

## How is Sound Produced?

Sound is produced when something vibrates. The vibrating body causes the medium (water, air, etc.) around it to vibrate. Vibrations in air are called traveling longitudinal waves, which we can hear. Sound waves consist of areas of high and low pressure called compressions and rarefactions, respectively.

## How Sound Travels

Sound waves exist as variations of pressure in a medium such as water. They are created by the vibration of an object, which causes the air surrounding it to vibrate. Sound waves travel through air in much the same way as they do water. In fact, since water waves are easy to see and understand, they are often used as an analogy to illustrate how sound waves behave.

## Sound Wave Movement

There are three types of mechanical waves: longitudinal waves (Incident wave), transverse waves (Shear wave), and surface waves.

### Longitudinal Wave

A longitudinal wave (Incident Wave) cause the medium to vibrate parallel to the direction of the wave propagation. It consists of multiple compressions and rarefactions. The rarefaction is the farthest distance apart in the longitudinal wave and the compression is the closest distance together. The particles do not move. It is much like standing in the ocean as the waves move you back and forth between the crests. Sound is considered a longitudinal wave.

### Transverse Wave

Transverse waves (Shear Wave) causes the medium to vibrate at a right angle to the propagation through a medium. Transverse waves have two parts—the crest and the trough. The compression is the highest point with the density of particles in the wave and the rarefaction is the lowest density of particles. The distance between a compression and a rarefaction is half of wavelength. The wavelength is the distance from compression to compression or from rarefaction to rarefaction.

### Surface Waves

This type of wave travels along a surface that is between two media. An example of a surface wave would be waves in a pool, or in an ocean, lake, or any other type of water body. There are two types of surface waves, namely Rayleigh waves and Love waves.

Rayleigh waves, also known as ground roll, are waves that travel as ripples with motion similar to those of waves on the surface of water. Rayleigh waves are much slower than body waves, 90% of the velocity of body waves for a typical homogeneous elastic medium.

A Love wave is a surface waves having horizontal waves that are shear or transverse to the direction of propagation. They usually travel slightly faster than Rayleigh waves, about 90% of the body wave velocity, and have the largest amplitude.

## What is a Sinusoidal Wave?

A sinusoidal or sine wave is a repetitive oscillation in a medium. It is the only periodic waveform that keeps its wave shape when added to another sine wave. This allows for the sine wave to be run through Fourier Analysis. As defined in Merriam-Webster “A waveform that represents the periodic oscillations in which the amplitude of displacement at each point is proportional to the sine of the phase angle of displacement and that is the visualized as a sine curve”. The repetitive nature of these waves is what produces the pressure wave we can hear with our ears or when using ultrasonic heterodyning equipment.

## The 9 Components of a Sound Wave

There are 9 components of a sound that we will discuss. Most people know of a few of the components like pitch, loudness and decibels. However, there is more to it then these three components here is the basic break down on these 9 components.

- **Amplitude:** The height of a wave's crest which determines its loudness.
- **Compression:** A region in a sound wave where particles have been pushed together and are the densest part of the wave.

- **Decibels:** Are the measurement of the loudness or intensity of the sound wave.
- **Frequency:** The number of waves produced in a given period of time.
- **Hertz:** Named for the German physicist who produced the first electromagnetic waves artificially.
- **Loudness:** The intensity of the pressure wave resulting in the levels of intensity perceived by the someone.
- **Pitch:** Is a term used to describe the highness or lowness of a sound wave and the differential between them.
- **Rarefaction:** The region in a sound wave where the particles have been spread out and are the least dense part of the wave.
- **Wavelength:** The measurement of a sound wave from compression to compression or rarefaction to rarefaction.

## Amplitude

Amplitude of a sound wave is the magnitude of the Crest (Compression) or Troughs (Rarefaction) we can see here in this diaphragm. Amplitude does not depend on the frequency of the wave. The Magnitude of the Crest or Trough can be measured in Peak to Peak, Peak Value, Semi-amplitude, Root Mean Square (RMS), or Averaging.

### Peak-to-Peak Amplitude:

Peak-to-peak amplitude is the change between the crest and trough. With Sonus Vue Software, peak-to-peak amplitudes of ultrasound can be measured by viewing the waveform in Time Signal (Amplitude scaled in percentage above or below Zero) or Spectrogram (A 3D scaling comparing amplitude, frequency of occurrence and decibels). Peak-to-peak is a straightforward measurement of amplitude in Sonus Vue, the peaks of the sound wave can easily be seen and measured against each other. This is the most common way of specifying amplitude, but sometimes incidences other measures of amplitude are more effective for fault analysis.

### Peak Amplitude

In ultrasound, it is the measure of a signal's magnitude above and below a 0% value. Peak amplitude is used with a 0% value as the constant reference point. This is the absolute value of the signals the amplitude.

### Semi-Amplitude

Semi-amplitude measurement looks at only half of the peak-to-peak of the amplitude displayed. There is some scientific debate over the use of the term's amplitude or peak amplitude in reference to mean semi-amplitude.

### Root Mean Square Amplitude

Root mean square (RMS) amplitude is the most commonly used setting when viewing sound waves in spectral analysis software. The Definition of RMS is a square root of the mean over time of the square of the crest magnitude on a graph from the 0% value. For sound waves, especially non-repetitive sound waves like noise, RMS amplitude is not subject to misinterpretation. Example: the average sound energy transmitted by an electromagnetic wave or an electrical signal is proportional to the square of the RMS amplitude (and not, in general, to the square of the peak amplitude).

### Averaging

Averaging is normally taken to mean the average value of only half a cycle of the wave. If the average of the full cycle was taken it would of course be zero, as in a sine wave symmetrical about zero, there are equal excursions above and below the zero line.

## Rarefaction & Compression

In the physics of sound there are two segments in a longitudinal wave during its travel or motion. One segment is Rarefaction and the other segment being compression. Sound Waves are a Pressure Wave that have two key components that move molecules in the medium and allow the transfer of that energy through the medium, they are Compression & Rarefaction. A Pressure Wave is a type of kinetic energy that compresses molecules together and allows the passing of kinetic energy to other molecules. Thus, sound energy travels outward from the source. These molecules are part of a medium, which is anything that carries sound. Sound

travels through air, water, or even a block of steel, thus, all are mediums for sound to travel through. Without a medium, there are no molecules to carry the sound waves. In places like outer space there is no atmosphere, so the molecules are spread-out to far apart for compression & rarefaction to occur.

A perfect example of this is a tuning fork. If we hit a tuning fork against a table, the prong of a tuning fork vibrates in the air. The layer of air next to the prong begins to emit a pressure wave that compresses the air around it when it moves. Those causing the air molecules push together. When the tuning fork prong springs back in the opposite direction however, it leaves an area of reduced air pressure where the air molecules are spread out. This is rarefaction. A succession of rarefactions and compressions is what makes up the longitudinal wave motion that radiates from source. Pressure Waves travel through a gas or liquid consists of compression waves. In solids, waves propagate as two different types, a longitudinal wave or transverse wave.

## Decibel

The decibel (symbol: dB) is a unit used to express the relative intensity of a sound on a scale from 0 dB (Least perceivable) to 130 dB (Pain Level). One of these values is often a standard reference value, in which case the decibel is used to express the level of the other value relative to this reference. There are two different scales used when expressing a ratio in decibels depending on the nature of the quantities: field quantity ratio or power quantity ratio. (Field quantity ratio is also referred to as root-power ratio or amplitude ratio.) When expressing power quantities, the number of decibels is ten times the logarithm to base 10 of the ratio of two power quantities. That is, a change in power by a factor of 10 corresponds to a 10-dB change in level. When expressing field quantities, a change in amplitude by a factor of 10 corresponds to a 20-dB change in level. The extra factor of two is due to the logarithm of the quadratic relationship between power and amplitude. The decibel scales differ so that direct comparisons can be made between related power and field quantities when they are expressed in decibels.

The definition of the decibel is based on the measurement of power in the telephony of the early 20th century in the Bell System in the United States. One decibel is one tenth (Deci-) of one bel, named in honor of Alexander Graham Bell; however, the bel is seldom used. Today, the decibel is used for a wide variety of measurements in science and engineering, most prominently in acoustics, electronics, and control theory. In electronics, the gains of amplifiers, attenuation of signals, and signal-to-noise ratios are often expressed in decibels.

In the International System of Quantities, the decibel is defined as a unit of measurement for quantities of type level or level difference, which are defined as the logarithm of the ratio of power- or field-type quantities.

Merriam-Webster defines Decibel;

1. a: a unit for expressing the ratio of two amounts of electric or acoustic signal power equal to 10 times the common logarithm of this ratio.  
b: a unit for expressing the ratio of the magnitudes of two electric voltages or currents or analogous acoustic quantities equal to 20 times the common logarithm of the voltage or current ratio.
2. a unit for expressing the relative intensity of sounds on a scale from zero for the average least perceptible sound to about 130 for the average pain level.
3. degree of loudness; also: extremely loud sound —usually used in plural.

Frequency is the number of occurrences of a repeating event per unit time. Scientifically it is also referred to as a temporal frequency, which emphasizes the differences between the spatial frequency & angular frequency. The duration of time of one cycle in a repeating event is known a period, so the period is the opposite of the frequency. Frequency is used in science and engineering to specify the rate of oscillation & vibration in mediums, such as mechanical vibrations, ultrasound, and light.

## Decibels

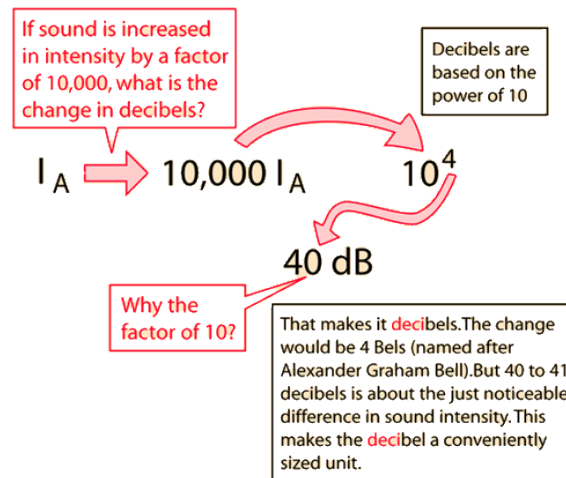
Source: <http://hyperphysics.phy-astr.gsu.edu/hbase/Sound/db.html#c1>

The sound intensity  $I$  may be expressed in decibels above the standard threshold of hearing  $I_0$ . The expression is

$$I(dB) = 10 \log_{10} \left[ \frac{I}{I_0} \right] \quad \text{Intensity in decibels}$$

The logarithm involved is just the power of ten of the sound intensity expressed as a multiple of the threshold of hearing intensity.  
 Example: If  $I = 10,000$  times the threshold, then the ratio of the intensity to the threshold intensity is  $10^4$ , the power of ten is 4, and the intensity is 40 dB:

$$I(dB) = 10 \log_{10} \left[ \frac{10,000 I_0}{I_0} \right] = 10 \cdot 4 dB = 40 dB$$



The factor of 10 multiplying the logarithm makes it decibels instead of Bels, and is included because about 1 decibel is the just noticeable difference (JND) in sound intensity for the normal human ear.

Decibels provide a relative measure of sound intensity. The unit is based on powers of 10 to give a manageable range of numbers to encompass the wide range of the human hearing response, from the standard threshold of hearing at 1000 Hz to the threshold of pain at some ten trillion times that intensity.

Another consideration which prompts the use of powers of 10 for sound measurement is the rule of thumb for loudness: it takes about 10 times the intensity to sound twice as loud.

## Frequency

Higher frequencies are usually measured with an ultrasonic detection equipment. These units are electronic instrument which measures the frequency of an applied repetitive electronic signal and displays the result in decibels on a digital display and some can tune the frequency allowing the inspector to test different applications. It uses the Heterodyne method translate the raw signal to a translation of just the High Frequency. This can be used on sound waves and then can be converted to a repetitive electronic signal by transducers that can then be analyzed, and decibels trended.

## Hertz

Hertz is defined as a unit of Frequency equal to one cycle per second. Hertz (Hz) is the unit of measurement the International Systems of Units uses to measure wave length. It was named after Heinrich Rudolf Hertz who proved the first proof of the existence of Electromagnetic waves.

Heinrich Rudolf Hertz (German: 22 February 1857 – 1 January 1894) was a German physicist who first conclusively proved the existence of the electromagnetic waves theorized by James Clerk Maxwell's electromagnetic theory of light. The unit of frequency



cycle per second was named the “hertz” in his honor.

Heinrich Hertz received his Ph.D. magna cum laude from the University of Berlin in 1880. There he studied under Hermann von Helmholtz. In 1883 he began his research into James Clerk Maxwell’s theory on electromagnetic. Between 1885 and 1889, as the professor of physics at the Karlsruhe Polytechnic, he was able to produce electromagnetic waves in his laboratory. He was then able to measure their length and velocity. He showed that the nature of their susceptibility to reflection and refraction as a byproduct of their vibration, and that they have the same properties as those of light & heat waves. Thus, he proved beyond any doubt that light & heat are electromagnetic radiations. The electromagnetic waves were initially called Hertzian and, later they were called radio waves. Hertz was instated professor of physics at the University of Bonn in 1889, where he his research continued the discharge of electricity in rarefied gases. Although Hertz was the first to correctly understand electromagnetic waves nature, he was not the first to produce such waves. It was accomplished in 1879 by David Hughes but his work was universally ignored.

Examples:

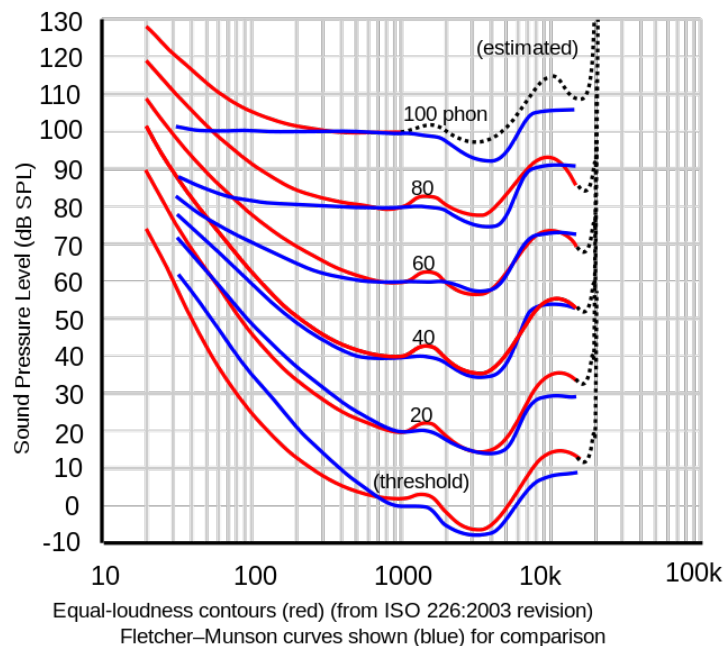
- 1 Hz = 1 cycles per second
- Kilohertz (kHz) = 1,000 cycles per second

## Loudness

The term loudness is a word best used in describing the levels of sound in the human hearing experience. It is collusively related to the strength of the pressure wave the human hearing experience. The sensitivity to certain frequencies contained in the sound can trigger reactions of a strong physical response of pain. This is one of the motivations for using the decibel scale to measure sound intensity. A widely used “rule of thumb” for the loudness of a particular sound is that the sound must be increased in intensity by a factor of ten for the sound to be perceived as twice as loud.

In general, the “rule of thumb” for loudness is that the power must be increased by about a factor of ten to sound twice as loud. To assess sounds loudness more realistically the Fletcher Munson Curve can be used to show Human Hearing Experience.

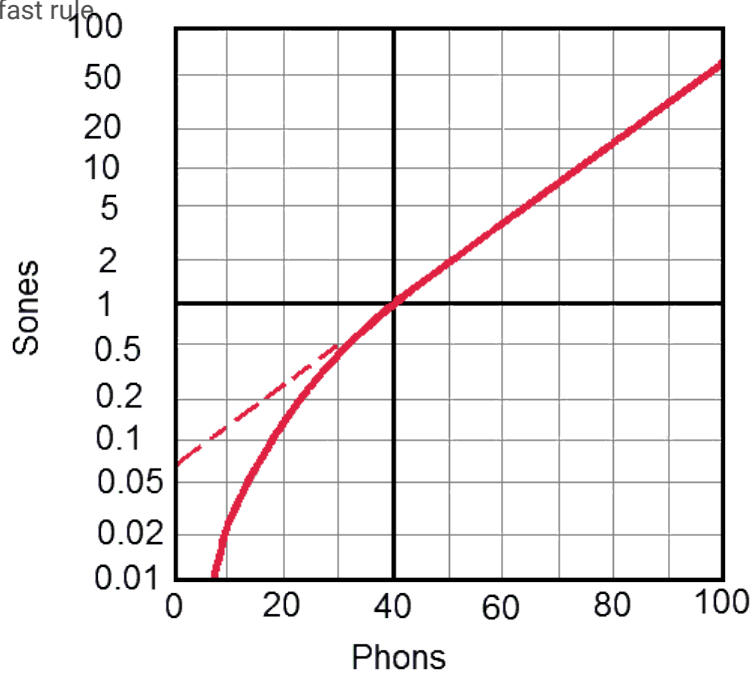
It is factored in to show the loudness based on a phon scale. The factor of ten rule of thumb can then be used to produce the sone scale of loudness. In practical sound level measurement, filter contours such as the A, B, and C contours are used to make the measuring instrument more nearly approximate the ear.



A common way of stating it is that it takes 10 violins to sound twice as loud as one violin. Another way to state the rule is to say that the loudness doubles for every 10 phon increase in the sound loudness level. Although this rule is widely used, it must be emphasized that it is an approximate general statement based upon a great deal of investigation of average human hearing, but it



is not to be taken as a hard and fast rule



## Pitch

Pitch is defined as the property of sound that allows their comparison on a frequency-related scale. More commonly, pitch is known as the tone that allows us to judge some sounds as “higher” or “lower” associated with music or a voice. Pitch can be determined only in sounds that have a frequency that is free from background noise. This makes pitch a part of the human hearing experience that can determine musical tones, along with the duration, loudness, and overtones.

## The Wavelengths of High vs Low Frequency

Higher frequencies tend to be more ‘directional’ than lower frequencies. They also have a higher average power for any given section of the wave, than low frequency waves do. This does not mean they are ‘louder’ or have a higher peak amplitude. High frequencies are narrow, because of their higher power, and very tightly packed. They have the tendency to ‘bounce’ off objects in their way.

Low frequencies, because of the big distance between the peaks and troughs of the wave... tend to go ‘around’ objects that are in their way. That is, the wave can keep its shape and still bend. Foghorns have a very high amplitude, and a very low frequency. That is why they cannot be blocked by ships or rocks in the water. This means that they tend to ‘bend’ along the curvature of the Earth when they travel.

**Source Frank DiBonaventuro, B.S., Physics Graduate, The Citadel, US Air Force Officer.**

## Heterodyning

Heterodyning is the process of combining two or more frequencies to create a new and different one. It was first shown in 1901 by Reginald Aubrey Fessenden. This process allows the ultrasonic unit to translate a high frequency sound wave to a low frequency sound wave that can be heard in the human hearing range. This is done by shifting one frequency range into another new one. It also involves the modulation and demodulation of the signal. The process begins with the pressure wave from the raw signal interacting on the piezoelectric crystals in the transducer. That electrical signal is then oscillated splitting the high frequency from the low frequency. It is then amplified and tuned to a specific frequency range which oscillates the signal again, and then amplified one more time thus converting it into a translation of high frequency to an audible signal.

Reginald Aubrey Fessenden (October 6, 1866 – July 22, 1932) was a Canadian-born inventor, who did much of his work in the

United States and claimed U.S. citizenship through his American-born father. During his life, he received hundreds of patents in various fields, most notably ones related to radio and sonar.

Fessenden is best known for his pioneering work developing radio technology, including the foundations of amplitude modulation (AM) radio. His achievements included the first transmission of speech by radio (1900), and the first two-way radiotelegraphic communication across the Atlantic Ocean (1906). In 1932 he reported that, in late 1906, he also made the first radio broadcast of entertainment and music, although a lack of verifiable details has led to some doubts about this claim.

# ASU Module 1-3 Introduction to Ultrasound Testing Devices

There are many different type of Predictive Maintenance and Condition Based Maintenance Test Equipment on the market today. Some are easier to pick up and use right away like a spot radiometer, and others like vibration analysis are very accurate at picking the slightest of vibration that can indicate a fault, but it takes a lot of studying and practice to become proficient at it. Ultrasound is right in the middle when it comes the time it takes to become proficient at its use and understanding what you are hearing. From the use of Ultrasound to pick up Partial Discharge to use it for analysis of the sound waves to determine the difference a tracking fault vs an arcing issue. These tools all have their specialty applications, but Ultrasound is one of the easiest to start using and learn how to analysis what is going on.

## The Benefits of Ultrasound

The biggest benefit to ultrasound testing equipment is its ability to do so many things. From electrical analysis of 480 transformers, MCC's, switchgear to testing transmission lines with a parabolic dish. It can even be used to test bearing for inner & outer race, ball pass, cage, and stray voltage issue in motors and VFD's. It has proven to be a great condition analysis tool when it comes to valve leaks and steam trap testing as well. It is also being used for air leak surveys for annual cost avoidance to reduce energy consumption and reduce the sites carbon foot print.

This make Ultrasound one of the most versatile Pd/M & CBM testing devices on the market and it works hand in hand with other technologies to help find, confirm, or deny the existence of a fault. It can pick up the earliest indications of faults in equipment and eliminates background noise through is ability to heterodyne the signal it receives allowing the user to isolate the source of the emission quickly and effectively.

## Knowledge is The Key

The key to any testing is the inspector's knowledge and understanding of both the equipment they are using and the assets they are testing. Without proper exposure to field training the inspector will not be able to experience the real World of NDT testing that is difficult to experience in the class room or manual. If the inspector only understands how to turn a unit on but, not operate it then its will be frustrating for them to try and interpret what the sound coming from the asset actual is or why it is happening.

It is also important to know what that device can be used for and what applications as well. It is just as import to know what frequencies work best as well and what modules to use. The inspector must also know where the best sound will be picked up when making contact and the angle of approach when doing airborne scans.

## Finding The Correct Tool For The Job!

When considering doing an ultrasound survey it is important to know the difference between the responses of the module and what frequencies they work best at. Not all units are set up for the ability to change frequency and this limits their ability to pick up frequency that are near their peak response. Also, specialty modules like the Flex Probe or Parabolic Dish can be used for application that may be hard to reach.

## Sensitivity Validation vs Calibration

The inspector must perform a Sensitivity Validation prior to and at the conclusion of each usage to insure the equipment wasn't damaged during the testing. This activity must also be logged and documented should that site ever have a catastrophic failure due to an asset that was being tested by that unit. The following is the procedure used to perform a sensitivity validation on a Sonus XT. The same steps can be used for another type of ultrasound testing equipment.

ISO/IEC 17025 General requirements for the competence of testing and calibration laboratories is the main ISO standard used by testing and calibration laboratories. In most countries, ISO/IEC 17025 is the standard for which most labs must hold accreditation in order to be deemed technically competent. In many cases, suppliers and regulatory authorities will not accept test or calibration

results from a lab that is not accredited. Originally known as ISO/IEC Guide 25, ISO/IEC 17025 was initially issued by the International Organization for Standardization in 1999. There are many commonalities with the ISO 9000 standard, but ISO/IEC 17025 is more specific in requirements for competence and applies directly to those organizations that produce testing and calibration results and is based on somewhat more technical principles. Laboratories use ISO/IEC 17025 to implement a quality system aimed at improving their ability to consistently produce valid results. It is also the basis for accreditation from an accreditation body.

## Ultrasound Sensitivity Validation Procedure

The following procedure illustrates how to perform a QA validation on of the Ultrasonic Testing Devices. This is different from the Calibration which is recommended annually on each unit. The Sensitivity Validation Procedure is a method through which the user can insure that the Ultrasonic Unit, Modules and Headphones are in proper working order. Use the Sensitivity Validation Log to enter the readings this will insure that the user can quickly identify a failing unit or module. This procedure can be used to check the validity of Ultrasonic Units between Calibrations and in no means, is it to replace the recommended Calibration of any Ultrasonic Unit. A drop-in decibel of 1-5 dB's is usually related to Tone Generators not being fully charged. A drop between 6-10 dB's can usually be attributed to equipment damage. The user will be able to determine this through the following steps:

- If only one item shows a decrease, then it is the module that will need to be repaired.
- If all modules show a decrease, then it's the Ultrasonic Unit itself that's in error.

The QA/Sensitivity Validation procedure meets the intent of ASTM Standard E 1002-11 and should be performed before each use. The following items will be required to perform the Sensitivity Validation Procedure.

### Equipment List:

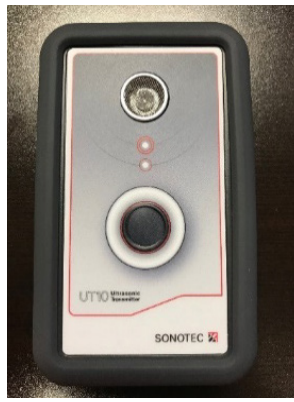
1. Ultrasonic Unit
2. Head Phones
3. Tone Generator
4. Contact Module
5. Airborne Module
6. Parabolic Dish
7. Flex Probe

### Procedural Steps:

1. To begin, clear off a spot on a table or desk to perform the Sensitivity Validation Process



2. Always turn on your Tone Generator to the Low Setting when performing a Sensitivity Validation. Place the TG on its back side with the light facing up.



3. Plug in the Headphones and place them on the table and keep them plugged in the entire time. This will verify the headphones are in working order.
4. Power up the Ultrasonic Unit and ensure the Light and Max Reading are working.



5. Place the Contact Module in the front of the unit and touch it to the Sensitivity Validation Test Point and let the weight of the unit rest there with little movement.





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- A close-up photograph showing a hand holding a black cable. The cable is plugged into a black power supply unit (PSU) on the left, which has a 'DC Output Voltage' knob and a 'DC Output Current' meter. The PSU is connected to a blue and silver digital multimeter (DMM) on the right. The DMM's LCD screen displays '52.8mV'. The background is a striped fabric surface.

- | <i>Date</i> | <i>Unit Serial #</i> | <i>Contact Mod#</i> | <i>dB's</i> | <i>Volume #</i> | <i>Non-Contact Mod#</i> | <i>dB's</i> | <i>Volume</i> |
|-------------|----------------------|---------------------|-------------|-----------------|-------------------------|-------------|---------------|
| 6/26/2017   | 10035                | 10035               | 53.2        | -22             | 10035                   | 52.7        | -22           |
| 6/27/2017   | 10035                | 10035               | 53.2        | -22             | 10035                   | 52.7        | -22           |
| 6/28/2017   | 10035                | 10035               | 53.2        | -22             | 10035                   | 52.7        | -22           |
|             |                      |                     |             |                 |                         |             |               |
|             |                      |                     |             |                 |                         |             |               |
|             |                      |                     |             |                 |                         |             |               |
|             |                      |                     |             |                 |                         |             |               |

Use this sheet to log your findings each day of class.

[illegible]

One of the most important things to remember about Pd/M & CBM Testing Equipment is to ensure that the Calibration is maintained annually. The inspector must also insure that the unit stays charged and what type of batteries the units takes. Nickel Cadmium batteries will develop a memory and over time lose their ability to maintain a charge. Lithium Ion batteries won't develop a memory, but some can malfunction and catch fire in the case if the spare batteries contacts are resting against something else metal. It is also import that the modules get put away in the proper place and are not just thrown into the case to get jostled around and possible damage the modules. Also, always try and insure that you do not leave anything hanging out of the case before you go to close it.

## How Transducers Work

Ultrasound transducer only receive exterior ultrasounds and not to transmit ultrasound. The process of receiving airborne or structure borne ultrasound involves the use of piezoelectric transducers. Piezoelectricity is defined as the property exhibited by some nonconducting crystals of becoming electrically polarized when mechanically strained and of becoming mechanically strained when an electric field is applied

The piezoelectric effect was studied by Carl Linnaeus and Franz Aepinus in the mid-18th century. It was then researched by both René Just Haüy and Antoine César Becquerel where they noticed a relationship between mechanical stress and electric charge. However, their experiments by both proved inconclusive.

It wasn't until the 1880's that two brothers Pierre & Jacques Curie where able to demonstration the direct piezoelectric effect. They used their knowledge of pyroelectricity and understanding of the crystal structures to predict crystal behavior. They used several different crystals the effect on tourmaline, quartz, topaz, cane sugar, and Rochelle salt. They found that Quartz and Rochelle salt exhibited the most piezoelectricity.

It was not until Gabriel Lippman applied the converse piezoelectric effect in 1881 to the Curies research to account for the change in shape of these crystals and how they produced a voltage that the curries did not account for. The Curies set about to confirm the converse effect and were able to prove quantitatively the complete reversibility of electro-elasto-mechanical deformations in piezoelectric crystals. For the next several decades, piezoelectricity became a laboratory curiosity. Then 1910 there was publication of Woldemar Voigt's Lehrbuch der Kristallphysik (Textbook on Crystal Physics), which went into detail how 20 natural crystal classes were capable of piezoelectricity.

Piezoelectricity is useful in many applications, such as the production and detection of sound, generation of high voltages, electronic frequency generation to name a few. It is also used in everyday items, such as the ignition source for cigarette lighters, and push-start propane barbecues, as well as the time reference source in quartz watches.

## Scanning Module

The Scanning Module is designed to detect airborne emissions at distances up to 50 feet. This makes a great module for the detection of electrical anomalies, pressure & vacuum leaks. It also works well for non-contact conveyor systems for the detection of bad roller, belt rub and misaligned belts. The sound wave is easily picked up with the transducer since it is the second medium the pressure wave interacts with. The first one being the atmosphere its traveling through. These modules only detect the and do not transmit any ultrasound.

## Focusing Probe

The Focusing Probe is an accessory designed to put on over the Scanning Module to help narrow the field of listening. It can be used to seal up on the suspected source of the emission and help to confirm the source of the emission. It is not designed for distances greater than 10 feet.

## Long Range Horn

The Long-Range Horn slides over the Scanning Module and allows for the enhance of the detection distance. It is not a module just an accessory used to help isolate the emission. It can detect some anomalies up to 75 feet away.

## Parabolic Dish

The Parabolic Dish allows the inspector to test up to 150 feet away. With the Red Dot sight, the inspector can easily see where the location of the anomaly is emitting from. The dish can actual detached from the handle. This makes so a much smaller foot print for storage.

## Contact Module

The Contact Module was designed to pick up the structure borne ultrasound. Since the Contact Module is made of metal it has little to no acoustic impedance since the two mediums have similar characteristics. This module is suited for testing Bearings, Gear Boxes, Valves, and Steam Traps. The Contact Module is also known as a Wave Guide since it allows the sound wave to travel up to the piezoelectric crystal to be translated.

## CBM Recommended Technologies

One Technology Does Not Rule Out the Use of Another. Airborne Ultrasonic uses sound phenomenon as a basis of inspection. The inspector must also be knowledgeable about leak physics and machinery basics. Airborne Ultrasonic Inspection is a multi-use inspection system. It performs many testing, monitoring and trouble-shooting tasks with efficiency and ease. Often it will stand alone as part of a comprehensive Preventative / Predictive Maintenance program. However, we often say that one technology does not preclude the use of other technologies. Every technology has its areas of strengths and weaknesses. We understand that there will be situations where airborne ultrasound will be called upon to support other technologies. In this section, we are going to briefly discuss other forms of nondestructive tests. When we get into our section on Leaks, we will talk about a few other nondestructive tests that are used.

Here is the introduction from ISO 18436-8:2013 (E)

The use of ultrasound technology in condition monitoring is one of the key activities in predictive maintenance programmed for most industries. Other non-intrusive technologies including acoustic emission, infrared thermography, vibration analysis, lubricant analysis, wear debris analysis, and motor current analysis is used as complementary condition analysis tools. Those in the manufacturing industry who have diligently and consistently applied these technologies have experienced a return on investment far exceeding their expectations. However, the effectiveness of these programmed depends on the capabilities of individuals who perform the measurements and analyses the data. This part of ISO 18436 defines the requirements for personnel to become qualified to apply the non-intrusive machine condition monitoring and diagnostics technology of ultrasound. A programmed, administered by an assessment body, has been developed to train and assess the competence of personnel whose duties require the proper theoretical and practical knowledge of machinery condition monitoring and diagnostics.

This part of ISO 18436 defines the requirements against which personnel in the non-intrusive machinery condition monitoring and diagnostics technologies associated with ultrasound for machinery condition monitoring is qualified and the methods of assessing such personnel.

## Online Systems

Online monitoring is taking off in use since so many facilities are running lean and do not have the man power to test the assets. The fact that several pieces of equipment can be surveilled 24/7 and gives the program manager a piece of mind that they can deploy resources to specific assets when need in between scheduled testing.

## E Sentry Systems

The E Sentry Connect™ is a next generation intuitive asset information tagging system. The E Sentry Connect system utilizes Near Field Communication (NFC) contactless Smart Card technology that allows smart phone devices with NFC to easily access critical data relating to the equipment being inspected and save up-to-date inspection data directly to the assets E Sentry Connect tag via a free App from IRISS. The E Sentry Connect system has been designed to be operated on 2 platforms, a standalone system and a subscription-based cloud system allowing historical data back-up and complete access to the current status of all assets utilizing E Sentry Connect tags.

E Sentry Connect Cloud allows you to document and access information relating to IR & Ultrasound inspection parameters on Electrical distribution assets. Data is stored on the asset tag directly and backed up to the cloud for future reference and maintenance trend analysis. Routes can be set and monitored. Users can submit data using their android app covering a wide set of data including temperature, barometric pressure, voltage and more. This information can be easily exported for further review and used to provide information to system administrators allowing them to generate maintenance routes for their staff to ensure



optimal equipment efficiency and safety.

[https://www.youtube.com/watch?v=5t\\_QZgnUQrc](https://www.youtube.com/watch?v=5t_QZgnUQrc)

## The Power of Sonus Vue Software

Although decibels can be used to trend bearings they cannot however, be used to trend electrical systems until enough historical information has been gathered. This is where the use of sound analysis software like Sonus Vue Software is used to look for harmonic indications which can then determine what faults are present. The use of the Time Signal and FFT can pick out the exact harmonics and their repetitive value. This can help the inspector determine if there is a bad bearing, inner & outer race, or a cage fault in a motor. It can even determine whether an electrical fault is a corona discharge or an arcing fault.

These events all have distinct fault signatures in time signal, spectrum analysis and 3D Surfacing. Much like an EKG each event will have tell-tale signs that can be seen that will tell the inspector what they are looking at. The reporting abilities of this software can help the inspector explain to management or a client what is actually happening instead of saying they simply heard something.

## Manual Report

Some users have designed their very own reports in Word or Excel Spreadsheets. The following items should be logged on the reports. Date, Time, Inspectors Name, Temperatures, Humidity, Decibel, Indications of fault, Asset ID, Asset Brand, Voltage, Horse Power, Pressure, Visual condition seen and any other useful information to use in CMMS or SAP.

# ASU Module 1-4 Propagation of Sound Through Mediums

Ultrasonic testing (referred to as acoustics) is based on how materials allow for time-varying deformations or vibrations. All materials are formed from atoms, which may be forced into vibrational motion about their equilibrium positions. There are many waves with different patterns of travel through these mediums. As the energy travels through a medium it experiences absorption and reemission of the wave energy by the atoms of the material. When the electromagnetic wave impinges upon the atoms in the medium, the atoms absorb the energy of that wave. This causes the electrons in the atoms to vibrate in what is known as a Vibrational Motion. The absorption of this energy by the atoms which creates a new electromagnetic wave that is emitted with the same frequency as the first electromagnetic wave. This process keeps repeating till the wave loses its energy or encounters a new medium.

The actual speed of an electromagnetic wave traveling through a medium is directly proportional to the temperature, elasticity, and density of that medium. Different mediums will cause a different amount of delay due to the absorption and reemission properties of the medium they are traveling in. So, the warmer & denser the material, the closer together the atoms are and the faster the sound will travel through that medium. In the example of outer space, the medium is a vacuum and the atoms are spread so far apart that sound wave motion cannot occur.

Most of the time these are irrelevant (Background or Antagonistic Ultrasound) when performing ultrasonic testing. Ultrasound is focused on listening for the mechanical waves that are created by the many atoms that move in unison. When a medium is not stressed by tension or compression exceeding its elastic limit, the particles spring back to their original position and this is known as an elastic oscillation. It is these elastic properties of the particles in the medium, combined with their inertia, that allows for the oscillation in of the medium.

## Inverse Distance Law of Sound

If we look at the effect of Inverse Distance Law of Sound in the real world, we would experience that the further away from the sound source the quieter it would get. If we think of this sound energy as a pebble being thrown into a still pond, we would see that the crest of the wave would be taller closest to the initial impact and as it travels outward, we would see the circumferences of the wave expanding and cover more surface area while the crests of the waves get smaller. If we use this analogy to think about the propagation of sound through a medium it will help us to understand the effects of the Inverse Distance Law of Sound.

When talking about the Inverse Distance Law of Sound we must assume that the sound pressure is exactly the same in a controlled environment free of any obstruction or reflective materials. This summation can be achieved a little more effectively than an environment that has obstructions and reflective surfaces that will attenuate or intensify the sound pressure. If we consider the sound source to produce a spherical wave front emitting out from it as it travels away from the source, it loses 6 decibels every time the distance is doubled. If we take a reading at 1 foot (.3048 m) from the source of a leak and double our distance to 2 feet (.6096 m) the inspector would notice a 6-decibel depreciation. The inspector would also notice a larger area the sound can be detected from the further distance. That is because at the distance of 1 foot (.3048 m) the energy is only detectable 1 square foot area when the input amplitude is reduced on the unit. As we double our distance to 2 feet (.6096 m) we have not only doubled the distance, but the detectable area is also doubled. If we double the distance from 2 feet (.6096 m) to 4 feet (1.2192 m) not only will we lose another 6 decibels but the detectable area would now be three times large. Doubling up the distance from 4 feet (1.2192 m) to 8 feet (2.4384) again we lose 6 decibels but now the detectable area is 4 times large than from 1 foot away. This process will continue till the energy from the sound source attenuates and dissipates all of its energy.

## Inverse Distance Law of Sound Calculator

Use this Calculator to determine your expected decibel loss after your distance of inspection away from the sound source.

Distance from sound source	1 foot (.3048 m)	2 feet (.6096 m)	4 feet (1.2192 m)	8 feet (2.4384 m)	16 feet (4.8768 m)	32 feet (9.7536 m)	64 feet (19.5072 m)	128 feet (39.0144 m)	256 feet (78.0288 m)
Sound Pressure (-decibels)	78	72	66	60	54	48	42	36	30
Number of times doubled	1 X	2 X	3 X	4 X	5 X	6 X	7 X	8 X	9 X

Use this Calculator to determine your expected decibel gain from your distance of inspection to the sound source.

Distance from sound source	1 foot (.3048 m)	2 feet (.6096 m)	4 feet (1.2192 m)	8 feet (2.4384 m)	16 feet (4.8768 m)	32 feet (9.7536 m)	64 feet (19.5072 m)	128 feet (39.0144 m)	256 feet (78.0288 m)
Sound Pressure (+decibels)	88	82	76	70	64	58	52	34	28
Number of times doubled	1 X	2 X	3 X	4 X	5 X	6 X	7 X	8 X	9 X

Inverse Distance Law of Sound Calculator will allow you to see how many decibels drop off or increase as you change the distance from the point of source. It will even allow for the calculation of the acoustic.

Check out this website to see another calculator. <http://hyperphysics.phy-astr.gsu.edu/hbase/Acoustic/invsqs.html#c3>

## Acoustic Impedance; Angle of Incidence

The Angle of Incidence is the angle between an incident wave interfacing on the surface of a secondary medium and the line perpendicular to the secondary surface at the point of incidence, called the normal. The ray can be formed by any type of X-ray, optical, microwave, acoustic etc. The Angle of Incidence at which sound initially interacts with secondary medium and is reflected in the incipient medium is known as the critical angle. This also creates what is known as Angle of Reflection and Angle of Refraction that occur during the Mode Conversion.

Calculating the Angle of Reflection with respect to an airborne ultrasonic detection is not necessary. It can confuse the inspector however if it is not taken in to account when tracking down the source of the emission. This will be explained more in-depth in the next slide.

Sound waves exist as variations of pressure in a medium such as water. They are created by the vibration of an object, which causes the air surrounding it to vibrate. Sound waves travel through air in much the same way as they do water. In fact, since water waves are easy to see and understand, they are often used as an analogy to illustrate how sound waves behave.

## Acoustic Impedance; Mode Conversion Incident Wave

Mode conversion takes place when a sound wave interfaces with a different medium other than its incipient medium. These differences in mediums because what is known as acoustic impedances which is defined in Merriam-Webster Dictionary as the ratio of pressure to volume displacement at a given surface in a sound-transmitting medium (<https://www.merriam-webster.com/dictionary/impedance>). As the energy travels through it incipient medium it is known as an Incident Wave. When it reacts the second medium the Incident Wave will change its characteristic through the process known as Mode Conversion. This is caused by the difference between the two mediums elasticity and density. These slight differences what allows for Mode Conversion to occur.

## Acoustic Impedance; Mode Conversion Reflected Wave

The first Mode Conversion to discuss is the Reflected Wave. This is as it sounds, a reflection of the Incident Wave. Both waves are categorized as a Longitudinal Wave as they are experienced in the incipient medium. A Longitudinal Wave creates a displacement of particles as it travels parallelly to the waves path. This energy can either travel in the form of an oscillatory motion or via a series

of Compressions & Rarefactions. This is just one category of Mechanical Waves that sound can produce.

## Acoustic Impedance; Mode Conversion Shear Wave

Another one of these Mechanical Waves is known as a Transverse Wave. The Incident Wave changes from a longitudinal wave to a Shear Wave. This wave also has an oscillatory nature to it, but it travels in a perpendicular direction to the Incident Waves motion. This occurs at the interface with the secondary medium.

## Acoustic Impedance; Mode Conversion Surface Wave

The Mode Conversion of the Incident Wave will also produce a Rayleigh Wave which is otherwise known as a Surface Wave. These waves are a combination of the Incident Wave and the Shear Wave it produces. This wave travels along the interface of the incipient medium & the secondary medium at a perpendicular angle to the impact of the incident wave.

## Acoustic Impedance; Mode Conversion Plate Wave

The Mode Conversion in addition to the above-mentioned waves also produces a Lamb Wave better known as a Plate Wave. This type of wave can occur in three mediums if the material is thinner than that of the second medium. This wave is more useful for those doing Non-Destructive Testing for flaw detection. These waves are very indistinguishable from the shear or surface waves.

## Acoustic Impedance; Mode Conversion Refracted Wave

A Refracted Wave is what happens to a sound wave as it passes through the second medium and changes its path and exits into the third medium. The second medium can either speed up or slow down the sound wave as it passes through the second medium. This is due to the elasticity and density of the second medium.

## Acoustic Impedance; Reflection

When a sound wave is produced, it will travel through its incipient medium until it encounters the secondary medium and depending on its characteristics a couple of things can occur. In the case of a smooth surface the sound wave will reflect off the secondary medium with little to no acoustic impedance. So, the reflected sound wave can be mistaken for the source of the emission if the inspector does not know the proper techniques to isolate the source of the emission.

## Acoustic Impedance; Diffraction

According to the Huygens–Fresnel principle diffraction refers to various phenomena that occur when a wave encounters an obstacle or a slit. The sound wave's ability to bend around the corners of an impediment or opening in the region of geometrical shadowing from the hindrance. In classical physics, the diffraction phenomenon is described as the interference of waves. The features of the surface will cause the acoustic impedance of the reflected wave as it sends it in multiple directions. This accounts for the decrease in decibels at the Angle of Incidence. So, this causes only part of the sound energy to return to the transducer. The rougher the surface the more the sound energy will be Diffraction.

## Acoustic Impedance; Absorption

Acoustic Absorption refers to the interaction of the incident wave with the secondary medium and its abilities to take in sound energy, as opposed to reflection or diffraction of the energy. Part of the absorbed energy is said to be transformed into heat and the other part is transmitted through the absorbing medium. It is also said that the energy is lost that is absorbed.

## Acoustic Attenuation of Sound

In physics, Acoustic Attenuation is known as the gradual loss of flux intensity through a medium. For instance, water and air attenuates both light and sound at different rates attenuation rates. The use of hearing protection helps to reduce this flux from affecting the ears. This is called acoustic attenuation and it can be measured in decibels (dBs). This is also seen in the telecommunications and electrical engineering as the acoustic attenuation directly effects the propagation of waves and signals in electrical circuits and in air.

# ASU Module 1-5 Principals of a Leak

Leak inspection are one of the simplest of test methods that can be performed using an ultrasound device. It also can be the biggest return on investment for any Pd/M program. As each leak contributes to wasted energy and carbon emissions. However, identifying the source of the leak is just the first step of the process as they must be fixed to reduce their cost to a facility and maintain the life of the compressors.

## How A Leak Generates Ultrasound

A leak creates a source of ultrasound as the higher-pressure rush through an orifice. The higher the pressure the greater the energy lose is associated with the leak. Many companies have enough wasted air loss to shut down 2 full compressors but, instead of finding and fixing them they just add another compressor to the systems to keep up with the leaks.

## Pressure Leaks vs. Vacuum Leaks

Pressure leaks will generate a louder sound than vacuum leaks because the turbulence is exiting the vessel instead of entering it. This makes vacuum leaks a little harder to find especially in the presence of a pressure leak nearby.

In the case of vacuum leaks the inspector can also use a contact module to test for the source of a leak. This is caused by the shear wave traveling through the vessel walls as the incident wave is in the first medium inside the vessel.

## Things to Consider When Looking for Leaks

Some of the things to consider prior to running a leak survey are;

- What type of leak is it? IE Pressure, Vacuum, Gas, Nitrogen, Natural Gas, etc.
- Do you need an intrinsically safe device or a hot work permit?
- Are there atmospheric conditions that need to be dealt with while operating in that area?
- What equipment will you need to operate in that area. IE Scissor Lift, Flashlights, Tags, Camera, etc.
- How to overcome any Antagonistic Ultrasound in that area.
- What Is the distance from the leak and what module or accessories to use?

## Accessibility to Leak

Accessibility to leaks is a key part to any survey. The inspector must take into account their distance first and foremost as that will help to decide which module to use or accessory. The Focusing Probe is great for confirming a pressure or vacuum leak up close but is of no use for a leak over 5 feet away. The Long-Range Horn is great to add onto the scanning module for up to 100 feet away but not for more than 150 feet. At that distance, the Parabolic Dish would be the best option and it would be limited in distance based off the pressure of the leak.

## Hazards to Consider

One of the biggest things to keep in mind are what atmospheric conditions will the inspector be working in. Some areas may be considered a confined space simply because of the air quality in that area. The inspector also must consider whether their unit is rated for a Class 1`Division 1 Groups A-D area. If the unit is not intrinsically safe IRISS does not recommend using the equipment in these areas. However, some plants have Hot Work Permits procedures for operating in these areas and it will be up to the inspector to insure their safety and those around them when operating around flammable gases. Again, IRISS does not recommend or recommend using any non-intrinsically safe units in any Class 1 Div. 1 Groups A-D areas.

Other things to consider while performing an Air Survey is the fact that the inspector can get tunnel vision while tracking down the source of the emission and lose sight of what's around them. Fork Truck traffic in the area or palletizer robots that can start up in a moment's notice so, the inspector must follow LOTO procedures in these areas or while walking around keep their heads on a swivel

to account for traffic.

Another key item to watch for are any electrical hazards or lighting that could get in the way while operating on a man lift. Never perform Ultrasound inspection while standing on a ladder. There is no way to maintain 3 points of contact. For this reason, it is much safer to operate from a scissor, or man lift than a ladder. This however could require a second technician to be the ground guide during the survey.

## Why Check for Leaks?

The reason leak detection testing is so important is it offers a plant with so many avenues of ROI. The first ROI is Safety. Toxic & Asphyxiate gases can quickly overcome workers and can cause serious or life-threatening events inside a plant. The loss of life and production can become very costly when you factor in the possibility of law suits from family members for wrong death or long-term disability employees.

In the same vein some of these gases are known greenhouse gases and the release of these can cause damage to the environment not to mention the potential of fines for their release. An air survey can account for the cost avoidance of annual usage of electricity and the greenhouse gas emissions reduction. This gives the inspector a powerful addition to just reporting there is a leak at 35 dBs on that regulator.

Where a company can really justify, the ROI is doing an Air Survey to show the annual cost avoidance that can be achieved by fixing identified leaks. Some air leaks can cost a plant as much as \$1,000 annual where as a Nitrogen leak can cost that daily. So, finding these leaks and totaling them up quickly pays back the money invested in the equipment used, the training the inspector should receive and the operational hours of the inspector/s. Not to mention the increased efficiency of the compressors and insuring they run to full operational life span.

## Safety Tips

It is very important that the inspector/s always take into account any and all safety hazards that can be present on site. This can be simply overlooked because the inspector becomes complacent in the work place. Take 5 minutes to huddle up and go over the risk factors prior to going out. Insure that all equipment is rated to operate in that area. If a scissor lift or man lift will be used, is the inspector properly trained and authorized to operate it. If asphyxiate gases are present will there be a multi gas meter present as well as SCBA or other respiratory protection.

Over pressurization can be catastrophic as well as a vacuum system that becomes plugged up. NASA test satellites under pressure and vacuum with pressures exceeding 4500 psi. In the case of leaks at this pressure the inspector will need to be cautious and not reach in too close to the source of the emission and should never place their hands on any pressured leak.

Also, with the use of fork trucks (Automated or manual) and robots the inspector/s will need to keep their heads on a swivel to insure their safety. It is too easy to start focusing on the source of the emission and forget all about what you are around. When not actively performing a survey, the inspector should keep one headphone cracked to be able to listen for fork trucks and robots.

Palletizer robots are another area where we can perform air surveys, but the inspector should Lock Out Tag Out before entering these areas. If operating overhead the prohibited area, make sure there is no chance of being struck during the robot's motion as most guards are only designed with floor restrictions in mind.

## Quality Assurance

With so many applications for quality assurance testing the ultrasound device is truly the multitool of leak detection. From testing hatch covers to the use by the US Navy under NAVSEA 9820-4025 9820-4029 for the testing of Bulkheads it is the quickest and safest way to avoid or confirm pressurization testing results. If your vehicle has a whistle in it when you drive, there is an air ingress somewhere and is difficult to pinpoint the exact location of the sound. Using ultrasound can quickly pinpoint the location when a tone generator is placed inside the vehicle and scanned from the outside. Have a draft in the winter use the same steps to confirm the exact spot where the air infiltration is coming from.

## Environment Conservation

Air Surveys help find leaks that waste energy and contribute to greenhouse gases. This can allow companies after repairs are made to show an annual cost avoidance & reduction in their electrical usage which can then be calculated to figure out over all carbon foot print reductions. This is a can then be sent off to the power companies, state, or federal government to apply for tax incentives for reducing their energy usage. This can also be used as a marketing strategy to the community for some great public relations ads and feel good stories. This really help in the case of some sites who use compressed gases that can harmful to the environment or people living nearby. Where the release of these gases can lead to fines and potential lawsuits in some cases when leaks effect the surrounding area.

## Energy Conservation

The Energy Conservation is the biggest ROI for an ultrasound program, because it can quickly identify annual cost avoidance for a site. One print mill was starting to consider getting a 6th compressor for their site. They were going to rent a diesel compressor to help with the demand the system needed. Prior to finally committing a technician who had just attended a Level 1 course told the Maintenance manager what he had learned to do with his ultrasound equipment for finding and documenting leaks. He was sent out to start an air survey and in a 2-week period he had found \$150,000 in leaks. Over the next several months they started fixing these larger leaks since they were the low hanging fruit. During the first month, they shut down one compressor down completely. The next month they shut a second one down and eventually got to a point where they were running 1.5 compressors on site.

## The Cost of Compressed Air

Compressed air has been used and abused for years and is often treated as something that is free. Some operators will even put small holes in the plastic pneumatic tubing near their operating station to cool off. Some will even clean themselves off or the shop with an air tool. This is another source of wasted air but also a safety hazard. This chart above is a general guide to calculate the losses by estimating the orifice size. The 1/64" diameter leak can create a \$50.00 a day loss, or a 3/32" diameter leak can create a \$1,904.00 a day loss based on 100 psi, \$0.25 /mcfm, 8760 hours / year.

## How to Calculate the Cost of a Leak

According to Compressed Air Challenge of the U.S. Department of Energy's Office of Industrial Technologies, the total cost of 100 psig compressed air has been calculated to be in the general range of 18 to 32 cents per 1,000 manufactured cubic foot per minute. (Source: Best Practices for Compressed Air Systems by Compressed Air Challenge). This varies from state to state based off the cost to the site. This formula will produce an estimate that is 85% accurate on the conservative side as to what the annual cost avoidance is for each leak as well as the total of the sum of all leaks.

The formula breaks down as follows:

CFM= Cubic Feet per Minute, this can be the value for one leak or the total sum of leaks.

60= The number of minutes in an hour.

AHRS= The total number of hours the system is operating annually.

1000 MCFM= Based off the cost off of Manufactured Cubic Feet per Minute.

kWh= The cost per Kilo Watt Hour.

Annual Cost Avoidance= The annual cost avoidance of a leak or the total sum of all leaks that can be negated.

The formula used to determine annual cost avoidance of a leak is

$$\frac{(CFM \times 60) (8760 AHRS) \times \text{Cost kWh}}{1000 MCFM} = \text{Annual Cost Avoidance}$$



Using this formula let's figure out the cost of leaks totaling 58 CFM at a kWh cost of \$.20 kWh.

Step 1.  $(58 \times 60) = 3480$       Step 2.  $(3480)(8760) = 30484800$

Step 3.  $\frac{30484800}{1000} = 30484.8$       Step 4.  $30484.8 \times .20 = \$6,096.96$

1000 MCFM

Try this:

$$\frac{(40 \times 60)(8760)}{1000} \times .20 =$$

1000 MCFM

# ASU Module 1-6 Leak Inspection Techniques

For year companies have allowed their leaks to go unfixed. The sound of hissing becomes the norm, and everyone goes about their business as usual never taking into account how much money is actually wasted with the escaping gases around their plant. Several companies that I have visited over the years have sent guys out with soapy bubble solution such as snope or shaving cream to identify these leaks. Some companies even use smoke sticks to see where the leak is coming from. Other companies invest in gas sniffers which are great for detecting the parts per million in the area but can quickly become over saturated and cannot be efficiently used on windy days as the gas cloud gets pushed around and dissipates. This methods are old and outdated with the development of ultrasound detection devices.

During one training class in the Philadelphia area we spent the better part of 2 days tracing nitrogen lines from the tank farm all over the site. During the initial size up it was state they were losing \$500,000 a month in nitrogen gas leaks. So, the survey was started at the source which was a large tank farm of compressed gases. We walked the path on the underground piping out from the tank farm with the thought that if the leak was that large, we would surely pick something up. As we approached the first T in the line going to a building, we followed the line and to the footprint of the building.

I asked if we could enter the building, but it was locked up and we would need to get permission from the sites Safety Officer and the Security Supervisor before entering the building. So, we continued on our way and over the 2 days were only able to locate around \$18,000 in leaks. I keep asking if there was any way we could get into that first building but the guy said it would be next to impossible in such short notice.

A couple months later I received a call from the site saying they have found the source of the and it was located in the building that was locked up. Apparently, the header pipe in the basement has been damaged during the move out work and it wasn't reported. Had we continued to follow the flow we would have located the leak early in the survey and easily saved them a million dollars.

## Compressed Air System Layout

In the Mid-19<sup>th</sup> Century the development of compressed air systems for industrial applications to power equipment and tools started to replace steam systems since they lost pressure due to the friction generated by the condensate. The first major use of compressed air came in 1861 during the drilling of the Mont Cenis Tunnel in Switzerland, where a compressor was set up with a pressure of 87 psi to power the pneumatic drills, which greatly increase the effectiveness over the old manual drilling methods. Even George Westinghouse was known for inventing an air braking system for trains that increased the safety of train operations around the World.

Here is a generic layout of a pneumatic system. A distribution system transports compressed air to the location where it is needed. A "prime mover" powers the compressor. Controls regulate the amount of compressed air that is produced. Contaminants are removed from the compressed air and accessories to keep the system running properly.

Inspectors who are familiar with the pneumatic system and proficient in scanning techniques are able to complete the Compressed Air Leak Survey without spending a lot of time aimlessly search for leaks. It is important that the inspector understands the lay-out and function of a pneumatic system before performing the inspection, interpreting inspection results, and avoid making unnecessary repairs. It is also important to always verify your diagnosis using techniques taught to you in this class.

**Air Inlet Filters:** An air inlet filter protects the compressor from atmospheric airborne particles.

**Compressor Cooling:** Air or gas compression generates heat. Compressor units are cooled with air, water, and/or lubricant oil.

**Intercooling:** Multi-stage compressors use intercoolers, which are heat exchangers that remove the heat of compression between the stages of compression.

**Aftercoolers:** As mechanical energy is applied to a gas for compression, the temperature of the gas increases. Aftercoolers reduces the air temperature after the final stage of compression. As the temperature is reduced, water vapor in the air is condensed, separated, collected, and drained from the system. Sometimes the aftercooler is an integral part of the compressor package.

**Filters & Separators:** Compressor filters and separators remove contamination from the air before it enters, and as it exits, the compressor.

**Pressure Regulators:** Deliver varying volumes of air in respond to the changing demand in addition to regulating pressure.

**Air Receivers:** Receivers are used to provide compressed air storage capacity to meet peak demand periods. Where peaks are intermittent, a large air receiver may allow a smaller air compressor to be used and can allow the capacity control system to operate more efficiently and improve system efficiency.

**Traps and Drains:** Are used to prevent the loss of air through open petcocks and valves. Drain valves should allow removal of condensate but not compressed air. There are mechanical and electrical traps.

## Keys to A Successful Air Survey

The reasons sites should perform an air survey are all the same and it does not matter if it's a waste water treatment facility or a major automotive manufacturer. Ever site uses electricity to manufacture compressed air and this has a direct effect of profitability for that company. It will also identify wasted air that drains on the system and insure that the compressor will last long enough to achieve its maximum life span.

Prior to starting an Air Survey, a meeting should be set up with Plant Management, Engineering and Production to identify current estimations of energy consumption from the compressed air systems. This meeting can also be used to establish critical equipment or areas that should be targeted first. The surveys should be performed while the system is at maximum operations. This will insure that the system is under full load and all downstream legs will be pressurized. One of the most crucial factors in the success of the air survey is to have qualified personnel preform the survey. This would entail having some formal training and not just reading the manual.

Once ready to start the air survey the inspector should have a camera to document the leak and tags to easily identify the leak for repairs. There are many different leak tags available on the market. These leaks should be documented for calculation of the annual cost avoidance. The repairs should be made based off the size of the leak so that the ROI can quickly paid back. From there a review of the systems usage can be done to analyze and identify any areas of efficiency improvements that can be made to the system.

## Reasons for An Air Leak Detection Survey

Sometime these leaks are man-made events like using air to blow packages without a photo sensor being installed so, its constantly blowing air when it could be turned off and on as the packages go by. It can even be caused by someone not placing thread tape on the threads of the gauge of the regulator, maybe it's a split hose in the middle of an air hose reel, or even the quick connect being used are an inferior quality because the bean counters wouldn't spend the money on a higher quality quick connect that hold up better. These quick-connects of inferior quality usually cost 1,000 times more in wasted air than the savings achieved by buy them vs the higher quality ones.

All of these leaks being fixed will increase the effective usage of air in the system and reduce the electricity consumed by the site. The site could even see the benefit of shutting some compressors down once the leaks are repaired and the system id back in a healthy state.

## Logistics of A Compressed Air Leak Survey

Every Air Survey should start at the compressor room and follow the headers out to the plant floor. From there the inspector will need to determine if they are going to follow the header all the way around or stop and trace every down leg off of it to the end of the line and come back to the header. This will help to ensure that a valve isn't shut off and potential causing the inspector who starts at the end and works their way back up stream hasn't wasted time and effort on a shut off line.

It will also be important that the inspector knows how to use the proper techniques for locating, isolating and confirming the leak source. Many techniques over the years have been proven to be over complicated and irrelevant since they contradicted themselves. This chapter will train the inspector on the easiest ways to go about preforming an air survey based off real-world experiences.

## The Importance of Adjusting Volume

It is very important the inspector adjust the volume on the unit to, so they can increase or decrease the detectable distance. This helps to eliminate antagonistic ultrasound, isolate the location since the unit is very directional, and confirm the location of the leak.

If the inspector fails to do so they can miss or mistake the leak sight. When the volume is a set to 0 it is taking in the full intensity of its surroundings and the leak will appear to be coming from everywhere if it is a large pressure leak. In the case of a vacuum leak it may have to be set at 0 since the turbulence is inside the piping. By reducing the volume, the inspector can help to eliminate most of the antagonistic ultrasound in that area. To confirm the location the inspection can use several techniques including the use of the Focusing Probe to seal up on the suspected leak.

One of the other reasons to adjust the volume is avoid overwhelming the inspector's ears. If the volume is not adjusted, they will hear the maximum volume of sound in the headphones which is 85 decibels. Once the inspector has found the source of the leak, they will then need to use the principals taught in the Inverse Distance Law of Sound and move to 1 foot away from the source to document the decibel value.

## Considerations for The Leak Survey

When preparing for a leak survey it is very important to consider what type of gases maybe in the area, is it pressure or vacuum, do I have approachable access to the leaks and what modules and accessory will help insure the successful detection of the leak. If there are several leaks in line the inspector will need to isolate those leaks from the others as a larger leak can mask one that has a lower level of leakage. One way to isolate a leak is to use the Focusing Probe to seal up on the suspected leak. If the level of dB's increases the inspector has confirmed the source of the leak.

## Is The Equipment in Working Order?

It is important to start every inspection by performing a sensitivity validation test on the ultrasound equipment to ensure that the unit, modules, and headphones are in working order to perform the inspection. As a minimum recommendation, calibration should be performed annual on the equipment to ensure that it meets all manufacture standards. Before the inspection to ensure that equipment is working properly and at the end of the inspection to ensure that equipment has not malfunctioned. Below is the Scope of what is covered in the standard and like so many others the full standard can be purchase for \$40.00 from ASTM on line.

## Antagonistic Ultrasounds

Although the ultrasound devices don't pick up low frequency sound waves, they can encounter antagonistic ultrasound. These antagonistic ultrasound waves can make it challenging at times for the inspector if they aren't properly trained on how to overcome them. Therefore, it's important to listen to the are prior so the inspector can identify potential sources of antagonistic ultrasound. One of the other key pieces of the equitation are the headphones which attenuate 23 dBs of sound waves.

## Leak Inspection

Leak inspection can be either an airborne or structure borne event. Therefore, the inspector must take this into consideration when planning the leak survey. If a compressor valve is leaking by or a valve is by passing a Scanning Module will not pick up the sound because the first medium is the interior of the body and the housing is the second medium. So, this would require that the inspector use a Contact Module to test for the source of the leakage. Airborne inspection is the easiest to perform as the inspector is in the first medium and the Scanning Module is the second medium. The Long-Range Horn and Focusing Probe could also be used in this test procedure to help identify the source of the ultrasound emission versus the antagonistic ultrasound.

## Follow The Flow

The First step to an Air Survey is to Follow the Flow. It's just as easy as it sounds. The inspector will start at the compressor room or the Header as it enters another room and follow the flow of the piping. As the inspector finds a down leg, they can continue to follow the header around or that down leg. Never start at the end of the flow and try and work back to the compressor. This can lead to wasted time if a valve is closed upstream.

## Positioning

No matter the inspector's distance from the potential source of the leak, they need to consider the distance they are at and try and move 360° around the target to confirm the Angle of the Incident. This can be done from 12 inches away to over 100 feet away

depending on the pressure of the leak. By moving from one around the target or moving the device around and observing the ultrasound readings, the inspector can determine the actual area emitting the ultrasounds through a process of elimination.

## Reducing The Distance

They need to follow the flow and reduce the distance between the leak and the ultrasound device. If the inspector follows the flow of the system this helps to eliminate using over complicated procedures that companies were taught in the past and expedites the leak survey. There is no need to enter a room and start waving the unit around like a magician waving his wand to casting a spell.

## How to Overcome Distances

If the inspector knows that they will be working at a distance further than 20 feet, they want to use the Long-Range Horn or Parabolic Dish to help narrow the field of listening. These help to minimize the field of listening and extend the distance of listening. Since the sound was attenuate over a distance the use of the Long-Range Horn and Parabolic Dish help to increase the ability of the unit to focus on the source at these great distances. As the inspector reduces the distance, they will notice the display will show higher dB's levels as the approach the source.

## Long Range Horn

The long-Range Horn is a simple accessory designed to slide over the Scanning Module to help narrow its field of listening while extending its distance of detectability. Its effectiveness will be directly affected by the energy of the sound wave from the source. It is not effective beyond 60 feet or 18.28 meters.

## Parabolic Dish

The Parabolic dish is the most effective module for detecting emissions over 100 feet or 30.48 meters. It will narrow the field of listening down to 10°. This is perfect for those sites with the Headers more than 60 feet off the floor. With the Walther Red Dot Sight, it makes the identification of the source of the emission much easier for the inspector to visualize what they are targeting. Its two-piece design for easy storage in the same case as the Sonus XT is also a convenience.

## Confirming Leak Locations

Once the leak site is thought to be identified there are several methods to confirm the location of the leak.

- Using Focusing Probe.
- Sealing up the target.
- Blocking with the body.
- Blocking with a clipboard or some sort of barrier.
- Use a wipe rag.
- Use a gloved hand.
- Snoop or soapy water.

## Blocking With The Body

One of the fastest ways to shield against antagonistic ultrasound is for the inspector to block the sound with their bodies. Because the ultrasound waves are so weak, they will not penetrate through the body to the ultrasound unit. By positioning themselves between the target emission and the antagonistic ultrasound the inspector can continue with minimalize interference.

## Blocking With a Clipboard

Blocking with a clipboard is another easy method to use to block against antagonistic ultrasound. Just like the blocking with body the clipboard is thicker than the distance between the peaks sound the sounds waves will not be able to pass through it. This will

help minimize interference.

## Wipe Rag & Gloved Hand Techniques

The hand has been used for years for finding leaks, but this can be an unsafe practice as materials can become embedded in the skin and in the case of higher pressures the loss of digits is possible. So, it is recommended that inspector never place a bare hand or fingers directly over the leak to seal it off. Instead a gloved hand is a safer option for less hazardous pressures. When the inspector places their gloved hand around or over the leak the sound & dB's will decrease if the leak is covered.

Likewise, a wipe rag can do the same if the inspector does not have a glove. The benefit of the wipe rag over the glove is the inspector can tie it off over the leak if it overwhelming loud and causing too much antagonistic ultrasound. This will allow the inspector to continue down the line and find much smaller leaks in that area. This technique can be repeated several times over if need.

## Sealing Method

The Focusing Probe is an accessory that can be used to seal up on the target to help confirm or deny the existence of the source of the leak. The Focusing Probe is also excellent for identifying vacuum leaks. Once the leak site is thought to be found seal up on the target and listen for a sucking sound. Then pull back from the target and if the inspector can introduce a small amount of water to the target the sound will temporally disappear and return when the water is pulled into the vessel being tested.

## Bubble Solution

For beginner and mature inspectors alike, the bubble solution as known as a surfactant, is a great confirmation for the source of the leak after its been found with the ultrasound device. This is because the inspectors, especially beginners, still are confident in what they are hearing and we as a society believe the human experience of sight over audible experiences. Therefore, the bubble solution has also been used for years an inexpensive leak detection method. It is however a limited test and can take up to 20 minutes (10-2 mbarl/s on an air system or 10-3 mbarl/s in Helium systems) for a bubble to develop on lower pressure leaks. This is a great secondary test to show nay Sayers the existence of a leak when they can't see it, feel it or hear it after it was found with the ultrasound device.

## Vacuum Leak Testing

Vacuum leaks are usually tougher to locate than pressure leaks since the turbulence is inside the vessel. If the inspector can introduce a surfactant to the vacuum line this can be used to help aid the testing and confirm the leak site. When the inspector isolates the area suspected of being the source of the leak the surfactant can be applied to the surface which will cause the sound to disappear temporarily as the surfactant is pulled through the orifice. The inspector would then apply again over the source of the leak and use their close focusing probe to seal up over the source. When the sealing method is used the inspector will notice little to no sound at first but, once the surfactant exits the orifice into the vessel the turbulent sound will start up again. A vacuum leak will have more of a sucking sound rather than a hissing sound of a pressure leak. The inspector could also follow the same procedure when using a contact module as the surfactant will make a sound as it smacks against the wall of the vessel. This process can also be used on vacuum valve stems test as well.

## Mid-fine Leak Detectors

Mid fine leaks are easy for ultrasound devices to detect but there are other test methods and devices out there but, they are usually limited in their capabilities. Helium Gas Sniffer use a micro thermal conductivity sensor to detect the presence of leaks down to 10-7 mbarl/s. Multigas sniffer are designed to tell what the PPM are in the atmosphere and quickly become over saturated in higher levels of the gases they are trying to detect.

## Dye Penetrant

Dye penetrant testing has been used for several different applications. From leak through on vacuum systems, phone lines, heat exchangers, pipe leaks and even at the famous Oak Island Money Pit. It comes in many colors and even a fluorescent dye that

require the use of a black light. It can be very time consuming, but effective.

## Airborne Ultrasound Tone Test

Tone testing is a procedure that utilizes high frequency sound as an artificial pressure to find small leaks. These leaks can cause bulkheads to fail when needed or cause a whistle while driving your car. For the building envelope testing it is a great aid at finding where leaks of water and air are coming into a building. Building envelope testing is best suited to be performed with IR Cameras as well as Ultrasound to help pinpoint the area of air ingress & egress.

The Navy regulation that covers Water Tightness Integrity Testing is NAVSEA 9880.4025-9880.4029. This test procedure came about to replace the old soapy bubble test that a 5-man crew would perform on large naval vessels like an aircraft carrier. The normal operation is to pressurize that compartment with only 3 PSI and have the crew members on the opposite sides of the hatch covers, doors and walls that needed to be checked. This proves extremely difficult to do in areas like the hanger bays on an air craft carrier not to mention very time consuming to boot.

During the initial trials of the validity of Ultrasound Tone Testing two teams were used to do the standard bubble test method and the other team using the ultrasound tone test in a controlled environment. During this testing the teams found that in under 30 minutes the ultrasound team identified the same leaks the bubble test team took over an hour to find. Satisfied with their findings they tried this same comparison testing on an aircraft carrier and when the results came back with similar results, they rewrote the standard to include the use of Ultrasound Tone Testing.

Another test that IRISS took part in was with a company that manufactures the panel windows for skyscrapers. Their concern was to find where the wind, noise, and water leak issues in panels after they assembly and installation. They had been using the bubble test method as well as pressure decay testing in the manufacturing site and were looking at other options for testing pre and post install. They used a chamber to apply water to one side of the panel and look on the other side for bubbles to develop and, was ineffective once it reached levels leaks ranging in size from 1-5 SCC/min (standard cubic centimeters per minute) and as high as 10 SCC/min. The reason for this is the bubble solution clog the orifice and the air flow will actual change from a vicious flow to a molecular flow. This makes testing using bubble solution under these low pressure the solution's molecules will clog the path of the leak making bubble testing impossible to do.

The Sonus XT was however able to detect at a much lower level and was successful down detecting leaks down to reaching below . However, once the pressures started getting below the ultrasound was ineffective. There are some draw backs with bubble testing and ultrasound pressure testing and therefore Tone Testing could be used as an artificial pressure and the sound will penetrate the smallest of openings because nothing is blocking the orifice. In one case a client was looking to use ultrasound for micro-porosity evaluations in a fuel cell component.

They had been using Nitrogen Gas and an IR Camera to try and look for these micro-porosity leaks in the fuel cell components with little to no success. When they looked in to ultrasound as a choice it was decided that the best way to test these components was to design a housing that was 2 inches thick and place a tone generator in the bottom at 1 foot from the bottom of the component. The shape was that of a four-sided funnel to direct an even field to the underside of the component and a seal at the top insured no sound would exit in an undesirable way. As the benchmarking testing proceeded the inspector would swap back and forth across the plate looking for a rise in decibels. it was determined that 23 dBs was the norm a leak free component and anything above that was an issue.

## Bulkhead & Compartment Testing

Years ago, the US Navy approved the use of the Ultrasound to assist with bulkhead and hatch cover testing. One jet mechanic used a tone generator and pressured the cockpit of a fighter jet while it was inside. He used a grease pencil to mark the areas he heard the tone generators sound and in about an hour he had identified several leaks that he then used his bubble solution and it took him 7 hours to find all the same leaks he had found in an hour with his ultrasound device.



# ASU Module 1-7 Compressor Testing

Due to the nature of the beast the compressor rooms can sometimes be the toughest challenge for an inspector. This is because the inherent noise levels associated with compressors as they can produce a lot of antagonistic ultrasound as well as the rare case of a strong acoustic pressure wave that can literally rattle the inspector's brain from the reverberation in the room. This can cause the inspector to cause severe stress to the inspector and cause health risk not worthy of continuing. This is similar to the use of a the LRAD (Long Range Acoustic Device) used by the military and police around the World as a non-lethal crowd control device. The sound waves it produces is not only deafening it literally rattles the brain and makes those that are exposed run in retreat.

The use of ultrasound for the testing of compressors can be two-fold. First the inspector can perform an airborne detection for air ingress or egress around valve covers and other areas in and around the compressor. The process would be the same as an air leak survey and all the methods that are used for a standard leak detection survey. The second test would be a structure borne test using the contact module and placing it directly over the valves to listen and record the sound wave of the valves. This allows the inspector to use the Time Signal on the sound analysis software to compare and see the timing of the valves operation to determine if they are all function at the same rate. This method is called the comparison method and it can be used for all test application.

## Compressor Testing

There many types of compressor so the inspector will need to understand what type they are prior to testing them so, they know where to test for effective readings. There are several types of compressors that a site could use. From Rotary Screw to Centrifugal, Axial, Reciprocating and Scroll. Each of these are different and the inspector will need to know which type they will be testing to be successful.

The comparison method is the easiest of methods for inspectors to use to determine if there is an issue with the equipment they are testing. Since there are several compressors valve it is easy to compare on of the inlets to each other and do the same with the outlets as well. The inspector can also use the contact module to test for issues with thrust bearing, crank shaft bearings, pistons, split pieced timing gears, and rotor issues.

## Compressor Valves

Since the compressor produces turbulence the inspector can easily use the comparison method to listen in for the difference between all of the suction lines and discharge lines opening & closing. This would be greatly aided by using a Time Signal Analysis software to see the duration of the discharge in the tenths of seconds it takes to open & close. A noticeable difference not only could be seen but calculated as well.

## Keys to Testing

If the inspector's unit is capable of frequency tuning, they can set the unit to 40 kHz for airborne testing of air egress or ingress or for structure borne, they can tune the unit to 25 kHz for structure borne testing. The inspector will need to listen to the sounds to pick up subtle difference in sound patterns and hints that the timing is different. The inspector would also be best suited to record the sound wave, so it could be analysis in a time signal format. Then produce a report to show the difference between valve or any other comparison of similar equipment.

# ASU Module 1-8 Heat Exchangers, Condensers & Chillers

Heat Exchangers have evolved over the years and testing them has always been a labor intensive. Some programs have gotten creative with their test procedures and determined how to test while the units are still operating. Some sites are limping theirs along till they can pull the funds together to install newer plate heat exchangers and as such ultrasound would not be the best test method for plate heat exchangers. The best option for plate heat exchangers is Infrared. So, for those still using Tube or Bundle systems these next methods will be the best at determining the condition quickly and easily when the system is off line.

## Pressure Testing

Pressure testing is always recommended as the first test method for heat exchangers & chillers. Pressure Testing is an offline test that is done by isolating the unit from all potential downstream or upstream source air pressure can be introduced into the shell side. The inspectors will open the heat exchanger to gain access to the tubes. Then by scanning across the face of the bundle they will listen for the sound of air leaking. Then start sweeping the around the area of the sound and reducing the volume down on the until they barely hear the leak. They will then move in to isolate the tube that is generating the sound of the leak. Next slip the Focusing Probe over the Scanning Module and place the tip at the opening of the tube, if the sound gets louder insert the focusing probe into the tube and listen for an increase of sound and decibel display on the unit. Back out place a glove hand or wipe rag in the opening of the tube and see if the sound goes away. If it has the source has been found and the tube can be plugged.

## Vacuum Testing

In some cases where a system cannot be placed under pressure vacuum testing could be used. It follows the same steps as pressure however, the inspector will place the shell under vacuum instead of pressure and proceed as above. The problem with vacuum testing however, is that the holes can become blocked and restrict the air flow being pulled into the shell, which also reduces the sound level. The inspector can use plastic wrap to cover the area on the face of the heat exchanger tubes to help enhance the vacuum effect on the other tubes being tested.

This test however, requires the added steps of cleaning out all the tubes prior to the inspection which can add considerable time to the test procedure. It is for this reason that the vacuum test method is not the preferred method.

## Tone Testing Method

Tone Testing also follows the same rules as vacuuming testing. It is dependent on the sound level it can generate inside the shell. This can be a problem with the baffles inside of the heat exchanger or chiller. For this test procedure, the inspectors may need to place tone generators on the inlet and outlet of the heat exchanger. This will insure the shell side has an even level of ultrasound present in the unit. The inspector will also need to ensure that zones are set up to separate exterior tubes from central tubes as the shear wave produced by these tone generators will be affected more by these shear waves and as such will have a higher decibel value than those further away from the center tubes.

## Battleship Method

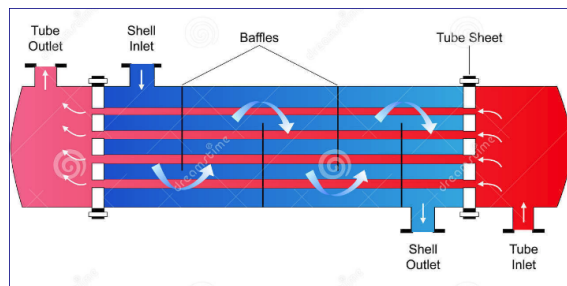
The Battleship Method is a contact test done while the unit is online. This involves setting up zones to test. Once the zones are established (Recommend using geographical reference points IE; North, East, South, and West) the inspector will start in that zone and make contact and move the contact module every six inches. As the inspector moves, they will watch and listen for a jump in sound. When the sound hits the hits level and drops again the inspector will change direction up or down 6 inches from the highest reading to see if it is from above or below that point. If the sound level goes down as the inspector moves away from the highest level, then they have isolated the source of the emission. This test however does not tell the inspector how many or which tubes are leaking. A leaking to will make a popping or crackling sound. If there any installation test holes will need to be made for future testing. Do not use the Contact module to make these holes.

The inspector can even check fittings, headers, boiler casings, condenser tubes, inlet end erosion, stress corrosion cracking, crevice corrosion, tube OD damage and valve stems with the scanning modules as the pressure exiting the orifice will produce ultrasonic emission. The Condensers can be tested the exact same way as Heat Exchangers and Chillers.

## Confirmation Methods

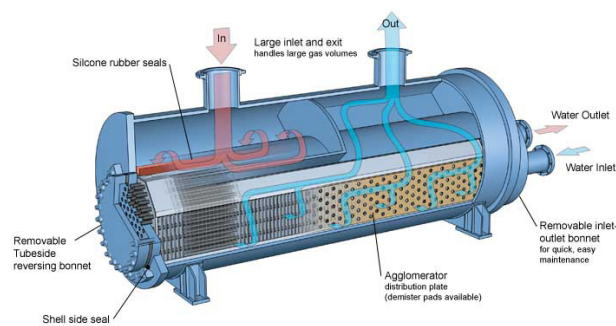
To confirm:

1. Use proper positioning to locate the tube with an emission.
2. When a smaller area is identified reduce volume to the lower level till the emission can just barely be heard.
3. Once the inspector feels they have isolated the leaking tube use the Focusing Probe to seal up over the tube.
4. If the emission becomes louder the reduce the volume again till its barely heard and insert the focusing probe into the neighboring tubes.
5. If the sound level drops in neighboring tubes the leak is confirmed.



What steps need to be taken to test this heat exchanger?

1. \_\_\_\_\_
2. \_\_\_\_\_
3. \_\_\_\_\_
4. \_\_\_\_\_



What steps need to be taken to test this chiller?

1. \_\_\_\_\_
2. \_\_\_\_\_
3. \_\_\_\_\_
4. \_\_\_\_\_

# ASU Module 1-9 Valve Testing

In Structure Borne Ultrasound Valve Testing the inspector needs to remember that the turbulence will be produced in the first medium. In the case of Valve Testing that means it will be inside the pipe and not the exterior like in the case of air leaks. This means the inspectors module must be placed on the second medium. The contact module then becomes a continuation of the second medium and will pick up the energy from the Shear and Plate Waves that is being produced by the turbulence on the inside of the piping and valve body.

## Valves Types

One of the keys to Valve testing is to understand the type of Valve that is being tested and the and how it operates. Even though there are many different body types the primer function is to close and hold back material. If the valve is not seating properly because of sediment or wear, it will allow an orifice to be present and it's this orifice that will produce a source of turbulence as the higher-pressure side pushes through the orifice in an attempt to equalize pressure.

## Turbulence Produces Ultrasound

One major factor to consider is the viscosity of the materials in the system. Next the inspector will need to consider the actual pressure of the system and what the potential differential would be on both sides of the valve seat. Other consideration could be caused by defects, poor systems health such as a valve not seating from wear, obstructions, intersections, elbows or maybe the valve is not fully open.

## Contact Testing

Since the source of the turbulence is inside the valve and piping the Contact Method must be used to test for leaks. There are 3 methods that can be used for testing valves for leaks. The inspector will also need to ensure that contact is made directly on the piping and never on the thread fittings. Contact should be at 90 degrees to the surface of the body being tested.

The first on is the comparison method. The inspector can compare similar valves in a closed position to listen and observe the decibels received on the downstream side of the valve. The inspector will need to ensure that the test points are the same distance away from the valve body to compare the reading. If one of the valves is louder the inspector will need to check to see that the positioning of the valves is the same, pressure is the same and the pipe size is the same.

The second test procedure is the comparison method as well but this time the inspector will compare the upstream side to the downstream side. A valve in the open position should have decibels levels that are very similar to each other when comparing the upstream and downstream side. If the valve is closed and the downstream side is louder there could be a leak. The way to confirm this is to continue with the Battleship Method to move away from the downstream test point and look for a rise in decibels and intensity of the sound present. This will help confirm whether there is downstream interference from an elbow or intersection of piping.

The third method is the 4 Point Test Method. This involves establishing 4 test points across the valve. 2 points upstream and 2 points downstream. This test points will be spaced based off the diameter of the piping. So, if it is a 1-inch pipe diameter the spacing from the valve to test point 2 & 3 will be 1 time that of the pipe diameter and test points 1 & 4 will be 3 times the pipe diameter from the valve body.

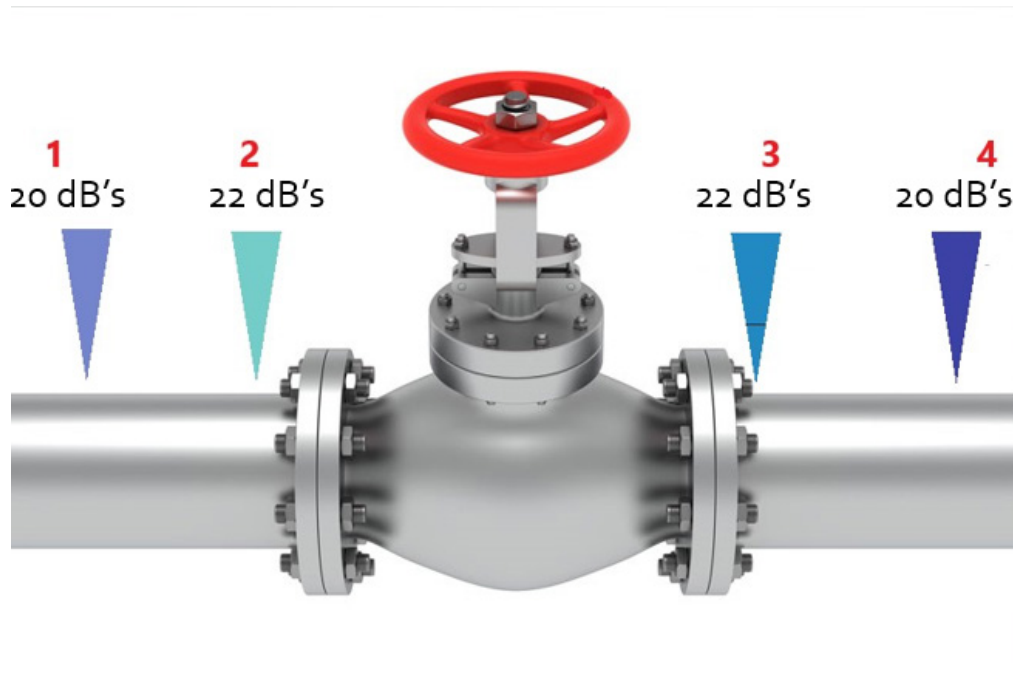
## 4 Point Test Method

As the inspector sets up the 4 Test Points, they should insure that test point 1 is on the upstream side of the valve. From there the inspector will insure that its placement is 3 times the pipe diameter away from the valve body and test point 2 will be 1 times the pipe diameter away from the valve body. These steps will be mirrored for test points 3 and 4. Never make contact on thread fittings or insulation. The Contact Module should make direct contact on the pipe as this will insure the module becomes a continuation of the second medium the sound wave interacts with.

As the inspector begins the test, they must verify the that the valve is in the desired position for testing. If the valve is open the

decibel readings should be familiar similar compared to their equal on the opposite side of the valve body. For example, if the test results should a 20-decibel value for 1 & 4 and then a 22 decibel for 2 & 3 the valve would be open and flowing normally.

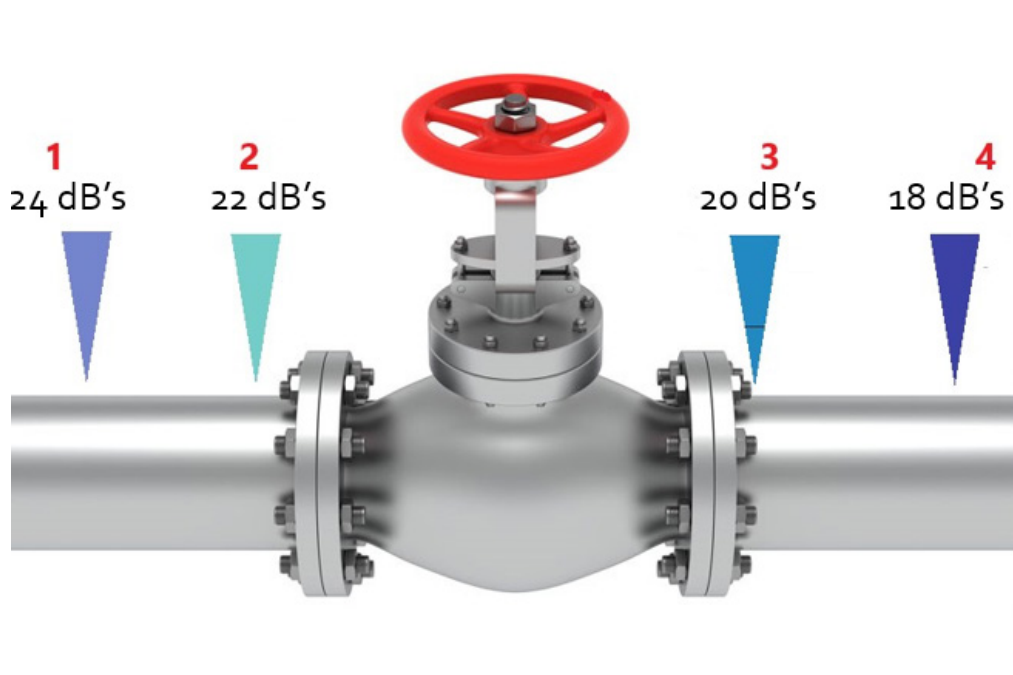
#### Open Valve: Good



### Always Take into Account

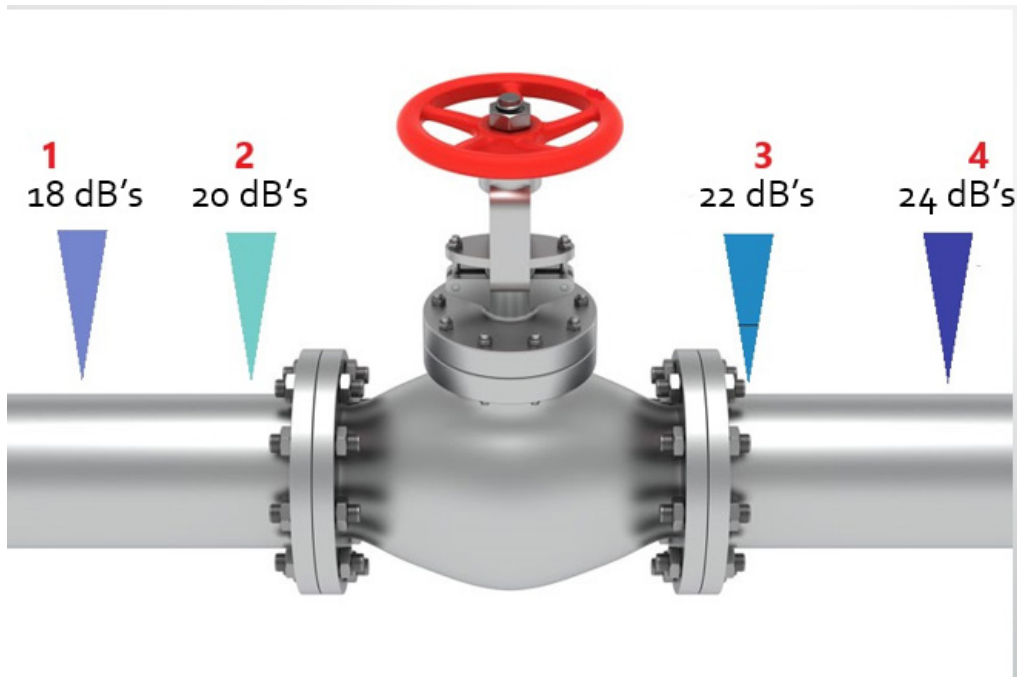
When testing a closed valve, the inspector will take the same steps but now will be able to determine 3 conditions that could be present. The first condition is a properly closed valve. The inspector would experience a decrease in decibels as they move through the 4 Test Points. For example, if test point 1 received a reading of 24 decibels and each test point declines in decibels the valve is properly closed.

#### Closed Valve: Properly Closed



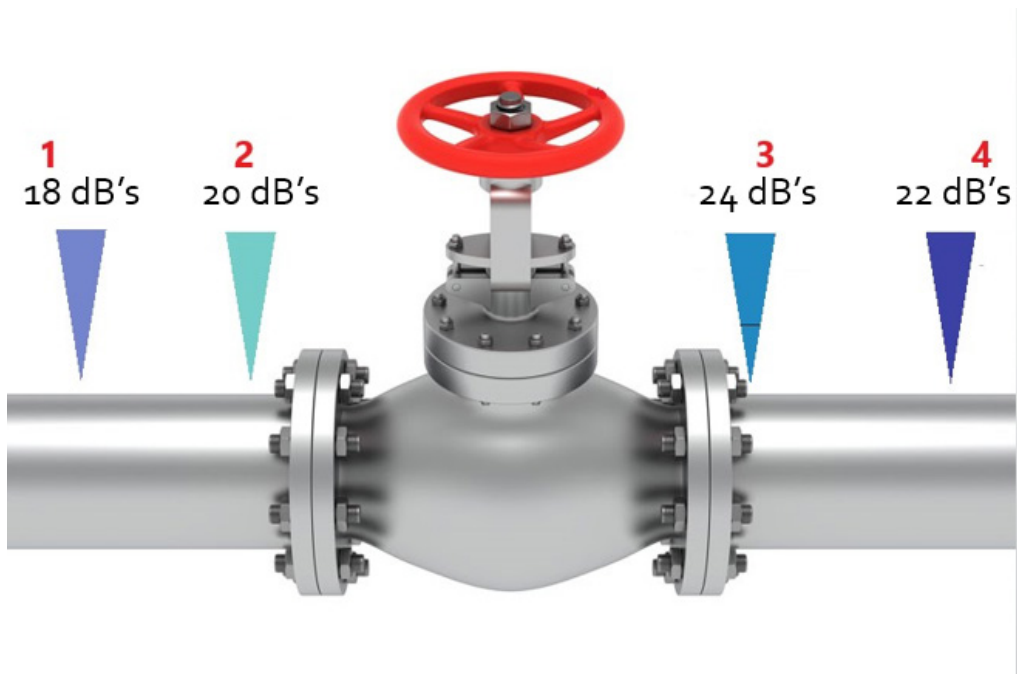
The next condition that can be identified is antagonistic downstream ultrasound interference. The decibel indications for this event would be the opposite of a properly closed valve. The inspector would experience a rise in decibels across the 4 Test Points. To locate the source of antagonistic downstream ultrasound the inspector would then use the Battleship Method at an interval of 2 times the pipe diameter to verify the decibels increase as they move downstream of the valve. This antagonistic downstream ultrasound can usually be attributed to the elbows or intersecting piping.

#### Closed Valve: Downstream Interference



The last condition that can be determined is a leaking valve and its indication is that test point 3 is higher than all others. This is because its closest to the source of the turbulence being generated as the higher-pressure material attempts to equalize with the lower pressure downstream of the valve seating.

#### Closed Valve: Leaking



When testing valves, the inspector must always consider the volume and placement of the module on the surface they are testing. The Contact Module will slip off if too much pressure is applied to the module. So, it is usually best to place the module on the top or hold it against the bottom of the pipe. In some cases, a magnetic mount could be used and since the dBs are only being compared across the 4 test points the loss of signal will not matter since trending is not being performed. Similar valves can be used to also perform a comparison method test to see if there are any noticeable differences between similar valves. In the case where the insulation is covering the piping and it can be removed an upstream vs downstream test method is the next best thing to determine the condition of the valve. The Battleship Method can even be used to help rule out antagonistic ultrasound.



# ASU Module 1-10 Steam Trap Testing

Steam Systems are the second largest contributor to energy efficiency losses in a plant. Steam is a costly process that many sites never really have a handle on the waste and just like a compressed system a blind eye is cast on it and the leaks just become part of the process. The testing of Steam Systems with ultrasound devices is predominantly a contact test method. Just like testing valves the comparison method can be used to hear the differences between similar steam traps. Some of the keys to a successful steam trap test is to know what pressure the system is operating at and then use a spot radiometer or IR Camera to check the temperature to determine if there is the proper temperature differential between upstream and downstream. The Ultrasound can then be used to determine efficiency by recording a sound wave and playing it back on sound analysis software. When reviewing the sound wave the inspector should use the Time Signal Analysis Format to count the number of Discharges Per Minute.

Several issues can be determined when testing with ultrasound equipment these days. A trap cycling too frequently could be grossly under sized and one not cycling enough could be oversized. The inspector can now even record the sound waves and analyze them in a software platform where the Time Signal would be able to determine the cyclical rate of discharges of the trap and then rate its efficiency or inefficiency of that trap. This is a look away from the old days of just say pass or fail when testing with ultrasound.

The best practice however, would be to use a spot radiometer or IR Camera to first look for temperature differentials between the inlet and outlet of the trap. This will also expedite the survey as the inspector can clearly identify if the trap is even to temperature or not. This is key because if the system isn't the correct temperature there will be no change in the sound patterns making it impossible to test the steam trap Ultrasonically.

## Steam Generation

Steam is derived from one of the World's most abundant re-cyclable elements, WATER. That is unless you live in the middle of the Sahara Desert or similar climate where water is not so readily available. If we heat water, it turns into Steam. While most people think that steam is the white clouds, they see coming out of their tea kettle, this is not so. What is commonly thought to be steam is actually water vapor, or steam giving up its energy.

Steam gives up its heat very quickly and a boiling kettle is a fantastic way to see this heat transfer taking place. If you look very closely at the kettle spout you can observe that the first 5mm from the mouth of the spout of the kettle you can't see anything. This is where the steam is, but as we stated it's invisible to the human eye.

Immediately after this invisible section the steam starts to give up its stored energy then turn into water vapor and eventually back into the water. If we were to talk about superheated steam, then this would be a different story as super-heated steam leaks tend to stay in the atmosphere for a lot longer as an invisible gas. On ships and power stations, superheated steam leaks tend not to condense until they are well outside the area of the leak. This makes them very dangerous, because you can only hear them not see them. Many plants still use a broom stick to determine the area of the leak while others use an IR Camera.

## What Is Steam?

Understanding that one of the keys to a steam system's efficiency is the pressure of the system. The increased pressure raises the boiling point of the water and as such the temperature in the systems. The steam can be used for power generation, heating, sanitation and food grade applications. This process involves insuring the quality of the water added to the systems. If it's not balanced properly its sludge can build up in the systems. The PH & Alkalinity need to be monitored and adjusted on a regular basis. If left unchecked they can trigger several types of faults in a steam system.

So, there are many sources of waste that can occur, but this section is going to concentrate on the use of ultrasound to test the efficiency of the steam traps and help determine the exact condition of the trap.

## When Inspecting Steam Traps

When inspecting steam traps, it's very important to research what types of traps will be tested, systems pressure & temperature, and the discharge location. The inspector must also adjust the volume on the unit to insure the antagonistic ultrasound is isolated as well as ensuring that it's not so loud that it causes the inspector to have to rip the headphones off when the trap discharges. When

capturing a sound wave the inspector will need to ensure they listen for a complete cycle of the trap and capture a couple of cycles so the Discharges Per Minute can be calculated to see if the trap is working efficiently.

Pressure	Temp in F	Temp in C	Pressure	Temp in F	Temp in C	Pressure	Temp in F	Temp in C
0 PSIG	212	100	85 PSIG	328	164	290 PSIG	419	215
1 PSIG	215	102	90 PSIG	331	166	300 PSIG	422	217
3 PSIG	219	104	95 PSIG	335	168	320 PSIG	428	220
5 PSIG	227	108	100 PSIG	338	170	340 PSIG	433	223
8 PSIG	235	113	110 PSIG	344	173	360 PSIG	438	226
10 PSIG	239	115	120 PSIG	350	177	380 PSIG	443	229
15 PSIG	250	121	130 PSIG	356	180	400 PSIG	448	231
20 PSIG	259	126	140 PSIG	361	183	420 PSIG	453	234
25 PSIG	267	130	150 PSIG	366	186	440 PSIG	457	236
30 PSIG	274	134	160 PSIG	371	188	460 PSIG	462	239
35 PSIG	281	138	170 PSIG	375	191	480 PSIG	466	241
40 PSIG	287	142	180 PSIG	380	193	500 PSIG	470	243
45 PSIG	292	145	190 PSIG	384	195	520 PSIG	474	246
50 PSIG	298	148	200 PSIG	388	198	540 PSIG	478	248
55 PSIG	303	150	215 PSIG	394	201	560 PSIG	482	250
60 PSIG	307	153	230 PSIG	399	204	580 PSIG	485	252
65 PSIG	312	155	245 PSIG	404	207	600 PSIG	489	254
70 PSIG	316	158	250 PSIG	406	208	620 PSIG	492	256
75 PSIG	320	160	260 PSIG	409	210	640 PSIG	496	258
80 PSIG	324	162	275 PSIG	414	212	660 PSIG	499	259

## What Does a Steam Trap do?

The design of a steam trap is to hold back steam and discharge condensate back to the boiler and some traps can even bleed off air. When these traps are under sized, they will cycle more frequently that indicating that the trap could be grossly undersized. The opposite is true if the trap doesn't cycle frequently enough and this would indicate that is oversized.

## Types of Steam Traps

With so many diverse types of trap on the market it is critical that the inspector know what the traps look like, is the tag numbered tag system in place, how they operate, what pressure the system should be at and what is the corresponding temperature that the trap should be operating at. These factors will help the inspector to quickly identify they have the correct trap and know what they should expect so see in their readings. There are many ways to tag the traps and the most common is the standard brass tag hung on the pipping. There are more modern options available that not can identify the asset but can store data about that trap and the inspector can update the tag and trend the results. An increase in downstream decibels and temperature can be in indication that the trap is becoming inefficient and nearing its end of life.

## Inverted Bucket Trap

An inverted bucket trap works by using buoyance as a mechanism for lifting the bell housing inside as the steam rise to the top. As it feels the bell housing the condensate sinks to the bottom and allows it to raise to the top because the steam is more buoyant. As the steam cools down and returns to a state of condensate the bell housing loses its buoyance and sink toward the bottom of the trap housing. As it sinks down the arm of the trap also moves downward and opens the opening to the valve allowing the discharge of the condensate back to the boiler.

## Float & Thermostatic

This mechanical trap uses a closed float to determine the condensate level within the trap body. As the level increases, with incoming condensate, the float rises and pulls the valve away from the orifice by means of pivoting linkage. The function of condensate

removal is achieved. Discharge of condensate causes the level to decrease. As the float lowers, the valve is sucked into the orifice by pressure differential. Flow is stopped before steam reaches the orifice, because the orifice is located below the minimum water level. The function of steam loss prevention is positive. This cycle repeats to provide the functions of condensate removal, and the prevention of steam loss.

## Thermodynamic – Disc

These kinds Thermostatic Trap that operates on the difference in temperature between steam and condensate. When closed, they should have little to no sound during hold back and during the discharges you will hear an increase in sound. A slight “hissing” sound indicates leakage. Never test during start up, as they can take a long time to get up to temperature. This discharge would last for a prolonged period and the inspector would make the wrong call.

## Bi-Metallic Traps

Are traps that fall into the Thermostatic Trap category. They operate the same needs of the temperature differentials between steam and condensate only they have 2 opposing metal that flex away from each other when the steam is inside the trap. When condensate is present, they flex towards each and this opens the orifice to allow the discharge to occur.

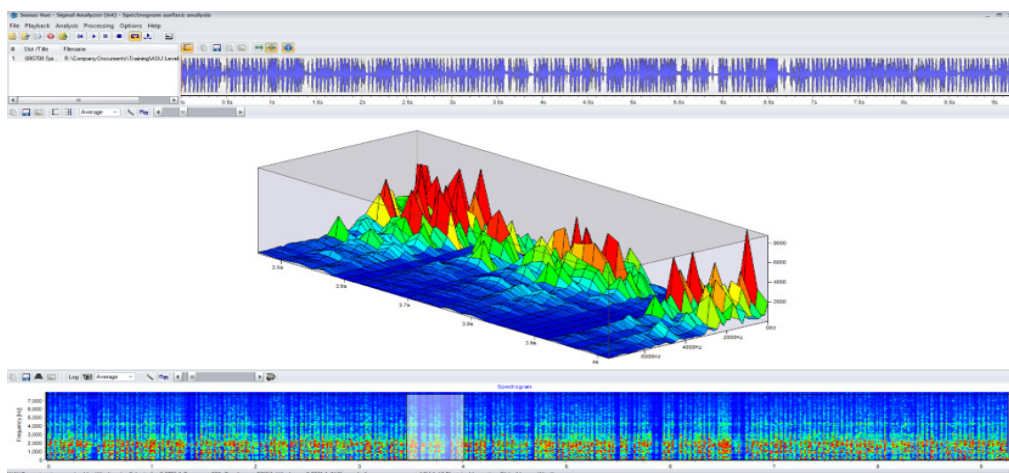
## Dangers of a Steam Systems

Steam Systems are a main-stay in many plants and cities for heating and power production. A lot of these systems are past their designed life cycle and as such can fail and will fail. It's a matter of whether or not the catastrophic failure kills someone. With Water Hammer and Carbonic Acids being the most destructive to the steam systems it's really important that they be well maintained. Testing the condensate for contamination, testing traps with IR and Ultrasound. These are just a couple of the basic steps needed to maintain a steam system. The use of Sound Analysis Software to help an inspector diagnosis the condition of Steam Traps is critical.

## How Sound Analysis Helps

The use of Sound Analysis Software to help an inspector diagnosis the condition of Steam Traps is critical. Temperature can let the inspector know if a steam trap is in range of working efficiently but, a sound wave can show the total number of discharges per minute which can then be used to determine how inefficient a steam trap is working. This extra step can help to give the inspector the key piece of information in reporting the condition of the trap. Using Time Signal analysis is the easiest way for them to also show management how they were able to determine a good, bad or inefficient steam trap.

In addition to the Time Signal an inspector can also map out the intensity of the discharge by using a Spectrogram, Spectrogram Analysis of Spectrogram Surfacing to further highlight the condition of the steam traps. Frequency Spectrums are not that useful in analyzing the condition of a steam trap so, it always best to use Time Signal. A comparison analysis can even be done by using the Time Signal over lay in a 2D or 3D format. This will allow the inspector to conclusively show that one trap is not functioning properly when overlaid against like traps that are operating efficiently.





# ASU 1-11 Hydraulic Systems Inspection

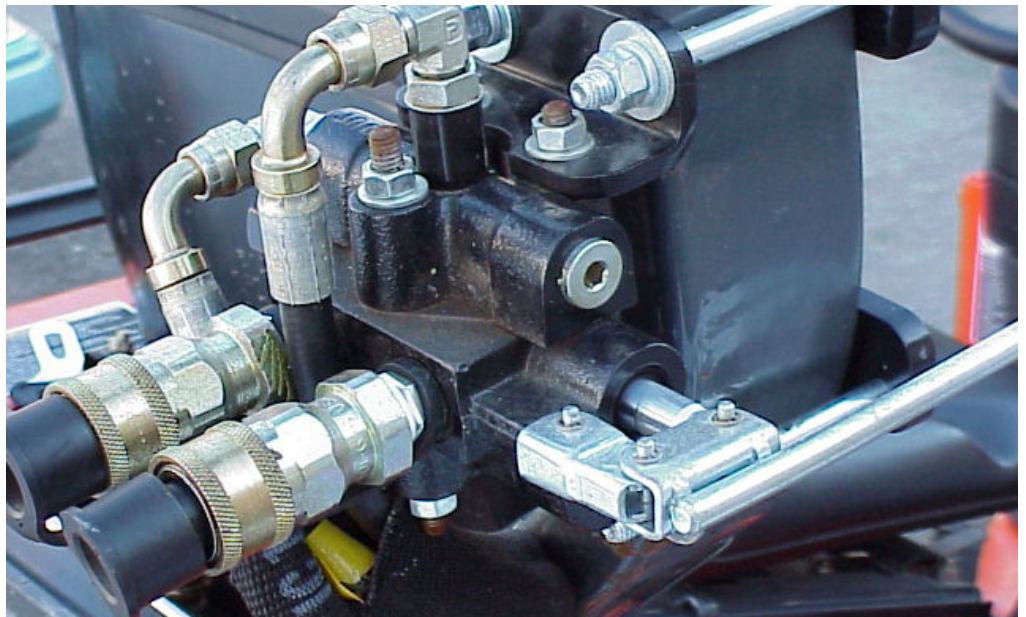
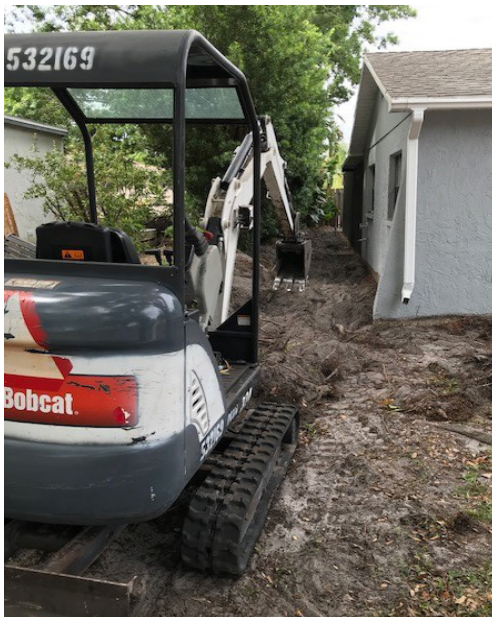
Hydraulics Systems have been used for thousands of years dating back to Mesopotamia and it was not until 1785 when Joseph Bramah and Sir William George Armstrong took inspiration from the common water wheel and designed a hydraulic piston engine to move a crane. They applied the Pascal's Principle which state "that a pressure change occurring anywhere in a confined incompressible fluid is transmitted throughout the fluid such that the same change occurs everywhere". This advancement helped to aid the industrial revolution in its growth and is still used today for a wide array of equipment we use in everyday life. From Elevators to the brakes on your car Hydraulic Systems are still in use today.

## Why Ultrasound Testing for Leaks is Safer

If we apply all of the same principals, we have learned in the previous modules on leaks to Hydraulic Systems we will see that turbulence and friction will also be detectable in this system too. This make the use of an ultrasound device a quick and easy choice to use for the detection of leaks in valve, rams or even cavitation in the pump. Since these systems operate at high rates of pressure the inspector will need to insure, they perform these tests safely at all times since hydraulic leaks can cause amputations or death. These types of injection injuries can go miss diagnosed and lead amputation from the damage to the injected area caused by the inflammation and the chemical makeup of the fluid. Proper diagnosis is critical and will need several surgeries in order to insure minimizing the long-term damage to the affected are.

## Hydraulic Valve Testing

Testing Hydraulic Valves, the inspector will need to listen upstream and downstream like a regular valve however, since these valves usually change direction and the piping changes direction so quickly there is not enough room to use the 4-point method like a gated valve for example. So, the inspector will need to listen up stream and take note of the decibels and then do the same downstream as the valve are used. A distinct turbulent sound will be present when the valve is leaking by or little to no sound downstream if the valve has failed closed. Having used a mini excavator for years the effect of these valves failing is usually very noticeable in the turning of the tracks or the during the use of multiple actuations simultaneously. When driving and operating the tracking steering valves the mini excavator bucked like a bucking bull when moving forward or in reverse while trying to turn.



## Comparative Method of Pumps

Pumps are a key piece of the hydraulic systems. If there is a presence of cavitation in the pump it will damage the pressure side of the impellers vanes and erode the surfaces making them rougher which in turns adds to the volume of cavitation occurring in the pump. Not only can this damage the vanes in the pump, but it can lead to detrition of the piping and significant vibration of the

pump and motor increasing the thrust load on the bearings. Cavitation can be used to our advantage however with such application as ultrasonic cleaning equipment. This process uses ultrasound to generate cavitation in a fluid and the item that needs cleaning is then dipped in this fluid. The implosion of the bubbles in the solution knocks the dirt off the dirty item.

When using the Comparisons Method is one of the quick ways to determine if a pump is failing. When a pump has a smooth rushing sound and a steady decibel level compared to one with a large amount of popping sound. The inspector would also notice these ultrasonic indications accompanied by higher decibels, noticeable to significant vibration and higher temperatures when compared to like pumps. A pump with these indications would be considered as inefficient and should have action taken sooner than later.

## Cylinder Leaks

Cylinder Leaks can be either classed as a vacuum or pressure leak since the cylinders direction of travel will cause the pressure as it extends and pull a vacuum upon contraction. This can be a source of the cavitation heard in the cylinder and left in place long enough the hydraulic fluid will start to flow out and give a clear visual indication of a leak. The use of a contact module or airborne module can confirm this prior to any visible indications and help to ensure that more severe damage does not occur.

# ASU Module 1-12 Mechanical Inspection Techniques

Mechanical inspection is one that has expanded over the years from just being trouble shooting tool to a full-on diagnostic assist. By recording sound waves the inspector can determine the difference between inner, outer race faults, to bearing faults and cage faults. With the deployment of VFD's there has been another item that ultrasound is successful at determining and this is one of the top contributors to VFD failures. Its stray voltage! It will show up with the same harmonic value as the line frequency driving the motor. Loose connection in a pecker head will also generate a distinct 2-time line frequency harmonic that can be seen in the Time Signal analysis as well as the FFT.

Add the ability to trend the bearings and the inspector can start setting up lubrication routes based off actual data and not a time-based interval. This greatly reduces the chance of over lubrication of motors. One key though to any lubrication route is to know the type of motor being tested. Some companies are shipping their motors to clients with the grease fittings attached even though the motor bearings are sealed. This has led to many motors receiving lubrication and shorting out once the lubrication starts entering into the windings.

## Reasons to Perform Mechanical Inspections

One of the least talked about reasons for testing mechanical assets is Safety. In a by R. John Phillips, P.E., CFEI article titled Fires Involving Bearing Failures he talks about the cause of two fires his company The Warren Group, INC. did forensic investigations on and found that in both cases the fires were started when a bearing failed and created an increase in heat that ignited combustible material in the area of the failure.

### Fires

A computer monitors beeps in the control room of a manufacturing plant during the night shift. A supervisor reads the alarm message flashing on the screen indicating a system error and the initiation of process equipment shutdown. Maintenance personnel are dispatched to the remote area of the plant where the monitored equipment is located. The maintenance technicians are surprised to discover a large growing fire in the equipment room. The fire department is able to extinguish the fire, but the damage sustained is extensive. The equipment and product were destroyed and the building itself severely damaged. The additional loss of production time and the required repairs created a very expensive loss.

Meanwhile, many miles away, a conveyor system operates unattended and unmonitored in a warehouse facility. A security guard happens to observe smoke rising from one of the warehouses and notifies the owners. The fire grew out of control and destroyed the entire building, creating another costly loss.

### Common Ignition Source

Although the two fires described above involved different types of processes and machinery, the cause of both fires was determined to be the same. In both cases, a bearing failure on the machinery created the ignition source and combustible materials within the proximity of the bearings supported and facilitated the spread of the fires.

### Cause

The failed bearings in both cases involved ball bearings supporting rotating shafts. In the case of the manufacturing facility, the bearing failure occurred on a large motor used to produce high torque and speeds. The motor was used to drive a batch-processing machine. Although an error was detected by the monitoring system, due to the nature of the process, the system was configured to allow the continuous operation of the motor until the product in the batch-processing machine was evacuated. Consequently, the electric motor continued to operate for a brief period of time with the failed bearing at high torque and speed, generating extensive mechanical friction between the components. The mechanical friction produced extremely elevated temperatures igniting nearby combustible materials and compromising lubricating oil lines, allowing the fire to grow and spread quickly.

### Fires Involving Bearing Failures

In the case of the warehousing facility, a small electric motor was used to drive the conveyor system at relatively low torque and low speeds. The system was operating inadvertently and was unattended for an unknown period of time. The mechanical friction generated by a failed bearing supporting a pulley drive shaft produced hot metal slag, which fell into the product stored below the

equipment. The system was unmonitored, and the smoldering fire produced in the stored product grew substantially before it was detected.

## Eliminating Potential Bearing Fires

Bearings are mechanical devices used in machines primarily to reduce the mechanical friction between machine components that are moving relative to each other. The mechanical friction can quickly generate heat and temperatures hot enough to cause fires when oxygen and fuels are available. While this discussion has been limited to bearings on shafts, the concepts will generally apply to all bearings.

It is important to understand that all bearings will eventually fail even under ideal operating conditions if not replaced beforehand. Bearings have a calculated life expectancy dependent on the bearing capacity, imposed loading, operating speed and operating conditions. Any deviation from the ideal operating conditions can substantially reduce the normal life expectancy of a bearing, causing premature failure. Deviations from normal operating conditions include, but are not limited to, misalignment, overloading, corrosive environments, inadequate or improper lubrication, and vibration.

It is often important to parties involved in a machinery fire involving a bearing to know whether the bearing failed due to normal use and wear, or whether the failure can be attributed to another mechanism such as improper installation, inadequate design, or impact loading. In some cases, damaged bearings found after a machinery fire can be the result of the fire rather than the cause of the fire. Premature bearing failures can result from one or more of the aforementioned conditions and a laboratory examination of the complete bearing assembly is generally required to provide the exact mode of failure. The Timken Company bearing damage analysis chart<sup>1</sup> is a tool often used by engineers when conducting an initial determination of a bearing failure mechanism.

Determining the cause of a fire in a large manufacturing or warehousing facility can be a daunting task, especially when complex machinery or other equipment may be involved. Beyond determination of a bearing failure as the cause of a fire it is often important to evaluate the adequacy and operation of fire alarm and suppression systems that could limit the fire damage resulting from a bearing failure. In both situations described above the fire damage could have been minimal if fire alarm and suppression systems had been present and operated correctly.

The engineers at The Warren Group are experienced in these areas and would be happy to assist with these investigations.

## Benefit of Ultrasound Testing on Rotating Equipment

Brinelling of bearing surfaces will produce a similar increase in amplitude due to the flattening process as the balls get out of round. These flat spots also produce a repetitive ringing that is detected as an increase in amplitude of monitored frequencies. The ultrasonic frequencies detected by the Ultrasound device are reproduced as audible sounds. This “heterodyned” signal can greatly assist a user in determining bearing problems. When listening, it is recommended that a user become familiar with the sounds of a good bearing. A good bearing is heard as a rushing or hissing noise. Crackling or rough sounds indicate a bearing in the failure stage. In certain cases, a damaged ball can be heard as a clicking sound whereas a high intensity, uniform rough sound may indicate a damaged race or uniform ball damage. Loud rushing sounds similar to the rushing sound of a good bearing only slightly rougher, can indicate lack of lubrication. Short duration increases in the sound level with “rough” or “scratchy” components indicate a rolling element hitting a flat spot and sliding on the bearing surfaces rather than rotating. If this condition is detected, more frequent examinations should be scheduled.

## How Structure Borne Ultrasound Travels

When it comes to Structure Borne Ultrasound the incident wave transfers its energy into the motor housing from the inside. By placing a contact module on the housing, the inspector’s ultrasound device becomes a continuation of the motor housing. This is because the motor housing and the contact modules have similar characteristics so there is little to no acoustic impedance the incident wave to the transducer. This allows the inspector to successfully hear what is going on inside of with the motor bearing and the presences of stray voltage.

## What to Do When Inspecting Bearings

The key to performing dependable Ultrasound inspection of bearings is to ensure that the inspector/s test points are the same every



time the asset is tested. The best spot to place the contact probe is directly on the zerk fitting. The inspector should always clean the tip of the contact module and the zerk fitting prior to placing the contact probe on the zerk for the test. This position is the most direct path for the sound wave to travel through and give the unit the most energy. If the inspector placed the module on the Fan Shroud the sound of the turbulence from the fan will be a source of a huge amount of antagonistic ultrasound and the condition of the bearing will not be heard. The same will hold true for the frame as well the inspector will again be affected by the air flow from the fan itself as well as the electrical field from the stator which can also produce antagonistic ultrasound. In the case of a motor with sealed bearing and no zerk fittings the bolt on the fan shroud would be the next best test point on the out-board side and on the inboard side the end bell would be the best point. The inspector could even test the motor junction box to listen for loose connection which will present with a 120 Hz harmonic indication and will present a line frequency fault if their shaft voltage issues.

The inspector also doesn't need to press down on the contact module when testing for structure borne issues. They should place the contact module at a 90° angle to the surface contact point and not their orientation. The test points should be documented and clearly marked on the asset when possible. If due to environmental issues in the area that would eat away a paint pen marking the user could drill a small divot just deep for the contact probe to rest on. This isn't necessary for zerk fittings. A photo can be taken and added to the training of the inspector or placed in the work orders job plan the program can help to insure consistency in the data collected and minimize the human factors.

## Monitoring Operating Equipment

Over the years the trending of bearing has become more precious at determining at what decibel range a bearing could be considered bad. One of the first things a program should do is to ensure that the bearings being tested are similar Machine Classes per ISO 20816:2016. Horsepower range the best way to group together similar assets for trending. It doesn't matter if a motor is 1 month old or 10 years old. If they are operating at similar horse power, they should have a similar decibel values and similar action levels as well. The fastest way to establish this is to collect all the decibels values for these and look for the out-laying readings and remove them from the equitation. The remaining numbers would then be averaged to come up with an average value. This procedure is derived from the ISO standards of Broad Band Vibration Criteria for Specific Machine Groups Based on ISO 20816 which we will cover in the next module.

## Accessibility to The Source

The inspector should never stick the contact module into any rotating equipment. The simplest rule to remember is "If you can't see into the hole don't stick it in the hole!" Often the outboard side may have a hole in the fan shroud for the grease fitting, but no extension is in place for lubrication purposes. This open may look and sound inviting but it will not end well if a contact module is stuck in there to listen for the sound of a bearing. Also, when testing bearings in some insitences a static discharge can occur. The inspector may notice a small blue flash when placing the contact module on the grease fitting. When this occurs if the unit you are using is on it could power down or experience a temporary readings issue. It a good habit for the inspector to carry a tool to be used to dissipate a static charge in a known area of concern. In most case a grounding strap could help eliminate and risks created by the static build up. The inspector must also consider any high-speed rotating equipment that could be operating around the test area. These can't always be seen with the naked eye and the inspector must be aware of these hazards. Another area of concern is working around robots, just because the prohibited guarding only protects from the floor an inspector must be aware of this when operating overhead of the barriers and consider them extending to the ceiling. These are just some examples that have been encountered over the year in industry.

## High Noise Environment

In an area with an elevated level of background noise the inspector will need to reduce their distance to the asset being tested. Another technique to help the inspector is to reduce the volume in the headset to the point that the sound is just barely heard from the source of the antagonistic ultrasound. This should only be done once the acoustic emission the inspector is targeting has been closed in on. This will prevent the inspector from potential missing the emission all together. The inspector can also try tuning their frequency to a different range to try and isolate the antagonistic ultrasound in that area.

## Overcoming Antagonistic Ultrasounds

One of the hurdles new ultrasound inspectors must learn to overcome is Antagonistic Ultrasound. Antagonistic Ultrasound can be caused frictional rub, leaks, and ultrasonic motion sensors. The inspector will need to sweep the area to determine the location of the antagonistic ultrasound and try and mitigate the source. This can be done by shutting down the equipment or testing in that area when the equipment isn't operating. In the case of airborne leaks, a wipe rag could be used as a sort of temporary tourniquet (Not recommend on leaks with risk of injuries due to temperature differentials or chemical reactions) to help the inspector find smaller leaks in that area. In the case of frictional rub there can be many sources such as, belt rub from a miss tracked roller, finger guards that are misaligned and rubbing against the rollers, product traveling on the conveyors are just some examples of antagonistic ultrasound. If the inspector takes the time to listen to the sounds in that area, they may actually find a condition that wasn't previously known.

## Avoid Common Errors

The key to any inspection program to ensure that the collection of data and sound recording is done correctly. One of the keys is to insure the correct amount of volume is set on the unit. If it's too low the inspector could potentially miss out on the subtle indication of a fault condition. It is just as important to ensure that the contact module is placed at a 90° angle to the surface of the asset being tested and not the inspector's orientation to the position. If the unit allows for Frequency Tuning the inspector can try other frequency ranges outside of the recommended values that have been used for years to see if they can get a better sound quality of what is going on but, they must insure that if there has been any previous data collection that they tune back to that same frequency so as not to corrupt any of the trending. The inspector will also need to mark the test points and try to keep them standardized so anyone doing the data collection is trending at the same location every time. When unsure of the results the inspector can use the comparison method to test like equipment as they will have similar levels of decibels. In the next module we will explore classifying motors by HP and mountings.

## Gear Box Testing

Just like motors there are several sizes and types of gear boxes in use. Some are small enough to just require one test point to determine the condition of the gear box. To ensure that the inspector gets the best results they should set their unit to somewhere from 20 kHz to 25 kHz and capture the sound wave for further analysis. The sound wave can be used to determine if the one gear is failing vs another based off of the harmonic indications displayed in the frequency spectrum or the time signal. Gear Boxes are historical quieter than the motors driving them, and this should be considered when building alarm levels.

Often in the case of the smaller gear boxes and reducers they aren't repaired in place instead, they are thrown out and replaced with an entirely new motor. This practice is widely used in large warehousing and online sales companies during their peak seasons. Sometimes the site will strategically position motors and gear boxes along the conveyance ahead of peak seasons when the loss of a conveyor can cost hundreds of thousands of dollars in lost time. Some of these companies have started using ultrasound to give them a trendable value and alarm levels that can help them minimize or even stop this practice.

# ASU Module 1-13 Inspecting Bearings

The Screwdriver has been around for many years and it was used in Europe in the late Middle Ages. They were probably invented somewhere around the late 15th century, somewhere either in France or Germany. These earliest versions of the screwdriver had pear-shaped handles and were made for slotted screws and didn't change much till the Gilded Age. It has often been used in the modern age as wave guide in the Human Experience range. How many times have you or someone you know placed a screwdriver on a motor housing, placed your thumb over the top and tried to listen to the sound of that asset? While we can hear something by the time it's in the Human Experience range the damage is so significant that plans should be made to look at replacing that asset.

There is a better way however and it involves state of the art Heterodyning equipment. The modern Ultrasound devices can pick up the incipient stages of failure prior to even vibrations indications and way prior to the screwdriver or stethoscope. These devices allow the inspector the ability to trend decibels, listen to and record sound recordings. The recordings can then be analyzed to determine conditions previously unknown to the site. The can range from bearing faults, inner or outer race issues, cage faults or even shaft voltage to name a few. This method has soon its merit over the last half a century as the easiest of the Pd/M for inspectors to learn to use.

## What to Do When Inspecting Bearings

Ultrasonic inspection and monitoring of bearings is the most reliable method for detecting incipient (beginning stages) bearing failure. Ultrasonic warnings appear before a temperature rise or an increase in driving torque. Ultrasonic inspection of bearings is useful in recognizing the start of fatigue failure, brinelling of bearing surfaces, and lack or flooding of lubricant. As the ball or roller starts to begin to fatigue the small deformation begin to occur. These deformations cause an increase in ultrasound as the rolling elements impact against other surfaces. Actions can be taken once a bearing reaches different action levels that the user will determine with trending.

The most important thing an inspector can do is to listen to the condition of a bearing. The inspector cannot rely on simply looking at the display as the most important aspect of these devices is the Human Interpretation of the sounds the asset is making. A good bearing will have a static or white noise sound. A bearing that has a need for lubrication will appear to have some small amount of popping or cracking to it. As the decibels increase and the popping cracking sound increases the inspector will be able to see the decibels rise over time. When the inspector hears a severe amount of popping or a tonal quality the bearing is approach the end of useful life and plans can be made to change out this asset especially when indications are showing up with a vibration analyzer. It is key to understand that they don't want to call out a bearing out too soon as there may be no indications when compared to a vibration analyzer and this is because ultrasound will pick up well before vibration will when it comes to these deformations. This would be even more critical if infrared indications were seen in addition to ultrasound and vibration.

One of the easiest ways to get started trending or interpreting the condition is the comparison of like equipment. This will quickly identify an asset that is out of range from the other ones. This should only be used as a stop gap measure till historical information has been established to give a truer level for action to be taken. The inspector should also take the time to capture a sound recording so it can be run through sound analysis software to help determine harmonic indications that can give the inspector the confidence to make an educated hypothesis as to the condition of the asset in question.

## Keys Why Ultrasound Should Be Used

One of the biggest keys to successfully determining asset health in rotating equipment is to first establish what the average value of like assets is. This will allow the initial baseline to be set up and fine-tuned with more historical data mining over time. The trends that are established over time will give the inspector the true range for the action levels to be set at. These action levels can have used to improve lubrication practices and strategical plan for replacement during scheduled down time. This help to insure the maximum effective life of an asset.

## Comparative Bearing Method

If we look to ISO 20816 1-8:2016 which provides guidance for vibrational testing of machines operating at 600 to 12,000 RPM and the four classes of motors. It gives an RCM program a vast range of operating condition without the need for baseline data since this

information was collected and data mined to determine these thresholds. it is impractical to test a statistically considerable number of bearings, so engineers rely on standardized bearing-life calculations to select and size bearings for a particular application. If we use these same 4 classes of machines, we should be able to establish a similar table for ultrasound emissions as well. This will take time and historical data to prove this theory to be true.

VIBRATION SEVERITY PER ISO 10816						
Machine			Class I small machines	Class II medium machines	Class III large rigid foundation	Class IV large soft foundation
	in/s	mm/s				
Vibration Velocity Vrms	0.01	0.28				
	0.02	0.45				
	0.03	0.71		good		
	0.04	1.12				
	0.07	1.80				
	0.11	2.80		satisfactory		
	0.18	4.50				
	0.28	7.10		unsatisfactory		
	0.44	11.2				
	0.70	18.0				
	0.71	28.0		unacceptable		
	1.10	45.0				

That data has shown that seemingly identical rolling bearing operating in the same class will have a standardized baseline value that could be used to start out at for the action levels. Here are the 4 classes of machine that should be used when grouping equipment together for comparison and historical trending. These calculations will continue to evolve and become more accurate over time, reflecting the collective experience of the condition monitoring programs data, bearing industry, tribology, materials, and Historical data mining.

Machine Class:

Small	Medium	Large	
		Rigid Supports	Flexible Supports
Class I	Class II	Class III	Class IV
<20 HP	20-100 HP	>100 HP	>100HP

**Class I:** Small size machines (up to 15 kW) are subassemblies of larger machines.

**Class II:** Medium size machines (15 kW to 75 kW) without special foundations, or machines up to 300 kW rigidly mounted on special foundations.

**Class III:** Large rotating machines rigidly mounted on foundations which are stiff in the direction of vibration measurements.

**Class IV:** Large rotating machines mounted on foundations which are flexible in the direction of vibration measurement.

## Bearing Life Calculations

Over the last decade there has been a change in the what ultrasound could detect and determine. It used to be said that bearing life was primarily determined by speed load and fatigue, but that is no longer the case as trended data has soon a better way to determine bearing life through the historical information collected in the field. So, Bearing Life is now said to be defined as the



number of revolutions or hours the bearing can run before showing signs of failures. The bearings life is dependent on the operating conditions as well as the proper mounting and maintenance practices used to maintain the bearing.

The International Organization for Standardization (ISO) published a revision ISO 281:2007 Standard for the calculation of bearing ratings and life to account for such factors as internal stresses from mounting, residual stresses from hardening and other manufacturing processes, and material cleanliness. Also included are the effects of solid contaminants with various lubricating systems, as well as bearing material fatigue stress limits. Before going into further detail, it's probably an appropriate time to review the basics of bearing-life calculations, starting with the common definitions of life. Basic life or  $L_{10}$  as defined in ISO and ABMA standards is the life that 90% of a sufficiently large group of apparently identical bearings can be expected to reach or exceed. The median or average life, sometimes called Mean Time Between Failure (MTBF), is about five times the calculated basic rating life. Service life is the life of a bearing under actual operating conditions before it fails or needs to be replaced for whatever reason. The so-called specification life is generally a requisite  $L_{10}$  basic rating life and reflects a manufacturer's requirement based on experience with similar applications.

An impressive list of bearing failures was found on J A D Bearing Failure Analysis's website. This company specializes in Root Cause Analysis (RCA) of bearing and rolling elements and the information contain here is a reflection of their studies of the causes of bearing failure.



## Causes of Bearings Failure by JAD Bearing Failure Analysis

### Bearing;

#### Flaking and Surface Fatigue

Flaking due to rolling fatigue occurs when small pieces of bearing material are lifted and broken off the smooth surface of the raceway or the rolling elements. This flaking causes regions with a rough and coarse texture.



### Peeling

Dull or cloudy spots appear on the raceway surface along with light wearing. Tiny microscopic cracks are generated downward from

these cloudy spots to a depth of 5-10  $\mu\text{m}$ . Small particles of material then peel from the surface with areas of minor flaking starting to occur.



### Scoring

Scoring is surface damage due to accumulated small seizures caused by sliding under improper lubrication or severe operating conditions. Linear damage appears circumferentially on the raceway and roller surfaces. Cycloidal shaped damage on the roller ends and scoring on the rib surface contacting roller ends also occur.



### Smearing

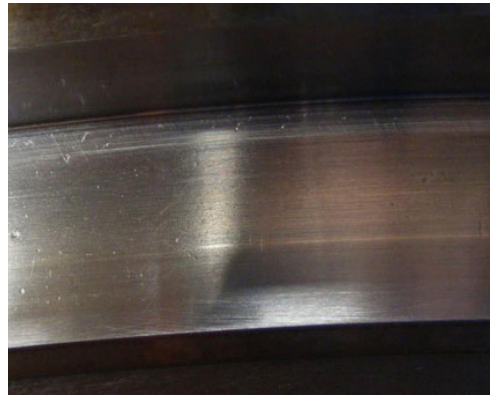
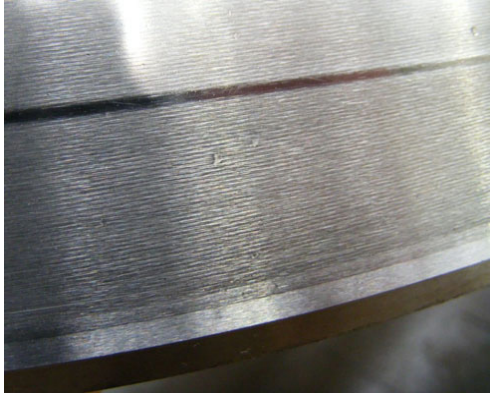
Smearing is surface damage which occurs from a collection of small seizures between bearing components caused by oil film rupture and/or sliding. Surface roughening occurs along with melting.





### Denting and Pear Skin

Flaking due to rolling fatigue occurs when small pieces of bearing material are lifted and broken off the smooth surface of the raceway or the rolling elements. This flaking causes regions with a rough and coarse texture.



### Bearing Wear

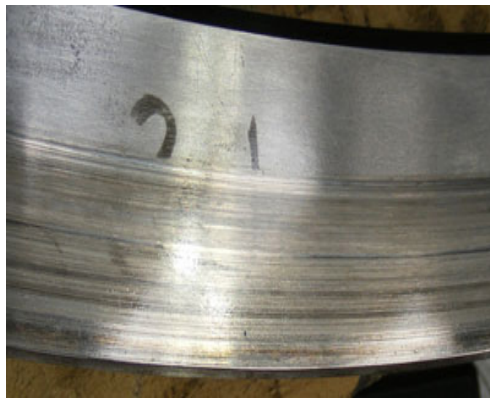
Wear is surface deterioration due to sliding friction at the surface of the raceway, rolling elements, roller end faces, rib face, cage pockets, etc.



### Fretting

Wear occurs due to repeated sliding between the two surfaces. Fretting occurs at fitting surface between raceway rings and the shaft or housing. Fretting corrosion is another term used to describe the reddish brown or black wear patterns often seen on old shafts and worn housings.





### False Brinelling

Among the different types of fretting, false brinelling is the occurrence of hollow spots that resemble brinelled dents and are due to wear caused by vibration and swaying at the contact points between the rolling elements and raceway.

### Creep

Creep is the phenomenon in bearings where relative slippage occurs between fitting surfaces and thereby creates a clearance between the surfaces. Creep causes a shiny appearance, occasionally with scoring or wear.



### Seizure

When sudden overheating occurs during rotation, the bearing becomes discolored. Then, the raceway rings, rolling elements, and cage will soften, melt and deform as damage accumulates.



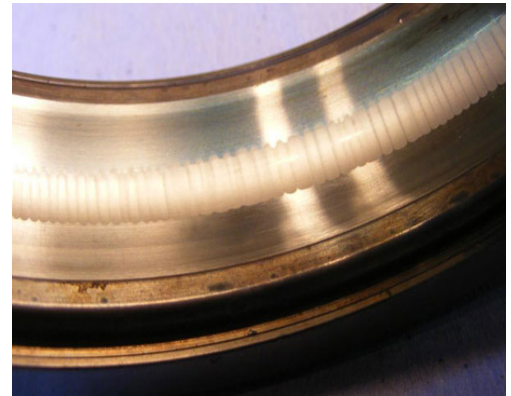
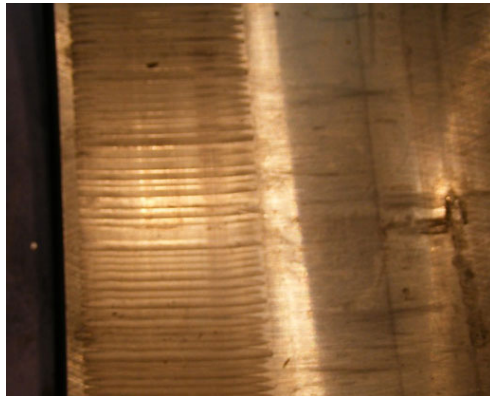
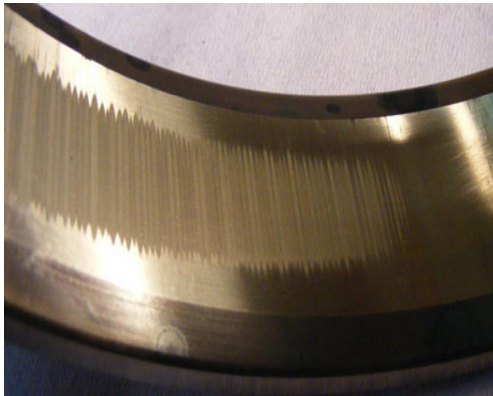




## Corrosion

### Electrical

When electric current passes through a bearing, arcing and burning occur through the thin oil film at points of contact between the raceway and rolling elements. The points of contact are melted locally to form “fluting” or groove-like corrugations which can be seen by the naked eye. Magnification of these grooves reveals crater-like depressions which indicate melting by arcing.



### Rust

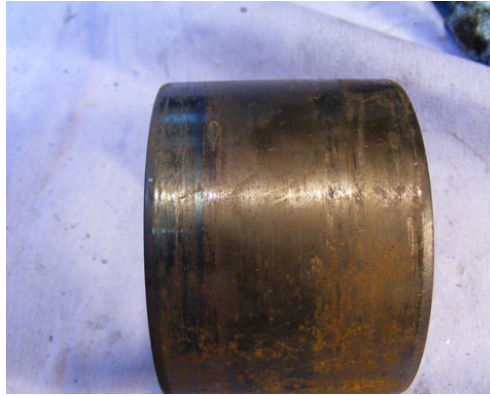
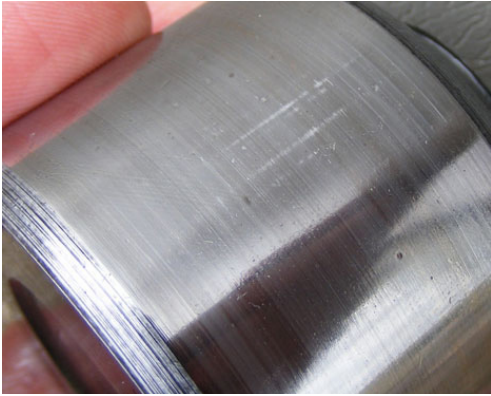
Bearing rust and corrosion are pits on the surface of rings and rolling elements and may occur at the rolling element pitch on the rings or over the entire bearing surfaces.





## Mounting

Straight line scratches on surface of raceways or rolling elements caused during mounting or dismounting of bearing.



## Cage



## Damage

### Deformation

Cage damage includes: Cage deformation, Fracture and Wear Fracture of cage pillars.



### Fracture:

Fracture refers to small or large metallic pieces which were broken off due to excessive load or shock load acting locally on a rolling element, rib or section of a raceway ring.

### Wear

## Rolling Elements and Raceways;

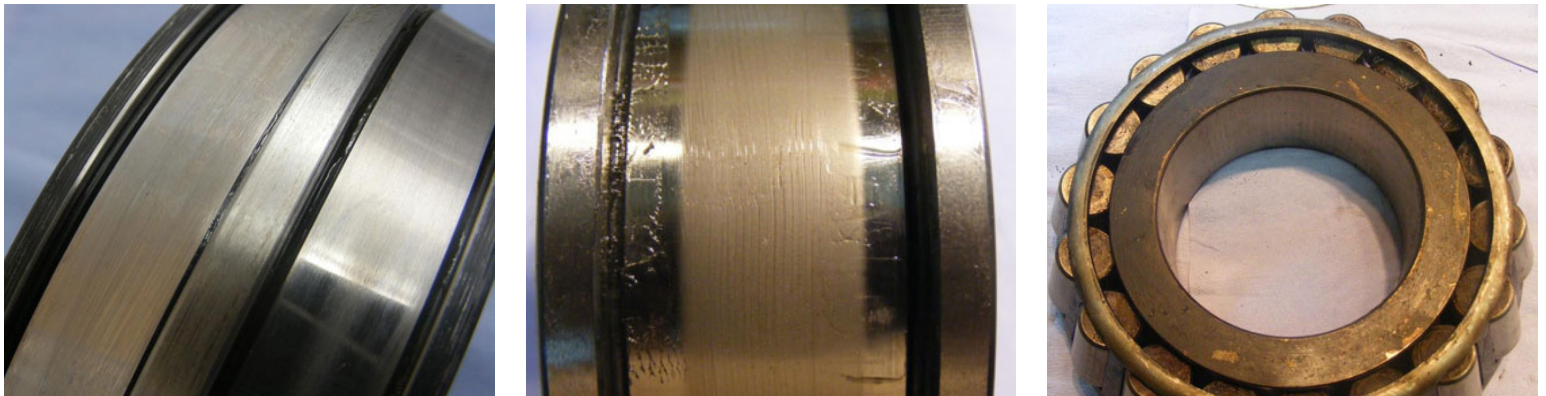
### Cracks

Cracks in the raceway ring and rolling elements. Continued use under this condition leads to larger cracks or fractures.



### Pitting

Pitting has a dull luster and appears on the rolling element surface or raceway surface.



### Housing or Shaft Damage

Wear, corrosion and burrs caused by repeated replacement of new bearings, a contaminated or moist environment or heavy handling during bearing removal.

## Lubrication Is the Biggest Cause of Failure

Over the years many studies have been conducted on the cause of early life bearing failure and one of the biggest causes of shortened life of a bearing is improper lubrication. There are 5 main categories of improper lubrication and their lack of lubrication, improper type of lubrication, aged lubrication, over lubrication and contamination of lubrication. These are all events that can be minimized to help insure the life of the bearing. The use of ultrasound can help to determine if there is a lack of lubrication by setting action levels and listen to the sound of the bearing. If it presents with a slight static or needle on a record sound the inspector can look at the trended data to see if its slightly elevated. If there is a baseline sound recording it could then be used to compare to the current sound recording and compared in both Time Series and FFT to look for harmonic indications of a change.

The inspector could then present a report to their lubrication crew that would show which assets actually need lubrication. This takes the PM based lubrication program and improves upon its effects by only targeting the assets that are in need of lubrication. The lubrication crew then could take the ultrasound device out to listen to asset while its being lubricated to ensure that the asset isn't over lubricated. This is achieved by listening as the lubrication is pumped in a little at a time. Once the sound level quiets down the lubricator can stop pumping grease in and move on to the next asset. If the they were to continue lubricating the sound level would increase letting them know they have added too much lubrication.



At the time of writing this book no one has shown what indication improper, aged or contaminated lubrication would present with their sound indications but, it stands to reason that they would show an increase in the decibel's levels being emitted by the asset.

## Action Levels for Bearing Conditions

Actions levels for bearing condition trending are based off years of testing and data mining and have yielded some action levels that can be used to help to determine the condition of a bearing. In order to use these Action Levels a baseline must be established first. The first baseline will be calculated using a selective average decibel level of the same class of motors. This is the starting point for a program that can quickly be deployed when comparing the same class of motors. Some companies have used a Delta Value technique that was widely used by an Ultrasound manufacture but, this often led too many programs missing a bad bearing that was already starting at 35 decibels hire than the mean of the rest and instantly put disbelief in the effectiveness of the ultrasound program they were starting. It was a problem with the equipment but how the Action Levels were set. Delta value assigns each bearing no matter its decibel level at the time of baselining above its own value. For example, if there is one bearing with a base line value of 72 decibels and the Action Level of 8 is chosen for the first alarm its first action would call for lubrication at 80 decibels. If its high alarm was set for 35 above its base line it would in theory be approaching 107 decibels as it hit catastrophic Action Levels but in fact the bearing at 72 decibels may already be in a state of catastrophic failure. If the sampling of the rest of the bearings had an average of 32 decibels their first Action Level would be at 40 decibels for lubrication and the catastrophic Action Level would be at 67 decibels. Therefore, it's so important for the inspector to listen, record and analysis the sound recording and not just trend the data.

With 8 decibels above the baseline value the indication would present with a slight popping sound letting the inspector confirm the Action Level recommendation of lubrication needed. At 16 decibels above the baseline there would now be visual damage to this bearing if it was taken out and observed. This is a fruitless pursuit as there is still plenty of life left in this bearing and there wouldn't even be any indications with vibration analysis testing equipment as it the beginning stages of faults in a bearing. 16 decibels above a baseline should only be used as a reference point if the bearing is able to be lubricated. In the case of sealed bearing this would be the first Action Level letting the inspector know the first signs of visual damage is occurring. Some companies have used the value of 20 decibels as the mark of approaching end of useful life of the bearing, so they can start to strategical plan for replacement in the future. It this threshold vibration will show indications of faults as well and help to confirm the diagnosis of the ultrasound program. The last action level is the most import one and that is 35 decibels above the baseline. It this level the damage is catastrophic, and failure can occur more frequently at this value. It doesn't mean it will happen in the next few minutes and it could go months before it fails violently. At this stage thou the cost of operating the motor in this state is significantly costlier as it takes the asset motor energy to overcome the fact the damage it is preventing the bearings from operating as designed.

## Sound Qualities to Watch Out For

As damage to the bearing, inner & outer races increase pitch & tone can start to be produced. This increase in sound will show up as a raise in decibels and well as a change in sound quality. These deformations will also produce significant Harmonic indications that can be calculated to determine if there is an inner or outer race issue, cage fault, bad bearing, lack of lubrication, loose condition, shaft voltage, dirty current and even a loose connection in the motor junction box. This is just like hitting a rumble strip at a higher speed.

## Slow Speed Bearings

For the analysis of these sound recordings the inspector will need to use Time Signal Analysis as there is general not enough energy to produce an FFT of the event. Even vibration experts recommend that the vibration inspector should switch to Time Signal Analysis when testing slow speed bearings. Time Signal Analysis will so the deformations in time as the inspector hears them and can then be mapped out for their harmonic occurrence. By using a Fault Calculation Spreadsheet or long hand the inspector can determine if it's the Bearings, Cage, Inner or Outer Race issue quickly and easily.

## The Benefit of Time Signal vs FFT for Slow Speed Bearing Testing

Slow speed bearings have often been a source of frustration for facilities all over the world when trying to test with vibration analyzers. These slow speed bearings in mills can often be placed in hot wet places making it hazardous for the inspector to be

exposed for an extended period of time not to mention the potential effects on the testing equipment. With vibration analyzer needing to test three points per end this can take a lot of time to get a proficient reading whereas the ultrasound only needs as little as 15 seconds of sound recording to determine the condition of a slow speed bearing. When it comes to slow speed bearing it a lot like a rumble strip on a highway. If we hit a rumble strip at 55 mph it takes less time for the tire to traverse the depression and it gives us high pitch sound versus hitting it at 5 mph where the tire takes longer to traverse the depressions giving the inspector a deeper more distinguished thumping sound. So too will the deformation of the surface will be more pronounced in slow speed bearings.

## Ultrasound & FFT Vibration Analysis

Since Ultrasound has so many capabilities it is still a recommended must have for all Pd/M & RCM programs. The one drawback is the cost of the equipment & software. Some companies also phase out their older equipment and will no longer support the equipment after a decade or so. The learning curve to become a good vibration inspector takes a lot longer than that of an ultrasound inspector. This is due to the fact that it is the simplest of the two to use and become proficient at. One of the other keys to ultrasound is how Early it picks up bearing faults. It will literal hear everything from lack of lubrication, stress deformation on the surfaces of races and bearings, to stray voltage and even the catastrophic end of life of a bearing.

## When Storing Data Beware of Errors

The inspector should always be aware of the amplitude the device is receiving especially when recording a sound wave. If the inspector has too much amplitude the recording will be distorted, and analysis will be next to impossible to determine harmonic indications in both Time Signal and FFT. The opposite is just as import, if the inspector doesn't have enough amplitude the sound wave will not have enough energy to clearly display harmonic indications of the fault. The inspector must also insure they are not moving the module around as any movement can cause frictional antagonistic ultrasound that could be misconstrued as mechanical noise.

## What Application Can Sound Analysis Software be Used For?

The use of Time Signal Analysis is fast becoming the go to means for determining fault conditions in assets. Take for example a steam trap. It may have a set rate of recommended discharge from the manufacturer. With the use of the time signal inspector can determine the total number of discharges per minute. The inspector can then use this information to determine if a trap maybe cycling too frequently which could indicate an undersized trap. For valve testing the inspector could record the sound levels across the 4 test points and then over them against each other to show a rise in decibels against the other test points to help prove to the client or management that a valve has failed. These are just some of the application that an inspector could use sound analysis for.



# ASU Module 1-14 The Theory of Electrical Inspection

Electrical systems for years have been put on an annual inspection cycle which has generally been mandated by insurance companies but beyond that these assets are usually just left alone. Sometimes it is simply because the plant does not have the personnel to do inspections and they get out sourced. Sometimes it is the mentality of the management and planners that these assets are as critical, or it takes too much time to inspect these assets. With the use of ultrasound, it had always been a process of just scanning the seams and opening in equipment to determine if there was a condition that need to be considered. With the invention of IR Windows and Ultrasound ports the time frame it took to perform Electrical inspections has dramatically been reduced also allows for a safer process of inspecting these critical assets. Now the site can have their assets inspected monthly if they wish because there is no need to wear an arc flash suit and remove the panels.

## Electrical Inspection

Ultrasound testing of electrical assets there is not anything it cannot be used for. Everything from transmission lines on down to breaker panels. It has always been relegated to scanning the seams and vent holes with some success. The problem with this however is the inspector cannot always achieve the Critical Angle due to diffraction of the sound wave and makes it tough recording the truest sound of the anomaly. This can lead to limited harmonic indications when trying to analysis in the FFT format in sound analysis software. This topic will be cover more in depth in an upcoming module.

When it comes to electrical inspection Infrared, Ultrasound and TEV detection devices are the best tools to use to test electrical equipment. Ultrasound and TEV can be used to listen to what is occurring inside of equipment by making contact on the exterior of the cabinet or scanning and seam or opening. If the site has VPDS installed it becomes a lot more efficient and minimizes any loss of signal caused by Diffraction. This is causes a loss of clarity in the signal clarity that can interfere with the ability to analyze sound waves in an FFT format while the Time Wave Form can still show some Harmonic occurrences of the emission as it isn't as dependent on the Critical Angle since it is capturing the emission as it happens in Real Time and is a transformation of the signal.

## High Temperature

Increased temperature from external sources as well as the electrical equipment can lead shortened life cycle and cause premature failures. When the electrical equipment is heating up it will produce ultrasonic emissions that can be captured and analyzed to help determine exactly what is occurring. These anomalies range from Treeing (Tracking), Arcing, to Loose Connections to name a few. Most of these events will also produce infrared in addition to ultrasound. As temperature increases it also thins the density of the surrounding air which reduces the insulation value of the surrounding air which in turn will allow for a worsening of the fault as well as an increase in ultrasonic emissions.

## Causes of Electrical Faults

Weather has always been a significant factor in disrupting the grid. In the case of Hurricane Irma in 2017 some 12 million people lost power due to the Hurricane. Parts of Puerto Rico as of December 2017 will still be without power for another year. In January of 1998 North America was hit with five smaller ice storms in close order. The accumulation was the most severe in Ottawa and Montreal but effected Ontario, Quebec, New Brunswick, Nova Scotia in Canada and in the USA New York, Vermont, New Hampshire and Maine were also affected as well. Some area the power was returned in a few days, but in the epicenter of the storm power was out for months. The ice in some area was as thick as 4 inches. This added weight even collapsed transmission lines towers.

## Causes of Electrical Faults

The age of electrical equipment is one of the other contributing factors to failures that is known but just over looked as part of doing business. Many facilities are running equipment beyond its designed life span and praying for the best. Others are at least using ultrasound to help determine the asset health, so they can plan accordingly to repair or replace the asset. Sometimes the equipment can fail due to animals interfacing with these assets. Recently at the Atlanta Airport a switchgear failed and took down the World Hub of Delta Airlines and caused a massive cancellation of flights. Here is an Article from Fox News about the cost of this catastrophic failure.



## Delta estimates up to \$50 million in losses after Atlanta airport outage - and wants somebody to pay up

Written by Emilie Ikeda 12/22/2017

Chaos caused by a nearly 11-hour power outage at the world's busiest airport Sunday is fizzling out, but consequences linger. Delta Airlines estimates losses between \$25 million and \$50 million – and the powerhouse airline wants somebody to pay up. The airline's CEO Ed Bastian announced they will be seeking reimbursement. This comes after 1,400 flights were cancelled as a result of Sunday's power outage. "I don't know whose responsibility it is between the airport and Georgia Power, but we're going to have conversations with both of them," Bastian told the AJC Tuesday.

Bastian cited plans for conversations with Georgia Power and the Hartsfield-Jackson Atlanta International Airport, but the question of who should be held accountable remains unanswered. Georgia Power said that while it owns the electrical equipment in the underground facility that caught fire, the airport owns the tunnel itself. According to a spokesperson from Mayor Kasim Reed's office, flames broke out when a piece of Georgia Power's switchgear failed in an underground electrical facility. This happened next to redundant circuit cables and switching mechanisms, which forced the loss of power from two separate back-up power substations – thus the delay in returning to full power.

"Understand that we've never had a situation like this, and our redundant system had been working flawlessly for us for probably about three decades now," Airport General Manager Roosevelt Council Jr. told Fox News Monday. A spokesperson for Georgia Power said in a statement that "we cannot and do not guarantee uninterrupted electric power service." Attorney Philip Holloway, a licensed commercial pilot, says it's too early to tell who Delta should take to court. The list of potential defendants ranges from Georgia Power and Hartsfield-Jackson to contractors responsible for maintaining the equipment and the engineers behind its design.

Though once blame is placed, we could see a settlement among the parties. Holloway says it serves no one to disrupt the strong relationship Delta has with its hub city. "These are relationships that everybody has a vested interest in maintaining, and so the best way to ruin a great relationship is through litigation," Holloway said. Litigation, Holloway added, "could literally go on for years."

Human error is another cause of Electrical Faults and power outages. Everything from car accidents, to ladders against or antennas placed against power lines, to people digging up power lines and even in some cases of people strung out on drugs trying to steal the wiring to feed their habits. These interruptions are not something is preventable with testing equipment but just reinforces the fact that these things can and will happen.

Wildfire can also cause the power to fault as well. As a wild fire burns it produces heat and smoke which both lead to the breakdown of the insulation value of the air around the lines. This thins out the air as well as making it more conductive and allows the current to pass through the air that once kept it insulated. In a report titled "California power company has resisted efforts to map risky power lines" written by Bill Gabbert and published in Wildfire News on 10/30/2017 some evidence was shown to the effect that the powerlines were seen exploding during the fire.

Following the Witch Creek, Guejito, and Rice Canyon fires that destroyed more than 1,300 homes and killed two people in Southern California in 2007, state officials began attempting to force the utility companies to produce maps designating areas where their power lines present the highest risk for starting wildfires. The three large fires in 2007 were sparked by issues with lines operated by San Diego Gas and Electric. CAL FIRE has not released the causes of the huge fires that started in Northern California October 8 during very strong winds, but at about the same time firefighters were first responding to numerous fires, they also received multiple calls about fallen power lines and electrical transformers exploding. In the next week, the stock price of the company that provides electrical service for large areas of Northern California, Pacific Gas and Electric, dropped 22 percent.

## Electrical Ultrasonic Emissions

**Corona:** Corona is the glow and audible discharge that occurs when there is an excessive rise in localized electric fields surrounding an object that causes the ionization, which in turn can lead to possible electrical breakdown of the air around this point. When the sound recording is analyzed it will present with repetitive 50 or 60 Hz (Dependent on the line frequency of the country) richer harmonic indications in the negative portion to scale in the Time Wave Form. This is due to the sound wave having a compression and rarefaction in the air around the anomaly. Rarefaction of the sound wave actually thins out the air on the negative side of the sound wave and reduces the insulation value of the air allow the partial discharge. If the inspector establishes the Critical Angle the FFT will also show repetitive harmonics at 50 or 60 Hz. It will not however produce any heat, making it undetectable with Infrared.

Corona is generally characterized by a colored glow frequently visible in a darkened environment with audible sound usually described as a subtle sizzling sound. These events produce ozone which is an unstable form of oxygen is frequently generated during this process and will be malodorous. Since rubber is destroyed by ozone and produces nitrogen oxide which exposed to moisture turns into nitric acid. These items have detrimental effects on materials, inclusive of electrical insulators.

**Treeing (Tracking):** Is an electrical pre-breakdown in solid insulation that causes damage due to stressed dielectric insulation which allows partial discharges to travel through a medium in a path resembling the branches of a tree. Treeing of solid high-voltage cable insulation is a common breakdown mechanism and source of electrical faults in underground power cables. This event will produce Heat and Ultrasound emissions. The sound wave will have line frequency harmonics with the Time Wave Form showing almost equal amplitude in the positive and negative portion while the FFT will present with a few intervals and taper off.

Electrical treeing occurs and begins to sprawl outwardly when a dielectric material is stressed over a period of time by highly divergent electrical fields. Electrical treeing is observed to originate at points where the sound source originates from which can be caused by impurities, gas voids, or mechanical defects. This can cause gases to ionize around the event creating small electrical discharges. A pollutant or defect may even result in a partial breakdown of the dielectric itself. This anomaly will produce ultraviolet light and ozone from these partial discharges (PD) and then react with the nearby dielectric, and further breakdown its insulating values. Gases are often discharged as the dielectric breaks down, creating more voids and cracks which leads to further weakening of the dielectric and accelerate the PD process.

**Arcing:** is an electrical breakdown of air or gas insulating an electrical connection that allows for an ongoing electrical discharge. The current passing through this normally nonconductive medium in turn produces a visible & ultraviolet light as well as a source of ultrasound. Electrical arcing creates ultrasound & heat. Arcing will show very distinct burst over the entirety of the sound recording when viewed in Time Wave Form and the inspector will need to zoom in on the burst where the interval of the line frequency will be apparent. In the FFT the inspector will notice the 1-time occurrence and from there it will be very random indications which will usually taper off by the 10<sup>th</sup> occurrence.

**Loose Connection:** is connection that becomes loose overtime from not being properly tightened at installation of the equipment which causes it to start to melt and oxidize from the excessive current its drawing. This will produce a source of ultrasound and heat. Loose connection will present with some 2-time line frequency harmonics in both the Time Signal and the FFT, but the Time signal will have a Fish Bone appearance that intensifies and wanes several times.

**Partial Discharge (PD):** is a localized dielectric breakdown of a small portion of a solid or fluid electrical insulation system under high voltage stress, which does not bridge the space between two conductors. While a corona discharge is usually revealed by a relatively steady glow or brush discharge in air, partial discharges within solid insulation system are not visible. PD can occur in a gaseous, liquid or solid insulating medium. It often starts within gas voids, such as voids in solid epoxy insulation or bubbles in transformer oil. Protracted partial discharge can erode solid insulation and eventually lead to breakdown of insulation. This will not produce any detectable heat but will generate a source of ultrasound and Transient Earth Voltage (TEV).

**Dirty power:** is electromagnetic pollution called transients and harmonics. Dirty power creates erratic spikes and surges of electrical energy traveling along power lines and building wiring where only standard 50/60-Hertz AC electricity should be. Also called electrical noise, line noise, and power line EMI, it is one fast-growing source of electro-pollution in homes, schools, and businesses today. Dirty Power may show some signatures of heat but at the time of publishing there is no science to back this up, however it will produce signatures ultrasonically that can be traced all the way down to the motors. In the case of a waste water treatment plant in Ohio they had a known condition coming from their substation yard that had burnt up several assets over the years and during one test of the MCC's a line frequency fault was found at 121.5 Hz that repeatedly showed up in both the Time Wave Form and the FFT. Upon further testing of other MCC's the presence off a 121 Hz & 122 Hz were found and confirmed to be present in the motors they were driving.

## Ionization

Ionization is the process by which an atom or a molecule acquires a negative or positive charge by gaining or losing electrons to form ions, often in conjunction with other chemical changes. Ionization can result from the loss of an electron after collisions with subatomic particles, collisions with other atoms, molecules, and ions, or through the interaction with light. Heterolytic bond cleavage can result in the formation of ion pairs. Ionization can occur through radioactive decay by the internal conversion process,

in which an excited nucleus transfers its energy to one of the inner-shell electrons causing it to be ejected.

## Corona Discharge

As the occurrence of ionization builds it creates nitrogen oxide. A corona discharge is an electrical discharge brought on by the ionization of a fluid such as air surrounding a conductor that is electrically charged. Spontaneous corona discharges occur naturally in high-voltage systems unless care is taken to limit the electric field strength. A corona will occur when the strength (potential gradient) of the electric field around a conductor is high enough to form a conductive region, but not high enough to cause electrical breakdown or arcing to nearby objects. It is often seen as a bluish (or other color) glow in the air adjacent to pointed metal conductors carrying high voltages and emits light by the same property as a gas discharge lamp.

In many high voltage applications corona is an unwanted side effect. Corona discharge from high voltage electric power transmission lines constitutes an economically significant waste of energy for utilities. In high voltage equipment like televisions, radio transmitters, X-ray machines and particle accelerators the current leakage caused by coronas can constitute an unwanted load on the circuit. In air, coronas generate gases such as ozone ( $O_3$ ) and nitric oxide (NO), and in turn nitrogen dioxide ( $NO_2$ ), and thus nitric acid ( $HNO_3$ ) if water vapor is present. These gases are corrosive and can degrade and embrittle nearby materials and are also toxic to people. Corona discharges can often be suppressed by improved insulation, corona rings, and making high voltage electrodes in smooth rounded shapes. However, controlled corona discharges are used in a variety of processes such as air filtration, photocopiers, and ozone generators.

### Corona Effect:

The phenomenon of violet glow, hissing noise, and production of ozone gas in an overhead transmission line.

### Reason:

Due to cosmic rays, ultraviolet radiations some ionization is always present in the air. Under normal condition air around the transmission cable contains ionized particles i.e. free electrons, positive ions, and neutral ions. When the line becomes live means when potential difference applied between the lines, potential gradient is set up in the air and have maximum value at the conductor surfaces. Because of this potential gradient the free electrons acquire greater velocity. With the increase of the line voltage the potential gradient increases and the velocity of the free electrons increase also. When the potential gradient of the conductor surface crosses the maximum limit then the free electrons get enough kinetic energy to strike a neutral molecule and make some more electrons free from that molecule. One electron free then creates one positive ion and some free electrons. Usually 30KV per cm treated as the limit of potential gradient. Those free electrons strike more neutral molecules and keep this process going all like nuclear fission. So, this process of ionization is cumulative. The result of this ionization is that either corona is formed, or spark takes place between the conductors.

### Factors affecting corona are:

- Atmosphere: During stormy or rainy weather corona occurs at much less voltage as compared with fair weather. Because during those cases ion density around the conductors is much more than that of fair weather.
- Conductor Size: The unevenness of the surface of the conductors decreases the breakdown voltage. Because of this reason with low voltage the insulation will breakdown and create sparks and corona. That's why solid conductors are used mostly instead of stranded conductors to reduce the corona.
- Spacing between conductors: Larger the gap between the conductors lesser the corona.
- Line voltage: Every line voltage has a limit. After that limit breakdown will occur and will create corona and spark. So, with the application of small line voltage possibility of occurring corona is lesser.

### Advantages:

- The area around the conductor becomes conductive because of corona formation. It creates a bigger virtual diameter of the conductor. As the diameter increases the electrostatic stress between the conductor decreases.
- Corona effect reduces the Surge voltage created because of switching and thundering. As greater applied voltage creates corona and sparks, that's why when surge voltage will become available the corona will form and will absorb the extra power by

creating violet glow, noise, and sparks.

#### Disadvantage:

- a. It reduces the transmission efficiency.
- b. Ozone created by this effect cause corrosion of the conductors.
- c. Due to corona effect non-sinusoidal voltage drop occurs across the line. This may cause inductive interference with neighboring communication lines.

#### Corona effects can be reduced by following methods:

- a. Increasing conductor size: If we increase the conductor size the value of potential gradient will increase. To create corona effect large line voltage will be required.
- b. Increasing conductor spacing: Corona effect can be eliminated by increasing the spacing between the conductors. Due to increase of the spacing large line voltage will be required to create corona effect.

## Conduction of Electricity by Air

The conduction of electricity through air it been study at the University of Florida by the Lighting Research Group. They launch model rockets with a metal filament wire trailing behind to the launch pad give the lighting a path to ground. This research is being used to test the ability to capture and store the energy from a lightning bolt which produces 1 million joules of Energy. Some theorize this could power a house from 8 Days to 30 Days if someone could create a way to store this energy. Lighting will produce ultrasound prior to seeing the flash of lighting if close enough to a strike. Even before there is any human experience of sound ultrasound will be the first thing experienced.

## Humidity

**Humidity:** is defined as the amount of water contained in air. In the human experience, this experienced as mugginess but in the ultrasound realm it is how much partial discharge or corona is present. As the humidity levels increases the air becomes more conductive and these events can become more prominent which can in turn lead to a faster end of life for that asset. For years it had been stated that corona is not always destructive, but it is now better understood that the continuous occurrences of corona due to high humidity will lead shortened life cycle of these assets.



# ASU Module 1-15 What Assets Can Ultrasound be Utilized For



## The Critical Angle of Ultrasonic Electrical Inspection of Transmission Line Testing and Enclosed Systems

### Abstract

Electrical Ultrasound Inspection is one of the most unique application as it isn't dependent on Decibels as much as the patterns the anomaly produces, and its limited approaches can make it difficult to get the truest former of the Incident Wave.

Drew Walts SME

Electrical systems for years have been put on an annual inspection cycle which has been mandated by insurance companies but beyond that these assets are usually just left alone. Sometimes it is simply because the plant does not have the personnel to do inspections and they get out sourced. Sometimes it is the mentality of the management and planners that these assets are as critical, or it takes too much time to inspect these assets. With the use of ultrasound, it had always been a process of just scanning the seams and opening in equipment to determine if there was a condition that need to be considered. With the invention of IR Windows and Ultrasound ports the time frame it takes to perform an electrical inspections has dramatically been reduced. It also allows for a safer process of inspecting these critical assets. Now the site can have their assets inspected monthly if they wish

because there is no need to wear an arc flash suit and remove the panels.

When it comes to Ultrasound testing of electrical assets there is not anything it can be used for. Everything from transmission lines on down to breaker panels. It has always been relegated to scanning the seams and vent holes with some success. The problem with this however is the inspector cannot always achieve the Critical Angle due to diffraction of the sound wave and makes it tough recording the truest sound of the anomaly. This can lead to limited harmonic indications when trying to analysis in the Frequency Spectrum (FFT) format in sound analysis software. This topic will be cover more in depth in an upcoming module.

Often when preforming Electrical Inspection, we might find that we hear something and as we move around the anomaly, we hear the sound characteristics actually change as we move our position. When we record these anomalies from different angles, we actually see different signatures of the same event. This is because there is only one Critical Angle of the anomaly.

The Critical Angle of Electrical Inspection is the Angle at which we achieve the best sound characteristic and decibel of the anomaly. The most important things when it comes to Ultrasonic Electrical Inspection is Sound Analysis. Decibels can only tell us that we have found the Critical Angle of the Ultrasonic Anomaly. The Critical Angle is much like a Radio Signal your car radio receives in that it receives a strong signal when we are in line with the transmission. However, when we drive into a valley or behind a mountain, we start to lose signal clarity. We can still hear some of the transmission, but we start losing the signal as it becomes distorted. We might still be able to pick out a voice or certain notes from an instrument, but it is not the clearest signal, so we experience distortion of the signal and miss the minute details of the signal. As we drive back in range of the Radio Signal, we achieve the Critical Angle we need to receive full signal strength, so we can enjoy our radio program.

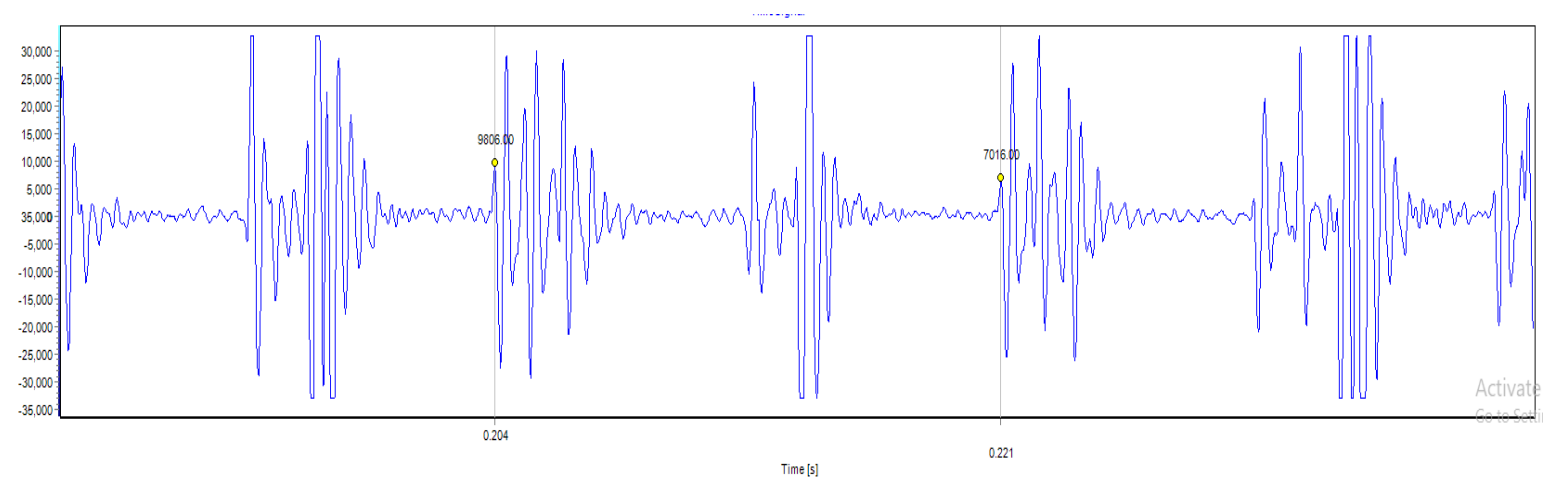
This is the same with Ultrasound Inspection of Electrical Equipment. We can often hear an Electrical Anomaly and record that anomaly for sound analysis. As we analysis that recording, we find that the Frequency Spectrum does not always show a 60 Hz Harmonic Marking in the Frequency Spectrum, but the 60 Hz Harmonics show up in the Time Series. This is what happens with the Sound Wave we capture when we are not at the Critical Angle. It is not the truest form of the Incident Wave, so we lose some of the resolution of the Signal and it a distortion of the signal. We however will still be able to see some indications within the Time Series as it is not dependent on any translation of the Signal into a Frequency of occurrence.

This is just like your car radio when you hear some of the signal, but it is distorted because we are not in line with Critical Angle of the Radio Transmission.

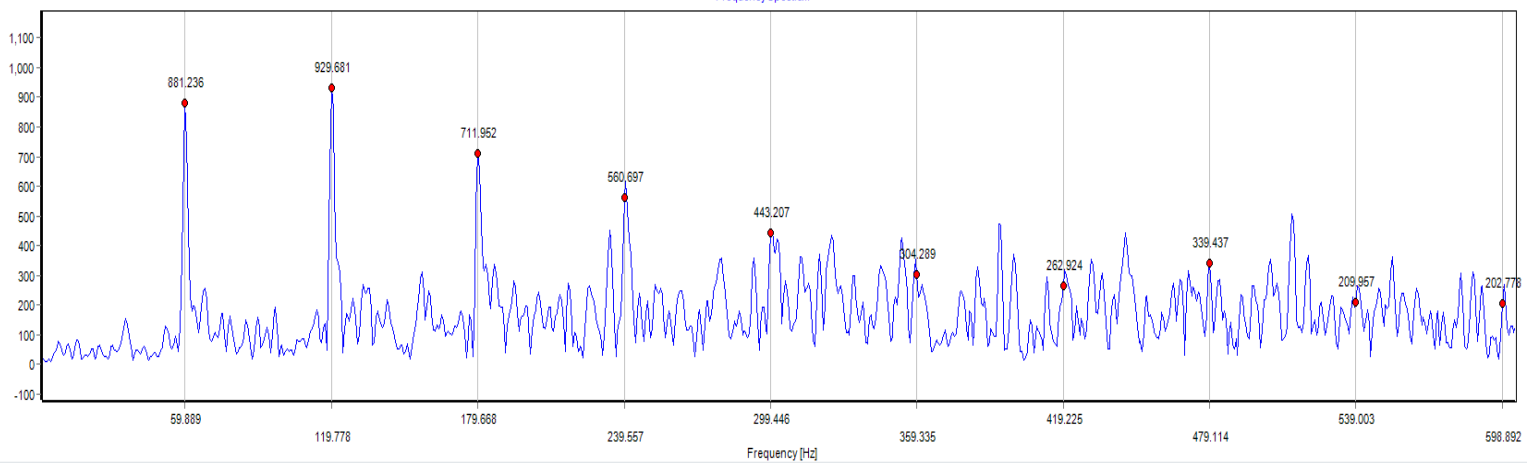
Here are some example of Sound Images showing the achievement of the Critical Angle.

## Critical Angle Achieved:

In image 1 the Time Series clearly shows peaks within a .016<sup>th</sup> of a second which indicates 60 Hz Harmonic indications.



In image 2 the Frequency Spectrum we can clearly see the first 1st, 2nd, 3rd, & 4th occurrence of a 60 Hz Harmonic. Critical Angle was achieved for this anomaly.



With clear indications in both Time Signal Analysis and in a Frequency Spectrum the inspector was able to achieve the Critical Angle of the Ultrasound Emission and determine the existence of Treeing. As such this allows for the correct diagnosis of the Ultrasound Emission by confirming the existence of a 60 Hz Harmonic and .016 seconds in both Time Signal and Frequency Spectrum.

You are currently converting frequency units from hertz to second(period)

$$60 \text{ Hz} = 0.016666666666667 \text{ s(p)}$$

hertz



second(period)

60 Hz

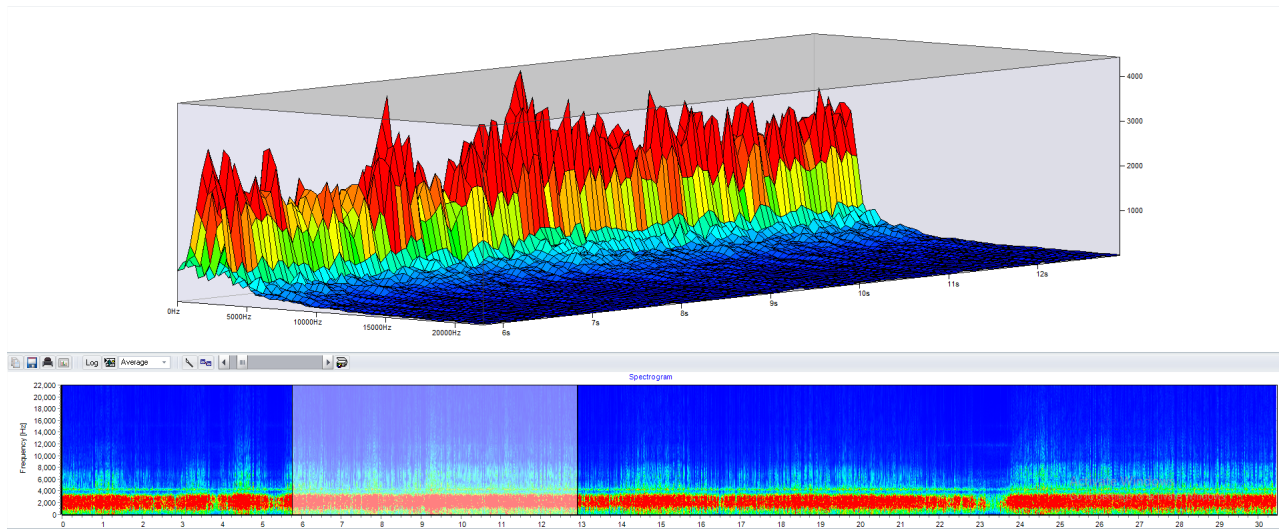


0.016666666666667 s(p)

Conversion base : 1 Hz = 1 s(p)

Conversion base : 1 s(p) = 1 Hz

With other advances in sound wave analysis like Spectrogram and 3D Surfacing (Image 3) the inspector can look even more in-depth to see issues at hand as well as produce stunning reports that help show the evidence to management or clients.



All these indications also show that this event is Treeing (Tracking). What is Treeing? Electrical treeing occurs and begins to sprawl outwardly when a dielectric material is stressed over a period of time by highly divergent electrical fields. Electrical treeing is observed to originate at points where the sound source originates from which can be caused by impurities, gas voids, or mechanical defects.

This can cause gases to ionize around the event creating small electrical discharges. A pollutant or defect may even result in a



partial breakdown of the dielectric itself. This anomaly will produce ultraviolet light and ozone from these partial discharges (PD) and then react with the nearby dielectric, and further breakdown its insulating values. Gases are often discharged as the dielectric breaks down, creating more voids and cracks which leads to further weakening of the dielectric and accelerate the PD process.



Electrical Treeing can occur in High Voltage Equipment just prior to failing. During an RCA, the treeing can be used to track down the source of the failure. There are 2 common types of treeing that can be produced when equipment starts to fail.

**Bow-tie trees** start to grow from within the dielectric insulation and grow outwards toward the electrodes. As it starts inside the insulation it does not have a supply of air which would allow the continuous support of partial discharges. Hence these trees have limited growth and do not usually result in a failure in the insulation or ability to sprawl out to the nearest electrodes.

**Vented trees** initiate at an electrode insulation and sprawl out towards the opposite electrode. Being exposed to atmosphere is a key for its growth. These trees will continuously grow until they are able to bridge the electrodes which will result in the failure of the insulation.

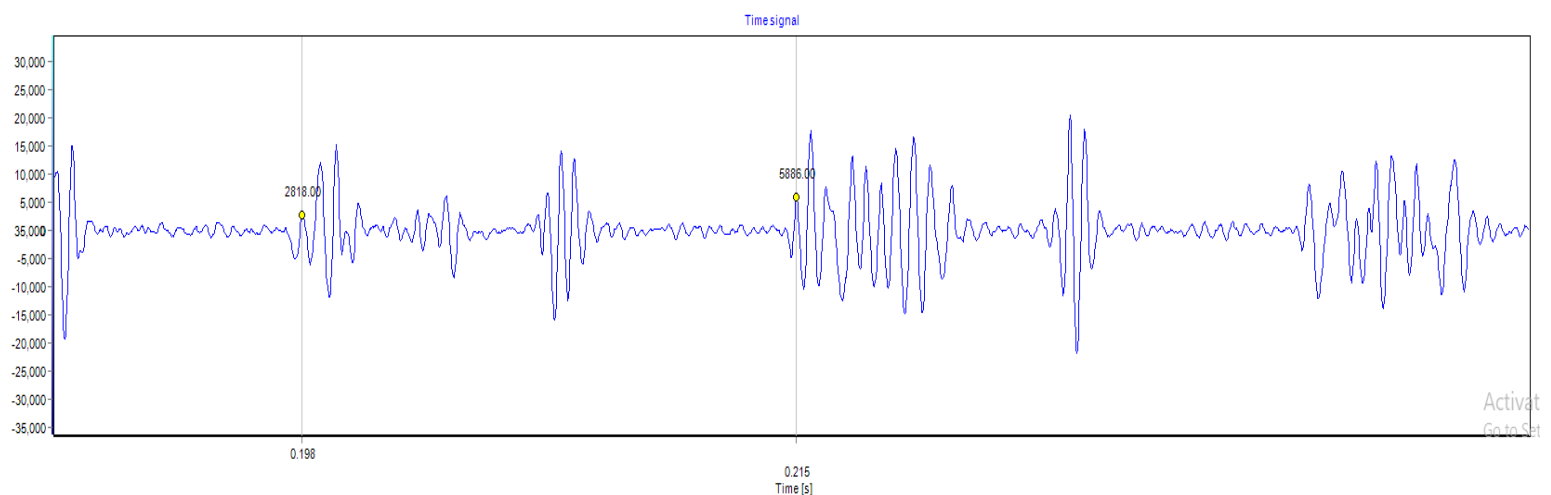
Treeing has actually been used to create some amazing artwork where you can clearly see how this electrical event got its name. The use of this in art work is known as Lichtenberg Figures and there are some pretty amazing images created when electricity is applied to the medium.

This is a Lichtenberg Figures

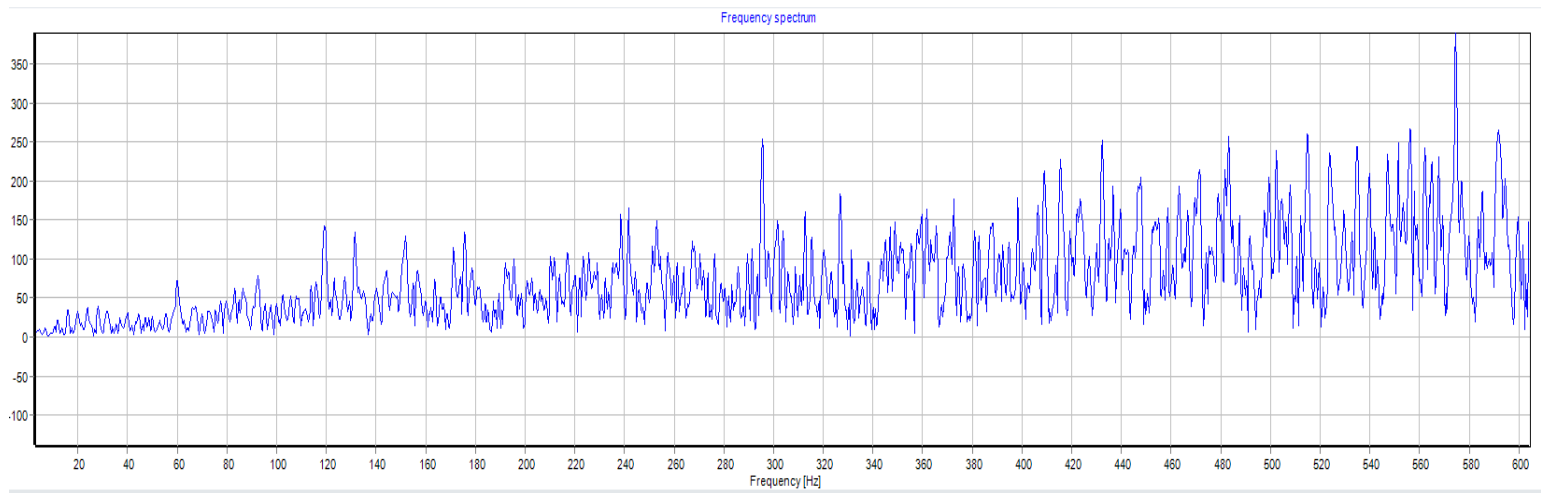
Next, we will look at what happens when the Critical Angle was not achieved on this Treeing anomaly.

**Critical Angle not achieved:**

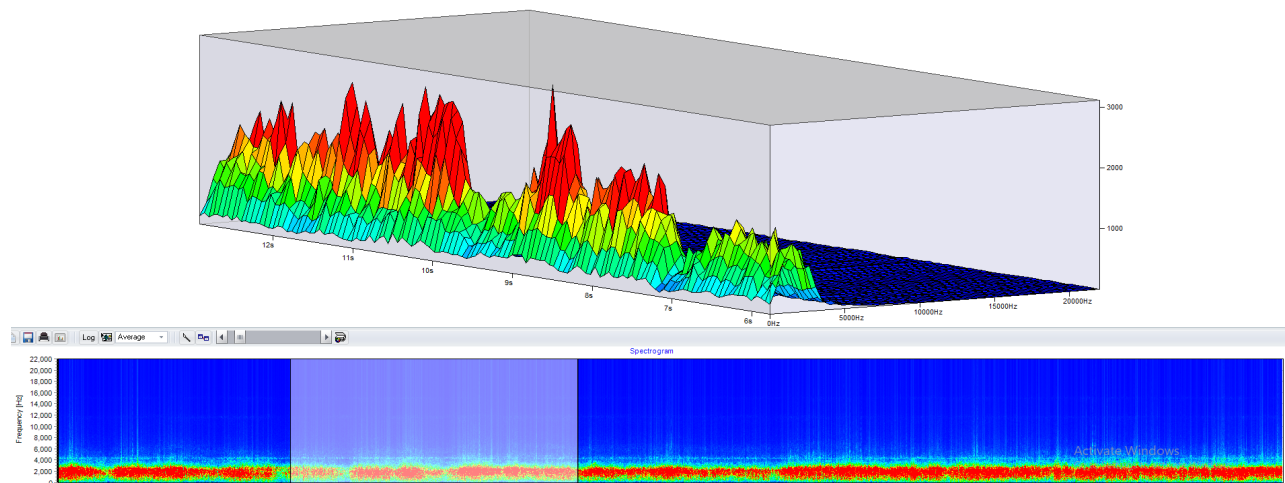
Notice that in image 5 the 60 Hz Harmonics clearly show up in the Time Series but are virtual absent in the FFT.



Notice in image 6 the lack of rich 60 Hz Harmonics in this Tracking Occurrence. There is a small indication at 60 Hz and another one at the 120 Hz Harmonic value but, it quickly despairs. The Critical Angle wasn't achieved in this recording and as such we do not have the signal strength to show rich harmonic intervals at 60 Hz.

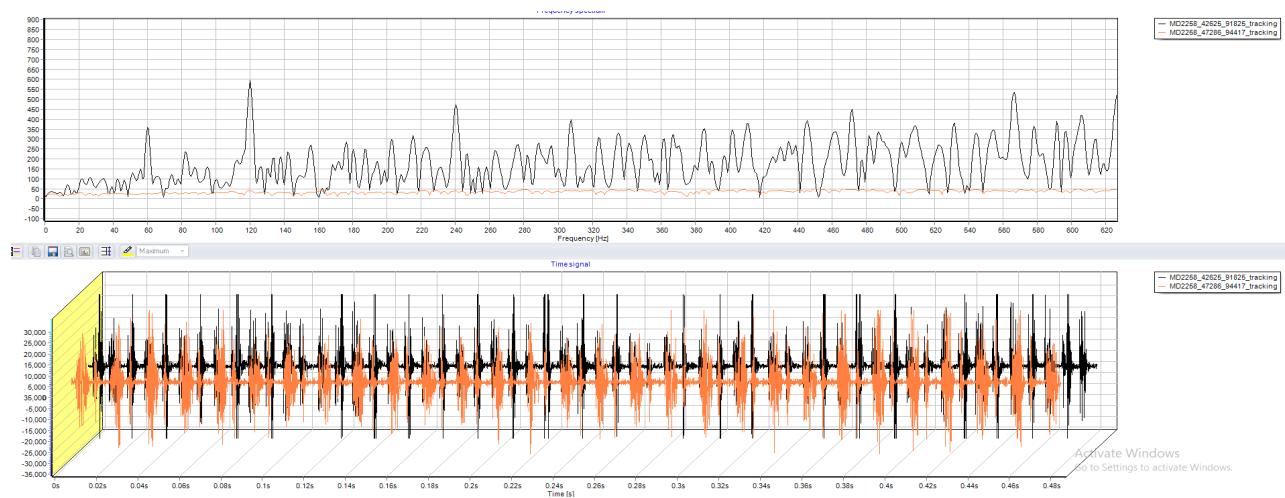


Notice in image 7 the lack of repeating amplitude in the 3D Surfacing & Spectrogram versus image.



When using the Sonus Vue Pro we can also use the overlay feature in both Time Signal Analysis and Frequency Spectrum to simultaneously compare multiple sound waves. This allows the inspector to quickly see the difference between different anomalies and help determine if they achieved the Critical Angle of the Ultrasound Anomaly.

Image 8 Shows the sound wave from image 1 & 2 in Black and Orange represents the sound wave from images 5 & 6.



These are splendid examples of Tracking when we listen to them but when we run them through the Sonus VUE PRO that the inspector can see that they have achieved the Critical Angle of these Tracking Events. Therefore, it is so very important to walk around and listen as you move around to try to find the Critical Angle of these Ultrasound Anomalies. The key to this is using your Decibels only as an indication of increased strength of signal. Decibels should never be used for gauging severity of Electrical Anomalies however. Decibels only indicate that we are in line with the Critical Angle.

## Enclosed Assets

When it comes to enclosed systems Diffraction of signal can also affect the ability of the inspector to achieve the Critical Angle of Electrical Inspection. The inspector is left to trace the seams around the panels of the assets and change their positioning of the airborne module when something is heard, to try and see if they can achieve a higher intensity of the emission.

So, what is Diffraction? It is what happens to a sound wave when it encounters an obstruction or an opening. As the sound wave bends and bounces off the material it is interfacing with its intensity can vary. Just like testing open air assets the inspector can see a harmonic appear in the Time Signal but due to the Diffraction of the signal as it exits the seam it will lose a sizable part of the emissions energy needed to receive a clear signal to be translated into a Frequency Spectrum.

When dealing with equipment with ventilation openings the inspector is afforded an opportunity to get a better angle through these openings. By simply changing the positioning of the module the inspector can try and pinpoint the area the emission is originating from. If the asset is totally enclosed and there are no ventilation openings the use of a CAP or VP Series Ultrasound Ports from IRISS will help to insure the truest form of the emission can be recorded with minimal Diffraction. These ports are more effective than scanning the seam on enclosed systems.

Some assets have hermetically sealed cabinets and the use of a CAP-ENV-PDS Series is the best choice as it ensures cabinet is still sealed. With a transducer mounted inside of the cabinet the inspector can eliminate antagonistic ultrasound source from bad ballast, ultrasonic motion sensors for lighting & security and other sources generated by the everyday noises associated with production areas.

In conclusion, it is very important that as we perform our Electrical Inspections that we take the time to note our surrounds and look before we step. We can easily get too tied up in just looking at the sound source and forget to watch our footing. We need to also insure that we are not just limiting ourselves while inspecting and only focusing on the sound and recording it. We need to also look at the display screen and what we can physically see with our own eyes. These are all important parts of any inspection program.

## High Voltage Cable Tests

With high voltage cable, there are many faults that can be detected. Voids in insulation is one of newer faults that has been heard over the years but gone undiagnosed. In the last few decades the science behind ultrasound anomalies has improved with the aid of sound analysis software. The Harmonic patterns of each fault have unique characteristics that allow the inspector to identify the fault by seeing the pattern instead of trying to interrupt the sound they hear. With this knowledge, the inspector can feel more confident in their diagnosis of the fault.

## Faults in Transformers

Transformers are electrical assets that transfer electricity between two or more circuits through electromagnetic induction. By alternating the current in one coil of the transformer it produces an alternating magnetic field, which in turn induces a voltage in a second coil. This magnetic field allows the power to be transferred between the two coils, without the need for a metallic connection between the two circuits. Transformers are used to increase or decrease the alternating voltages in electric power applications.

The invention of the first constant-potential transformer happened in 1885 and since that time transformers have become essential for the distribution, transmission, and utilization of alternating current electrical energy. When it comes to transformers there are several diverse types and styles that can be tested. There are a wide range of transformer designs and they range in size from 480 volts to 138 kV. Testing these assets could consist of airborne scan or a contact test. Both have their limitations but always take into account all safety issues. Ensure a Size Up or Huddle Up is performed prior to starting the inspection process.

## Bushings Failures

### Replacement of damaged substation equipment requires town-wide outage

June 1, 2015 By Paul Loveless

STEILACOOM – Electricity supplied to the Town of Steilacoom is delivered to a single point of delivery (BPA/Steilacoom substation) where it is then distributed to Steilacoom electric customers via four substation feeder lines. At approximately 2:00 p.m. last November 27th (Thanksgiving Day) one of the four feeder reclosers in the Town's substation catastrophically failed, rendering the Town out of power for several hours.

Crews were able to restore power to the Town by reconfiguring the distribution system using the three remaining feeders. To put the system back to normal, the damaged recloser and conductors need to be replaced and all collateral damage repaired. Due to safety concerns and the nature of the work, a town-wide power outage is required to complete the necessary repairs and equipment installation.

It is estimated that it will take approximately 8 hours to make repairs and install the new feeder recloser. In addition to the substation repairs, crews will be taking advantage of the outage to make additional improvements and repairs on other parts of the distribution system, avoiding the need for additional future outages.

While there is never an optimal time for a power outage, the Town in consultation with others, has scheduled an 8-hour, town-wide power outage for Friday, July 17, 2015. The plan is to shut off power at 8:00 a.m. and have it restored by 4:00 p.m. barring any unforeseen circumstances.

The Town of Steilacoom Electric Utility, a municipal utility in the state of Washington, is a preference customer of the Bonneville Power Administration. In 2014 the Town purchased and distributed approximately 39,000 megawatts of power to serve its 2,900 metered customers while maintaining an in-service system reliability rating of 99.94%.

## Insulators

There is no such thing as a perfect insulator, because even insulators will carry current. All insulators become electrically conductive when a sufficiently large voltage is applied. Some materials such as glass, paper and Teflon, which have a highly resistivity, are very good electrical insulators. Since the insulators are exposed to the elements, they can build up dirt or bird scat which then lowers the resistivity of the insulator. This could lead to Corona, Treeing, Arcing and eventual premature failure. These events do not have to start out as Corona and progress to Arcing, so any anomaly detected needs to be recorded and analyzed with sound analysis software. The inspector should always confirm the findings with an Infrared Camera.

## Switchgear

With so many seams, where does the inspector test? The answer is every seam if there are no Ultrasound ports. This leads to inconsistency in test location when testing seams. Especially when the sound could be coming from the cabinet above or below where the anomaly is heard. With the use of IR windows and ASU Ports the inspectors can assure consistency of the test location and cut the time it takes to do overall ultrasound inspections.

## Locating the Source of Radio & Television Interference

Everyone has driven by a powerline or transformer producing Ionization and experience a loss of radio signal temporally. This is caused by a Partial Discharge occurrence. This could be caused by Corona, Treeing or Arcing. This interference can sound similar to a sizzling, static, or sparking qualities to it. The intensity can increase and decrease due to the humidity in the air. The use of the Parabolic Dish is instrumental in the detection of these events since the distance is usually greater than 60 feet.

## Environmental Factors and Pest Can Cause Failures

Whether its dust build up on transmission lines and substation assets or prairie dogs building a burrow inside electrical assets. Many things can cause premature faults and could quit possibly be picked up during monthly inspection, but few companies go beyond the annual inspection due to time constraints or just lack of commitment to an CBM program for electrical assets.

# ASU Module 1-16 Safely Preforming Electrical Inspection

The use of Ultrasound Inspection devices is one of the safest ways to determine the condition of an asset without having to open any equipment. This saves the inspector from having to wear an Arc Flash Suit with an open panel. Being able to inspect electrical equipment use to involve scanning the seams and openings of equipment and recording the sound wave to analysis what the condition inside is. The one problem that the inspector runs into is the diffraction of the sound wave and the inability to establish the Critical Angle of the event. With the use of VP-12 US and VPDS the inspector can overcome the diffraction of signal. This will help to expedite the inspection process by eliminating the tracing of the seams of panels on equipment.

## Why Risk Opening Electric Cabinets?

Every site around the World should open their electrical equipment for maintenance or annual inspection. The problem has always been that this is usually done when the equipment is still energized. Using Ultrasound equipment can be used at any time without having to open electrical equipment. This would allow a program to safely inspect their electrical assets more frequently without having to risk opening any assets blindly.

Unfortunately, these actions expose us to electrical faults such as corona, treeing, tracking and arcing, which can cause very serious burns and even fatalities. It is necessary to know when one of our teams is going to fail, but doing so exposing the life of our electricians is not the best way to do it, that is why IRISS puts at your disposal our excellent products with which the ones in charge of monitoring all the cabinets online inspections without having to open them.

## Testing the Grid

For years the Grid has been there delivering electricity but have been left under serviced and aging. As such there have been significant failure over the years that have called in to question the stability of the grid. With more and more demand, we have seen the life cycle of the grid be tested. In some cases, the grid is taken down by human era. This usually comes from a lack of understanding of what can happen when working around electrical systems.

By Mark Harringtonmark.harrington@newsday.com @MHarringtonNews Updated March 22, 2016 8:59 PM

A painting subcontractor sealing a LIPA substation in Glen Head for PSEG Long Island on Tuesday suffered a severe electrical shock and burns and is in "very serious condition," according to Nassau County police.

The man, 47, whose name was not released, was sealing the roof of the substation near the Long Island Rail Road tracks on Glen Head Road when he "brushed up against roof bushings" and suffered a "severe electric shock," said a Nassau police spokeswoman. Substations convert higher-voltage energy from power plants to lower voltages distributed to homes and businesses. The worker encountered a 13,000-volt line.

Third Precinct officers, Emergency Service Unit officers, Ambulance Bureau AMTs and the Glenwood Fire Company responded to the scene, Nassau police said. Glenwood Fire Company responders used their ladder truck to assist emergency service officers to remove the victim from the roof and place him into a county ambulance, police said. The man has severe electrical burns and remains at Nassau University Medical Center in East Meadow, according to the spokeswoman.

## What Is the Biggest Problem in The World?

Statistics clearly show that exposure to electricity is still a major cause of deaths among construction workers. Among electricians, the most critical concern is working "live" or near live wires, instead of de-energizing and using lockout/tagout procedures. Among non-electricians, failure to avoid live overhead power lines and an apparent lack of basic electrical safety knowledge are the major concerns.

Electrocutions are the fourth leading cause of death among construction workers in the United States. An average of 143 construction workers are killed each year by contact with electricity (based on government data for 12 years, 1992 through 2003). Electrical



workers had the most electrocutions per year, followed by construction laborers, carpenters, supervisors of non-electrical workers, and roofers (chart 1). (These numbers do not reflect the risk for each trade, because no corresponding information is available on hours worked for each trade.)

## A Break Down of Electrocution Deaths

A study that ran over a 12-year period performed by the U.S. Bureau of Labor Statistics they determined that 1,715 workers were killed due to electrocution events. This isn't just a problem in the United States as many of these events occur on a daily basis around of the World. These events aren't always fatal, and we hear on the news about an electrical fire that injured several workers a mill. The press doesn't know that these events are caused by an Arc Flash event and these events can be reduced by using IR Windows and Ultrasound Ports as well as adhering to Safety Policies and Procedures.

### Power Line Kills Worker

Byline: By Lisa Hutchinson

A Newcastle man died when he was electrocuted at a power substation which has 400,000 volts running through overhead lines. Steve Kirkup was working away from home in Cambridgeshire when tragedy struck.

The 41-year-old was employed by contractors Siemens TD doing maintenance work from a cherry-picker in the middle of a National Grid substation on the edge of the village of Burwell when he received the fatal high-voltage electric shock.

He fell about 20ft although it is not yet clear whether he was electrocuted and then fell or fell from the crane and then received the shock. Emergency medical charity Magpas was called to the incident at 1.30pm on Monday and paramedic Andy Bates and Dr. James French rushed to the scene. Dr. French arrived in a police helicopter which had to circle the area three times before it was safe to land because of the hazards of the electric pylons.

## Airborne Ultrasound Safety Tips

The biggest factor in personnel getting hurt or killed in an Arc Flash Event is they are complacent. We have all heard or been that guy that says, "I done it 1,000 times!" Well it on takes that one time for it to all go wrong and destroy lives. So, it's important that the first step in your program be to ensure that all personnel obey all safety procedures. This include wearing the appropriate FR Level Clothing for the task. Never reach out with your Ultrasound device. Never break the plain of the asset. Keep a safe distance and stand on a rubber mat when possible.



## A True Story of an Arc Flash Event

It's not too often we hear about an Arc Flash Event Survivor. The few I have meet over the years have often been left with more than physical scars. Some survivors have said they wished they had died that day do to the long-term health effects and struggle of day to day life they continue to have to overcome. PTSD, Depression and Divorce are some of the factor's survivors will face after their event. None of these are easy things to deal with and no one considers these things prior to going to work but, it should be reinforced every time electrical work is going to be conducted.

## Electrical Injury

As morbid as this may be, it is necessary to discuss the effects of electrical injury to emphasize the necessity of always thinking safety. Electrocution is one of the leading cause of work place fatalities. As the current passes through the human body is burns skin and nerve ends, can split limbs wide open and blow



pieces completely off the human body. Not to mention stop the heart or vaporize the individual involved in the event.

The affects from the heat will cause catastrophic damage to the skin and will require the individual to spend months in a burn center. The severity of a burn is largely dependent on the depth of tissue destruction and the total surface area that suffered burns. 3rd degree burns will no longer hurt the victim as the nerve endings are burned away. Just 20 years ago someone with burns over more than 50% of their body stood a slim chance of survival, but today some victims are surviving with burns up to 80% of their body. The survival rate depends mainly on the age and health of the victim.

# ASU 1-17 Performing Electrical Sound Analysis

It is a good practice when performing an electrical inspection that it includes infrared and ultrasound equipment to detect fault conditions that could be occurring. When it comes to ultrasound it is critical that the anomalies are recorded so they can be analyzed in a sound analysis platform. These anomalies all have distinct characteristics when listening to them as well as distinct patterns when viewed in time wave form or FFT. In this module, we will briefly cover some examples of faults and the patterns that will traditional appear when being analyzed.

- ✦ Safety
- ✦ Adjust your position
- ✦ Scan at optimum speed
- ✦ Use VPDS Ports
- ✦ Adjust volume
- ✦ Confirm/compare
- ✦ Antagonistic ultrasounds
- ✦ Shielding techniques
- ✦ Accessibility to equipment
- ✦ Distance



## Things to Consider

Safety is paramount when it comes to Electrical inspection and as such it is important to always inspect from a safe distance and wear your PPE. The use of a Parabolic dish can help close the gap on the distance related inspections. Whether it is due to a limited approach or an overhead power line the dish allows the inspector to easily pick up anomalies from a far. The inspector should always try to change their positioning and walk completely around the asset being tested. The inspector should always watch their volume level to insure they are hearing the anomaly clearly with little to no antagonistic ultrasound. Once the anomaly is isolated the inspector can compare it to other like assets.

## Electrical Ultrasonic Emissions

It is important in Electrical Inspection that the inspector takes their time in locating the truest form of the ultrasonic emission. This will help to ensure that the sound wave can be diagnosed both in Time Wave Form, FFT and 3D Surfacing format. Since these events all have telltale signatures it is critical to take the time to insure the event is recorded properly. Some inspectors can interpret the patterns with very little training and others still struggle with it. When chosen someone to use advance software for analysis it might be best to choose someone who is not afraid of technology.

## Corona, Treeing, & Arcing

Many electrical issues generate ultrasonic emissions that can be determined by analyzing the sound wave pattern in a Time Wave Form, FFT and 3D Surfacing. These powerful platforms produce signatures that are very telling much like an EKG. The patterns will be distinct and show 50 or 60 Hz signatures depending on what part of the World the testing is being done in. Understanding these patterns is crucial to helping to decide the actual fault as well as give the inspector a heads up prior to opening an asset that something is occurring and all steps to insure their safety is taken. There is no set pattern to failure as an event could start off as Corona and slowly progress to Treeing and then on to Arcing or it could start off as an Arcing event and then fail. So, it is important that the inspector captures the sound wave of the event for analysis in addition to using the Sonus Vue App on their phone.

## Corona

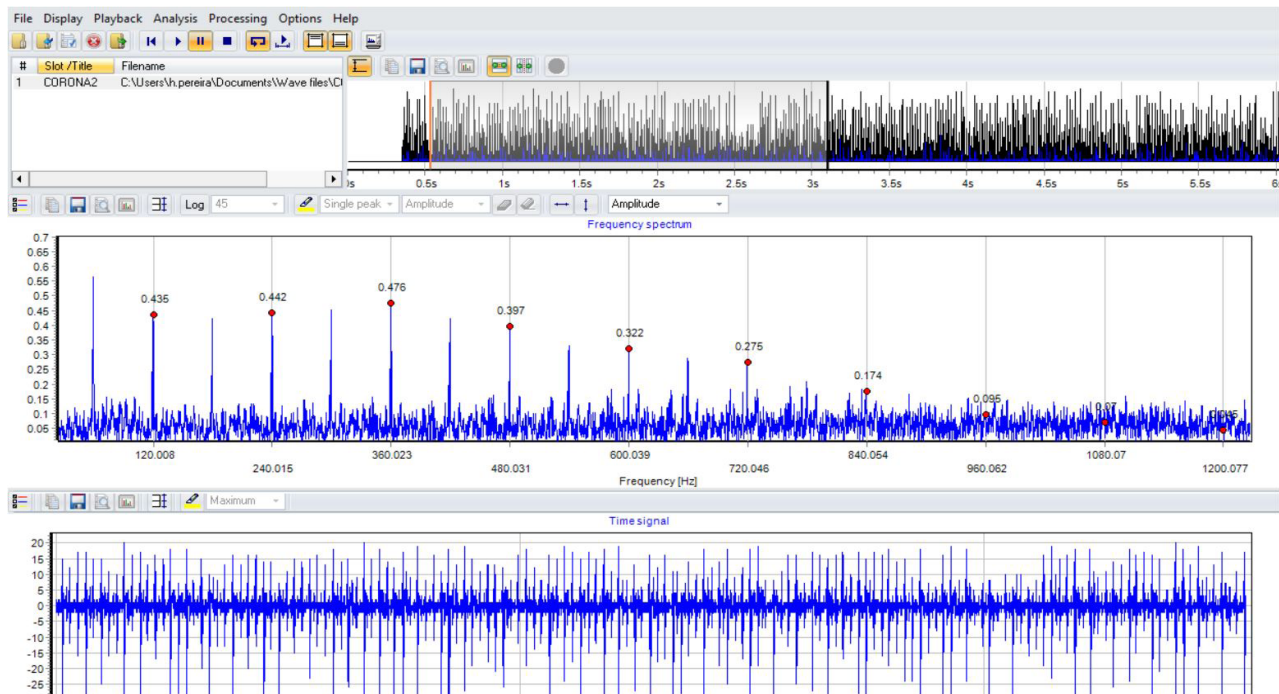
Corona is generally characterized by a colored glow frequently visible in a darkened environment with audible sound usually described as a subtle sizzling sound. These events produce ozone which is an unstable form of oxygen is frequently generated

during this process and will be malodorous. Since rubber is destroyed by ozone and produces nitrogen oxide which exposed to moisture turns into nitric acid. These items have detrimental effects on materials, inclusive of electrical insulators.

Corona can only occur above 1,000 volts and it will not produce any detectable heat, hence why IR will not see anything. If the inspector hears something Ultrasonic, they will need to record the sound and further investigate the harmonic indication in Time Signal. One of the unique factors with Corona is it will appear to have more amplitude in the Negative Portion than the positive portion. As the event generates its sound wave the compression of the air increases the air's density and prevents any spark of the corona event until the rarefaction portion of the wave moves through the area. Since the rarefaction actually thins out the molecules in the air the insulation of the air is negated and the current discharges into the air. These events will show a 60 Hz (50 Hz outside of the US) Harmonic throughout the Time Signal. These discharges will have more amplitude in the negative percent to scale. It is best to analyze the sound waves in only a 2/10<sup>th</sup> of a second interval for best analysis.

## Corona Sound Signature

Corona is the glow and audible discharge that occurs when there is an excessive rise in localized electric fields surrounding an object that causes the ionization, which in turn can lead to possible electrical breakdown of the air around this point. When the sound recording is analyzed it will present with repetitive 50 or 60 Hz (Dependent on the line frequency of the country) richer harmonic indications in the negative portion to scale in the Time Wave Form. This is due to the sound wave having a compression and rarefaction in the air around the anomaly. Rarefaction of the sound wave actually thins out the air on the negative side of the sound wave and reduces the insulation value of the air allow the partial discharge. If the inspector establishes the Critical Angle the FFT will also show repetitive harmonics at 50 or 60 Hz. It will not however produce a heat making it undetectable with Infrared.



## Treeing (Tracking)

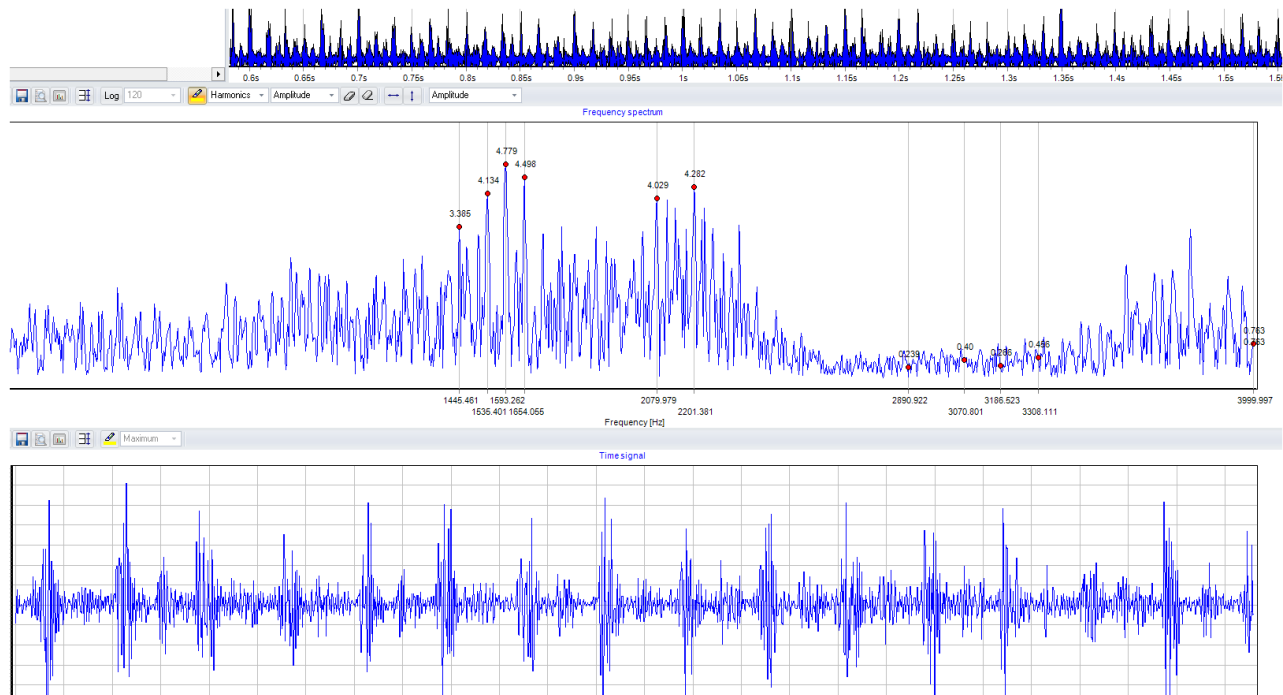
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Electrical Treeing can occur in High Voltage Equipment just prior to failing. During an RCA, the treeing can be used to track down the source of the failure. There are 2 common types of treeing that can be produced when equipment starts to fail. Bow-tie trees start to grow from within the dielectric insulation and grow outwards toward the electrodes. As it starts inside the insulation it does not have a supply of air which would allow the continuous support of partial discharges. Hence these trees have limited growth and do not usually result in a failure in the insulation or ability to sprawl out to the nearest electrodes. Vented trees start at an electrode insulation and sprawl out towards the opposite electrode. Being exposed to atmosphere is a key for its growth. These trees will continuously grow until they are able to bridge the electrodes which will result in the failure of the insulation. Treeing has been used to create some amazing artwork where you can clearly see how this electrical event got its name. The use of this in art work is known as Lichtenberg Figures and there are some pretty amazing images created when electricity is applied to the medium.

## Treeing (Tracking) Signature

Is an electrical pre-breakdown in solid insulation that causes damage due to stressed dielectric insulation which allows partial discharges to travel through a medium in a path resembling the branches of a tree. Treeing of solid high-voltage cable insulation is a common breakdown mechanism and source of electrical faults in underground power cables. This event will produce Heat and Ultrasound emissions. The sound wave will have line frequency harmonics with the Time Wave Form showing almost equal amplitude in the positive and negative portion while the FFT will present with a few intervals and taper off. The interval will present itself with 50 or 60 Hz harmonics in the Time Wave Form will have a rich amplitude with the positive and negative overall peaks being nearly equal. In the FFT harmonics will also show up at line frequency if the Critical Angle has been achieved.



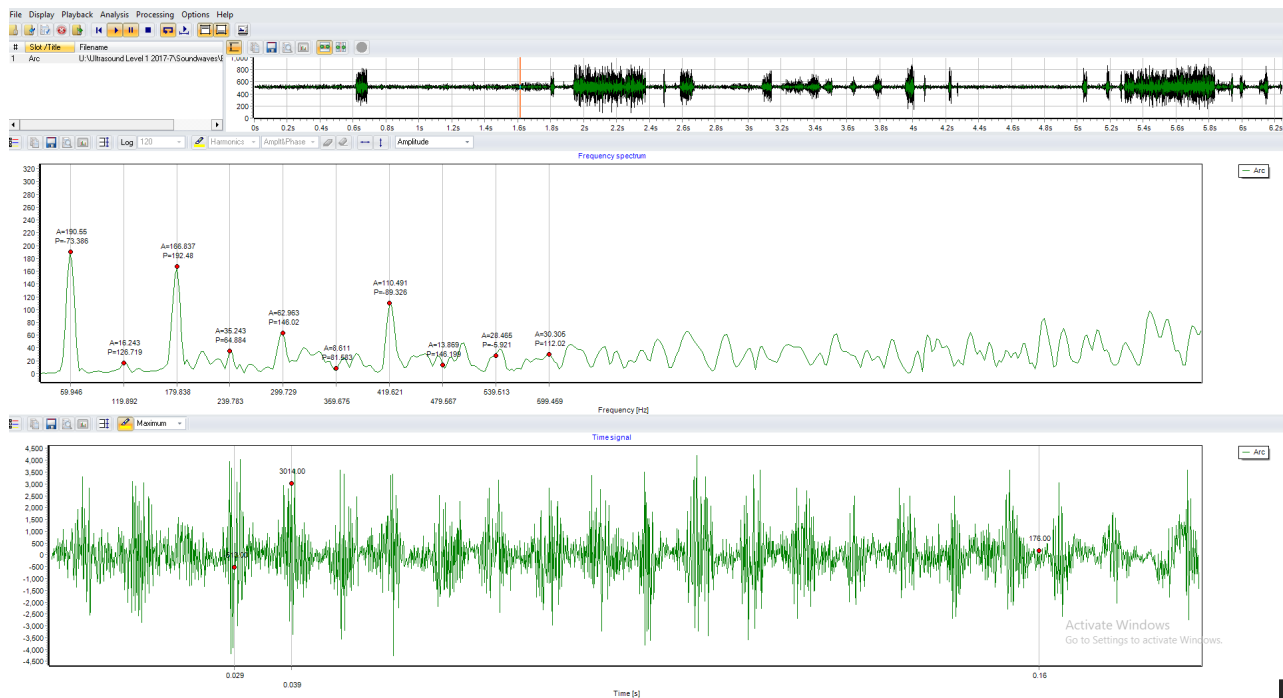


## Arcing

Arcing is an electrical breakdown of air or gas insulating an electrical connection that allows for an ongoing electrical discharge. The current passing through this normally nonconductive medium in turn produces a visible & ultraviolet light as well as a source of ultrasound. Electrical arcing creates ultrasound & heat. Arcing will show very distinct burst over the entirety of the sound recording when viewed in Time Wave Form and the inspector will need to zoom in on the burst where the interval of the line frequency will be apparent. In the FFT the inspector will notice the 1-time occurrence and from there it will be very random indications which will usually taper off by the 10<sup>th</sup> occurrence.

## Arcing Signature

Arcing will show harmonics in burst when looking at the Time Wave Form and sporadic Line Frequency Faults in the FFT that tend to dissipate after the 10<sup>th</sup> occurrence. The key to analyzing the Time Wave Form is to zoom in on a burst of sound and isolate 2 tenths of a second of time of that burst. The inspector will then clearly see the line frequency faults.

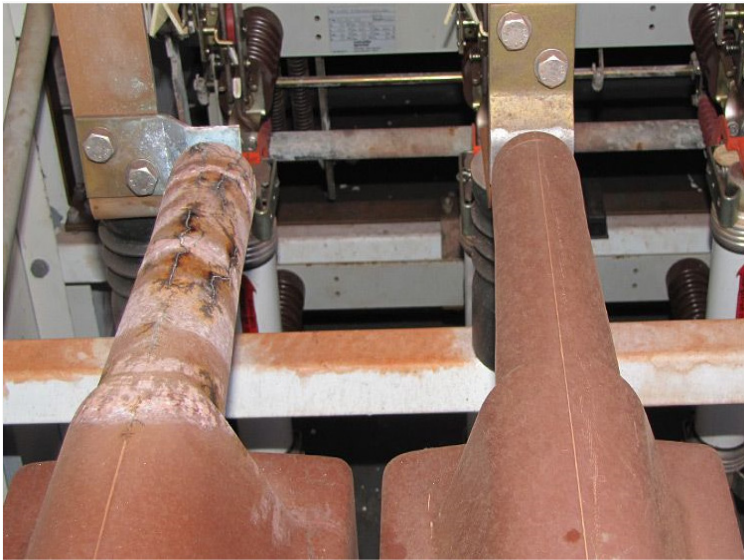
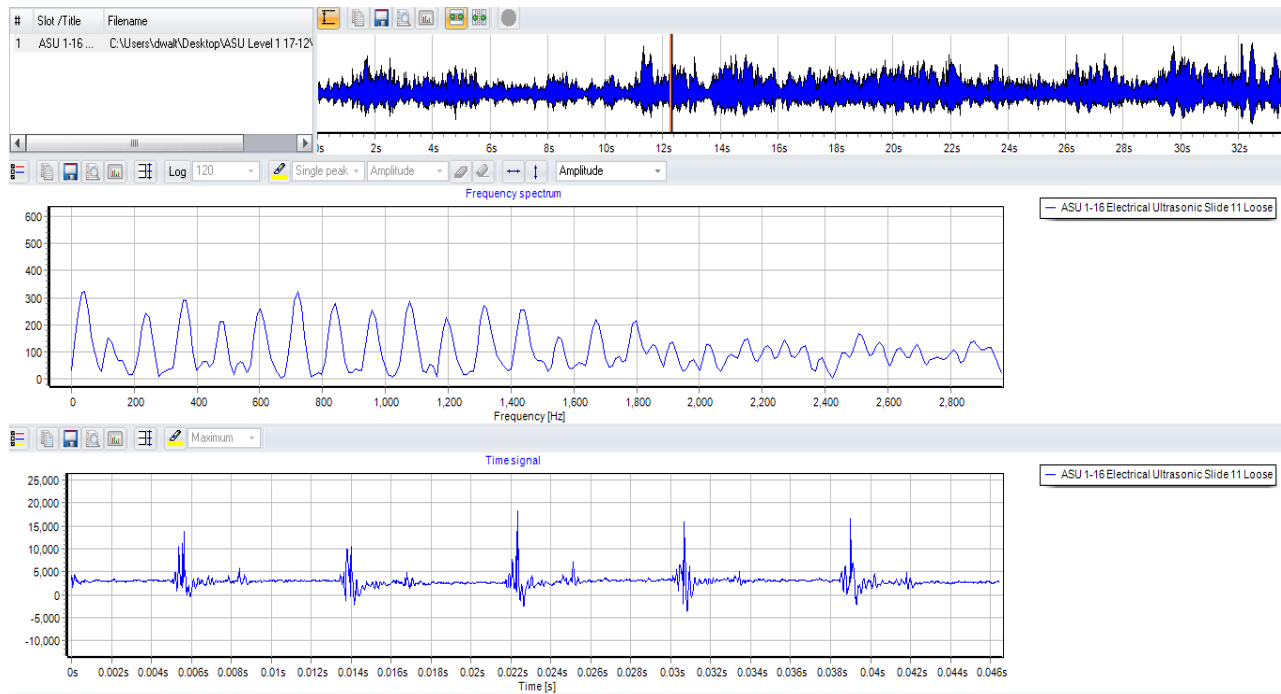


## Loose Connection

A Loose Connection is connection that becomes loose overtime from not being properly tightened at installation of the equipment which causes it to start to melt and oxidize from the excessive current its drawing. This will produce a source of ultrasound and heat. Loose connection will present with a 2-time line frequency harmonic in both the Time Signal and the FFT, but the Time signal will have a Fish Bone appearance that intensifies and wanes several times.

## Loose Connection Signature

A loose connection will show up with Harmonics at 2 times the line frequency. In the Time Wave Form it will even show the characteristics of a fishbones from a cartoon. What does this mean? The inspector will notice the amplitude increasing and decreasing across the Time Wave Form. The FFT will also show indications of a 120 Hz Harmonics have a much higher amplitude than the line frequency indication if any are even present.



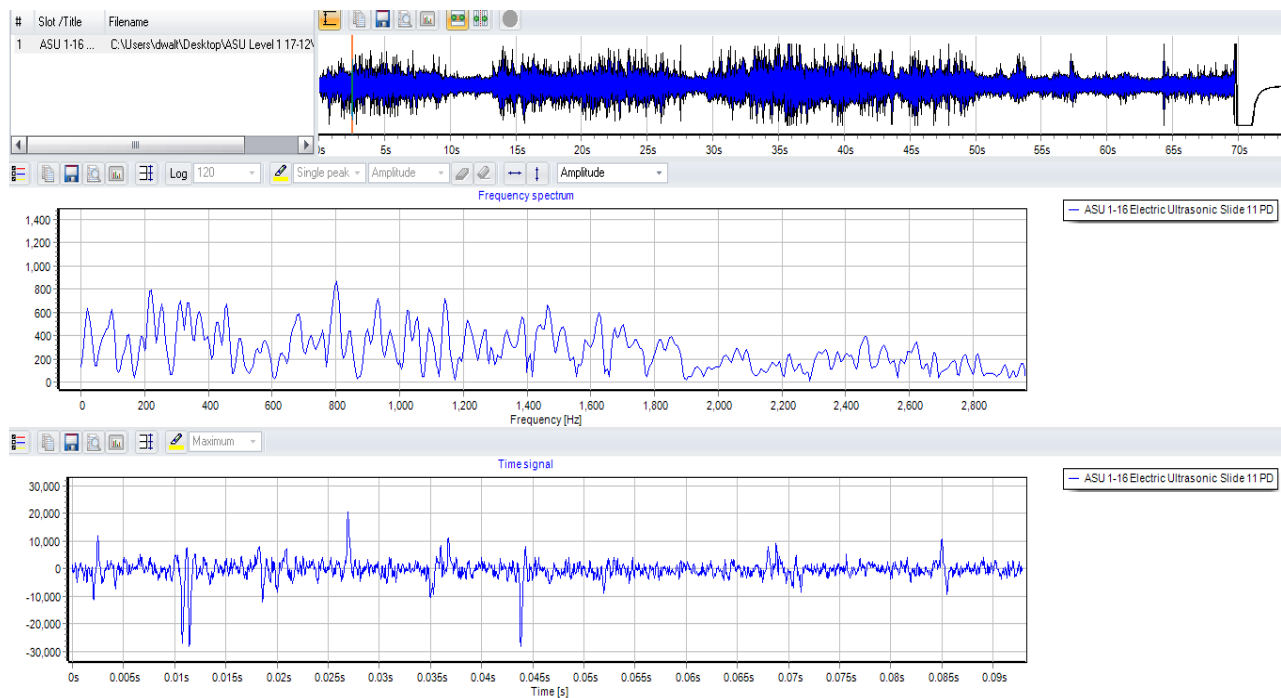
## Partial Discharge (PD)

Partial Discharge (PD) is a localized dielectric breakdown of a small portion of a solid or fluid electrical insulation system under high voltage stress, which does not bridge the space between two conductors. While a corona discharge is usually revealed by a relatively steady glow or brush discharge in air, partial discharges within solid insulation system are not visible. PD can occur in a gaseous, liquid, or solid insulating medium. It often starts within gas voids, such as voids in solid epoxy insulation or bubbles in transformer oil. Protracted partial discharge can erode solid insulation and eventually lead to breakdown of insulation. This will not produce any detectable heat but will generate a source of ultrasound and Transient Earth Voltage (TEV).

## Partial Discharge (PD) Signature

Partial Discharge will sound like a slight bit of static and can be tough to capture due to its lack of amplitude. For years this sound was dismissed as inherit or unknown, but now with the confirmation with PD units Ultrasound devices have been able to pick up the same events. Harmonics will also vary due to the lack of amplitude and limitation of the Critical Angle.



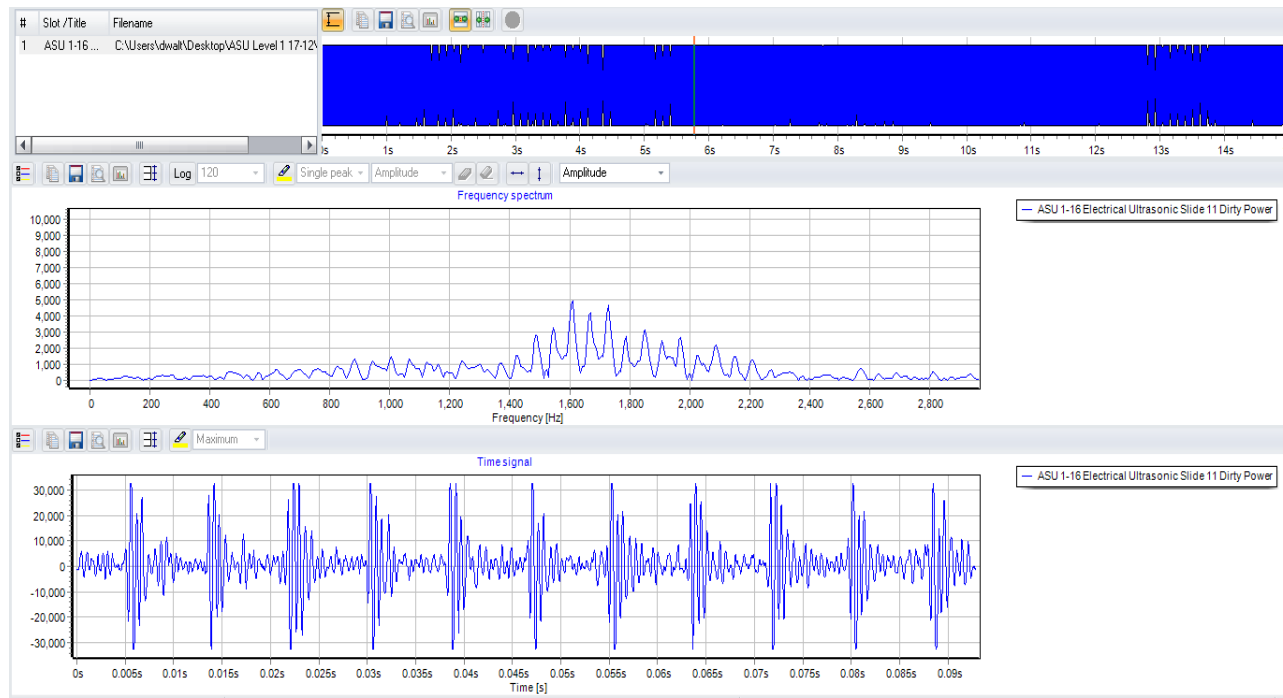


## Dirty Power

Dirty power is electromagnetic pollution called transients and harmonics. Dirty power creates erratic spikes and surges of electrical energy traveling along power lines and building wiring where only standard 50/60-Hertz AC electricity should be. Also called electrical noise, line noise, and power line EMI, it is one fast-growing source of electro-pollution in homes, schools, and businesses today. Dirty Power may show some signatures of heat but at the time of publishing there is no science to back this up, however it will produce signatures ultrasonically that can be traced all the way down to the motors. In the case of a waste water treatment plant in Ohio they had a known condition coming from their substation yard that had burnt up several assets over the years and during one test of the MCC's a line frequency fault was found at 121.5 Hz that repeatedly showed up in both the Time Wave Form and the FFT. Upon further testing of other MCC's the presence off a 121 Hz & 122 Hz were found and confirmed to be present in the motors they were driving.

## Dirty Power Signature

Dirty Power will produce a distinct buzzing noises with a lot of amplitude when viewed in the Time Wave Form. In the US, the Harmonics will stack up at one of the following values 121, 121.5 or 122 Hz. No information has been established outside the US at the time of publishing this book. The FFT will show similar harmonics and in the case of this example there is too much amplitude in the recording so the translation of the signal from a Time Wave Form to an FFT is not possible due to the distortion of the signal because the inspector had too much amplitude.



# DIRTY ELECTRICITY

An invisible pollutant in schools

BY MAGDA HAVAS

**“AS** the school year began in the late summer of 2002, Mindoro Elementary School teacher and principal Angela Olstad was ready to call it quits,” wrote Emily Winter in her article “Dirty electricity at center of debate” that appeared in the Aug. 2, 2006 issue of the Capital Times in Madison, Wisconsin.

“Since Olstad took the job at Mindoro three years earlier, she suffered from chronic illness and was eventually diagnosed with multiple sclerosis in April 2002. Other faculty members reported health problems as well, and 37 Mindoro students had developed asthma.

“Even after treating the school twice for mold, rampant illness persisted and its source remained a mystery.

“ ‘I was exhausted. I absolutely had no life for three-and-a-half years’ Olstad said. ‘I was afraid to go back.’

“But all that would change in October 2002,” continued the article.

In October 2002, the superintendent, Ron Perry, invited a power quality expert to measure the school for electrical problems. He found elevated levels of high frequency radiation on the wires in the school (commonly referred to as “dirty electricity”) and installed Graham Stetzer (GS) filters to remove these high frequencies. The staff knew that an electrical contractor was working in the building but were unaware of what work was being done. Within days they began to notice marked improvements in their health.

In a letter posted on the website, [www.electricalpollution.com](http://www.electricalpollution.com), Char Sbraggia, the district nurse, documented some of these improvements after the GS filters were installed: “Teachers are stating they are less fatigued and tired.... The students seem to have more energy and appear and seem less tired.... Several staff who doctored regularly for allergies have not had to take medication or see their doctors because they are having less problems.... Students who have been diagnosed with migraine headaches have had their headaches reduced, or no headaches at all.”

But perhaps the most impressive result was for students with asthma. Of the 37 students who required nebulizer treatments daily, only three students used inhalers for exercise-induced asthma before physical education classes after the filters were installed.

Two years later the results were the same. Absenteeism, due to illness, was reduced and students continued not to need inhalers and to have a lot of energy. According to district nurse Sbraggia in a follow-up letter on Jan. 14, 2005, “We are a much healthier school since the filters have been installed.”

The Wisconsin Department of Health no longer classified the school as a “sick” building and a lawsuit, initiated by the teachers’ union, was dropped.

Is the Mindoro school unique? No! The problem at the Mindoro school was dirty electricity generated by fluorescent lights, computers and typical office equipment like photocopy machines—equipment that is present in most North American schools.





# ASU Module 1-18 Risk vs Reward

## Infrared Windows and Arc Ratings – Dispelling the Myth of “Arc-Resistant IR Windows”

There exists a dangerous misconception regarding the “Arc Rating” of infrared (IR) windows or viewing panes. Many reliability and maintenance professionals are under the impression that an IR window will protect them in the event of an arc blast; still others are under the impression that installing IR windows will turn non-arc-rated switchgear or electrical equipment into “arc-rated” cabinets. Neither are the case and both misconceptions need to be corrected because they present very real safety concerns.

By Martin Robinson, CMRP Level III Thermographer President, IRISS Inc.

All three major brands of IR windows are available as standard options on various brands of switchgear, MCC buckets, and other electrical equipment. All three brands have undergone extensive evaluation and testing as parts of arc-rated systems. Yet none of these companies should ever lead the public to believe that any of these tests or system certifications has any broad-based or generic rating across all varieties of switchgear or electrical equipment. The simple fact is that there is no such “component rating” for generic “arc-resistance.” Any claims to the contrary are dangerous and negligent.

IR windows are not intended to protect a user from an arc flash - they are intended to eliminate additional triggers of an arc flash during an inspection and replace a high-risk activity with a risk reduction/elimination strategy during inspection. IR windows and closed-panel inspections help companies to comply with the OSHA and NFPA mandates to eliminate risk wherever possible; conversely, a protection strategy is acceptable only after other methods of risk elimination or reduction have been exhausted. The Anatomy of an Arc Flash An arc flash occurs when a phase-to-phase or phase-to-ground fault causes a short circuit through the air. The core of the arc flash can reach temperatures of up to 38,000°F (21093°C); at this high temperature copper turns to a plasma state instantaneously and expands 67,000 times its original volume in a fraction of a second. The heat and resulting expansion cause a pressure wave that carries thousands of pounds of force, a blinding flash of light and molten shrapnel.

Differences in the volume (cubic feet) of the switchgear, MCC bucket, or electrical cabinet will affect the amount of force that impacts the cabinet panel/IR window just like the result of an explosive device placed in a mailbox has compared to the result it has if it was placed in the back of an empty train car. Similarly, a cabinet with large amounts of copper available for expansion would be capable of producing an explosion with much more force than the same cabinet with very little copper cable or bus-bar. Other differences, such as use of current limiting fuses or distance and position of the arc flash relative to the panel door/IR window will have a major impact on the force that impacts the panel/window.

As a result, arc ratings are given to systems that can withstand a blast in a specific model of switchgear with a standard size and configuration.



## Safely Inspect Electrical Assets

Keep in mind that the forces and temperatures that a panel or window encounters in an arc flash in arc resistant gear are vastly different than those that are present in the same blast in un-rated gear. Since less than 1% of the switchgear and MCCs in the field have safety mechanisms designed to redirect the forces of a blast, 99% of consumers who are expecting a window to withstand a blast on un-rated gear are asking the laws of physics to be suspended. In a tightly closed box, an arc blast will blow a steel door right off steel hinges and steel bolts. With such extreme forces applied to an unyielding system, even the steel doors of a piece of switchgear cannot “protect” a worker who happens to be near the explosion. That is why switchgear had to be re-engineered to redirect and mitigate the blast effects.

## Solutions for Dry Transformers

Infrared windows are intended to allow safer, more efficient access to the thermographic data recommended in NFPA 70B: “Dependability can be engineered and built into equipment, but effective maintenance is required to keep it dependable. Experience shows that equipment lasts longer and performs better when covered by an EPM (Electrical Preventative Maintenance) program. Infrared inspections of electrical systems are beneficial to reduce the number of costly and catastrophic equipment failures and unscheduled plant shutdowns. Routine infrared inspections of energized electrical systems should be performed annually prior to shut down. More frequent infrared inspections, for example, quarterly or semiannually, should be performed where warranted by loss experience, installation of new electrical equipment, or changes in environmental, operational, or load conditions. Infrared surveys should be performed during periods of maximum possible loading but not less than 40 percent of rated load of the electrical equipment being inspected.

NFPA 70E lists removal of panels on electrical equipment as one of the riskiest activities that a worker can perform on that piece of equipment. The risk is elevated because the most common arc triggers occur either because the panel covers are open or as a result of removing the panel covers. Closed-panel inspection using infrared windows will eliminate 99.9% of arc flash triggers during inspection. Therefore, the core benefit of IR windows is that they comply with the OSHA and NFPA 70E focus on removing the risk of an accident - protection with PPE is only used as a last resort, and the implementation of engineered controls is only used where risk elimination and substitution are not feasible.

It is also important to understand that the test procedures defined in IEEE C37.20.7 are performed with the window in a closed position. When the switchgear “passes the test,” it does not matter if the optic material was damaged or even disintegrated, as long as the heated gas from inside the cabinet does not ignite a flag placed outside the cabinet. Therefore, any implied protection for a thermographer while using the window in an open position is not only questionable; it is a total misrepresentation of the test. Why Use IR Windows?

IR windows are intended to remove the risk of triggering an arc flash incident during a thermographic inspection. That being said, the windows should also offer the same level of structural integrity that UL746 requires of other common meters and controls, and the same integrity that IEEE C37.20.2 requires for impact and load of “viewing panes.” However, any claims by any manufacturer to have an arc resistant IR window are misleading and negligent since there simply is no test which offers a component level rating.

Due to the endless variety of switchgear geometry and contents that exists in the field, the forces that a given piece of switchgear or MCC might experience in an arc blast are equally varied. Therefore, regardless of how many arc faults tests the window may have been involved in, it is impossible to infer generic resistance. As manufacturer of the world’s first and only industrial-grade infrared windows, IRISS’s end-user-designed products are the heart of efficient and safer work processes for infrared electrical surveys and thereby provide the means with which companies can reduce and eliminate risk to plant assets and personnel. IRISS can help you and your company “save time, save money and stay safe.”

## Visual Inspection

Because of the near-infinite variety in size, contents, and position of connections, it would be impossible to have a one-size-fits-all rating for arc-resistance. As a result, arc fault tests are performed on systems, not on the individual components which make up a system. Consequently, any changes in design of the switchgear require retesting to verify the new rating even though it might be very similar to the previous arc-resistant version.

Arc rated switchgear and MCCs enlist a variety of safety mechanisms such as additional barriers and pressure relief mechanisms. These safety features redirect the forces and heat of an arc flash away from the panel doors and up through a series of plenums that systematically reduce the forces of the blast and minimize any damage that might have otherwise occurred had the blast escaped the confines of the system. Any IR window, visual viewing pane, or panel meter that happened to be in place during this test would not have been responsible for the arc-resistance of the system but would merely be shown to not interfere with any safety mechanisms which were in place to redirect the blast. Just as the bolts holding the panel in place are not universally arc-resistant, they were simply the proper strength to hold the panel in place on that specific model of switchgear. Consider the following analogy: A luxury car manufacturer is preparing its new sedan for crash testing. They include the high-end stereo option manufactured by Uber-Audio complete with voice activated MP3 catalog features. As expected, the crumple zones in the sedan’s frame absorb huge



amounts of force on impact; safety belts keep test dummies properly placed for maximum protection and airbags deploy to cushion the occupants; and the stereo, as expected, does not interfere with the proper functioning of any of the safety mechanisms as it stays on its mount and does not impale the test-dummies. The car receives a 5-star crash rating. Would you expect to see the Uber-Audio stereo company claim that its stereo system received a 5-star crash rating? Would you expect to see advertisements leading consumers to believe that this stereo could protect passengers in the event of a crash? Of course not.

## Are There Any Issues Here?

### Electricians Upgrade Power Sub-stations

Senior Airman Brandon Peterson, 375th Civil Engineering Squadron electrical systems journeyman uses compressed air to blow out 34.5k switchgear April 9, 2016 at Scott Air Force Base. Peterson does this to prevent electrical tracking and future facility power outages. (U.S. Air Force Photo by Airman Daniel Garcia)



## I.C.A.S.T Short Course

### Reducing Costs

We all know that this is a true statement and that the engineering budget is always the first and most times the largest hit. It reflects the world we live in financially and is not a derogative comment.

Ultimately, areas that used to receive regular attention have had the intervals of scheduled maintenance reduced, resulting in unintended consequences of exposing components to extended stresses, additional load demands from facility upgrades, and more extreme environmental operating conditions. A good way of keeping costs down, is to put into plan an effective Condition Based Maintenance program.

Condition based maintenance (CBM) is a maintenance strategy that monitors the actual condition of the asset to decide what maintenance needs to be done. CBM dictates that maintenance should only be performed when certain indicators show signs of decreasing performance or upcoming failure.



When a **massive power outage** struck southern California in the 1990s, Los Angeles residents reportedly called 911 to express alarm about **strange clouds** hovering overhead; they were seeing the **Milky Way** for the first time.

## Aging Components

Additionally, much of our aging infrastructure equipment has been in service for 20 years or more, increasing the probability of some type of malfunction or even failure, which could realistically devastate a planned maintenance budget.

## How Do Thermal Imagers Work?

Here's how thermal imaging works: A special lens focuses the infrared light emitted by all the objects in view. The focused light is scanned by a phased array of infrared-detector elements.

The detector elements create a very detailed temperature pattern called a thermogram. It only takes about one-thirtieth of a second for the detector array to obtain the temperature information to make the thermogram. This information is obtained from several thousand points in the field of view of the detector array.

The thermogram created by the detector elements is translated into electric impulses. The impulses are sent to a signal-processing unit, a circuit board with a dedicated chip that translates the information from the elements into data for the display. The signal-processing unit sends the information to the display, where it appears as various colours depending on the intensity of the infrared emission. The combination of all the impulses from all the elements creates the image.

## Common Materials That Are Transparent to Thermal Imagers

Although dozens of IR materials exist, only a handful is predominantly used within the optics, imaging, and photonics industries to manufacture off-the-shelf components. Calcium Fluoride fused silica germanium, magnesium fluoride, N-BK7, potassium bromide, sapphire, silicon, sodium chloride, zinc selenide and zinc sulphide each have their own unique attributes that distinguish them from each other, in addition to making them suitable for specific applications.

## Visible and Infrared Light

Visible light is light as we know it: Light we see with our own eyes, and photograph to document our lives. List the sources of visible light in this training room. Why do we "see" the walls, desks, ceiling, floor, and other objects if they are not the source of visible light?

There are other classifications of light that exist outside of human vision. X-Ray, Ultraviolet, and Gamma are types of light that have wavelengths shorter than visible light. Infrared, Microwave, and Radio are types of light that have wavelengths longer than visible light.

It travels at the speed of light in a vacuum and require no medium to exist. It can be refracted (the bending of light as it passes from one substance to another) and can be focused or reflected. There are d different wavelengths and frequencies of infrared light.

Infrared is a form of light that exists as a byproduct of molecular vibration. An object with a high molecular vibration will generate more infrared than the same object is at a lower vibration. How do we quantify an object's molecular vibration?

All objects that have a temperature above **absolute zero (-273.15°C)** will generate and emit infrared light. At a higher temperature, the same object will emit more total infrared light than it did at a colder temperature.

## Do all Infrared Cameras Measure Temperature?

Simply put no they do not. When an infrared camera is calibrated to measure temperature, it is defined as being radiometric. Some thermal imagers are not radiometric. What type of infrared camera do you need for your application? For electrical surveys, it is widely known that you must have a Radiometric imager.

## What Tools Can Be Used?

### Ultrasound

- Listen for arcing, tracking, and corona.
- Does not require direct contact/line of sight.

### Infrared

- Looking for abnormal heating.
- Usually requires line of sight.

### Millivolt Drop Test

- Uses true RMS multimeter to determine resistance.

### Current and THD Measurements

- Looking for load imbalance.
- Finding faults caused by more than just a bad connection.

## The Many Palettes of IR

Most thermographers have a favorite palette, but you will be surprised that certain palette is better than others for example the Rainbow High Contrast (HC) is excellent when surveying buildings or roofs. Iron brow is generally the best palette for electrical/mechanical surveys. There is no correct palette, but time and experience will dictate which one you will use.

## Non-Radiometric

There are advantages of having non-radiometric imagers: Cost can be lower, can have a built-in optical zoom and no calibration necessary. Other Non-Contact Temperature Measurement are known as a spot radiometer. They have the same basic technology as some infrared cameras and are affected by the same rules of physics as most thermal imagers.

## Thermal Imaging Applications

Thermography is the ultimate in troubleshooting technology. Infrared cameras deliver almost instantly verifiable thermal snapshots of circuits, systems and buildings. No plumber, surveyor, electrician, engineer or site manager can afford to be without a thermal imaging device with the capacity to deliver accurate measurement and documentation.

### Buildings

From a blocked pipe to faulty insulation, every unseen nook and cranny of a building can be revealed by thermal imaging. All private dwellings placed for sale or rent now receive a routine assessment of their energy performance, with areas that lose heat quickly and easily detected.

### Medical and Veterinary Work

Thermal Imaging has been proven to be a safe and non-invasive tool for doctors and vets. Parts of the human body with abnormal temperature readings can help to form the basis of medical diagnosis for a wide range of conditions, such as breast cancer, nervous, metabolic and vascular disorders, neck and back problems, arthritis and soft tissue injuries. Veterinary medicine has also benefitted from the application of IR technology, detecting irregularities in blood circulation, inflamed joints, muscle and nerve injuries.

### Utilities, Industry and Transport

IR thermography has become central to predictive maintenance in factories, industrial sites, transport and the transmission of utilities such as gas, electric and water. All depend on heat analysis to avoid costly electrical failures and industrial accidents, as infrared cameras help find anomalies before trouble strikes and service is affected. At manufacturing facilities thermal imaging

cameras are used for inspecting production equipment and components as well as the complete electrical power supply system.

## Other Applications

Specialist cameras monitor specific substances or gases. Cameras have been developed that are capable of detecting leaks of gases such as volatile organic compounds (VOCs), methane, carbon monoxide and other gases. Fixed-mount IR cameras are ideal for fire-safety applications, able to see through smoke, fog or complete darkness. This might be useful in warehouses, waste sites or coal tips where there is a risk of spontaneous combustion. Firefighters use the cameras to search for survivors in burning buildings, and airport staff used thermography during the 2009 swine flu epidemic to monitor travellers with signs of the infection.

Thermography can be used in a wide and various areas. The most common will always be engineering especially in Electrical area. The other areas that it can be used are in R&D, medical (used extensively on detecting breast cancer), It is now being used more in the veterinary. world on high breed race horses Very good at detecting bruising on the horse's legs but in this image looking at a cancerous tumour in the testicles.

## Thermal Imaging vs. Night Vision

There is a misconception that NVG and Infrared are the same medium, but this is untrue. Night Vision requires visible light whereas Infrared uses heat and its medium giving greater contrast. IR can see through mediums for example cloud, smoke or fog. These mediums reflect light so NVG cannot see through it. As everything on earth gives off heat IR can see through these mediums.

If you were looking at a wooded area with night vision goggles as there is no contrast the NVG cannot pick up the shape of the person standing just inside the tree cover but with the IR camera the persons heat silhouette can be easily seen. Thermal imaging sees heat left behind even after the source of energy is gone. Try rubbing your feet on the ground and then look at the area with your camera.

## Why is Thermography Useful?

It keeps the user out of danger. One example where this is important is electrical maintenance applications. Live components simply cannot be touched and if they are not carrying current, there will be no temperature rise to measure. Distance and accessibility is another problem we can overcome, as well as measuring on moving or rotating targets. Thermography does not intrude upon or affect the target at all. We only look at naturally emitted radiation that will be there, whether we look at it or not. This is an important condition for many applications.

# Glossary

**Amplitude:** the quality or state of being intense; especially or extreme degree of strength, force, energy, feeling, or the height of a wave's crest which determines its loudness.

**Compression:** is the compacting of molecule into a denser concentration in a medium.

**Decibels:** Are the measurement of the loudness or intensity of the sound wave and is a logarithmic unit used to express the ratio of two values of a physical quantity.

**Diffraction:** refers to various phenomena that occur when a wave encounters an obstacle or a slit. The sound waves ability to bend around the corners of an impediment or opening in the region of geometrical shadowing from the hindrance.

**Frequency:** The number of waves produced in a given period of time.

**Hertz:** Named for the German physicist who produced the first electromagnetic waves artificially.

**Heterolysis or Heterolytic Fission:** is the process of cleaving a covalent bond where one previously bonded species takes both original bonding electrons from the other species. During heterolytic bond cleavage of a neutral molecule, a cation and an anion will be generated. Most commonly the more electronegative atom keeps the pair of electrons becoming anionic while the more electropositive atom becomes cationic.

**Intensity:** the magnitude of a quantity (such as force or energy) per unit (as of area, charge, mass, or time).

**Ionization:** is the process by which an atom or a molecule acquires a negative or positive charge by gaining or losing electrons to form ions, often in conjunction with other chemical changes. Ionization can result from the loss of an electron after collisions with subatomic particles, collisions with other atoms, molecules and ions, or through the interaction with light.

**Logarithmic Unit:** the exponent that indicates the power to which a base number is raised to produce a given number the logarithm of 100 to the base 10 is 2.

**Longitudinal Wave:** a wave (such as a sound wave) in which the particles of the medium vibrate in the direction of the line of advance of the wave.

**Loudness:** The intensity of the pressure wave resulting in the levels of intensity perceived by the someone.

**Malodorous:** having a bad odor

**Medium:** a substance regarded as the means of transmission (see transmission 1) of a force or effect air is the medium that conveys sound (2)

**Orthogonal:** intersecting or lying at right angles in orthogonal cutting, the cutting edge is perpendicular to the direction of tool travel.

**Pitch:** Is a term used to describe the highness or lowness of a sound wave and the differential between them.

**Polarization:** the action or process of affecting sound so that the vibrations of the wave assume a definite form.

**Pressure Wave:** a wave (such as a sound wave) in which the propagated disturbance is a variation of pressure in a material medium —called also P-wave.

**Rarefaction:** it's the dispersion of molecules that lessens the density of the medium. The region in a sound wave where the particles have been spread out and are the least dense part of the wave.

**Sinusoidal/Sine Wave:** a waveform that represents periodic oscillations in which the amplitude of displacement at each point is proportional to the sine of the phase angle of the displacement and that is visualized as a sine curve.

**Shear wave:** a wave in which the propagated disturbance is a shear strain in an elastic medium.

**Sound:** when something vibrates. The vibrating body causes the medium (water, air, etc.) around it to vibrate.

**Transverse Wave:** a wave in which the vibrating element moves in a direction perpendicular to the direction of advance of the wave.



**Ultrasound:** vibrations of the same physical nature as sound but with frequencies above the range of human hearing.

**Vibration:** a periodic motion of the particles of an elastic body or medium in alternately opposite directions from the position of equilibrium when that equilibrium has been disturbed (as when a stretched cord produces musical tones or molecules in the air transmit sounds to the ear).

**Wavelength:** The measurement of a sound wave from compression to compression or rarefaction to rarefaction.

# Reference List for Level 1 Book

ISO Standard 18436-8:3013 (E)

## ISO Standards

ISO 13379 gives guidelines for the data interpretation and diagnostics of machines. It is intended to

- allow the users and manufacturers of condition monitoring and diagnostics systems to share common concepts in the fields of machine diagnostics;
- enable users to prepare the necessary technical characteristics that are used for the further diagnosis of the condition of the machine;
- give an appropriate approach to achieve a diagnosis of machine faults

### ISO 18436-1

**ISO/IEC 17024** This International Standard has been developed with the objective of achieving and promoting a globally accepted benchmark for organizations operating certification of persons. Certification for persons is one means of providing assurance that the certified person meets the requirements of the certification scheme. Confidence in the respective certification schemes for persons is achieved by means of a globally accepted process of assessment and periodic re-assessments of the competence of certified persons.

However, it is necessary to distinguish between situations where certification schemes for persons are justified and situations where other forms of qualification are more appropriate. The development of certification schemes for persons, in response to the ever-increasing velocity of technological innovation and growing specialization of personnel, can compensate for variations in education and training and thus facilitate the global job market. Alternatives to certification can still be necessary in positions where public services, official or governmental operations are concerned.

In contrast to other types of conformity assessment bodies, such as management system certification bodies, one of the characteristic functions of the certification body for persons is to conduct an examination, which uses objective criteria to measure competence and scoring. While it is recognized that such an examination, if well planned and structured by the certification body for persons, can substantially serve to ensure impartiality of operations and reduce the risk of a conflict of interest, additional requirements have been included in this International Standard.

In either case, this International Standard can serve as the basis for the recognition of the certification bodies for persons and the certification schemes under which persons are certified, in order to facilitate their acceptance at the national and international levels. Only the harmonization of the system for developing and maintaining certification schemes for persons can establish the environment for mutual recognition and the global exchange of personnel.

This International Standard specifies requirements which ensure that certification bodies for persons operating certification schemes for persons operate in a consistent, comparable and reliable manner. The requirements in this International Standard are considered to be general requirements for bodies providing certification of persons. Certification of persons can only occur when there is a certification scheme. The certification scheme is designed to supplement the requirements included in this International Standard and include those requirements that the market needs or desires, or that are required by governments.

This International Standard can be used as a criteria document for accreditation or peer evaluation or designation by governmental

authorities, scheme owners and others.

In this International Standard, the following verbal forms are used:

- “shall” indicates a requirement;
- “should” indicates a recommendation;
- “may” indicates a permission;
- “can” indicates a possibility or a capability.

Further details can be found in the ISO/IEC Directives, Part 2.

### \*\*\*ISO/IEC 17025 General requirements for the competence of testing and calibration laboratories (Source Wikipedia)

ISO standard used by testing and calibration laboratories. In most major countries, ISO/IEC 17025 is the standard for which most labs must hold accreditation in order to be deemed technically competent. In many cases, suppliers and regulatory authorities will not accept test or calibration results from a lab that is not accredited. Originally known as ISO/IEC Guide 25, ISO/IEC 17025 was initially issued by the International Organization for Standardization in 1999. There are many commonalities with the ISO 9000 standard, but ISO/IEC 17025 is more specific in requirements for competence and applies directly to those organizations that produce testing and calibration results and is based on somewhat more technical principles. Since its initial release, a second release was made in 2005 after it was agreed that it needed to have its quality system words more closely aligned with the 2000 version of ISO 9001.

The standard was first published in 1999 and on 12 May 2005 the alignment work of the ISO/CASCO committee responsible for it was completed with the issuance of the reviewed standard. The most significant changes introduced greater emphasis on the responsibilities of senior management, and explicit requirements for continual improvement of the management system itself, and particularly, communication with the customer.

The 2005 version of ISO/IEC 17025 comprises five elements that are Scope, Normative References, Terms and Definitions, Management Requirements and Technical Requirements. The two main sections in ISO/IEC 17025 are Management Requirements and Technical Requirements. Management requirements are primarily related to the operation and effectiveness of the quality management system within the laboratory. Technical requirements include factors which determines the correctness and reliability of the tests and calibrations performed in laboratory.

The 2017 version of ISO/IEC 17025 has modified this structure to be Scope, Normative References, Terms and Definitions, General Requirements, Structural Requirements, Resource Requirements, Process Requirements, and Management System Requirements. General Requirements and Structural Requirements are related to the organization of the laboratory itself. Structure Requirements cite those issues related to the people, plant and other organizations used by the laboratory to produce its technically valid results. Process Requirements are the heart of this version of the standard in describing the activities to ensure that results are based on accepted science and aimed at technical validity. Management System Requirements are those steps taken by the organization to give itself tools quality management system in supporting the work of its people in the production of technically valid results.

Laboratories use ISO/IEC 17025 to implement a quality system aimed at improving their ability to consistently produce valid results. It is also the basis for accreditation from an accreditation body. Since the standard is about competence, accreditation is simply formal recognition of a demonstration of that competence. A prerequisite for a laboratory to become accredited is to have a documented quality management system. The usual contents of the quality manual follow the outline of the ISO/IEC 17025 standard.

**ISO 18436-1** was prepared by Technical Committee ISO/TC 108, Mechanical vibration, shock and condition monitoring, Subcommittee SC 5, Condition monitoring and diagnostics of machines.

This second edition cancels and replaces the first edition (**ISO 18436-1:2004**), which has been technically revised. It also incorporates the Technical Corrigendum **ISO 18436-1:2004/Cor. 1:2006**.

**ISO 18436** consists of the following parts, under the general title Condition monitoring and diagnostics of machines — Requirements

for qualification and assessment of personnel:

- Part 1: Requirements for assessment bodies and the assessment process
- Part 2: Vibration condition monitoring and diagnostics
- Part 3: Requirements for training bodies and the training process
- Part 4: Field lubricant analysis
- Part 5: Lubricant laboratory technician/analyst
- Part 6: Acoustic emission
- Part 7: Thermography

The following part is under preparation:

- Part 8: Ultrasound

The following part is planned:

- Part 9: Condition monitoring specialists

**ISO 18436-3** Condition monitoring and diagnostics of machines are integral parts of an effective maintenance program. Non-intrusive technologies used in condition monitoring and fault diagnosis include vibration, infrared thermography, oil and wear debris analysis, acoustic and ultrasonic analysis, and electrical signature analysis. In many instances, these technologies act as complementary condition monitoring tools. The skills and expertise of the practitioners performing the measurements and analyzing the data are critical to the effective application of these technologies.

This part of **ISO 18436** defines the requirements for bodies operating training programs in the non-intrusive machine condition monitoring, diagnostic, and correction technologies. General requirements for training body personnel are contained in this part of **ISO 18436**. Specific requirements for personnel in condition monitoring and diagnostics are covered in other parts of **ISO 18436**.

## 1 Scope

This part of **ISO 18436** defines the requirements for bodies operating training programs for personnel who perform machinery condition monitoring, identify machine faults, and recommend corrective action. Procedures for training of condition monitoring and diagnostics personnel are specified.

**ISO 18436-8** (Still in development) Using thermography to monitor condition and diagnose faults in machinery is a key activity in predictive maintenance programs for most industries. Other non-intrusive technologies including vibration analysis, acoustic emission, lubricant analysis, and motor current analysis are used as complementary condition analysis tools. Those in the manufacturing industry who have diligently and consistently applied these techniques have experienced a return on investment far exceeding their expectations. However, the effectiveness of these programs depends on the capabilities of individuals who perform the measurements and analyze the data.

A program, administered by an assessment body, has been developed to train and assess the competence of personnel whose duties require the appropriate theoretical and practical knowledge of machinery monitoring and diagnostics.

This part of **ISO 18436** defines the requirements against which personnel in the non-intrusive machinery condition monitoring and diagnostics technologies associated with ultrasonic testing equipment for machinery condition monitoring are to be qualified and the methods of assessing such personnel.

## 1 Scope

This part of **ISO 18436** specifies the requirements for qualification and assessment of personnel who perform machinery condition monitoring and diagnostics using ultrasound.

A certificate or declaration of conformity to this part of **ISO 18436** will provide recognition of the qualifications and competence of individuals to perform ultrasonic inspections and analysis for machinery condition monitoring using portable ultrasonic testing equipment. This procedure might not apply to specialized equipment or other specific situations.

This part of **ISO 18436** specifies a three-category classification program that is based on the technical areas delineated herein

**ISO 29821-1** This part of **ISO 29821** provides guidance for the condition monitoring and diagnostics of machines using airborne and structure-borne ultrasound (A&SB ultrasound). A&SB ultrasound can be used to detect abnormal performance or machine anomalies. The anomalies which are detected are high-frequency acoustic events caused by turbulent flow, ionization events, and friction, which are caused, in turn, by incorrect machinery operation, leaks, improper lubrication, worn components or electrical discharges.

A&SB ultrasound is based on measuring the high-frequency sound that is generated by turbulent flow, by friction or by the ionization created from the anomalies. The inspector therefore requires an understanding of ultrasound and how it propagates through the atmosphere and through structures as a prerequisite to the creation of an A&SB ultrasound program.

## 1 Scope

This part of **ISO 29821** outlines methods and requirements for carrying out condition monitoring and diagnostics of machines using airborne and structure-borne ultrasound. It provides measurement, data interpretation, and assessment criteria. This technique is typically carried out on operating machinery under a range of conditions and environments. This is a passive technique that detects acoustic anomalies produced by machines.

**ISO 29821-1** was prepared by Technical Committee ISO/TC 108, Mechanical vibration, shock and condition monitoring, Subcommittee SC 5, Condition monitoring and diagnostics of machines.

**ISO 29821** consists of the following parts, under the general title Condition monitoring and diagnostics of machines — Ultrasound:

- Part 1: General guidelines

The following part is planned:

- Part 2: Procedures and validation

## ASTM STANDARD E 1002-11

### Scope

1.1 Practice A, Pressurization—This practice covers procedures for calibration of ultrasonic instruments, location, and estimated measurements of gas leakage to atmosphere by the airborne ultrasonic technique.

1.2 In general practice this should be limited to leaks detected by two classifications of instruments, Class I and Class II. Class I instruments should have a minimum detectable leak rate of  $6.7 \times 10^{-7}$  mol/s ( $1.5 \times 10^{-2}$  std. cm<sup>3</sup>/s at 0°C) or more for the pressure method of gas leakage to atmosphere. Class II instruments should have a minimal detectable leak rate of  $6.7 \times 10^{-6}$  mol/s ( $1.5 \times 10^{-1}$  std. cm<sup>3</sup>/s at 0°C) or more for the pressure method of gas leakage to atmosphere. Refer to Guide E432 for additional information.

1.3 Practice B, Ultrasonic Transmitter—For object under test not capable of being pressurized but capable of having ultrasonic tone placed/injected into the test area to act as an ultrasonic leak trace source.

1.3.1 This practice is limited to leaks producing leakage of  $6.7 \times 10^{-6}$  mol/s ( $1.5 \times 10^{-1}$  std. cm<sup>3</sup>/s at 0°C) or greater.

1.4 The values stated in SI units are to be regarded as the standard.

1.5 This standard does not purport to address all the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory

limitations prior to use.

USGS

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