

INTEGRATED CONDITION MONITORING TECHNOLOGIES FOR ENERGY SAVING APPLICATIONS

TRANSTECH
CONFERENCE
2018, PUNE

WHAT IF WE CANNOT SEE IT,
it is not there...

WHAT IF WE CAN NOT HEAR IT,
It is not there...

This is what we have been taught since
we were born....

Doing Things differently leads
to something exceptional



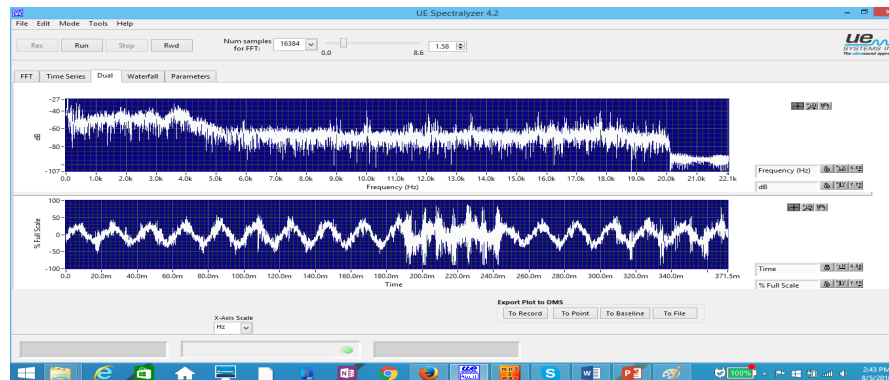
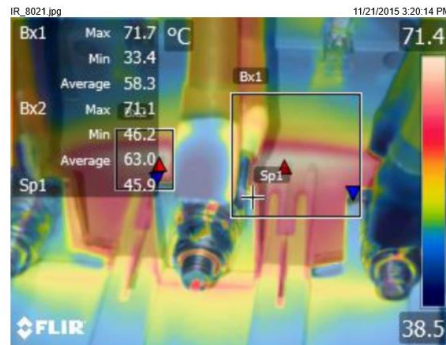
GREEN SAILS SINGAPORE CONDITION MONITORING TECHNOLOGIES FOR MARINE, OFFSHORE AND INDUSTRY

The general idea behind Condition Monitoring:

Condition Based Monitoring or Machine Health Monitoring is to save cost, improve performance, prevent accidents, crew confidence & environment

Preventive maintenance

Costs are high when we maintain on schedule, Too often, disassembly and reassembly create damage.



Reactive maintenance

Costs are high-run machines until they fail and replace machines as needed.

Predictive maintenance

Costs are lower when we maintain only when a known need exists, what is the defect, how high, where and what spares and services to correct the defect.

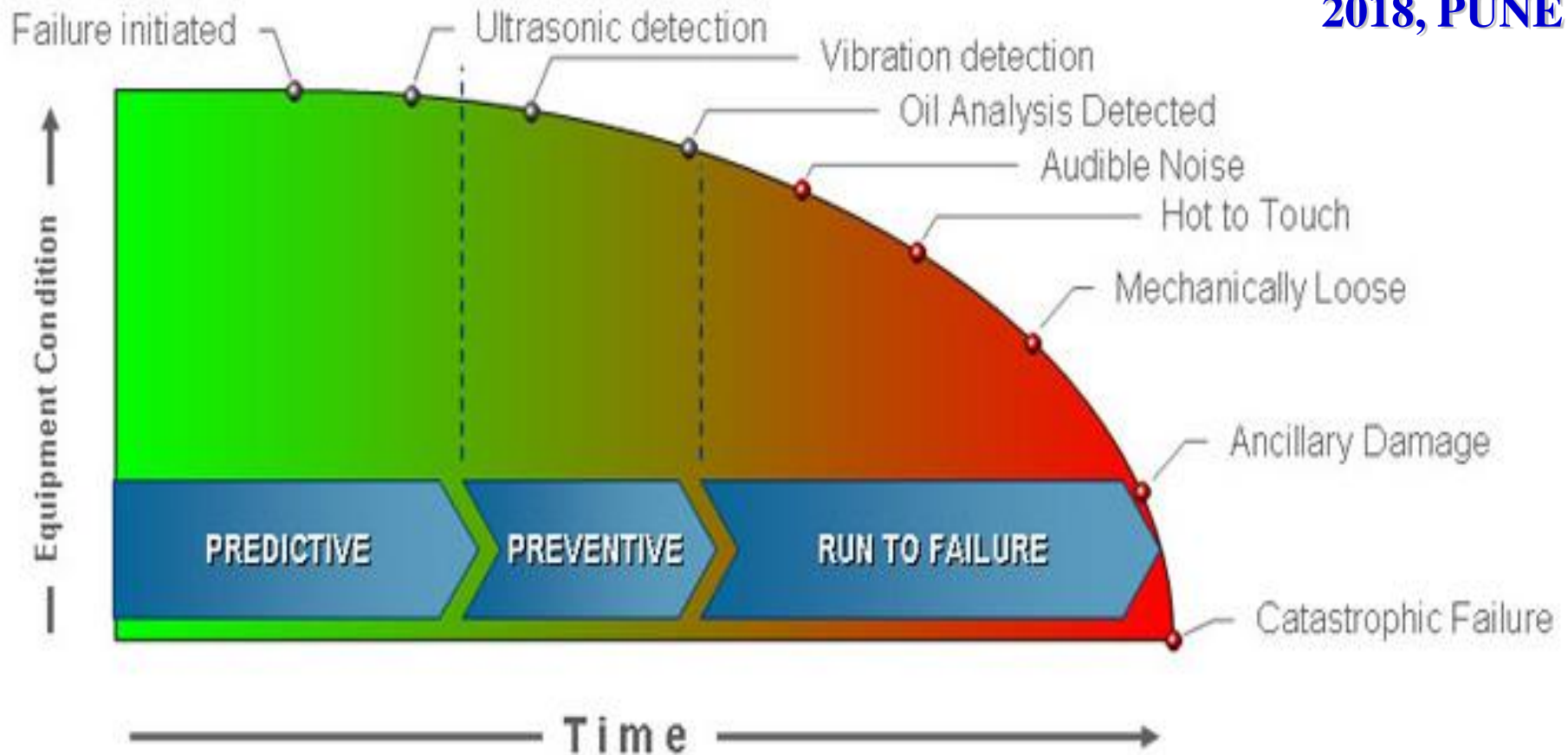
**Condition monitoring or Integrating
Vibration analysis with **Ultrasound** and
Infrared thermography applications for
Marine and off shore Industry**

Three Proven Technologies

**'To Help & Keep Your machinery running'
with best results in-**

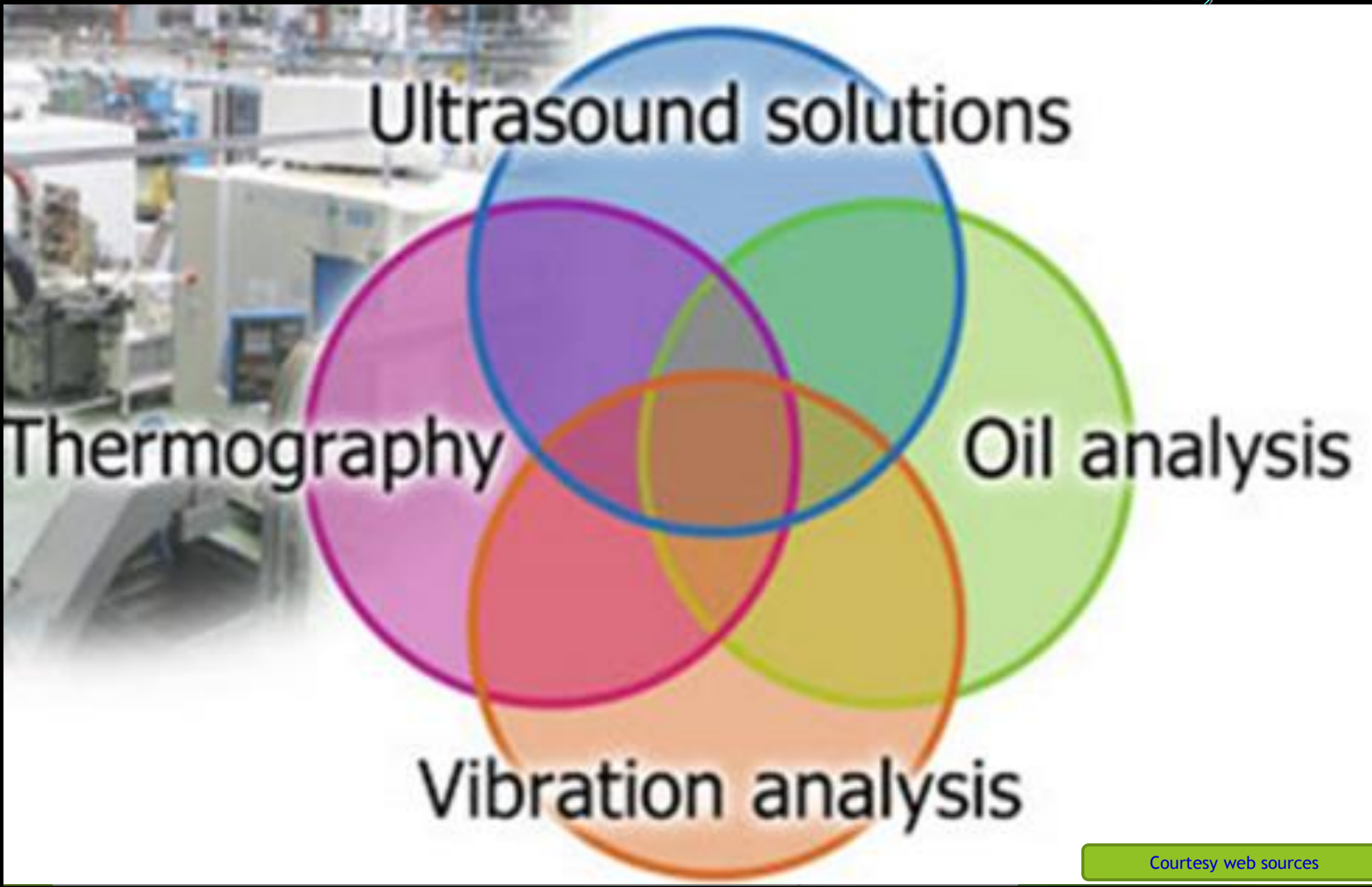
- Economy,**
- Prevent accidents and incidents,**
- Improve operator confidence.**
- Prevent environment pollution**

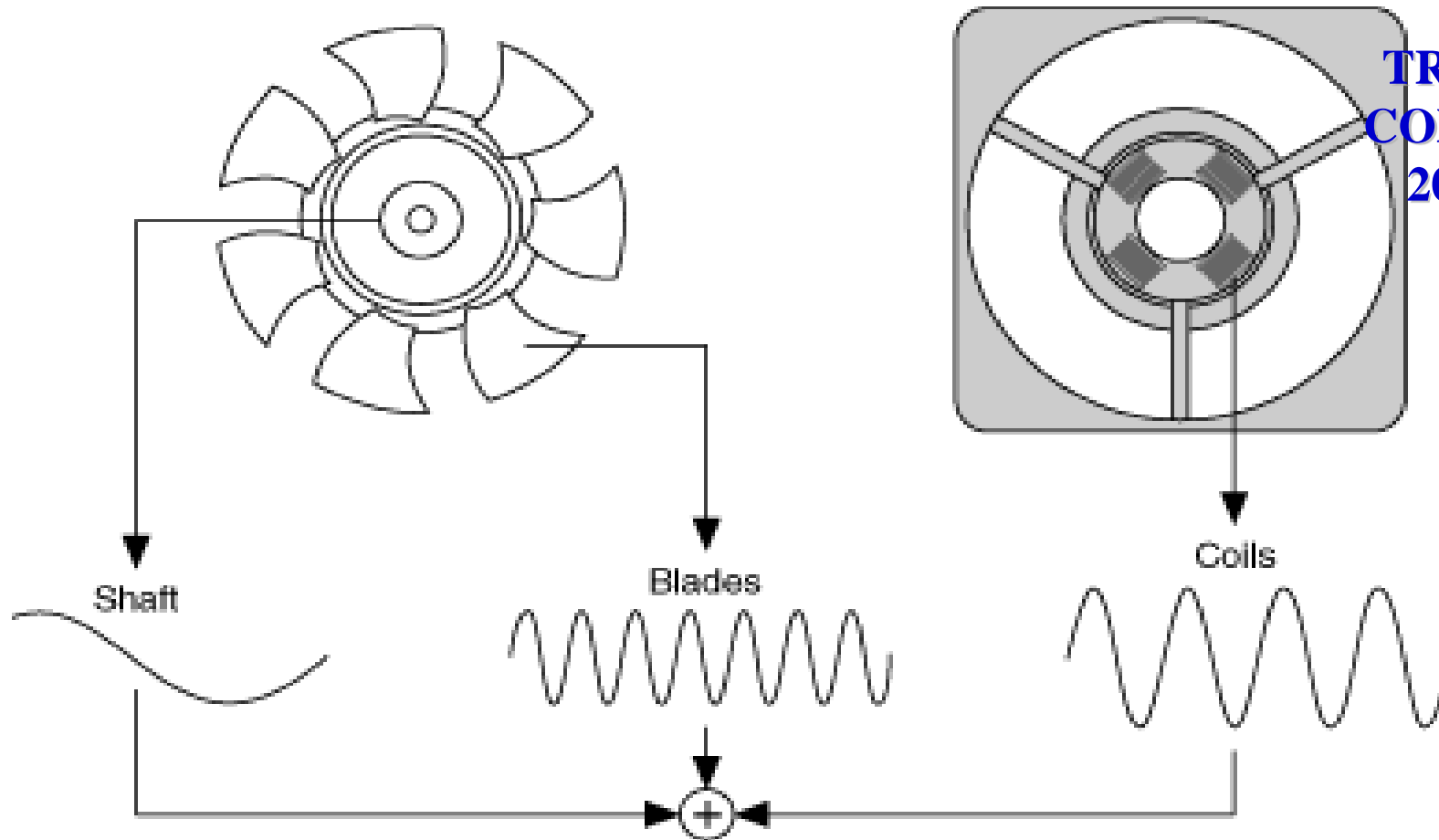




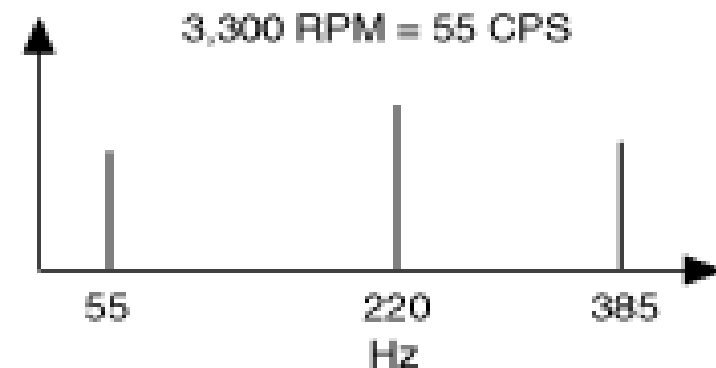
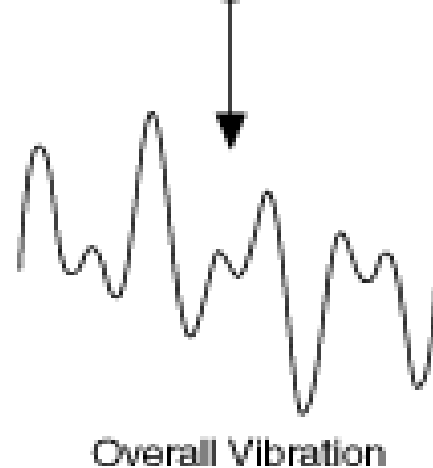
Lead times to failure offered by various conventional condition monitoring techniques

Integrating Infrared with Ultrasound and Vibrations
analysis applications for Marine and Off shore Industry





BASIC
understanding
of vibration and
component
frequencies
analysis



Vibrations of machinery

We basically compare today's vibration spectrum (or "signature") with other spectra obtained using the same instruments at the same locations last week, last month, or last year, or when the machine was first installed or immediately after an overhaul. We try to deduce internal changes (deterioration) from changes in the spectrum.



RMS values and temperature of bearing



Machine Expert



FFT spectrum with peaks detection



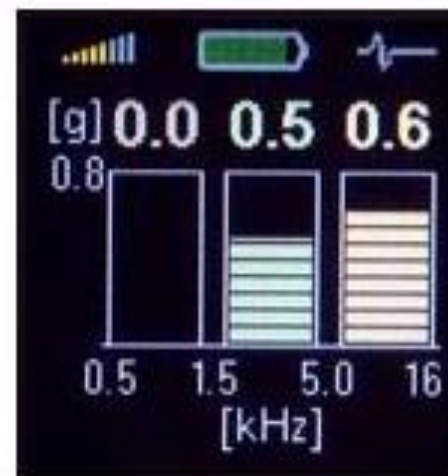
Acc time signal for bearing condition



Temperature



Peak values



Acc band values

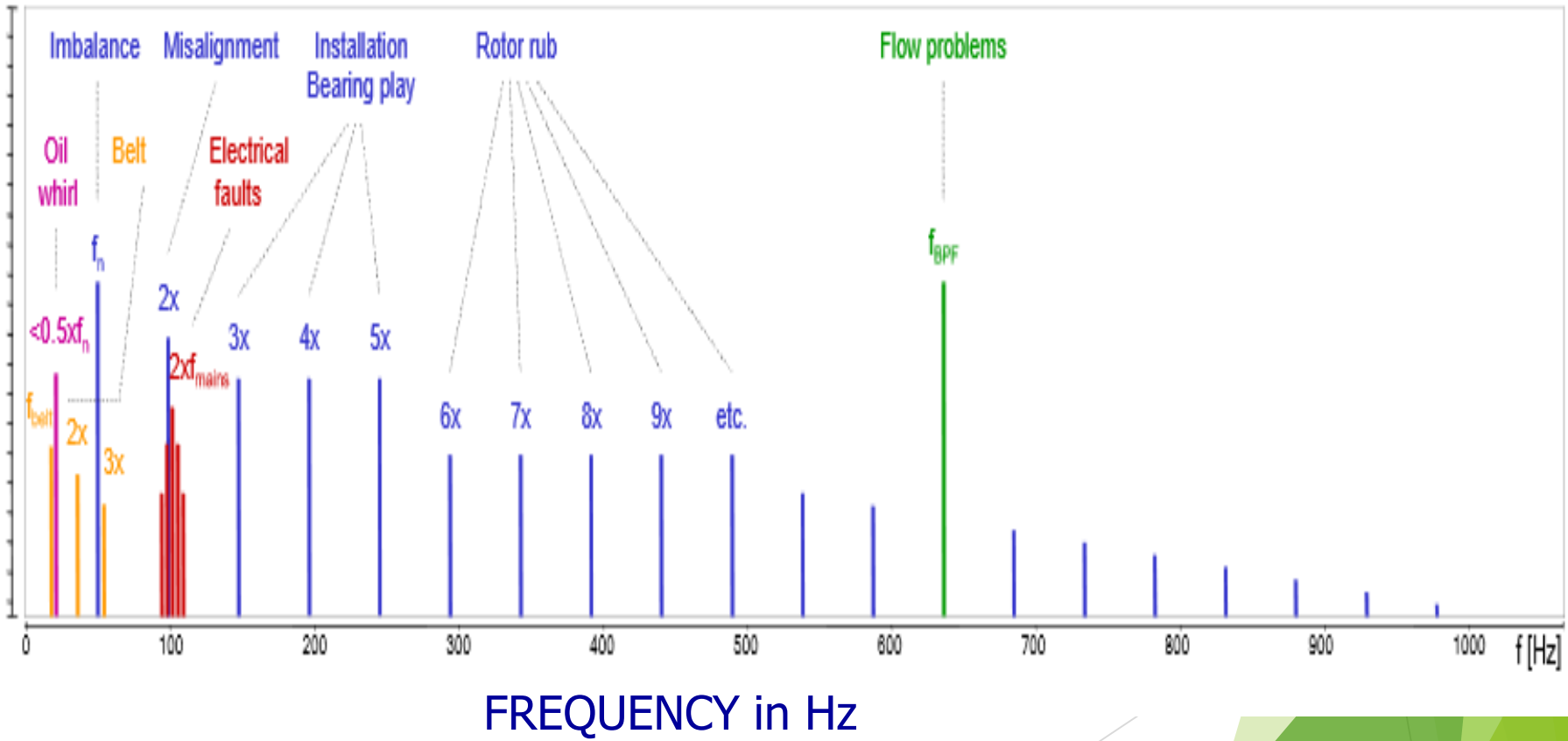


Displacement values

FFT Spectrum in **Velocity** Vibration and the possible faults can identify from the spectrum

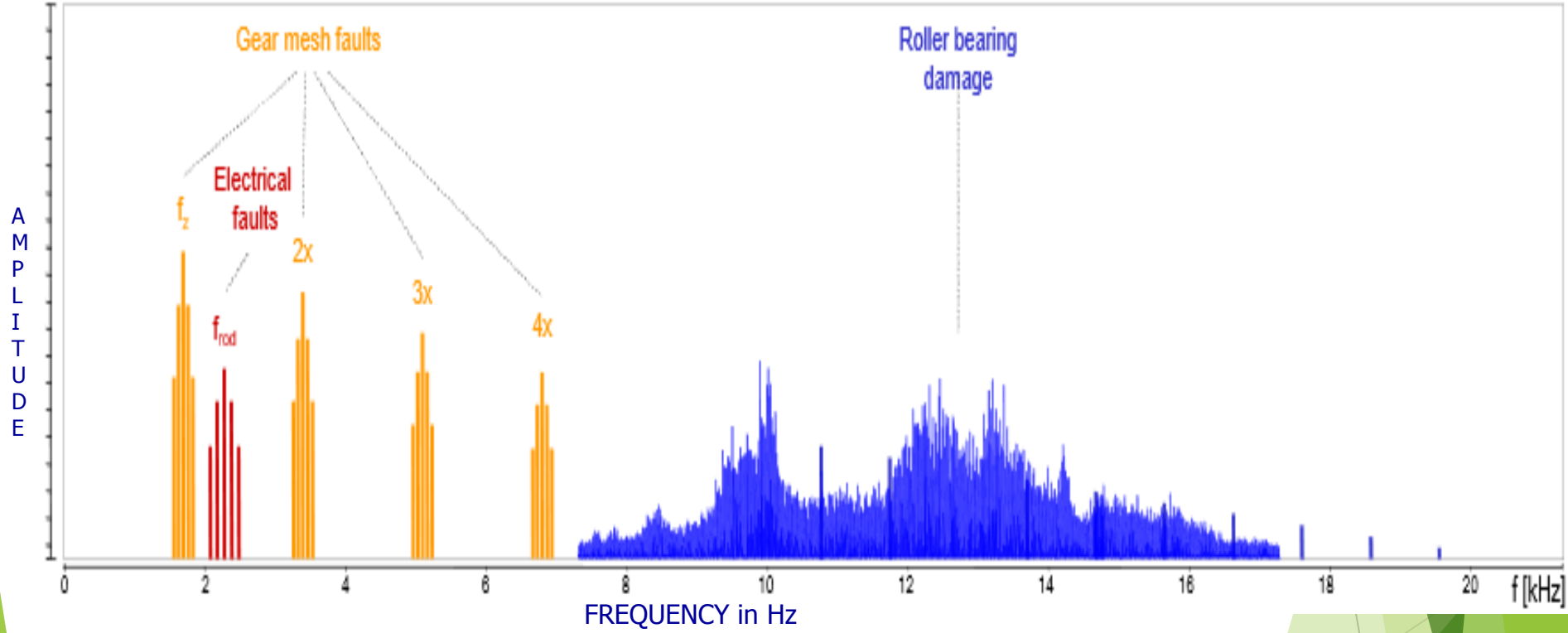
mm/s

A
M
P
L
I
T
U
D
E



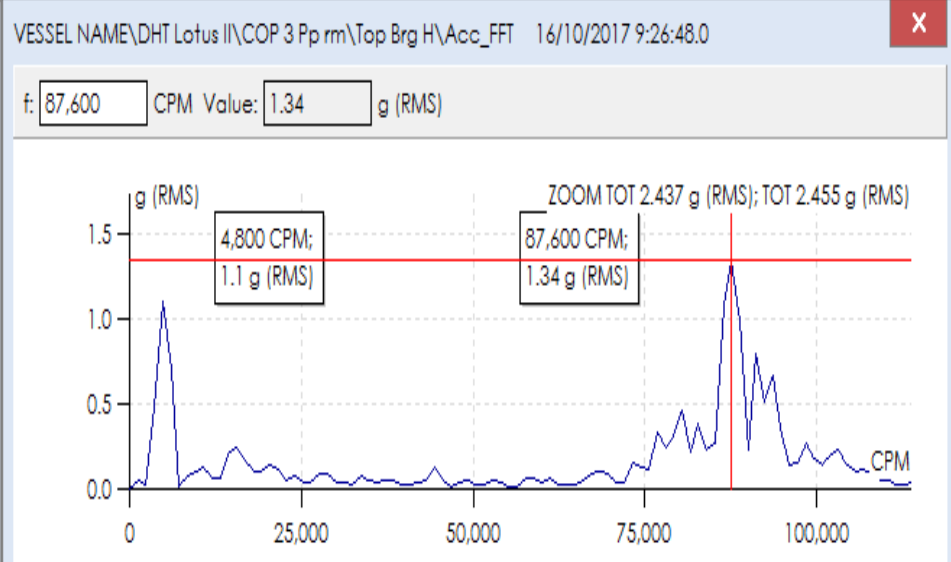
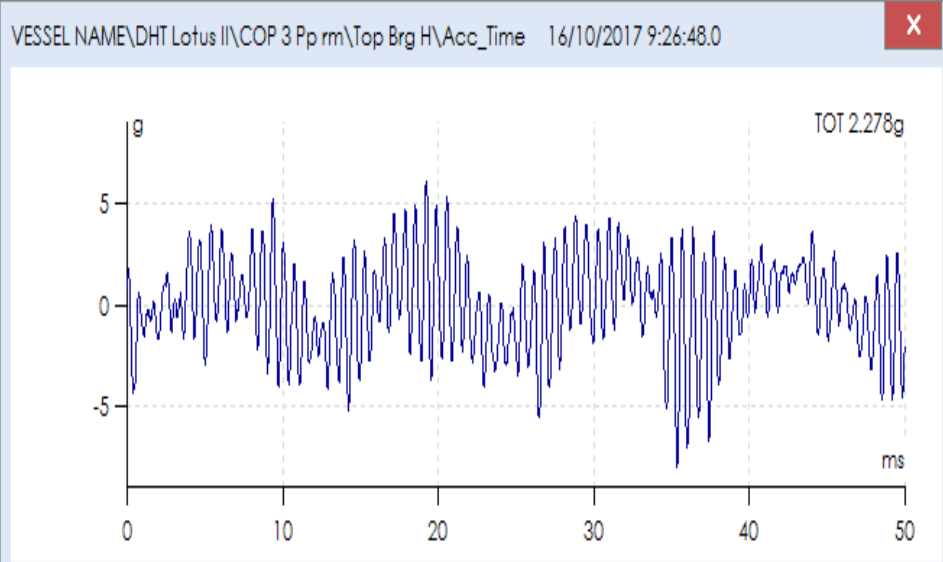
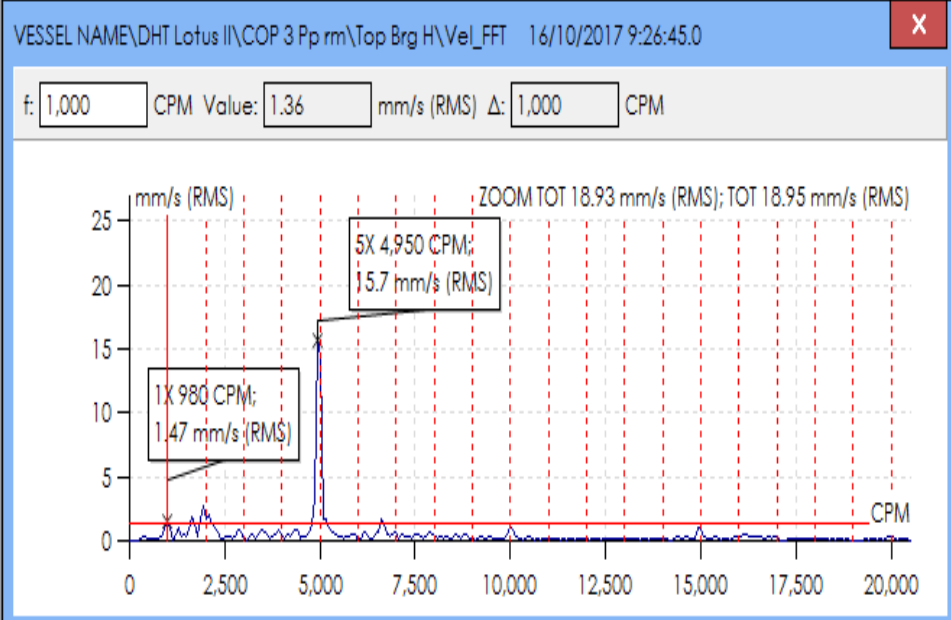
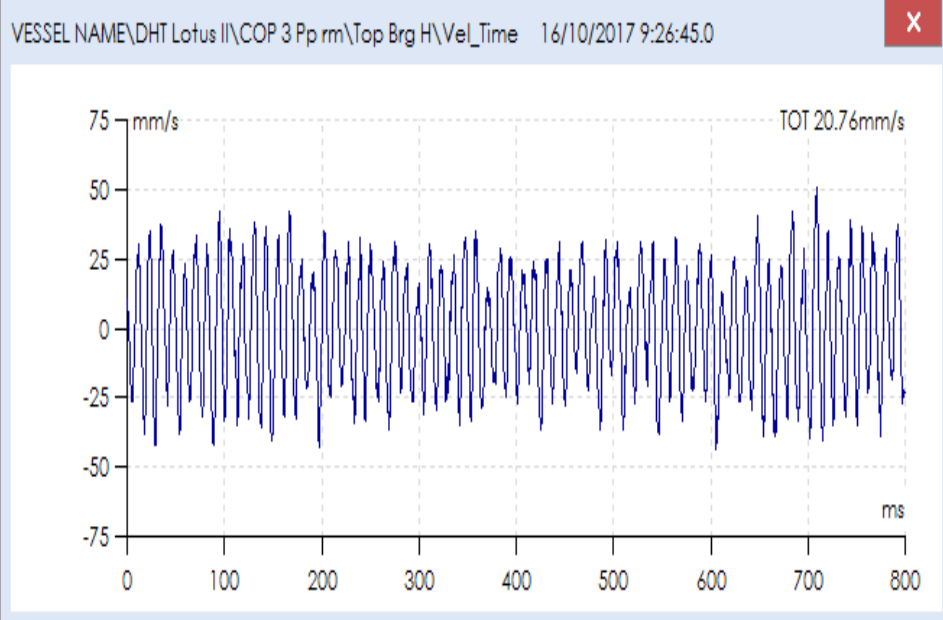
Vibration analysis in Acceleration broadband spectrum

a [m/s²]



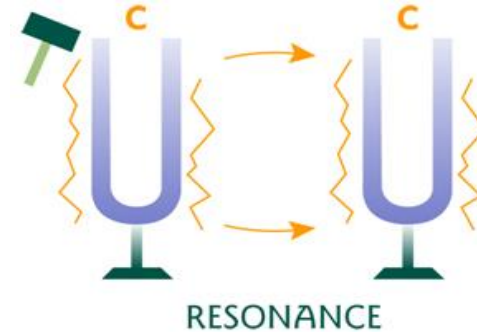
Time wave form - sample of random vibration

FFT spectrum of above wave form



Resonance

The Silent Killer of Rotating Machinery



- Resonance occurs in a system when the frequency of a vibratory force (forcing frequency) is at or near a natural frequency.
- Vibration levels at resonance are controlled through damping. Vibration amplification is determined by the proximity of the forcing frequency to natural frequency.
- When high vibration is noted in rotating machinery, the analyst should conduct a thorough vibration analysis before applying commonly used resonance fixes. After all, excessive vibration could result from one or a combination of the following non-resonance situations:
 1. pedestals, foundations, or structures
 2. loose or missing bolts, broken welds, soft foot, or
 3. mismatched parts excessive vibratory force
 4. lack of damping.

SOLUTIONS FOR RESONANCE

To confirm the state of resonance in machinery, the analyst must verify the location of the system's natural frequencies with a simple impact test, operating deflection shape, or modal test. The modal test will typically yield the most information.

Solutions

Reducing resonant-equipment vibration levels can involve any of the following actions, or a combination thereof:

1. Raising or lowering the natural frequency to distance it from the forcing frequency
2. Adding damping
3. Attaching an absorber.

1. 4.0 K Hz – 01:15:24
2. 6.35 Hz- 02:09:24
3. 11.35 Hz- 03:31:36



Tree Graph Report Route Tools Help

Lock Align Acc Vel Disp 1x Grid Bands Zoom Auto Scale Trend Limits

Type Peak Jump Graph Y-Unit X-Unit Quantity Enter Speed Setting

Cursor

Setting

Graphs Labels

Machine 01 [M]

- Point 1 AC compr no1 MDEV [1D]
- Point 2 Essen Bottom BT bit brg L0 [1D]
- Point 3 Essen BTaft bottom brgL1 [1D]
- Point 4 AC compr no2 motor DEV [1D]

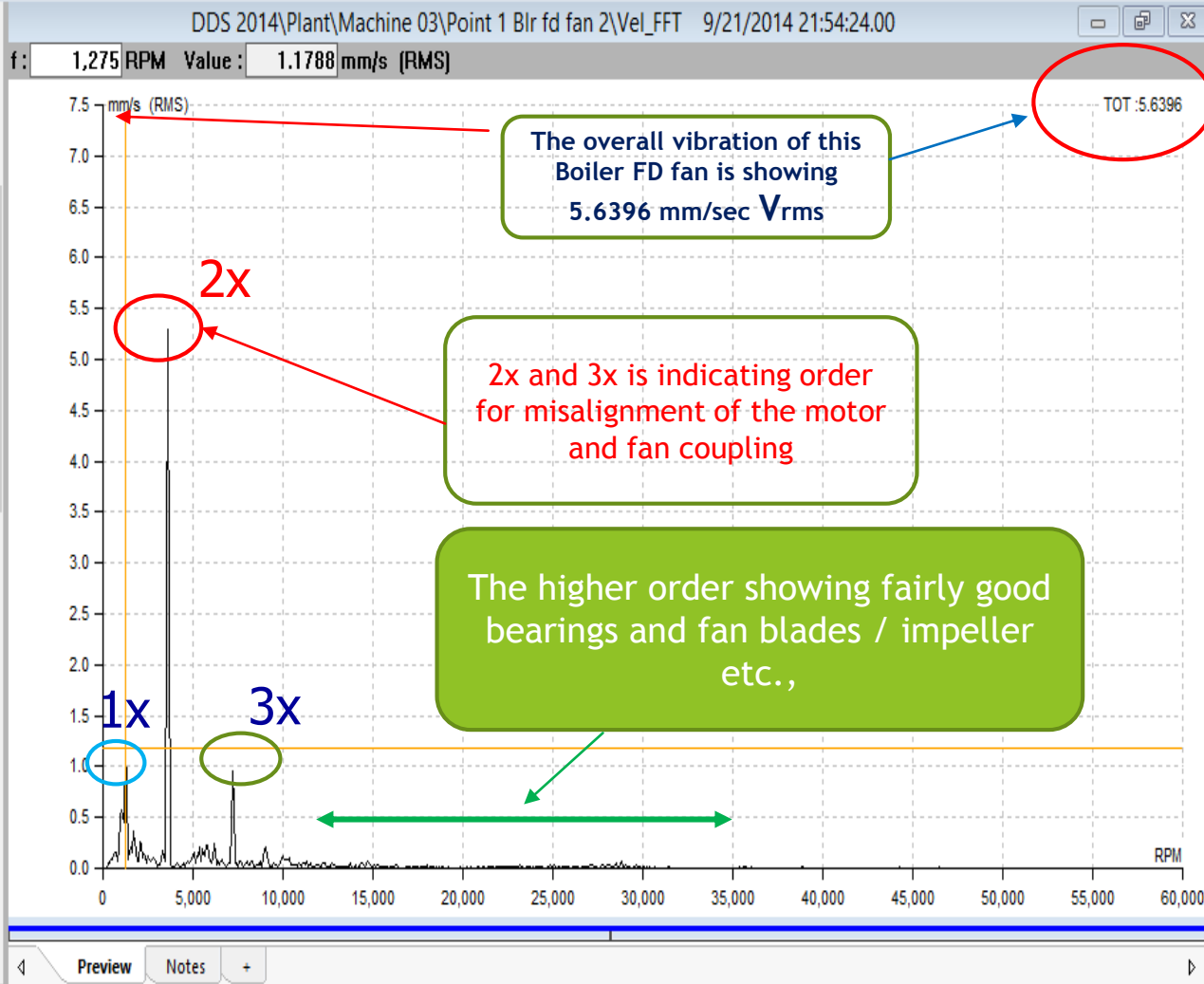
Machine 02 [M]

- Point 1 IG fan 1 Zambesi [1D]
- Point 2 IG fan1 casing [1D]
- Point 3 [1D]
- Point 4 [1D]

Machine 03 [M]

- Point 1 Blr fd fan 2 [1D]

- Vel_RMS
- Acc_RMS
- Vel_Time
- Vel_FFT
- Acc_Time
- Acc_FFT
- Demod_RMS
- Demod_FFT





VIBRATION ANALYSIS CHART

IMBALANCE

Unbalance occurs when the center of mass differs from the center of rotation, resulting in a heavy spot on a rotor. This heavy spot produces a centrifugal force causing high vibration amplitudes at a frequency equal to 1xRPM (1x rotational speed) in spectral data and a sinusoidal waveform in the time domain. On rigidly mounted machines amplitudes will typically be highest in the horizontal direction whereas the vertical direction, although raised amplitudes can also exist usually on overhung rotors. The imbalance amplitude will increase by the square of speed (when the rotating speed is below the 1st rotor critical frequency). Typically a 90° phase difference will exist between horizontal and vertical readings at each bearing with a pure imbalance problem.

MISALIGNMENT

Misalignment occurs when the shaft centerlines of two directly mating components meet at angles and/or are offset from one another. Misalignment of shafts and bearings typically results in high radial and/or axial vibration. Angular misalignment (flexion) produces radial axial amplitudes with a phase difference of 90° across speed couplings. Shaft misalignment typically produces high radial amplitudes with a phase difference of 180° radially across couplings. A misalignment problem will typically produce dominant frequencies at 1xRPM and/or 2xRPM, depending upon the degree of angular misalignment versus shaft offset misalignment, as well as the type and design of the coupling. In addition, when 1xRPM dominates due to a misalignment problem, phase readings are essential to distinguish from an imbalance problem. Waveforms typically show repetitive, steady patterns with one or two clear cycles per shaft revolution.

LOOSENESS (Structural & Component)

Mechanical Looseness occurs when rotating components do not fit correctly. A number of spinning and/or harmonics will dominate spectral data (i.e. 1x, 2xRPM). In certain instances and stages of deterioration, spectral data may also show sub-harmonic multiples of 1xRPM. Waveforms typically show high random irregular patterns, and in some instances the waveform may appear truncated. Looseness in the rotor or frame or disturbed machine feet (soft feet), loose foundations, weak grouting, loose bolts or fastenings. These conditions typically produce a frequency at 1xRPM and/or 2xRPM similar to spectral data (rotational amplitudes may be more predominant), depending upon the type of structural problem. Waveforms are typically periodic, with one or two cycles per shaft revolution.

BLADE / VANE PASS

Any machines which handle fluids such as water, gases, air and oil will typically produce an inherent vibration frequency (due potential harmonics) equal to: Number of Blades or Vanes x RPM. This inherent machine characteristic is normally referred to as Blade or Vane Pass Frequency (BPF or VPF). Excessive BPF or VPF amplitudes can result from issues of worn distributed gaps between rotating vanes and static diffusers. Should a BPF or VPF coincide with a system natural frequency that extremely high derivative amplitudes will be experienced.

BELTS

The Primary Belt Frequency (PBF) is equal to the number of times per sec (Hz) or RPM (CPM) that a belt rotates around the drive system, which can be calculated from the formula below. Belt problems, which produce PBF and/or harmonics (twice, wear, cracks, misalignment, incorrect tension, hard or soft spots, it is not unusual to see PBF frequencies in spectral, and often 2x PBF rate for the most dominant peak. The highest amplitude will typically be radial and in-line with belts. Misaligned pulleys/belts normally produce a 1xRPM frequency activity.

ROLLING ELEMENT BEARINGS

4 Stages to Rolling Element Bearing Failure

FTF = Fundamental Train Frequency
 BSF = Ball Pass Frequency
 BIF = Ball Inner Race Frequency
 BOP = Ball Outer Race Frequency

Cage Defects (FTF)

Fundamental cage defect frequencies normally occur between 0.35-0.45RPM (sub-synchronous energy). Cage defects are usually accompanied by other defective bearing components, such as ball/roller defects and appear as elevated frequencies. Cage defects often cause rapid bearing failures, making them more difficult to detect. Cage defects rarely produce high amplitudes and could potentially be confused with other problems, therefore it is important to capture high resolution conventional data, as well as use advanced troubleshooting techniques if available.

Ball / Roller Defects (BSF)

BSF appear when damage occurs to the surface of a bearing's rolling elements. Ball and roller defects are typically non-synchronous frequencies, which can appear at the fundamental BSF or 2xBSF with associated harmonics, that may be larger in amplitude depending upon the number of damaged rolling elements. It is common to see the fundamental BSF or 2xBSF and harmonics surrounded by cage (FTF) related frequencies. BSF defects can also be recognized from the time waveform where impacts equal to the fundamental BSF or related predominant BSF harmonics(s) may be present.

Outer Race Defects (BFO)

BFO are created as rolling elements pass across a defect(s) in the outer race. The fundamental BFO is generally non-synchronous, although on some bearings (depends on geometry) this is close enough to appear as a synchronous frequency. This problem typically shows severe harmonics of the fundamental BFO, which are often higher in amplitude. Where the outer race rotates and inner race remains stationary, BFO frequencies can be modulated by the shaft speed, resulting in BPF sidebands surrounding BFO defects. Time waveforms typically show distinctive high impact beats (1/2), spaced at the fundamental BFO or related dominant harmonics.

Inner Race Defects (BFI)

BFI are created as rolling elements pass across a defect(s) in the inner race. The fundamental BFI is generally non-synchronous, although on some bearings (depends on geometry) this is close enough to appear as a synchronous frequency. Spectral and waveform characteristics for BFI problems are very similar to that defined for BFO, although a relative difference is 1xRPM related frequencies will typically surround the fundamental BFI and/or harmonics due modulation by the shaft speed versus applies where inner race remains stationary). A once per revolution of the time waveform may also occur as a BFI fault passes through the load zone, making the waveform appear similar to a "half of angle" fault.

SLEEVE BEARINGS

Oil Whirl Instability

These bearings with excessive clearance allow small excitation forces, such as imbalance, to cause significant vibration amplitudes. Spectral data typically shows predominant synchronous frequencies between approximately 1 to 10RPM, depending on problem severity. In some cases 1xRPM and harmonics may also apply. Worn sleeve bearings can show higher vertical amplitudes compared with horizontal, and may show a pronounced 1xRPM. Oil whirl occurs when the oil film in some lubricated systems creates a force that causes the shaft to whirl within the bearing. This problem typically occurs between 0.4 to 0.6RPM, and may result from improper bearing design, or viscosity of pressure.

GEAR DEFECTS

Gearmesh Frequency

• Gearmesh Frequency: 1st and 2nd Harmonics of Gear Mesh Frequency
 • One GMP per pair of gears
 • Gearmesh Freq will always be present regardless of gear condition. Amplitude may increase due to load or gear condition.

Normal Gearmesh Vibration

Fundamental gear mesh frequencies (GMP) are calculated by # Gear Teeth x Shaft RPM (apply the same calculation to every shaft in the gear train). However, the fundamental GMP will normally represent a problem, due to the inherent nature of this frequency being present in virtually all gear systems. Changes in fundamental GMP amplitude may typically be the result of varying load. Waveforms should appear relatively steady with little sign of impacting, although amplitudes will vary with load. It is typical to see the spectral frequency range at least 3:1 to the fundamental GMP (where high speed shafts and high GMP occur, identify use treatment methods).

Worn Gears

A key characteristic of worn gear(s) is the presence of sidebands, which show up as frequencies equally spaced either side of the GMP or related harmonics. These sideband frequencies will be equal to the rotational speed of the shaft(s) with the defective gear(s) or, not only in the presence of sidebands surrounding the GMP important when analyzing worn gears, but the amplitudes of these sidebands in relation to the GMP. The higher the sideband amplitudes, the more severe the gear wear is likely to be. Worn gears can also excite the natural frequencies of the gears and/or casing.

Chipped / Broken Gear Teeth

A single chipped or broken gear tooth will produce a 1xRPM vibration. It is difficult to identify this problem using conventional spectral data alone, as the characteristic frequency can easily be confused with other problems occurring at 1xRPM. The best way of identifying this problem is by using the time domain, where a once per revolution (1xRPM) impact will be captured followed by a transient acceleration, ensuring that the time period set-up captures as many shaft revolutions as possible.

Misaligned Gears

Misaligned gears will generally produce raised vibration amplitudes at 2xGMP and 3xGMP, which will typically be substituted at 1xRPM or 2xRPM. Therefore, it is essential to always capture at least 3 GMP's when either troubleshooting or taking routine vibration data, in general terms viewing both the time waveforms and spectral data in acceleration provides the best representation of gear misalignment problem, particularly where the 1xRPM is greater than 1.5xRPM (3000RPM). Where gear misalignment exists this is likely to be accompanied by a degree of gear mesh, especially if the problem has been present for sometime.

BEAT VIBRATION

Beats occur when two or more primary frequencies are very close to one another causing them to "beat" together. Beats are common where rotational speeds are running close together, such as a ball drum motor and pump set with a 1:1 ratio, where the only difference between component speeds is slip. The beat frequency (BPF) is the difference between the two primary frequencies. Beats usually cause vibration amplitudes to increase and decrease at an equally rapid rhythm, and maximum amplitudes occur when these primary frequencies come into phase with one another. When a beat is suspected it is important to capture a high-resolution or true time approach to confirm the problem.

RESONANCE

Resonance is a condition where the frequency of an external force coincides with the natural resonant frequency of a system, resulting in dramatic (often disastrous) amplitudes. Using analytical analysis a 180° phase shift can be observed as a system approaches, enters (90° out of phase) and passes through a resonance. Taking 2D-D non-synchronous data also allow resonant frequencies to be analyzed. Steady testing allows resonant frequencies to be identified by repeating a system component and measuring the resultant frequency response time response linear averaging until machine cannot be stopped. When resonance is suspected, look for abnormally higher amplitudes in one axis versus others. Changing a systems damping, such as stiffness will alter the natural frequencies, allowing more operational speeds over treatment frequency regions. The speed should ideally be 30% higher or lower than the critical speed.

CAVITATION / RECIRCULATION

Occurs when the pressure of fluid drops below the vapor for the temperature of the fluid. When a system or localized pressure (drop occurs, voids or cavities (bubbles) will form in the liquid. These bubbles implode or collapse when the fluid moves through the impeller to the high pressure side of the pump, causing the impeller to vibrate. Spectra is typically dominated by high frequency broadband energy present above the impeller blade pass frequency, with random impacting in the time waveform. Recirculation occurs in the presence of a high pressure structure (such as a pump) that feeds from the output back through the pump. Recirculation is a hydraulic source of 1xRPM, as well as sub-synchronous broadband noise.

ELECTRICAL RELATED FAULTS

GENERALIZED STATOR FAULTS

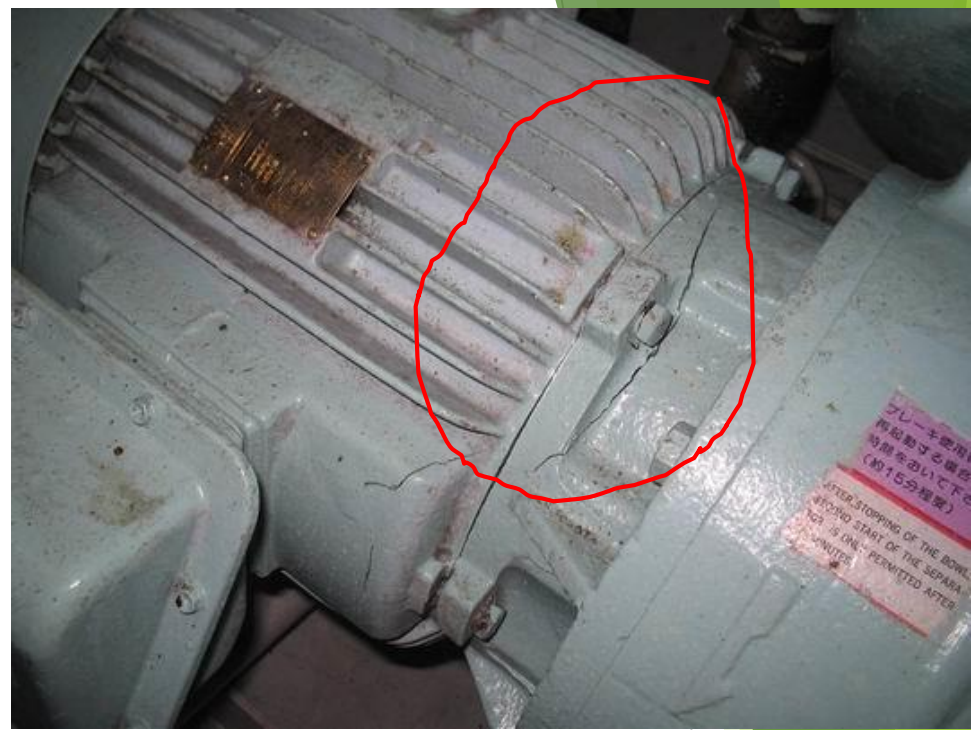
Presence of low amplitude electrical related faults in vibrations (i.e. are not uncommon in vibration data, particularly in 100Hz (50/60) and occasionally at 200Hz (100/120) in some countries). However, when raised amplitudes exist as the primary problem, spectral and waveform can be used to identify the cause. Electrical problems occurring at 2xLF include: motor eccentricity, unbalanced magnetic pull, loose connections, shorts or open circuits this can produce many harmonics of both the LF and SCR firing frequency. Where one SCR used on particular side of the circuit manufacturing this can also result in 1/2x (full-wave modified) or 1/3x (half-wave modified) and harmonics of the SCR firing rate. Electrical faults in another problem experienced on variable speed drives, and in the presence of electrical currents causing sparks between rotating bearing elements. Fixing is a form of advanced electrical expertise where the rotating surfaces give a "blue" or "white/blue" appearance. Filing isolated bearings or using special greases can solve some electrical problems.

FULLY SILICON CONTROLLED RECTIFIER (SCR) CIRCUIT SUPPLY

SCRs will introduce a low amplitude vibration equal to the number of rotated cycles in a firing cycle x LF. A DC full-wave rectifier with 6 SCRs will typically generate a vibration at 6xLF, where a half-wave rectified unit with 3 SCRs typically generates 3xLF. When a SCR unit develops a fault due to a diode contact, loose connections, shorts or open circuits this can produce many harmonics of both the LF and SCR firing frequency. Where one SCR used on particular side of the circuit manufacturing this can also result in 1/2x (full-wave modified) or 1/3x (half-wave modified) and harmonics of the SCR firing rate. Electrical faults in another problem experienced on variable speed drives, and in the presence of electrical currents causing sparks between rotating bearing elements. Fixing is a form of advanced electrical expertise where the rotating surfaces give a "blue" or "white/blue" appearance. Filing isolated bearings or using special greases can solve some electrical problems.

ROTOR DEFECTS

Overstated AC induction motors (particularly where the rotor is cyclic, many compressors and motors) under load develop problems with eccentricity and offset, broken, loose and tight connections occurring in the rotor bars, and rotor and/or stator faults. These problems can result in a predominant 1xRPM frequency (synchronously synchronous equal to the number of rotor poles x line frequency (50/60)), which is often accompanied by 2xRPM and 3xRPM. Where rotor bars are broken, where sidebands equal to the number of poles x LF will surround the rotor frequency (RF) and/or 2xRF. These sidebands amplitudes will fall if rotor bars or when rotor related problems exist.



WHEN Resonance and Unbalance occur together with change in revolutions can cause serious damages

1:20:00 add
Unbalance

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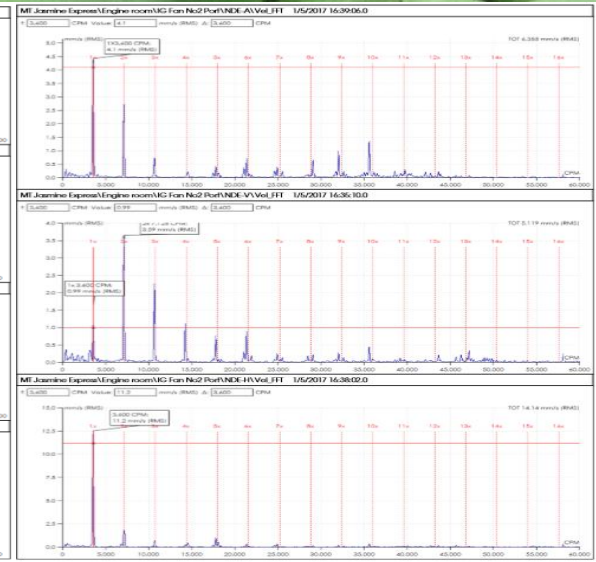
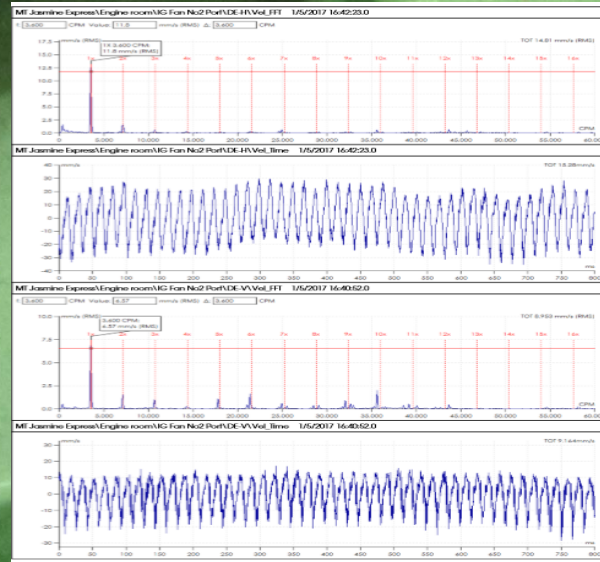
MOTOR DE vibrations recorded as following-

1. Vertical - **8.953** mm/s RMS
 2. Horizontal- **14.81** mm/s RMS
 3. Axial- **7.2** mm/s RMS.
- IACS limit for the Horizontal IG Motor is 7.0 mm/s RMS

Motor NDE side vibrations recorded as following-

1. Vertical - **10.75** mm/s RMS
2. Horizontal- **21.17**mm/s RMS
3. Axial- 4.208 mm/s RMS.

IACS limit for horizontal IG fan is 7.0 mm/s RMS



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02/05/2017 12:35

High Vibrations caused by Misalignment
case studies

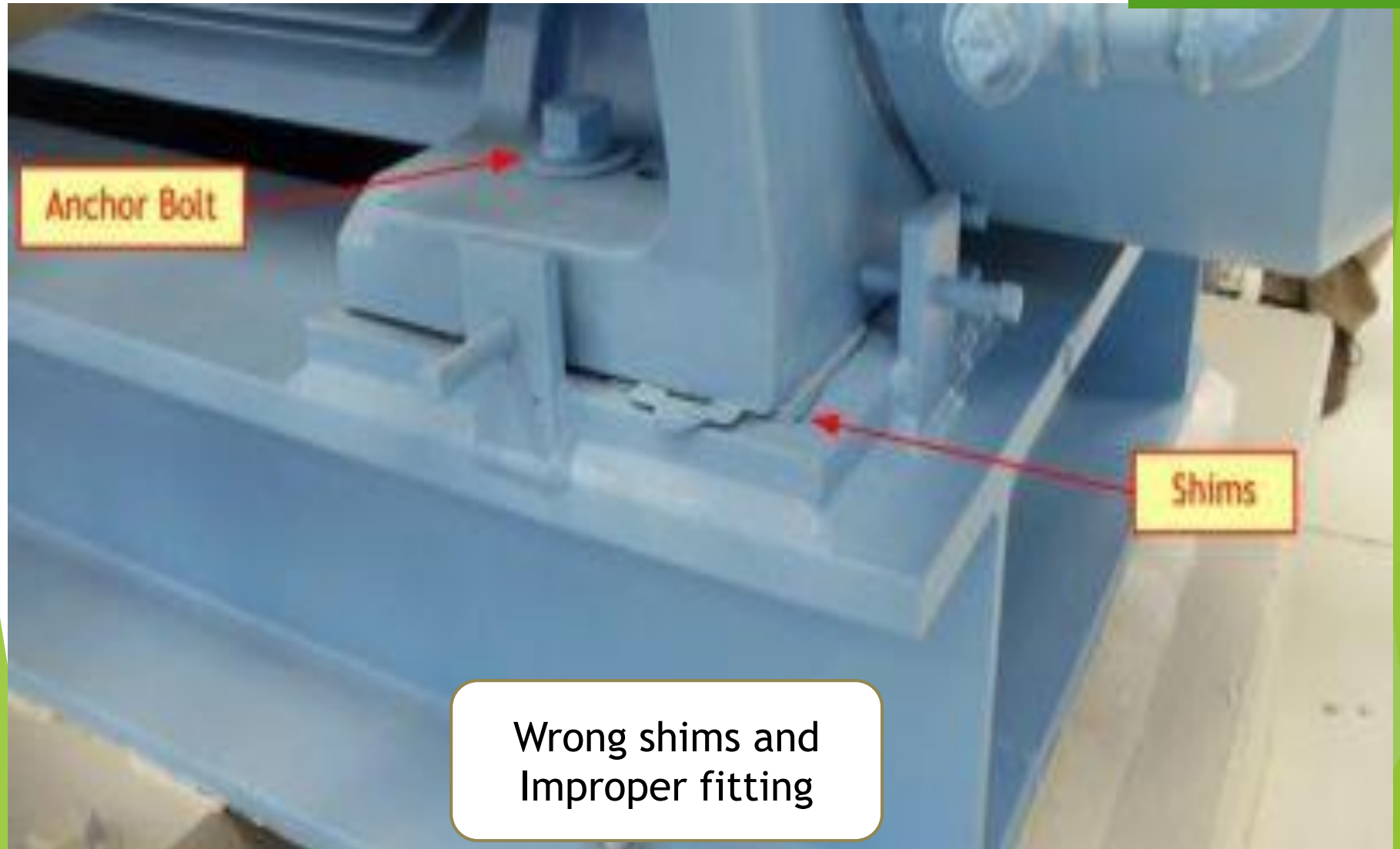
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TOO MANY SHIMS

High Vibrations caused by Misalignment
case studies

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High Vibrations caused by Misalignment
case studies

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02/05/2017 12:31

High Vibrations caused by Misalignment case studies

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High Vibrations caused by Misalignment case studies

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**Defective AV
Mounts or
resilient
mountings shrunk**

21/01/2016

High Vibrations caused by Misalignment case studies

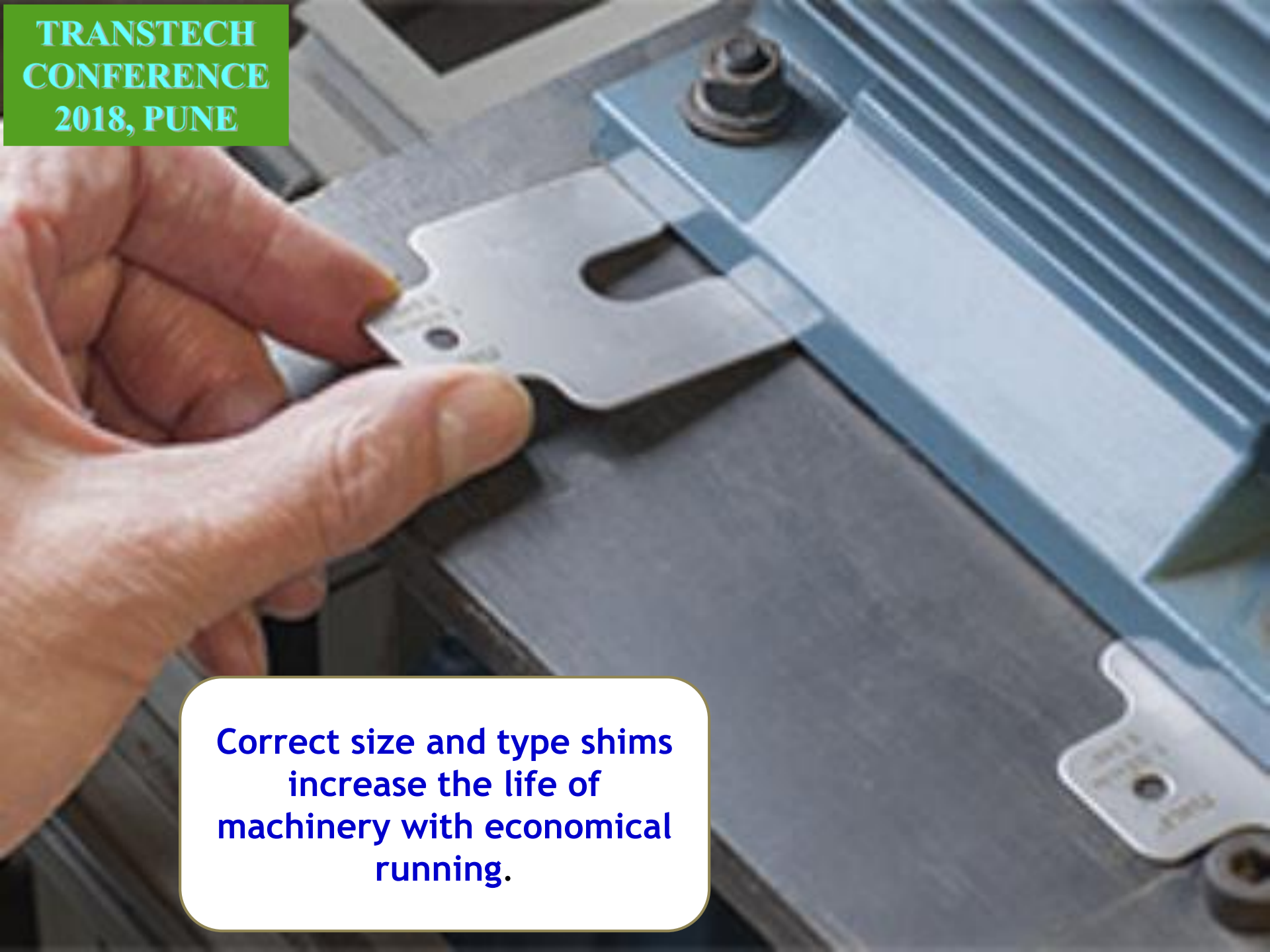
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DEFECTIVE SHIMS

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A close-up photograph showing a person's hand holding a thin, custom-shaped metal shim. The shim is being held in front of a piece of industrial machinery, which has a blue-painted metal housing and a dark grey base. The shim has a complex shape with a central cutout and a small hole. The background is slightly blurred, focusing attention on the hand and the shim.

**Correct size and type shims
increase the life of
machinery with economical
running.**

The ISO standards for the machinery vibration values limits

Velocity		Velocity Range Limits and Machine Class			
mm/s RMS	in/s Peak	Up to 15kW Class I	15 to 75kW II	>75 kW(Rigid) Class III	>75kW (Soft) Class IV
0.28	0.02	Good	Good	Good	Good
0.45	0.03				
0.71	0.04				
1.12	0.06	Satisfactory	Satisfactory	Satisfactory	Satisfactory
1.80	0.10				
2.80	0.16	Unsatisfactory (Alert)	Unsatisfactory (Alert)	Satisfactory	Satisfactory
4.50	0.25				
7.10	0.40	Unacceptable (Danger)	Unacceptable (Danger)	Unsatisfactory (Alert)	Unsatisfactory (Alert)
11.20	0.62				
18.00	1.00			Unsatisfactory (Alert)	
28.00	1.56			Unacceptable (Danger)	
45.00	2.51			Unacceptable (Danger)	Unacceptable (Danger)

Courtesy web sources



**VIBRATION MONITORING AND
ANALYSIS IS LIKE SEEING THROUGH
MACHINE**

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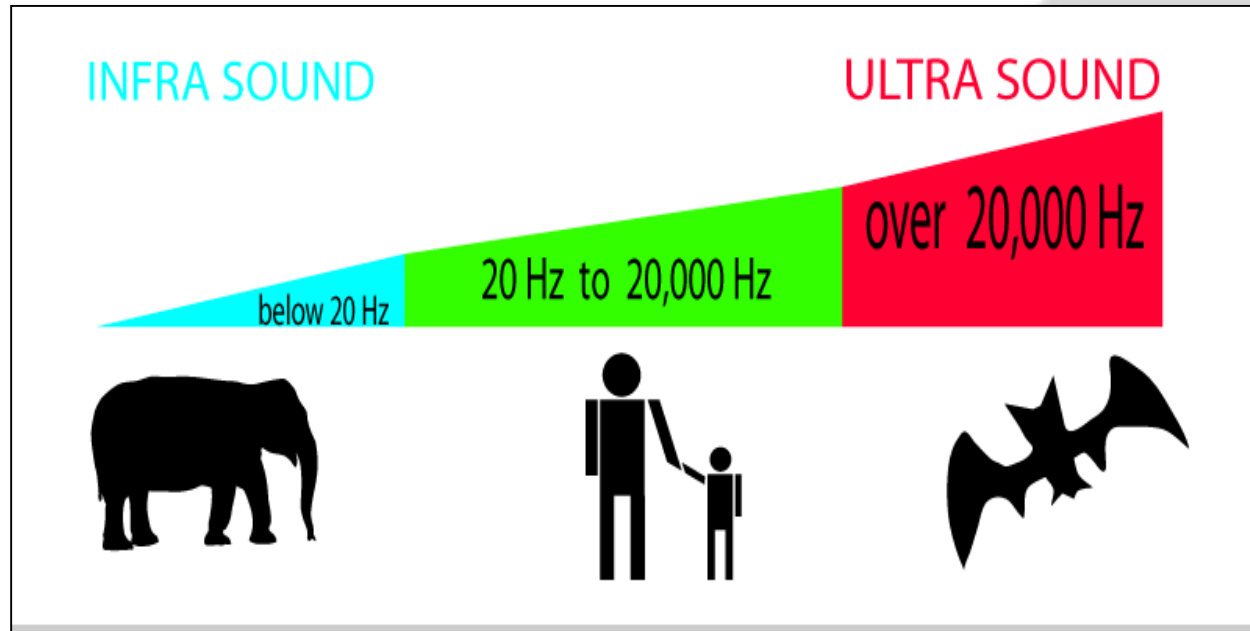
Increase your Equipment Reliability with Ultrasound Technology



**What is
Ultrasound?**

WELCOME

**Energy Management with air
borne ultra sound & structure
borne ultra sound applications**



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CONFERENCE
2017
SINGAPORE**

- Human range (16Hz to 18KHz)
- Industry Applied range (20KHz to 100KHz) is Heterodyned for Audible Human range
- Diagnostic Ultrasound is for Medical Imaging

Advantages of Ultrasound

- **Directional & Locatable**
- **Useful in any Environments**
- **Early Warning Failure Indication**
- **Wide Range of Applications**
- **Supports Other Technologies**

Applicable Ultra sound Inspections

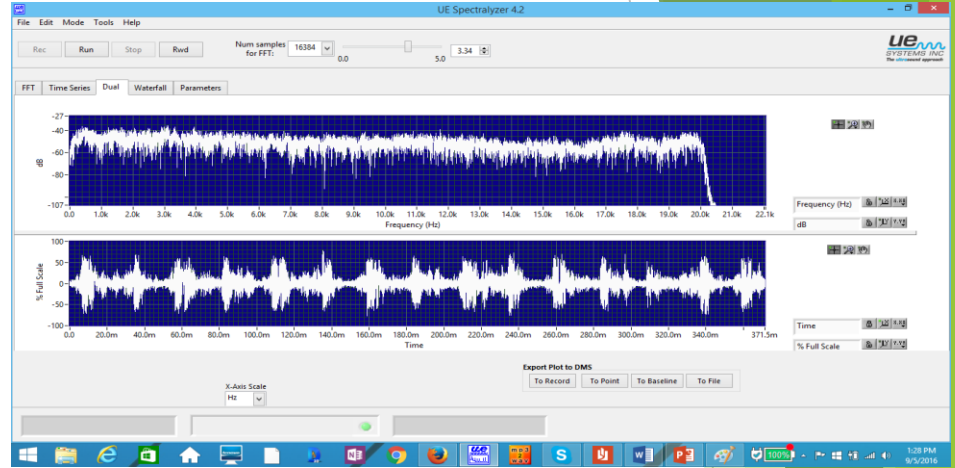
- **Leak Detection**
- **Electrical Inspection**
- **Mechanical Inspection**
- **Hydraulic components inspection**



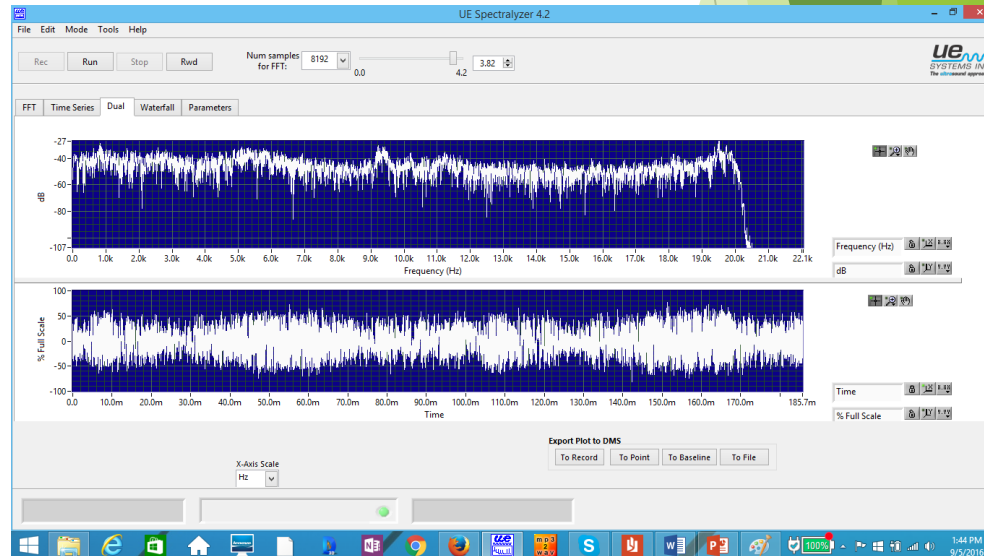
AIR/ GAS Compressor Valve Good n Bad



**GOOD
COMPRESSOR
VALVE**

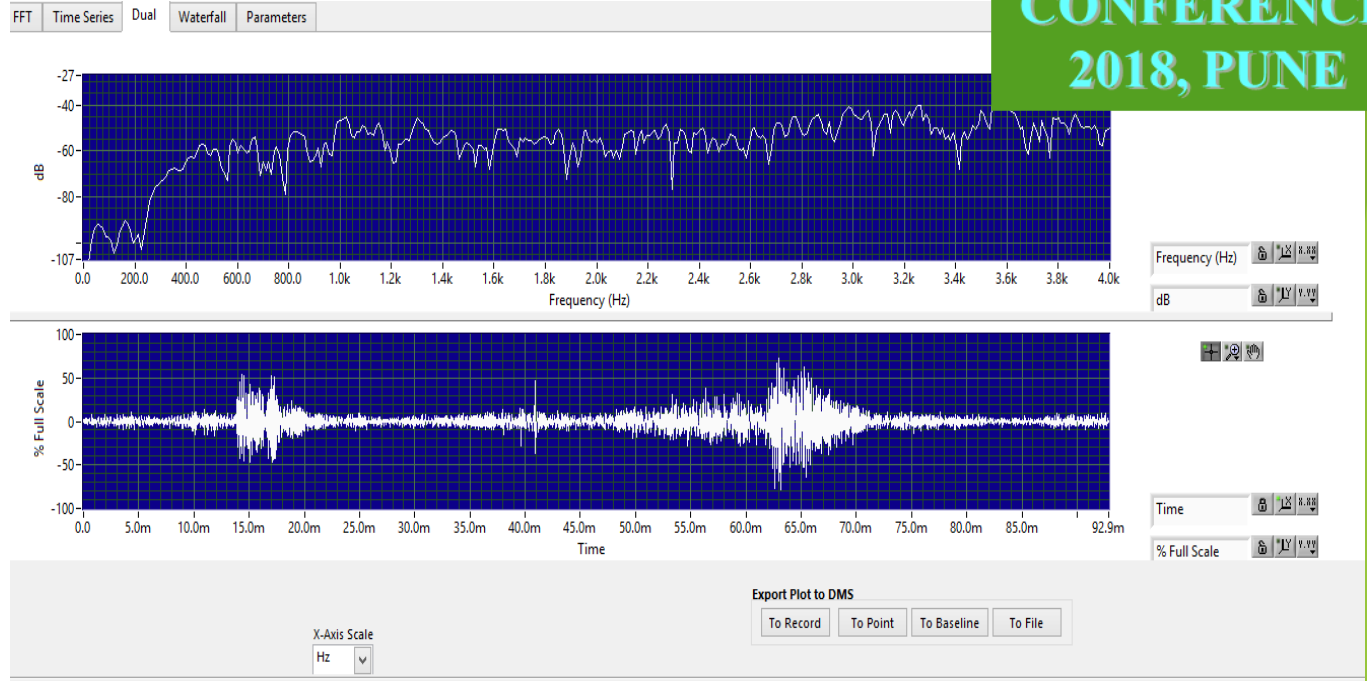


**LEAKING
COMPRESSOR
VALVE**

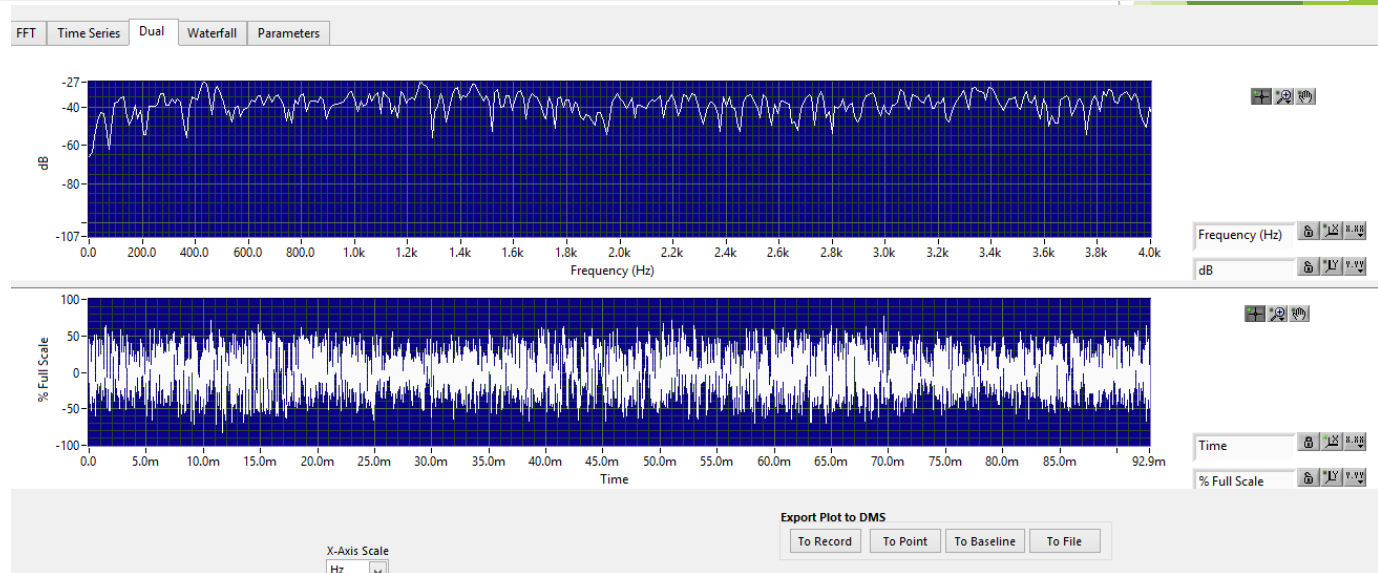




Typical LPG Valve
with defective
springs



Valve leak full
in LPG
compressor

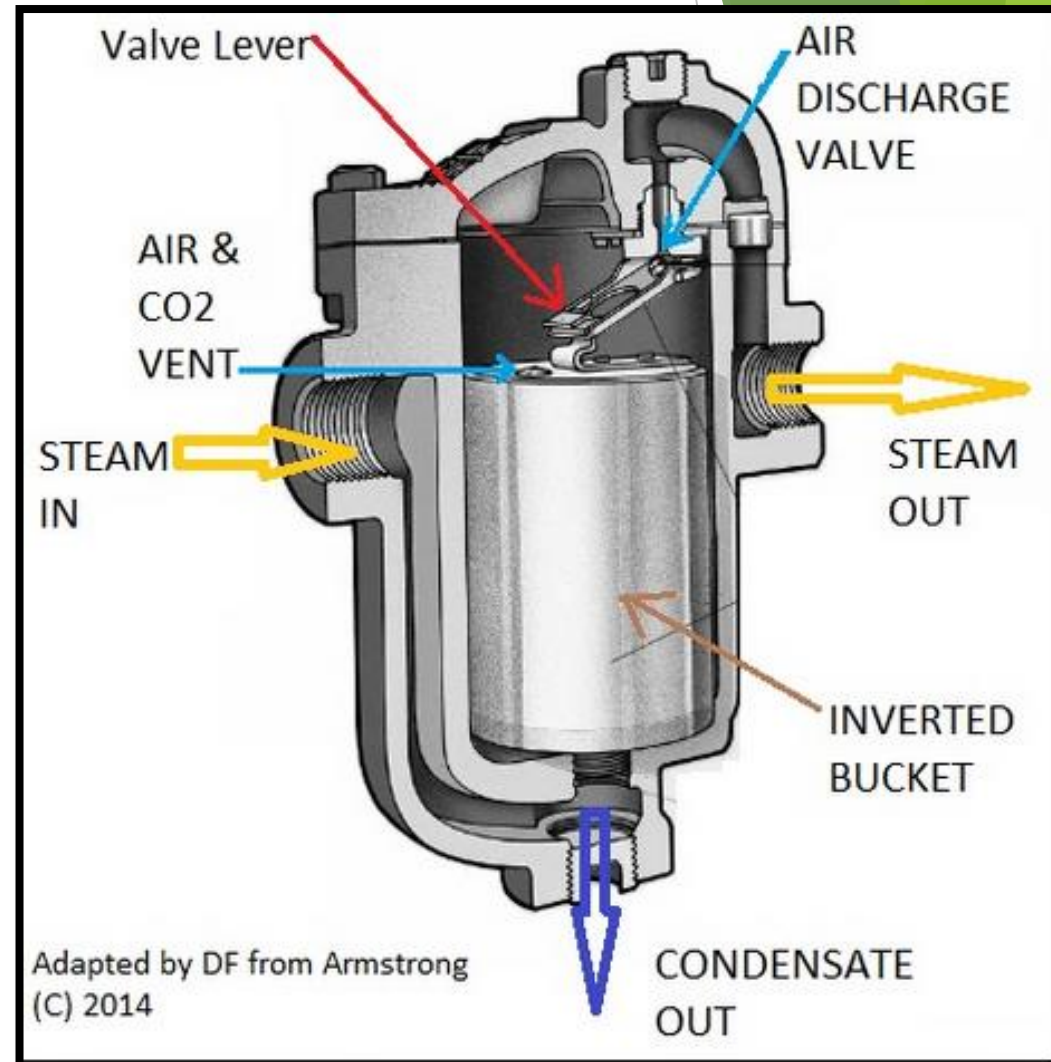


Inverted
Bucket Trap

Normal
Trap



Failed
Open

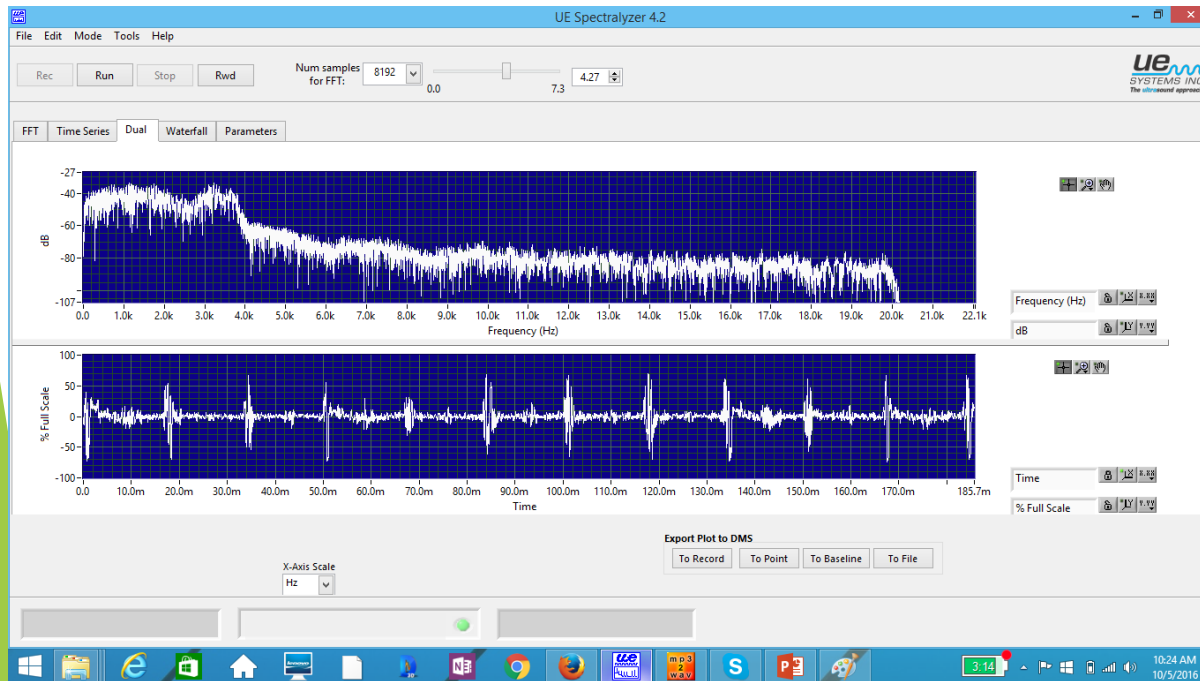
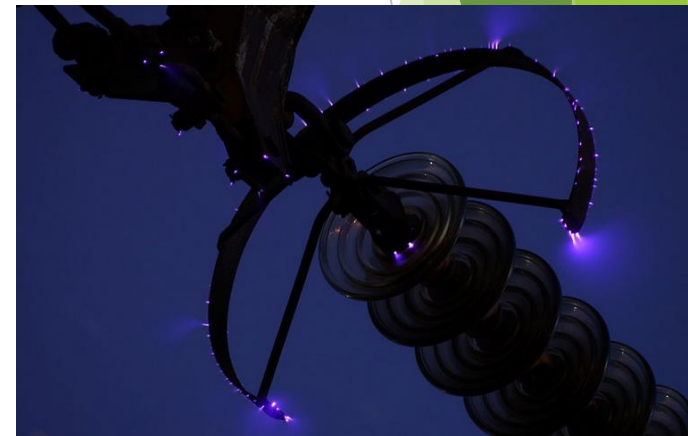


- Inspect enclosed systems while energized
- Scan switchgear **'before'** opening & inspect with infrared to
 - Prevent 'Arc Flash' injury
 - Sort equipment for further inspection
 - Safety PPE for arc flash is very important for HV switch gear.

High Voltage PD condition Corona

Only occurs at 1000V and above voltage.

This is a partial discharge(Leakage) activity.



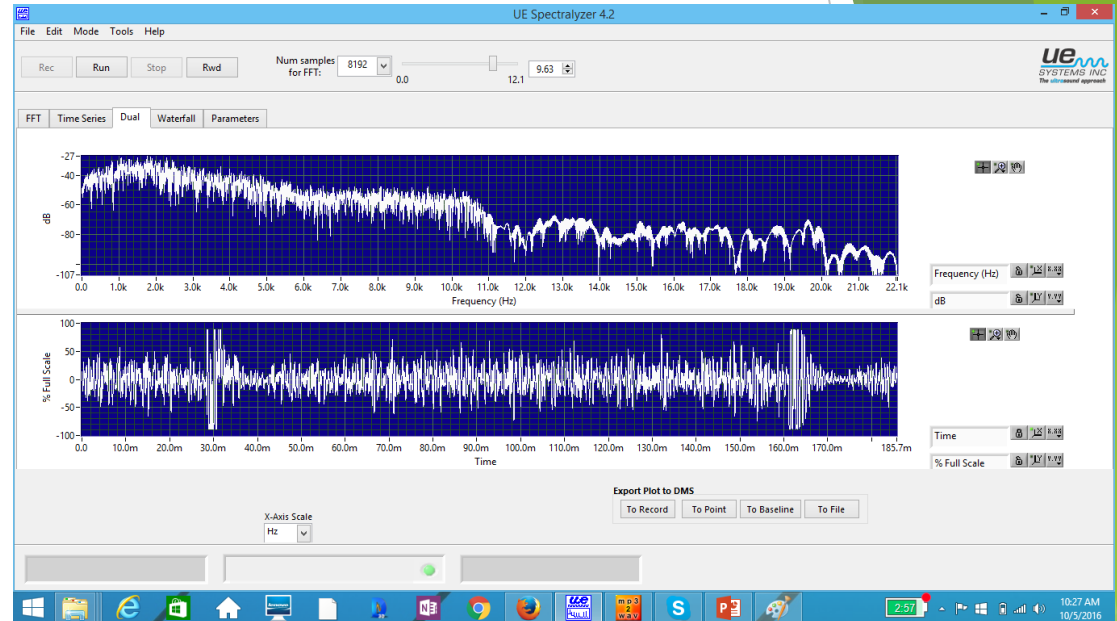
INSULATOR EARTH LEAK CONDITIONS

TRACKING

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- Tracking occurs where there is a low current pathway to ground across an insulator.
- There is a build up and discharge of the voltage that produces “popping” sounds.
- The discharge peaks correspond to the “popping” sounds.
- They are not uniformly spaced in time.



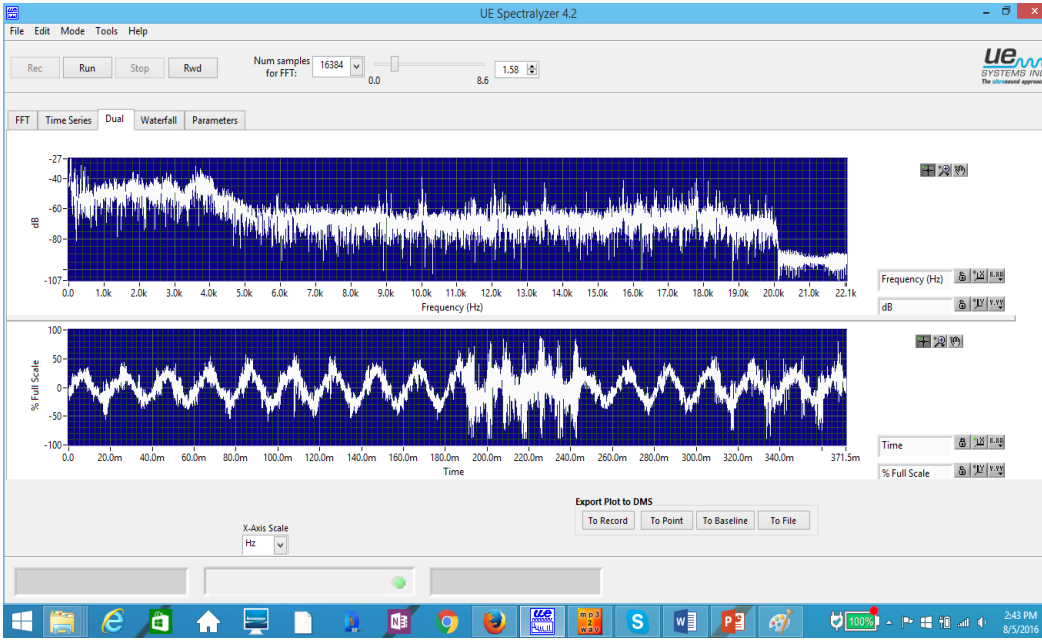
Arc Flash Conditions

ARCING

- Arcing, the discharge to ground is a high current pathway across an insulator.
- This is a “burst of energy” that has a long duration discharge



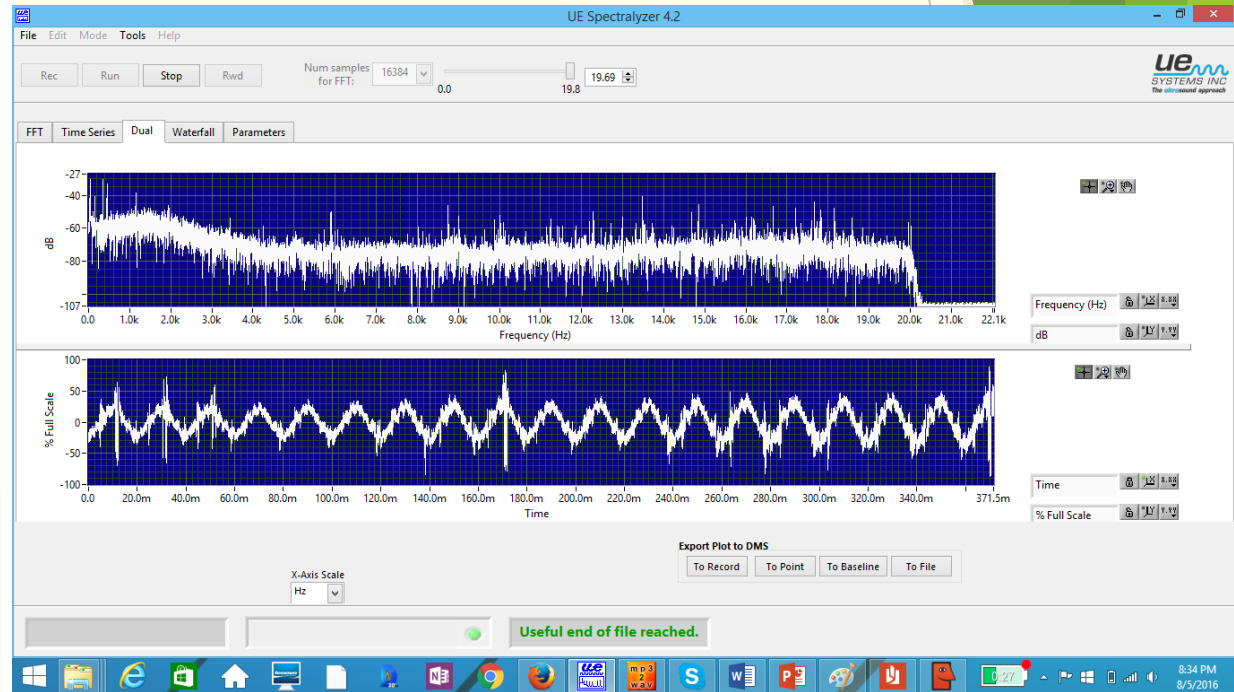
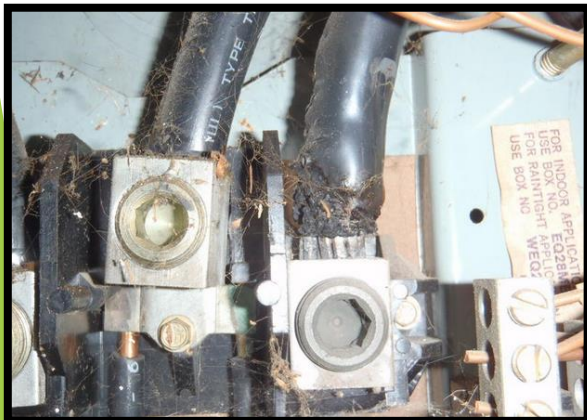
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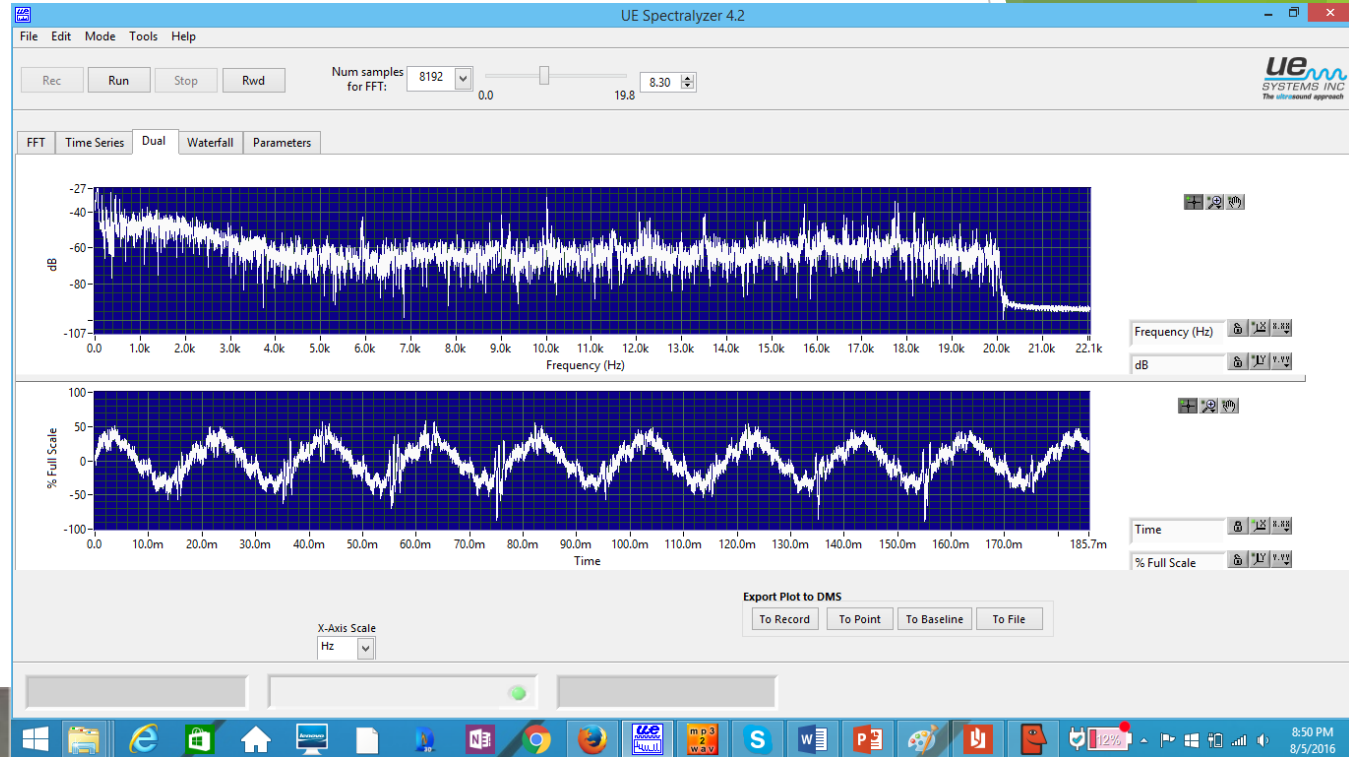
BAD AND SEVERE TRACKING OF THE ELECTRICAL INSULATION



High Voltage Components are well enclosed, making for poor or sometimes impossible infrared inspection



TRACKING IN HIGH VOLTAGE INSULATORS

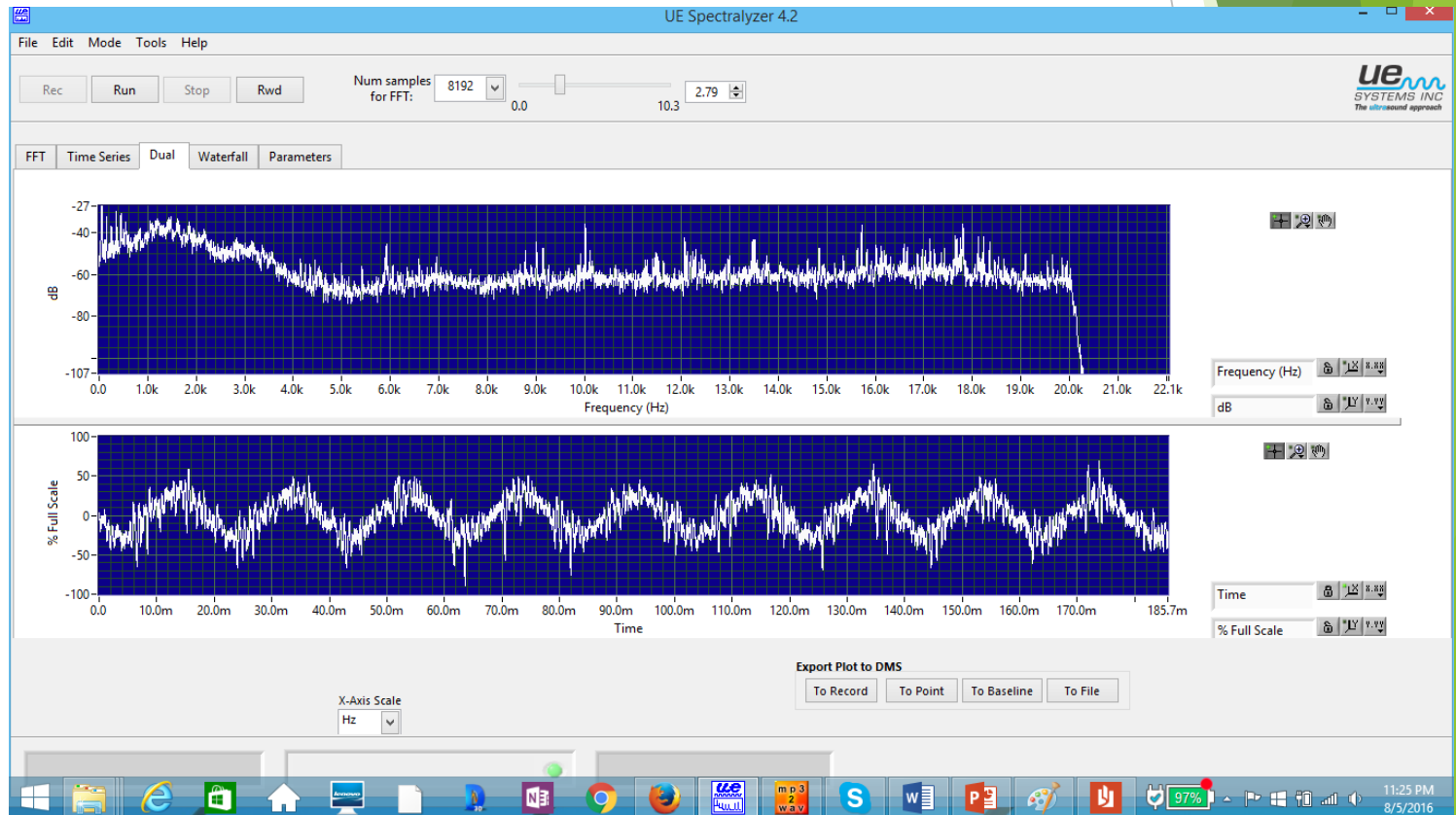
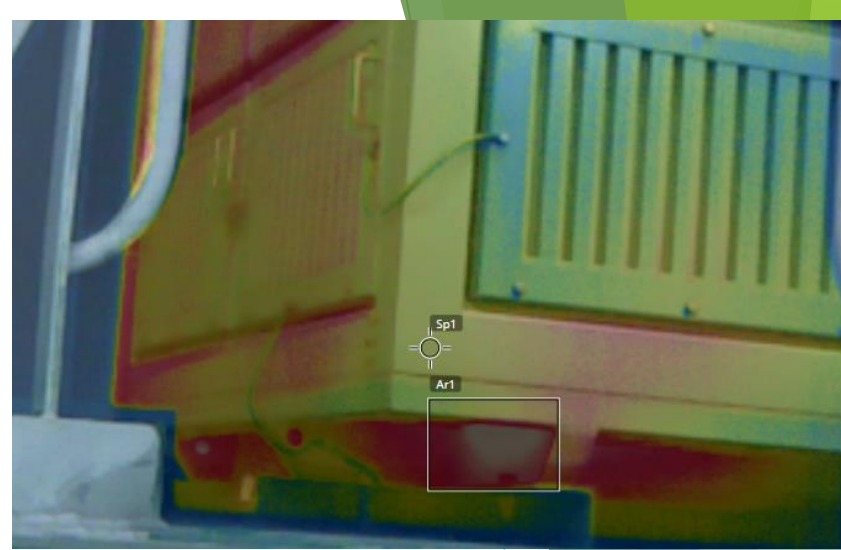


Switchgear Primary Stab
Surface Tracking

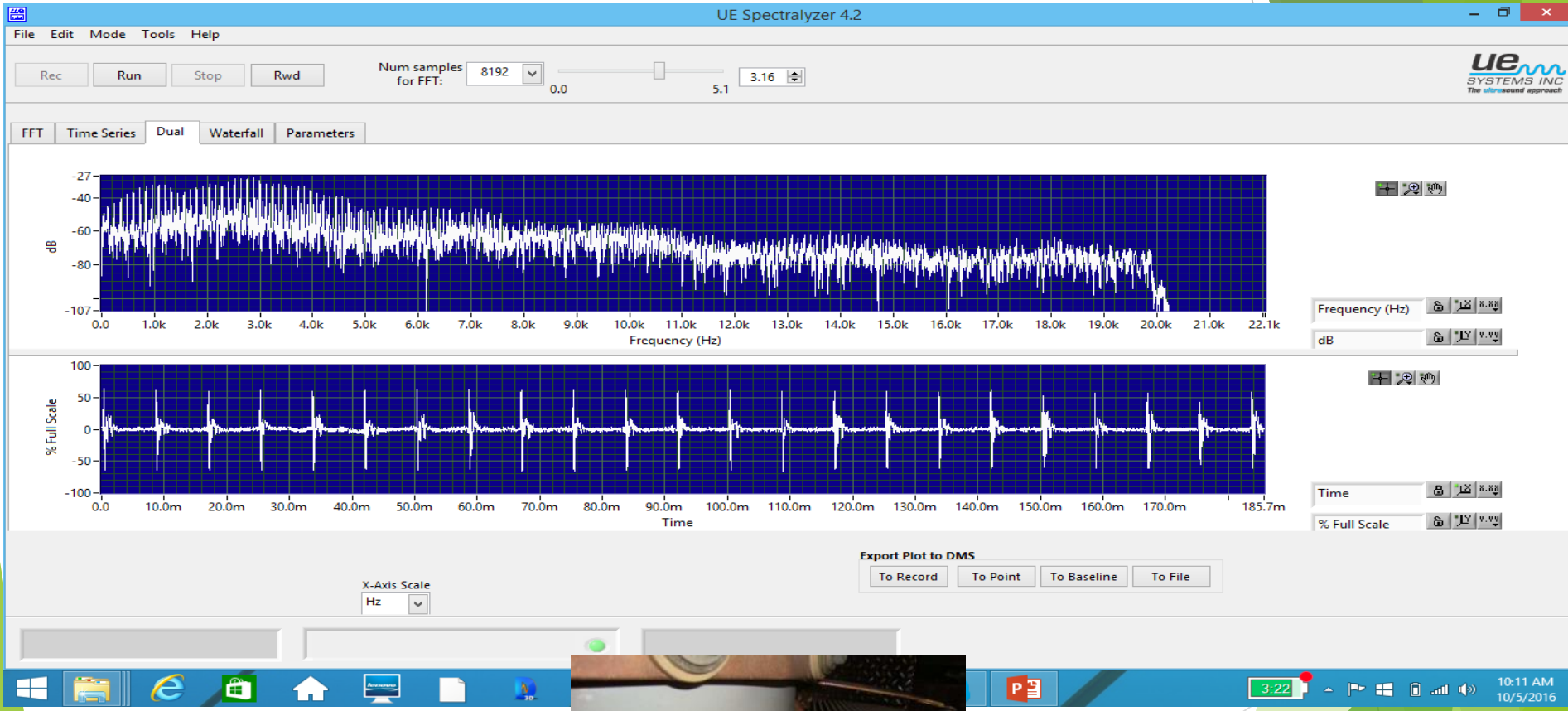


PD Tracking

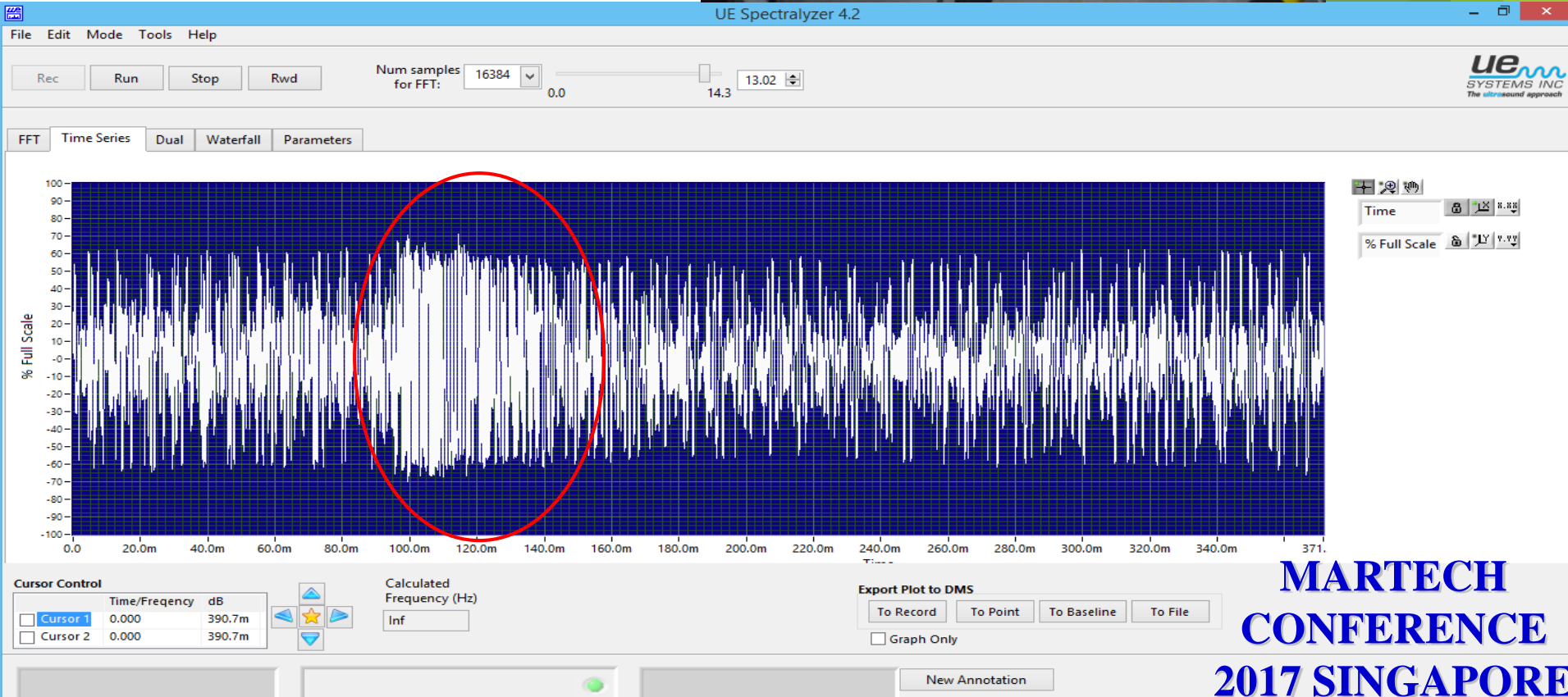
Good
Transformer



TRANSFORMER WITH LOOSE WINDING



Transformer with Tracking



Ultrasound Mechanical Inspection

- **Slow Speed Bearings**
- **Condition Based Lubrication**
- **Historical Trending**

Bearing Inspection

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- Very effective on Slow Speed Applications
- Types of testing performed
 - Comparison
 - Historical Trending
 - Spectrum Analysis

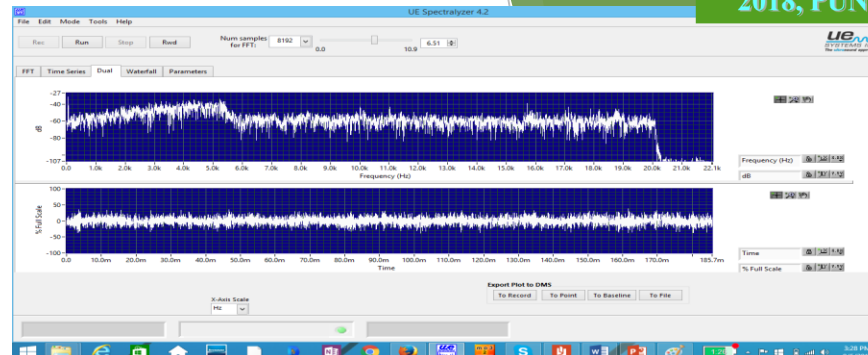




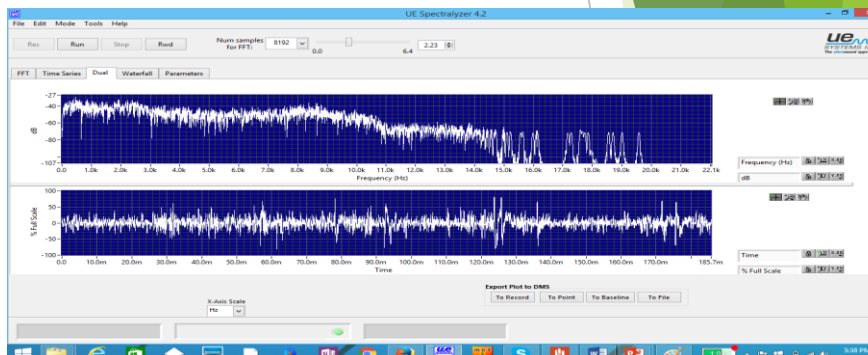
Green Sails

Bearing Testing

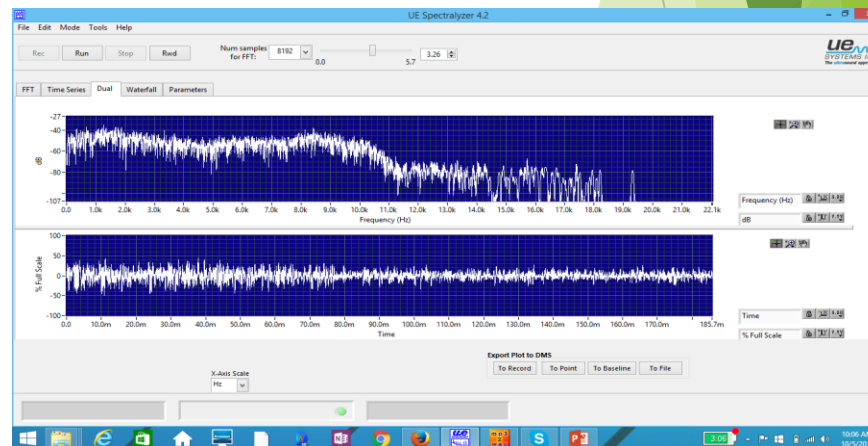
Good Bearing



Faulty Bearing



Receiving
Lubrication

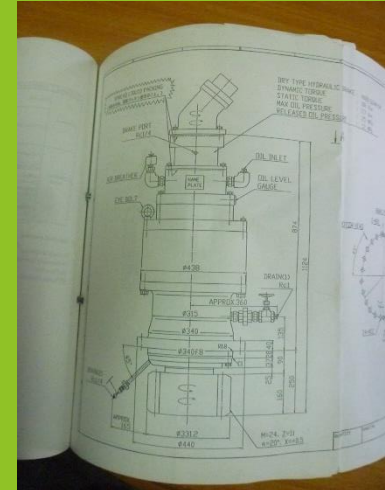
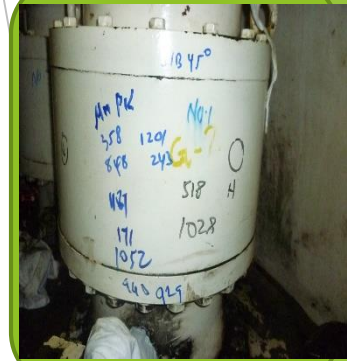




Ultra
sound
file



One of the ship crane
slewing operation
defect identified in
slewing motor counter
balance valves



**Levels of Severity
With ultra sound**

**Base on dB level
above baseline**

- 8 dB Lubrication Required**
- 12 dB Minor Damage
(microscopic faults)**
- 16 dB Damage (Visual faults)**
- 35+dB Failure Imminent**

Tracking: Electricity follows a pathway to ground utilizing dirt and other contaminants until it reaches

Arcing: An electric discharge through normally non-conductive media such as air. It is a failure condition in electric equipment and can lead to fire or an explosion.

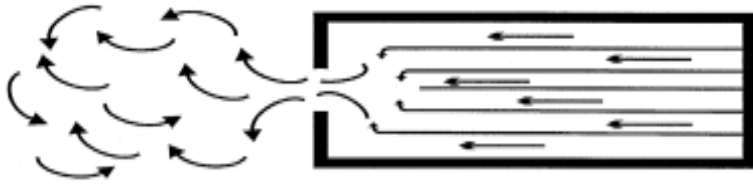


Figure 2 Pressure leak

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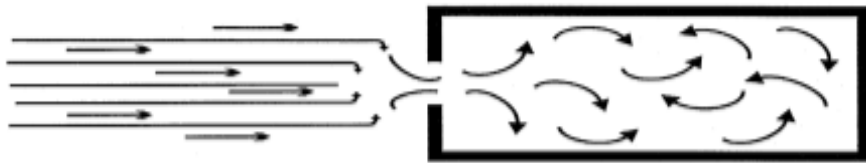
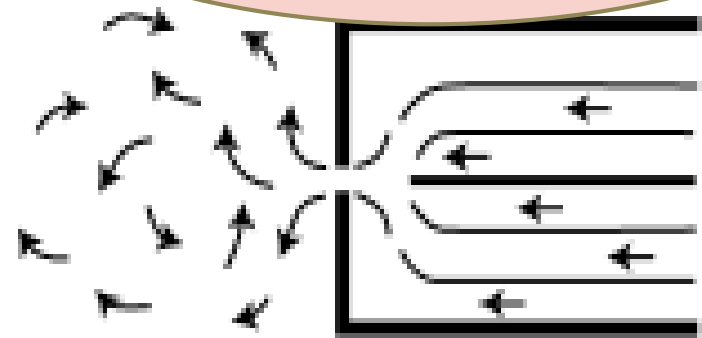


Figure 3 Vacuum leak

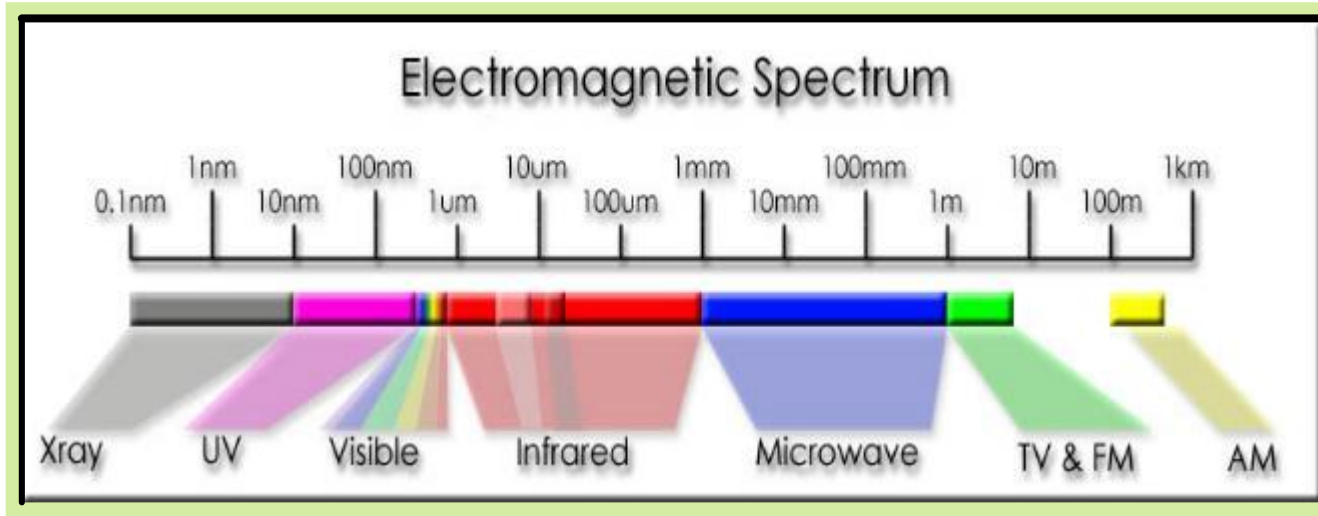


During a pressure leak, fluid escapes and produces a turbulent flow with strong ultrasonic components. Ultrasound is localized to the point of emission, making the leak readily detectable.

Corona: An electric discharge around conductors when the surrounding air is stressed beyond its ionization point without developing flashover.

FFT: Fast Fourier Transfer - A digital processing of a recorded signal representing data in terms of its component frequencies.

What is Infrared?

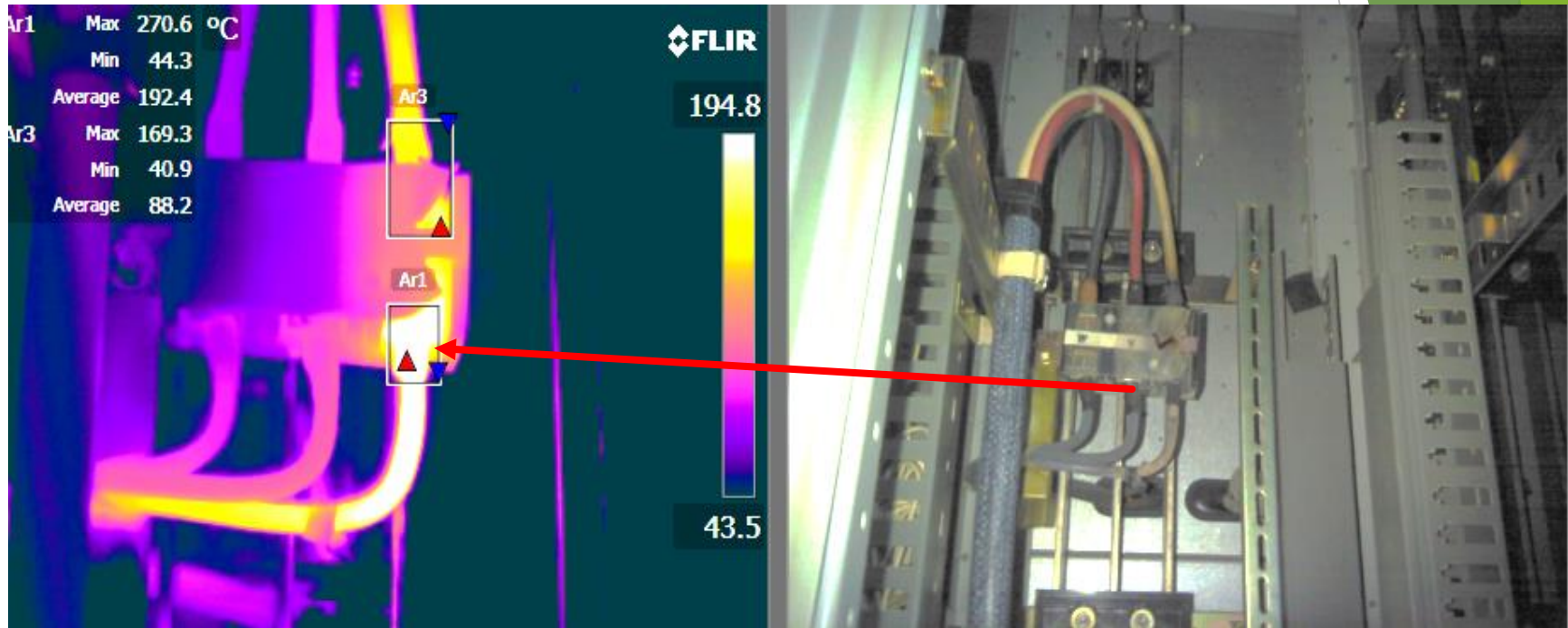


- ☛ Infrared is a form of electromagnetic radiation
- ☛ Everything above -273°C (absolute zero) emits infrared radiation
- ☛ The heat we feel from the sun is infrared energy

Advantages of Infrared

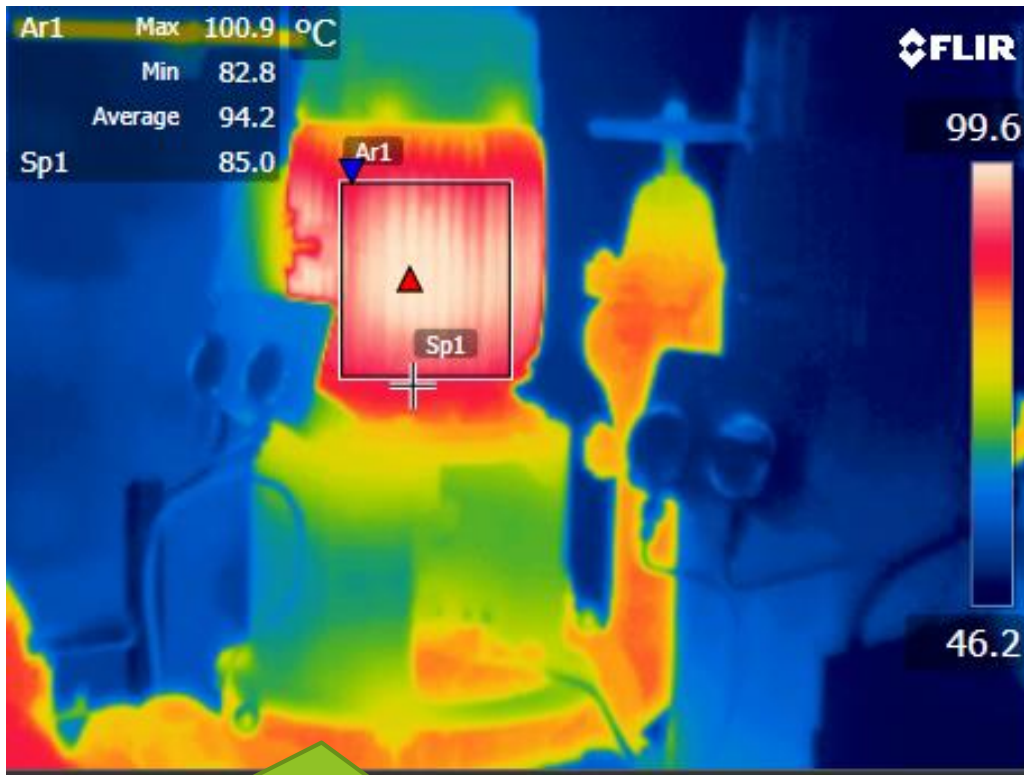
- Allows you to 'see' heat radiation
- Non-invasive & safe to implement
- Minimal downtime due to condition analysis electrical, mechanical and hydraulic problems
- Effective prioritization of repairs to plan for spares, manpower and sub contractor selection etc.,
- Improved employee safety and confidence of operators
- Energy savings
- Wide range of applications

**Increase machine Reliability
with
Infrred Technology**



This could be catastrophic failure on a VLCC can cause fire in main switch board

A TYPICAL MOTOR / PUMP PROBLEM - EXAMPLE



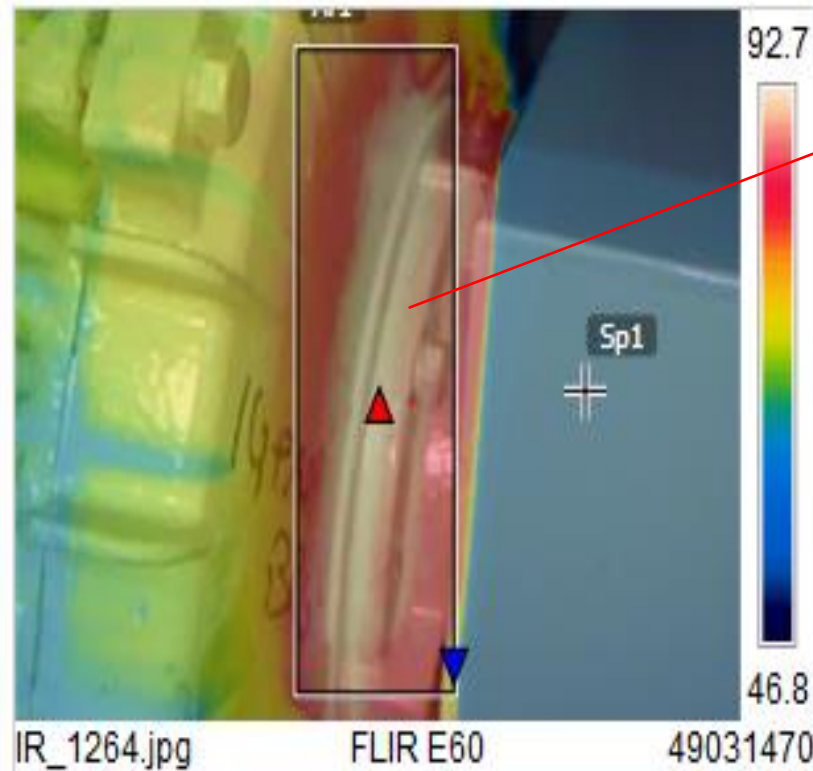
This photo is taken in a leading company tanker vessel and displaying as example.

The thermal image and related Digital image of Marine pump installation. In digital profile the pump and motor showing Good. In thermal image the motor is in trouble and drawing 10% excess amperes . The motor will burn if the action is not taken immediately.



A 250 kw motor inert gas fan in a vlcc operating with drive end bearing temperature of 93.3*c is going to cause damage to motor due to misalignment and overloading

2/14/2014 11:23:11 AM



Measurements °C	
Ar1 Max	93.3
Min	72.7
Average	87.6
Sp1	52.0

Parameters	
Emissivity	0.94
Refl. temp.	35 °C

Note	
IG FAN NO1 DRIVE END BEARING	

2/14/2014 11:23:11 AM



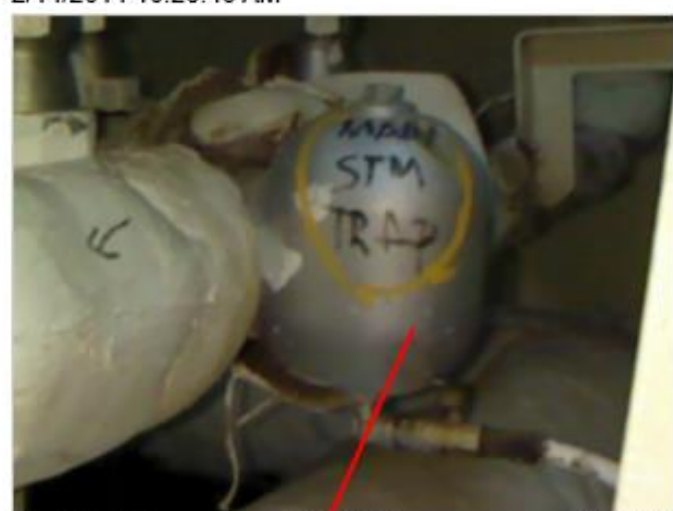
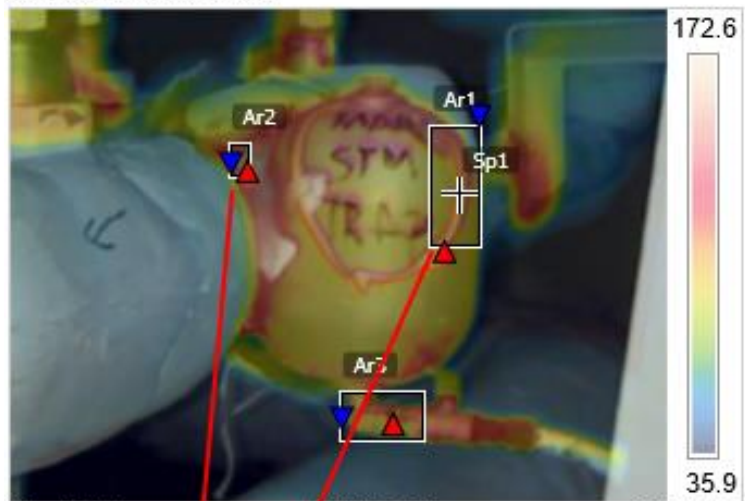
cause and effect of failed steam traps



- steam traps stuck (open) position:
 - waste of energy and damage to atmosphere condenser.(\$\$\$)
 - excess steam in system
 - create back pressure back pressure can cause other steam traps to malfunction
- steam trap stuck in shut (closed) position:
 - water hammer
 - line clog and corrode
 - possible rupture



DEFECTIVE STEAM TRAP



IR_1255.jpg FLIR E60 49031470

IR_1255.jpg FLIR E60 49031470

Measurements °C 2/14/2014 10:32:05 AM

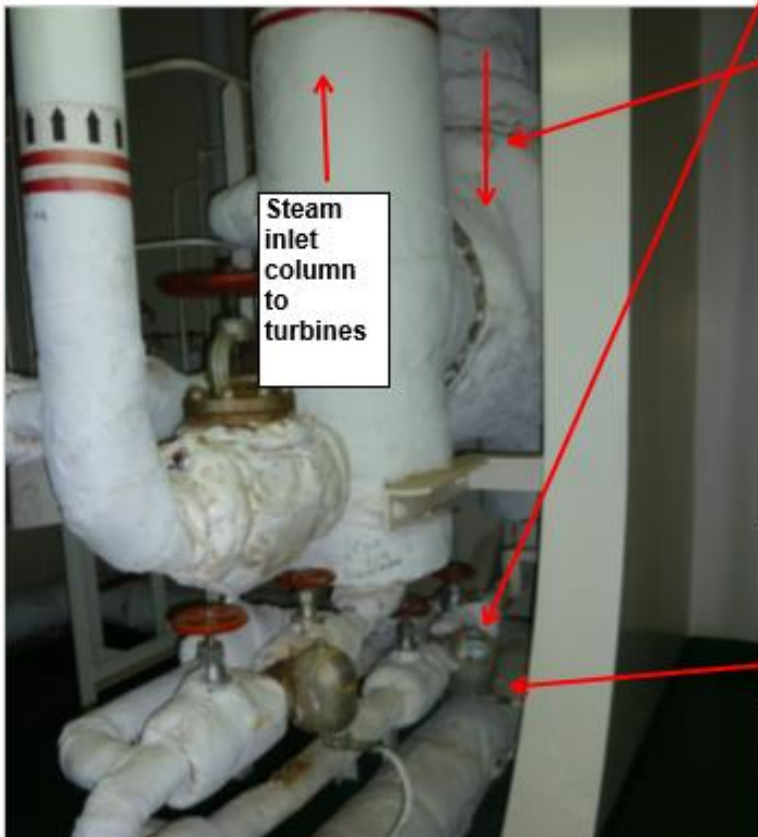
Ar1	Max	173.0
	Min	40.6
	Average	116.8
Ar2	Max	171.8
	Min	101.9
	Average	152.2
Ar3	Max	156.6
	Min	42.1
	Average	99.1
Sp1		165.8

Parameters

Emissivity	0.95
Refl. temp.	20 °C

Note

defective steam trap

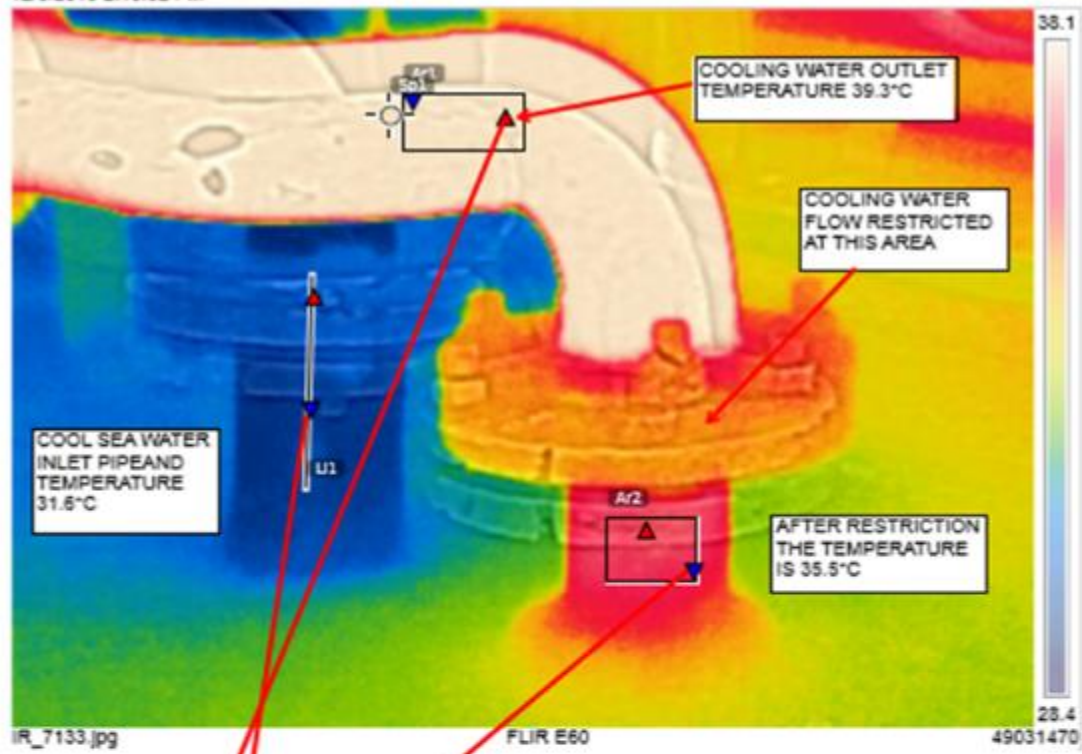


Main steam line from boiler to turbines

Steam inlet column to turbines

A sample steam trap operating onboard steam turbine plant

NOTE: THIS DEFECTIVE STEAM TRAP LOSS IS ESTIMATED ABOUT 5-10% OF LIVE STEAM LOSS BACK TO ATMOSPHERIC CONDENSER



IR_7133.jpg

FLIR E60

49031470

Measurements		
Ar1	Max	39.3
	Min	38.6
	Average	38.8
Ar2	Max	36.2
	Min	35.5
	Average	35.9
Sp1		38.8
U1	Max	32.3
	Min	31.6
	Average	32.0
Parameters		
Emissivity		0.95
Ref. temp.		20 °C
Note		
Inlet and outlet pipes of condenser		



IR_7133.jpg

FLIR E60

49031470

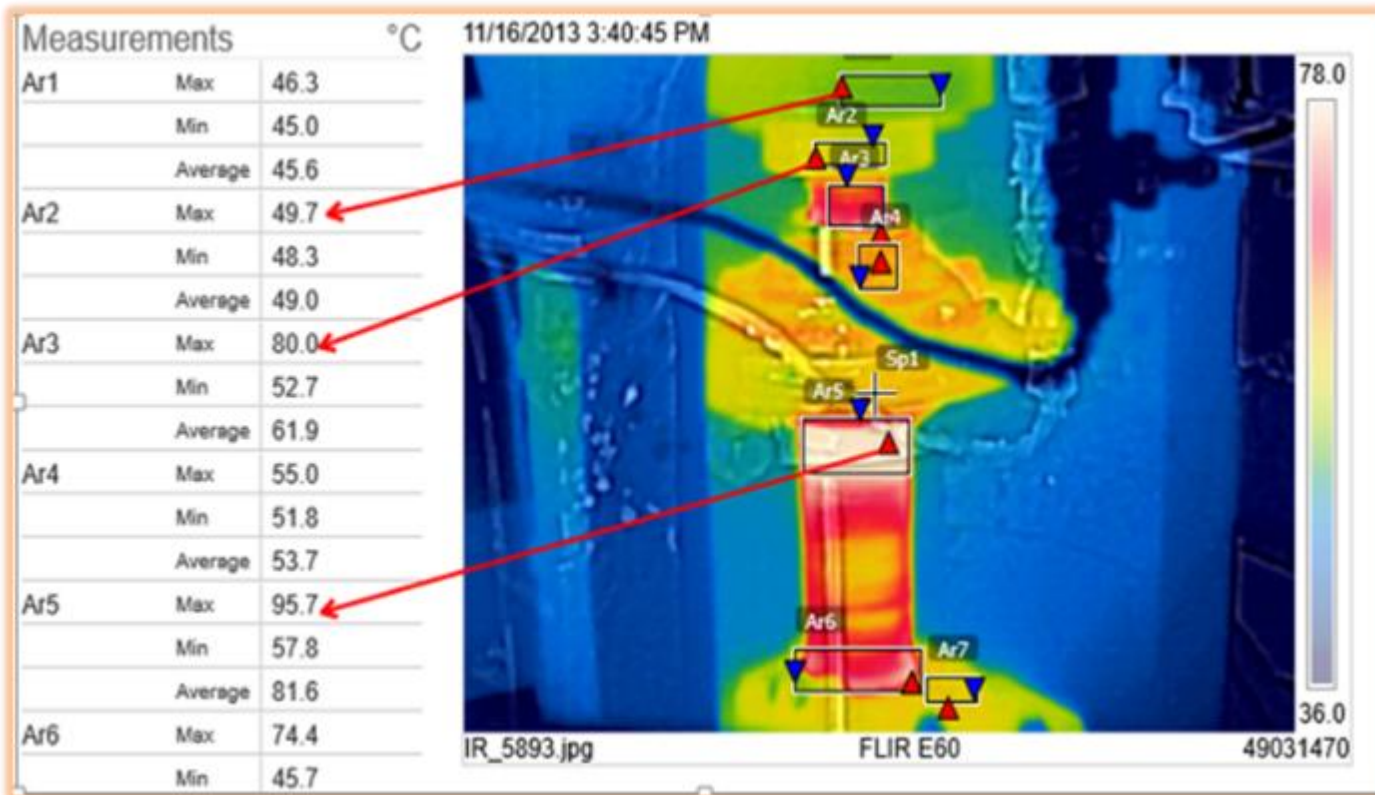


EXAMPLE OF MALFUNCTIONING OF PIPES, VALVES

The partially blocked pipe is an example of surface temperature effects in a pipe line

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COUPLINGS AND SHAFTS ALIGNMENT



- ▶ Couplings inspection is difficult in normal operation.
- ▶ We need to understand coupling, different coupling have different thermal signatures.
- ▶ Misalignment, excessive wear are general defects are observed with infrared thermography.

Measurements °C

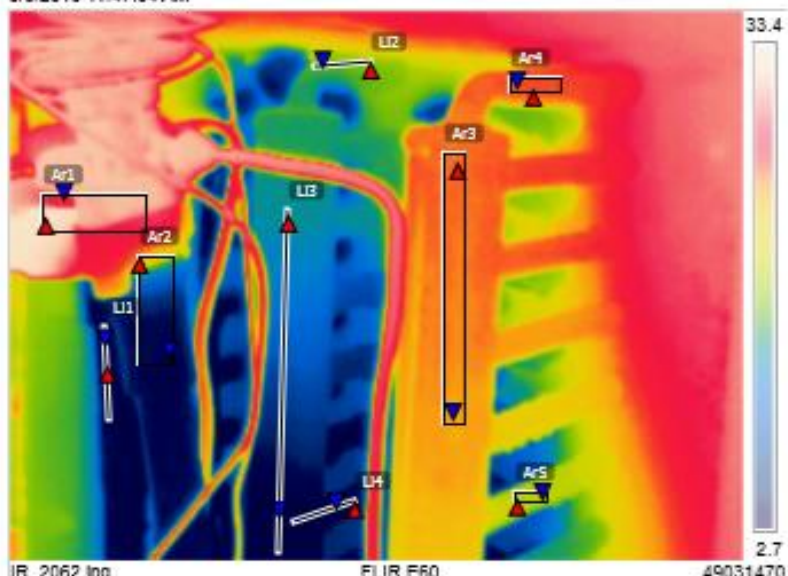
Ar1	Max	33.5
	Min	26.5
	Average	30.6
Ar2	Max	25.5
	Min	3.6
	Average	8.2
Ar3	Max	26.1
	Min	24.5
	Average	25.6
Ar4	Max	26.5
	Min	26.2
	Average	26.3
Ar5	Max	20.4
	Min	19.9
	Average	20.1
LI1	Max	4.2
	Min	3.4
	Average	3.7
LI2	Max	18.7
	Min	16.9
	Average	17.8
LI3	Max	15.0
	Min	2.8
	Average	8.5
LI4	Max	3.3
	Min	2.7
	Average	3.0

Parameters

Emissivity	0.95
Ref. temp.	20 °C

Note
AC EVAPORATOR RETURN HEADERS ANALYSIS

6/5/2013 11:47:04 AM



COMMENT 3:

1. THE EVAPORATOR RETURN HEADER NO1 (IN YELLOW N RED COLOUR) SHOWING HIGH TEMPERATURE AT AR4 26.5°C HIGH AND LOW AR5 19.9°C OF THE RETURN GAS TEMP.
2. THE EVAPORATOR RETURN HEADER NO2 IN BLUE COLOUR LI3 2.8°C LOW AND 15°C IS HIGH.
3. THIS EVAPORATOR RUNNING ON TWO COMPRESSORS AND STILL UNABLE TO PERFORM THE COOLING EFFECT DUE TO PARTIALLY CHOKED AND INADEQUATE REFRIGERANT CIRCULATION.
4. THE COMPANY HAS TO RENEW THE ENTIRE EVAPORATOR UNIT DUE TO THE FLOCCULATION AND FLOW RESTRICTIONS IN THE EVAPORATOR.

6/5/2013 11:47:04 AM

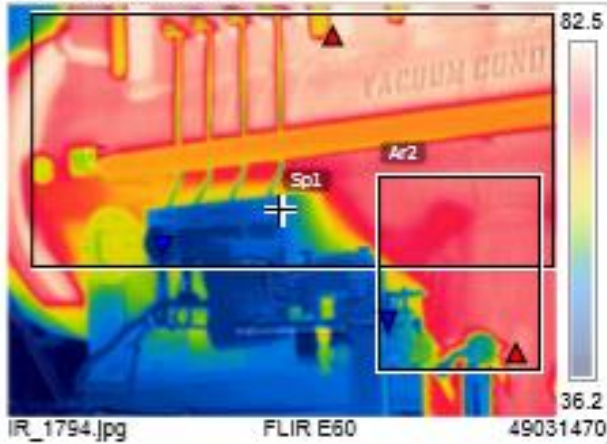


Sample evaporator liquid refrigerant inlet and expanded gas outlet at the return headers for each coil



Both above compressors connected to this defective evaporator coils. Loss of energy with 2 compressors running with minimum climate control effect

2/15/2014 12:15:08 PM



2/15/2014 12:15:08 PM



A vacuum condenser operating at high temperature loss of vacuum and burning more fuel for additional steam demand causing losses of energy

NOTE:

1. THIS IS A VACUUM CONDENSER IN A TURBINE PLANT OPERATING MORE THAN DESIGNED TEMPERATURE.
2. THIS HIGH TEMPERATURE OPERATIONN CAUSE8 LOSS OF VACUUM, LOSS OF STEAM ENERGY UTILIZATION, CONSUMING MORE FUEL INCREASE STEAM CONSUMPTION, MORE POLLUTION ETC..
3. THIS CONDENSER MAXIMUM TEMP OPERATION DESIGNED TO 86°C BUT OPERATING ABOUT 82.8°C.

Measurements °C

Ar1	Max	82.8
	Min	41.0
	Average	74.7
Ar2	Max	81.0
	Min	45.2
	Average	74.5
Sp1		48.7

Parameters

Emissivity	0.95
Refil. temp.	20 °C

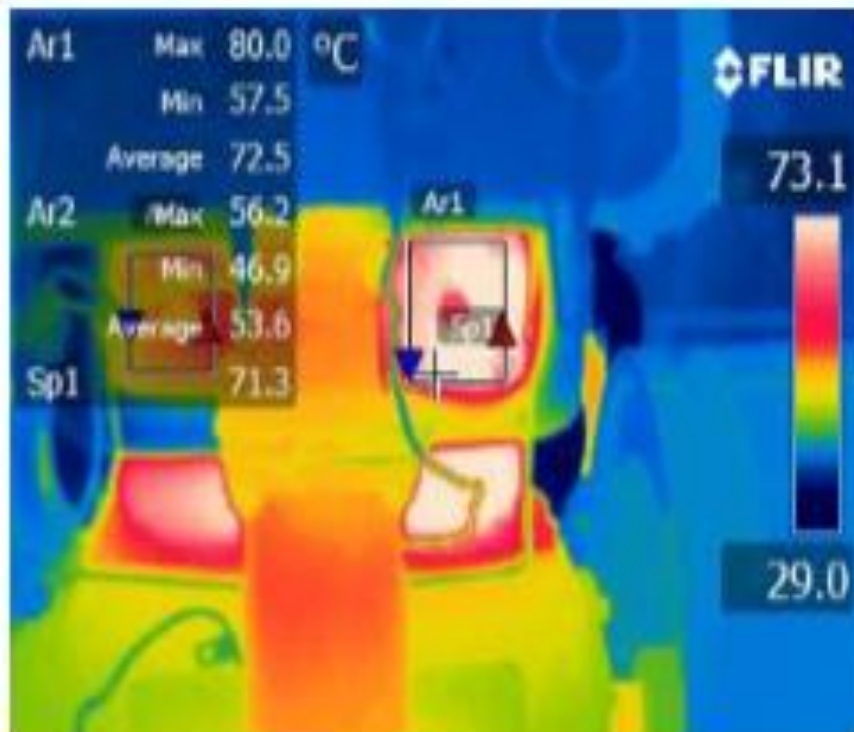


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Main air compressor high pressure suction valves one valve is leaking badly other valve is chocked with carbon trouble- energy loss/ damage to valves, carbonisation in inter and after coolers and reduced efficiency

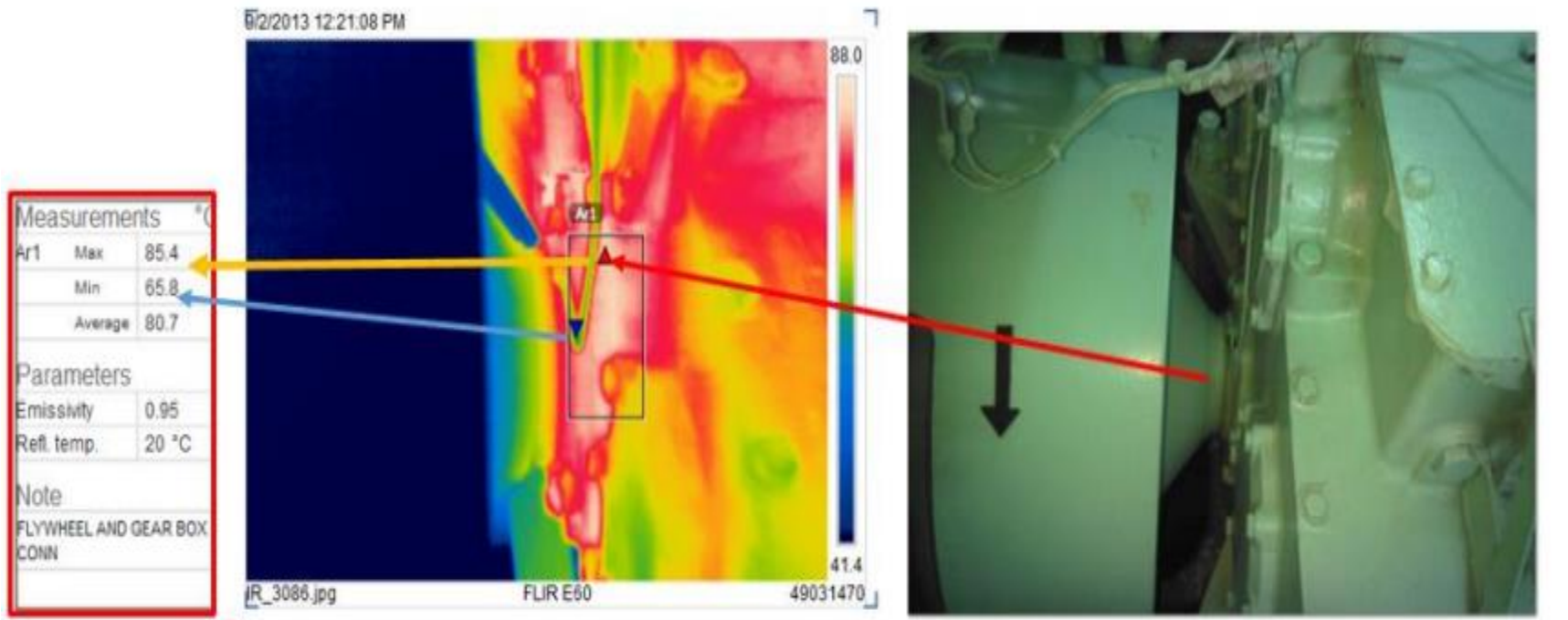


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Marine Propulsion Gear box showing high bearing temperatures

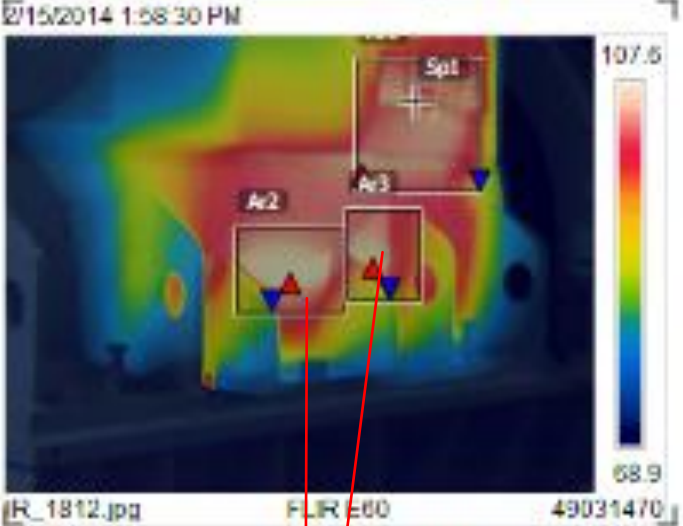
The Gear box drive end bearing showing 85.4°C where the Lube oil temperature at the cooler inlet 48°C indicating trouble at the bearing condition.





A diesel generator alternator showing high temperatures can cause damages loss of alternator life due to excess temperatures

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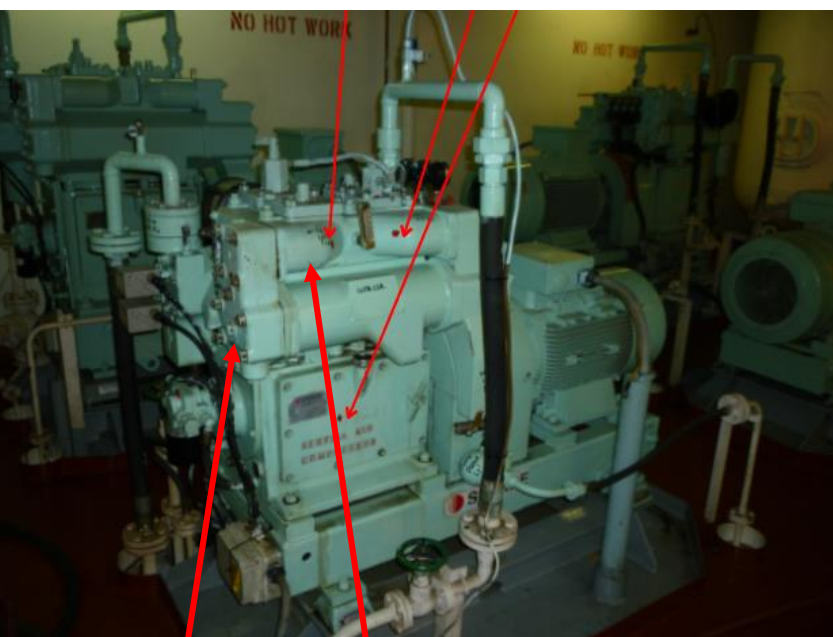


Measurements		
Ar1	Max	106.1
	Min	92.1
	Average	102.6
Ar2	Max	107.8
	Min	83.3
	Average	102.1
Ar3	Max	107.0
	Min	85.4
	Average	100.3
Sp1		105.9

Parameters	
Emissivity	0.95
Ref. temp.	20 °C

Note
ALTERNATOR WITH HIGH TEMPERATURES



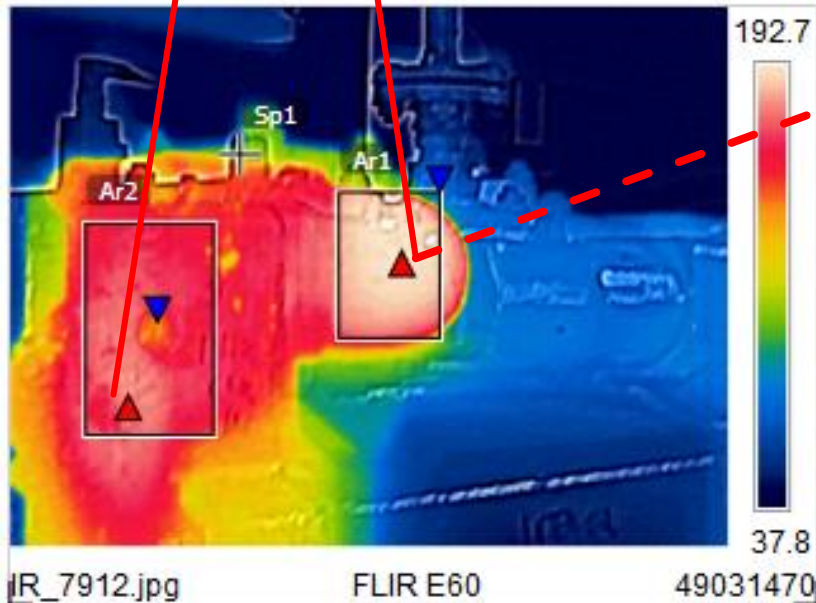


Main start Air compressor onboard running very hot with LP discharge inlet to inter cooler about 194.2°C reduce the efficiency, long running hours and damage to many components like valves, coking in inter after coolers etc.,



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12/19/2013 2:54:56 PM



Measurements °C		
Ar1	Max	194.2
	Min	65.2
	Average	182.5
Ar2	Max	180.6
	Min	142.5
	Average	169.6
Sp1		109.4
Parameters		
Emissivity		0.94
Refl. temp.		35 °C
Note		
lp disch into intercooler		

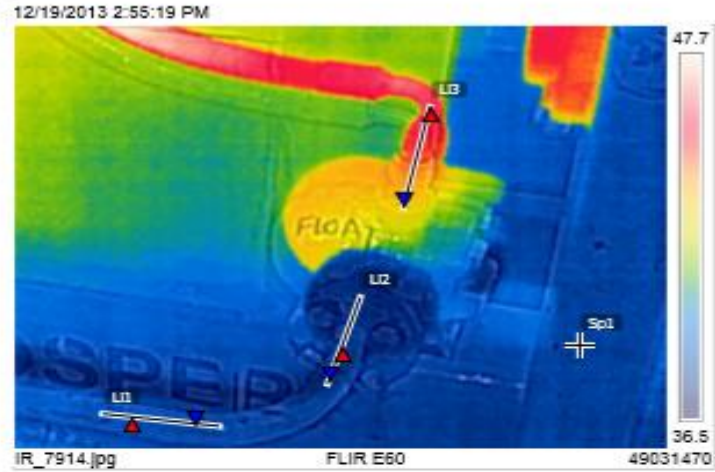
12/19/2013 2:54:56 PM



IR_7912.jpg FLIR E60 49031470



Measurements			°C
Sp1			38.1
LI1	Max		38.6
	Min		38.0
	Average		38.3
LI2	Max		38.1
	Min		37.5
	Average		37.9
LI3	Max		45.8
	Min		42.5
	Average		44.2
Parameters			
Emissivity			0.95
Ref. temp.			20 °C
Note			
to drain after 15mins running			



THE INTER COOLER DRAIN WAS CHECKED MANY TIMES AFTER THE COMPRESSOR STARTED FOR THE DRAINOUT THROUGH THE FLOAT BUT NO EVIDENCE OF DRAIN FLOW NOTICED.

12/19/2013 2:55:19 PM



IR_7914.jpg FLIR E60 49031470

Hydraulic applications



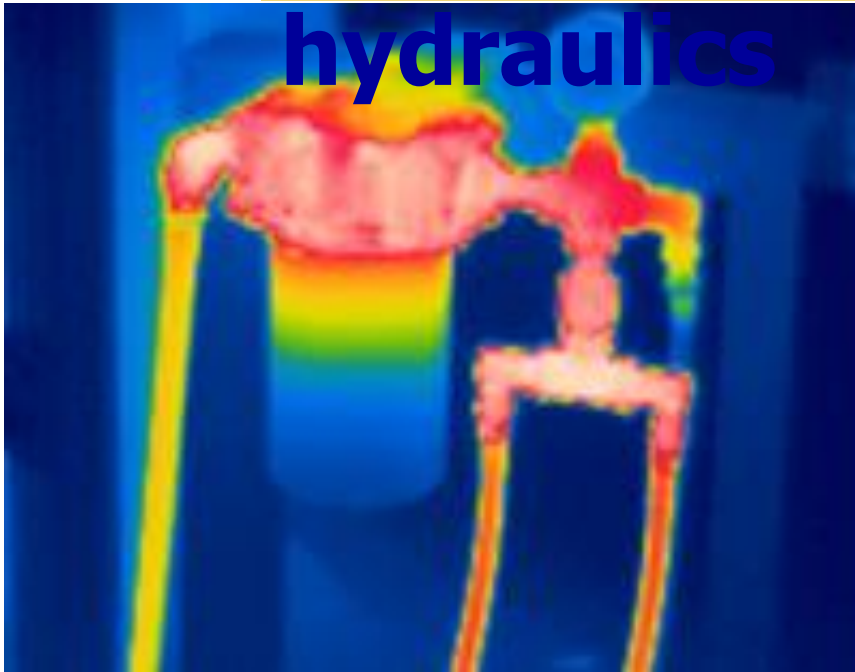
- Leaking hydraulic system valves
- Clogged filters
- Moisture and contamination in hydraulic oil
- Hot hydraulic motors, pumps condensers etc.,

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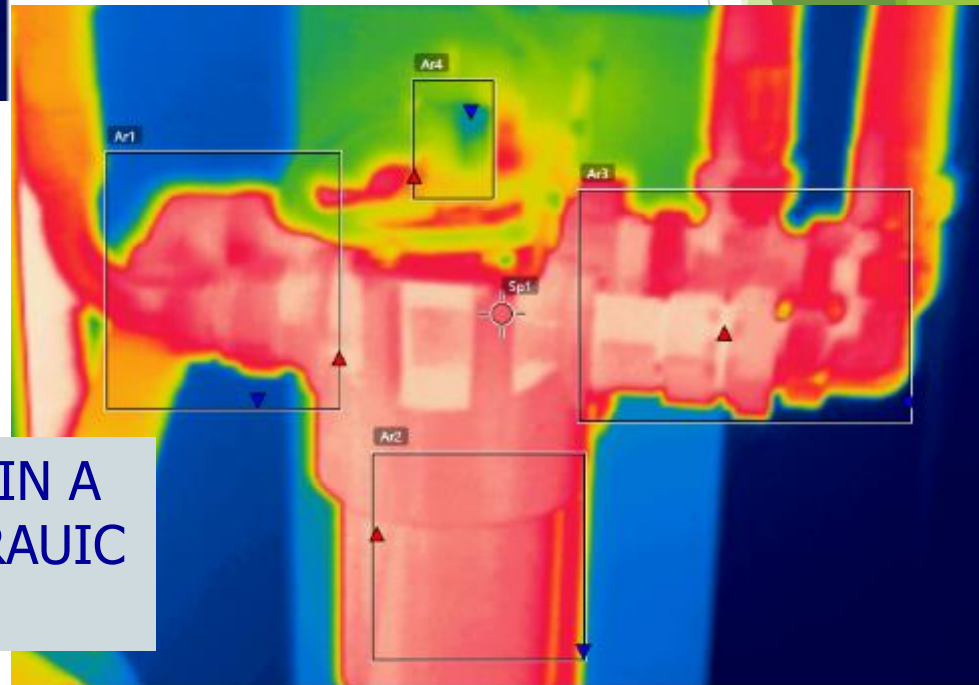
Pumps and hydraulics



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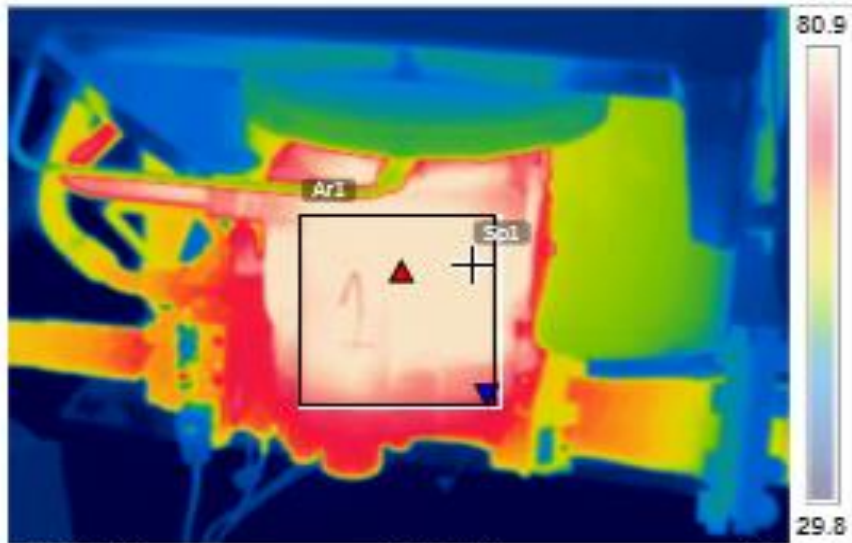


A blocked filter top side hot oil flowing, bottom side cooler and showing no oil flow (blockage) through filter.



A good filter IN A
CRANE HYDRAUIC
SYSTEM

1/23/2014 12:55:31 PM



IR_0463.jpg FLIR E60 49031470

NOTE:
 THE HYDRAULIC PUMP HEATED UP TO 83.2°C WITHING 30 MINS OF OPERATION WINDLASS HEAVING ANCHOR INDICATING OVER HEATING OF PUMP DUE TO OIL QUALITY OR COMPONENTS LIFE DETERIORATION.

1/23/2014 12:55:31 PM



IR_0463.jpg FLIR E60 49031470



A windlass hydraulic pump during heaving anchor operation

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Measurements °C		
Ar1	Max	83.2
	Min	71.2
	Average	80.5
Sp1		82.3
Parameters		
Emissivity		0.9
Refl. temp.		35 °C
Note		
hyd pump temp after half an our windlass operation during heaving anchor		

Ultrasound, Thermography and Vibration analysis combined survey

Ultrasound (US) - Ultra sound signature - Hear the sound radiation what we cannot hear

Thermography (IR) - Thermal signature- See the infrared radiation what we cannot see.

Vibration Survey (VS) - Vibration signature- The physical movement of machine language speaking about the condition.

Integration of US,IR and VS will produce a better integrated survey findings and diagnosis result

GREEN SAILS SINGAPORE Utilizing the condition monitoring technologies for Marine and offshore Industries

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Vibration monitor/ Analyzer with two accelerometers and laser eye for phase and balancing accessories

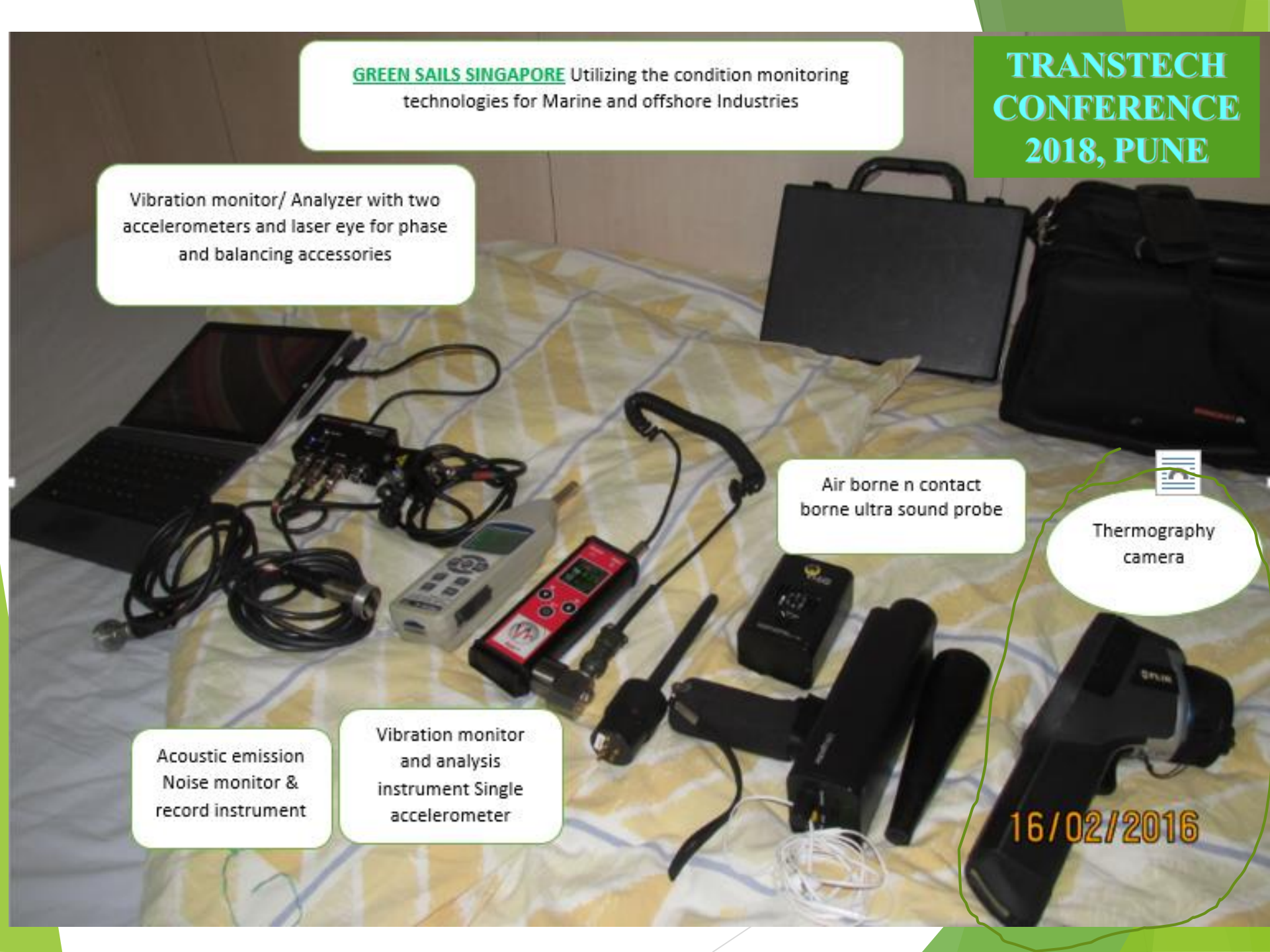
Air borne n contact borne ultra sound probe

Thermography camera

Acoustic emission
Noise monitor &
record instrument

Vibration monitor
and analysis
instrument Single
accelerometer

16/02/2016



**Thanks for your kind
Attention**

**Green sails Singapore contributing for energy
savings and thanks to
TRANSTECH CONFERENCE ORGANISERS
TOLANI MARITIME INSTITUTE, PUNE 2018.**

**Welcomes your
Questions
Comments n
Suggestions**

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