Predictive Maintenance

...for the masses

Have you reached an agreement with EHS/Ysa team regarding the status of the non ATEX

Ultrasound Inspection...

Predictive Maintenance for the Masses

Mekong Energy March 10 2014
SDT Ultrasound Solutions

Predictive Maintenance
...for the masses

Why Ultrasound

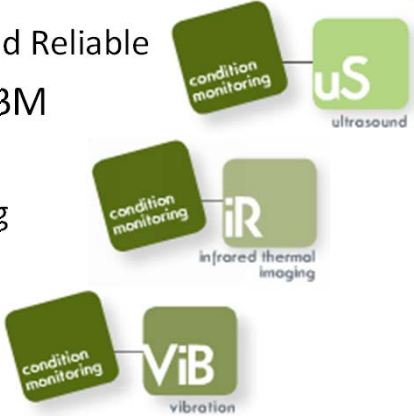- **Condition Monitoring with Ultrasound**
  - Versatility
  - Easy
  - Results regardless of competency
  - Hugely popular with PdM, Reliability

| Steam Traps | MCC Panels | Bearings | Couplings | Valve Leaks | Lubrication |

CBM Strategy

- Equip technicians with tools that are:
  - Complimentary
  - Accurate, Repeatable, and Reliable
- Core Technologies for CBM
  - Ultrasound
  - Infrared Thermal Imaging
  - Vibration
  - Motor Circuit Analysis
  - Oil Analysis

Some icons appearing on this slide are borrowed, with permission, from Uptime Magazine

PdM for the Masses

- Do all PdM instruments appeal to the Masses?
  - Lightweight and portable
  - Relatively low cost or a fast ROI or BOTH
  - Multiple users
  - Multiple departments
  - Multiple applications
  - Not a SPECIALIST'S tool
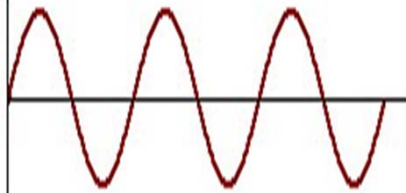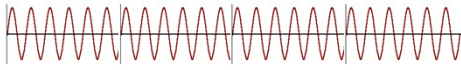
Definition

- Audible sound (things we can hear)
  - 20Hz → 20,000Hz (definition)
  - 2,000Hz → 5,000Hz (optimal)
  - Below 17,000Hz (reality)
- Ultrasound (things we can't hear)
  - 20,000Hz and above (definition)
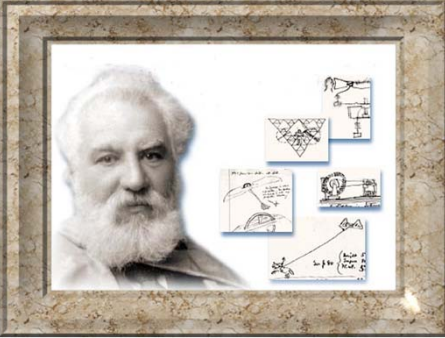
Characteristics

- Ultrasound
  - High frequency
  - Short wavelength
  - Lower amplitude
  - Directional
  - Quickly attenuated

- Sound
  - Low frequency
  - Long wavelength
  - Powerful amplitude
  - Multi directional
  - Transports well

Definition of the dB
Alexander Graham Bell

- dB is logarithmic unit used to describe a ratio. The ratio may be power, sound pressure, voltage or intensity.

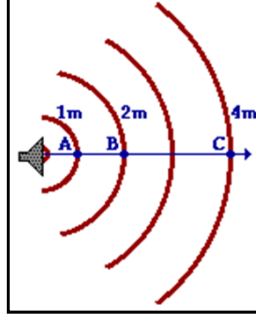- SDT's reference value is 0dB = 1 µv

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Intensity and Distance

Inverse Square Rule

Example
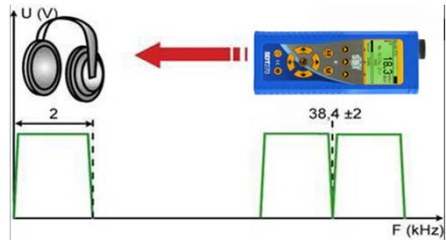
Distance	Intensity
1 m	200 units
2 m	50 units
3 m	22.2 units
4m	12.5 units
5 m	8 units

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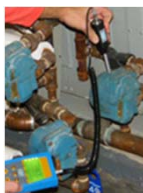
How Does it Work?

Predictive Maintenance *...for the masses*

- Convert ultrasound to sound
- Maintain characteristics of original signal
- Measure for trending
- Capture for analysis
- Ignores Auidable

Natural occurring U/S

Predictive Maintenance *...for the masses*

- Ultrasound is generated by many things
  - Plant machinery (rotating and non-rotating)
  - Leaks (pressure and vacuum)
  - Electrical faults
  - More later…

| Steam Traps | MCC Panels | Bearings | Couplings | Valve Leaks | Lubrication |

Two Ways to Detect

- Ultrasound moves through any medium
  - Gas, Liquid, Solid… ~~Vacuum~~
- Two modes of detection

Airborne Detection

Structure Borne Detection

Why is Ultrasound Inspection Effective?

- Fault conditions have US frequencies 1st
- Leaks overwhelmed by plant noise
- Useful during peak times
- Characteristics are maintained
- Directionality hastens detection
- Trendable and non trendable defects
- Time and Spectrum analysis
- Simple or Complex analysis
- Integrate to provide 2nd opinion

General Applications

Predictive Maintenance *...for the masses*
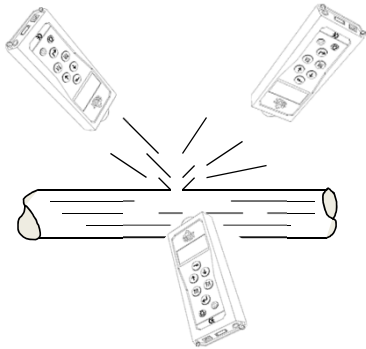
- Let's put is to work

Leak Detection	Pump Cavitation
Bearing Monitoring	Compressor Valves
Lubrication	Heat Exchangers
Electrical Inspection	Hydraulic Systems
Steam Systems	Tightness Control

Leak Detection

Predictive Maintenance *...for the masses*

- Turbulent flow at leak site
- Produces ultrasound with peaks at 40kHz
- Directional… easy to pinpoint
- Oblivious to plant noise
- Vacuum leaks

Method

- Leak detection procedure
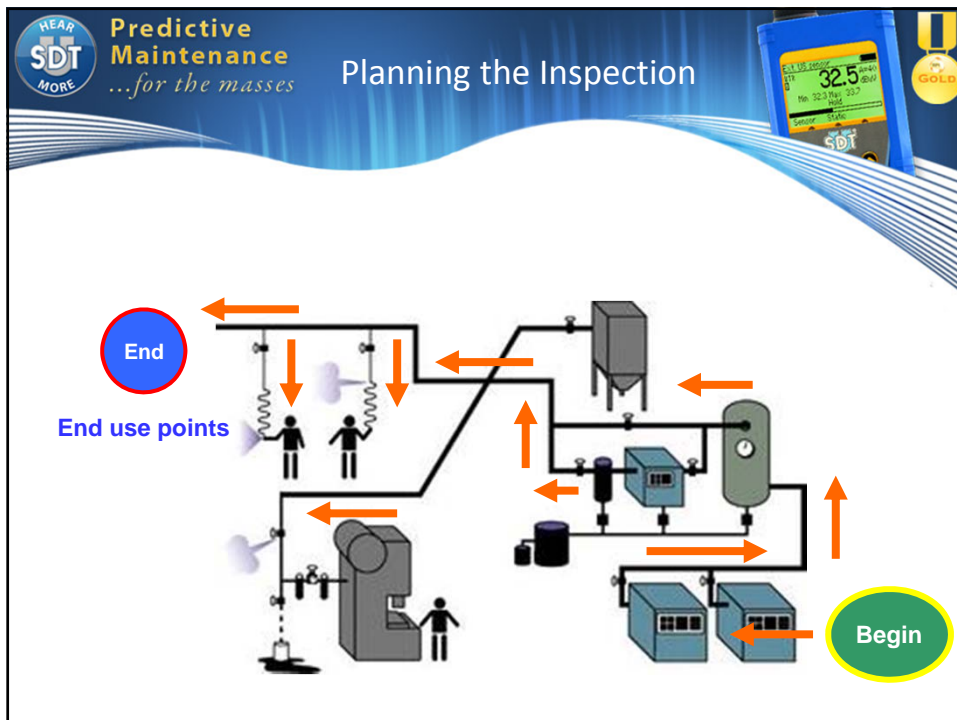 - Right/Left/Up/Down
  - Leak sound increases sharply
  - Adjust sensitivity and headset volume
  - Use focusing tip and shielding techniques
  - Ricochet

Planning the Inspection

End

End use points

Begin

A Favourite Quote

*"It is often noted that **finding a leak never saved a dime** and no truer words can be spoken on the subject of ultrasonic compressed air leak detection. As satisfying as it may be to spend 8 hours identifying 100's of compressed air leaks, there is no payback in wrapping a yellow ribbon around a leaking pipe fitting. **It has to be fixed to save** "*

Dan Durbin, Former Chief Engineer,
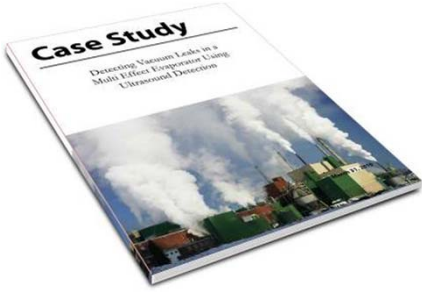**Anheuser-Busch, St. Louis, Missouri**

$

Costs

Vacuum Leak Program

- Vacuum leaks are quieter than air leaks
  - May need other sensors/accessories to find
  - May need different strategy to find
- Great case study about vacuum leaks in multi-effect evaporator
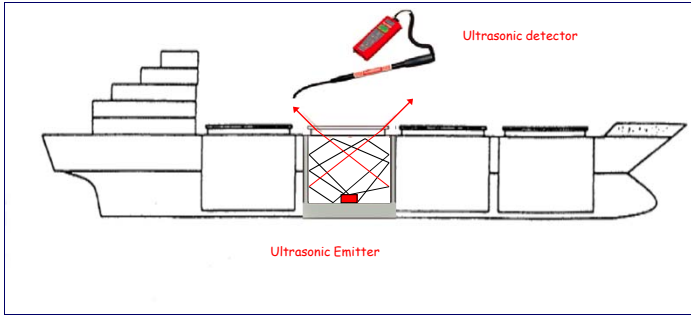 - Relevant to power gen

Case Study

Detecting Vacuum Leaks in a
Multi Effect Evaporator Using
Ultrasound Detection

Tightness Integrity

Predictive Maintenance *...for the masses*

Automobile – Wind and Water Leaks on Cars and other vehicles

Predictive Maintenance *...for the masses*

Marine Industry – Hatch Covers of Cargo Ships
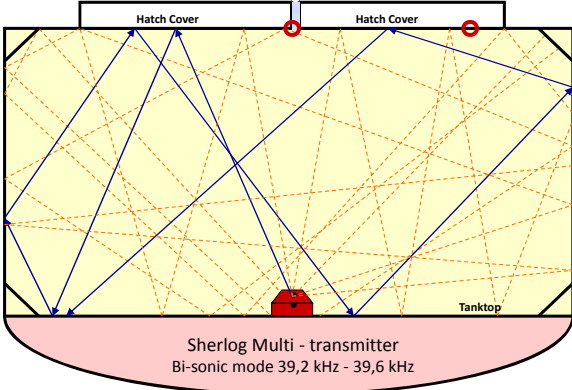
Ultrasonic detector

Ultrasonic Emitter

Tightness Integrity

Marine Industry – Hatch Covers of Cargo Ships

Hatch Cover   Hatch Cover

Tanktop

Sherlog Multi - transmitter
Bi-sonic mode 39,2 kHz - 39,6 kHz

Tightness Integrity

Marine Industry – Hatch Covers of Cargo Ships

SDT 8

Document Follow Up

- Numerically tag leaks
  - Date found
  - Date repaired
  - Repaired by ??
  - Type of leak
  - Location of leak
  - Criticality
- Repair on the spot?

This should get your attention

Electrical Applications

- Use ultrasound to find electrical faults
  - Arcing
  - Tracking
  - Corona
  - Special areas
    - Loose part monitoring

Electrical Applications

- The list of applications is huge
  - Transformers
  - Switchgear
  - Relays
  - Bushings
  - Transmission lines
  - Street poles
  - Junction boxes/circuit breakers
  - Buss bars
  - Sub Stations
  - Insulators

Predictive Maintenance ...for the masses

Electrical Applications

Setting up an Electrical Inspection Program

- Areas to cover:
  - High voltage
    - Corona, Tracking & Arcing
  - Low voltage
    - Tracking & Arcing

Predictive Maintenance ...for the masses

Electrical Systems

- Two methods of detection
  - Contact or airborne

Choose the right sensors

Flexible for ergonomics

Magnetic for consistency

Parabolic for safety

Arcing

Arcing characteristics
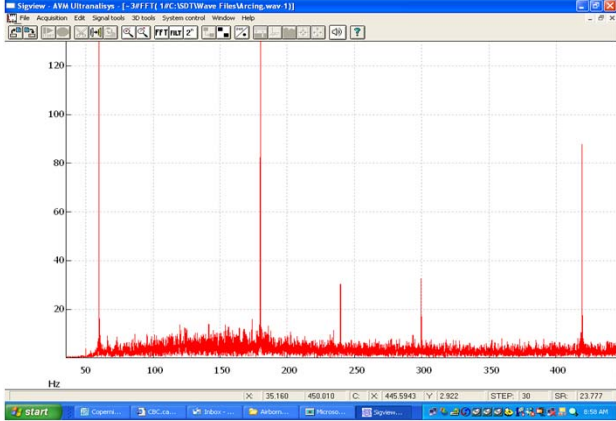
- Arcing can be seen with Infrared
- Infrared and Ultrasound used together is most effective in an electrical inspection.
- Arcing is often accompanied by heat
- Arcing can be identified as an "abrupt start and
- stop".
- Can be violent
- When heard, should be inspected by a qualified
- technician

Certification Training Level 1 Version 2.0

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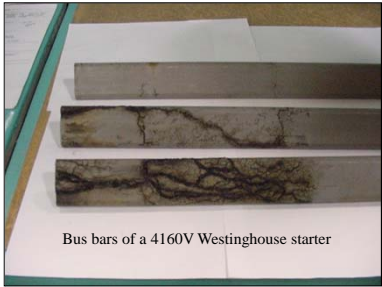
Arcing

- Arcing Signature as displayed using UAS

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Tracking

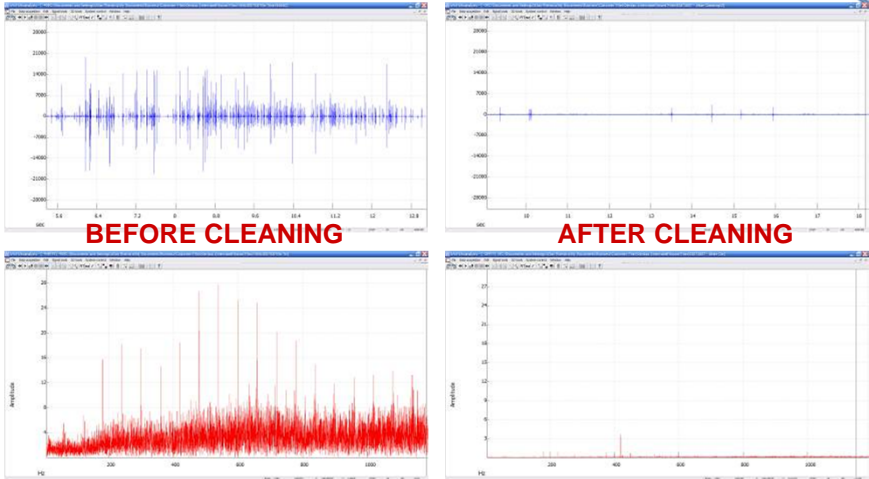- Tracking is sometimes called "baby arcing".

- Exists to Find Ground. Uses any carbon build up to track as it starts a path to ground.

- As intensity builds, and as the amplitude increases and builds to a point of "flashover", discharge occurs and starts this process all over again.

- This condition normally requires immediate attention.

- Record and save wave files for comparisons with colleagues.

Bus bars of a 4160V Westinghouse starter

Measurement Cycle

- Find it, Fix it, Check it

BEFORE CLEANING

AFTER CLEANING

Predictive Maintenance ...*for the masses*

High Voltage

- Corona, Tracking and Arcing
  - Corona and tracking do not generate heat
  - Corona produces a constant burbling sound
  - The ability to capture scalable data allows comparison

Predictive Maintenance ...*for the masses*
Corona Discharge

- Corona characteristics
- Two types of Corona activity
- Nuisance Corona
  - Can be caused from dirty insulators or bushings and high humidity
  - Does not pose an immediate threat
  - Is wasteful

- Destructive Corona
  - Steady frying or buzzing sound accompanied
  - with an intermittent popping sound
  - Lower deeper sound
  - Oxidation by-products are being produced
  - Does not generate heat

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Corona discharge

- a discharge, frequently luminous, at the
- surface of a conductor or between two
- conductors of the same transmission line,
- accompanied by ionisation of the
- surrounding atmosphere and often by a
- power loss.
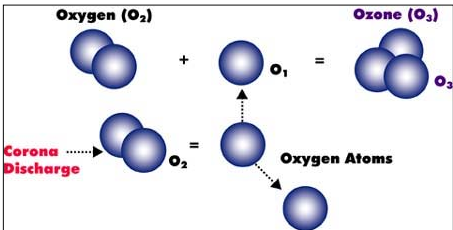
- **Does not generate heat**

Ultrasonic Sound Characteristic
Steady, regular, popping sound

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Corona – what is it?

- Atomic reaction which produces ionisation due to
- electron movements
- Ozone and nitrogen oxide are produced
- High humidity makes it worse
- Result: Breakdown of insulating compounds

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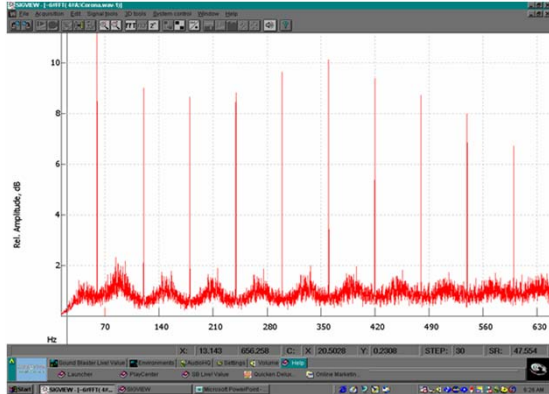
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Corona Discharge

• Why locate corona discharge

- Leads to more serious electrical problems

- Breakdown of components - corrosion

- Unexpected shutdowns

- Fire and explosion

- Waste of electricity

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Corona Discharge

• Corona signature displayed using UAS

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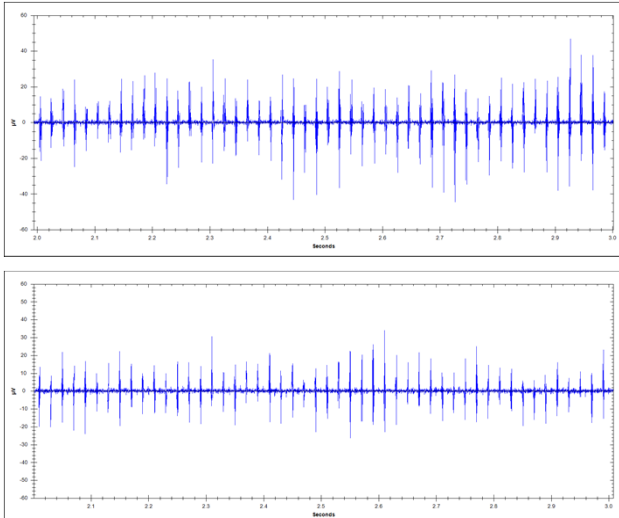
The Environment affects readings
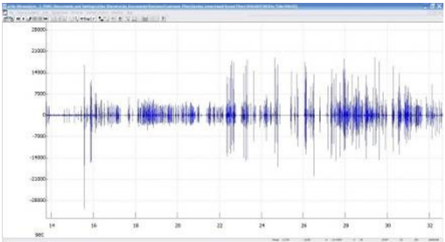
Scalable Time Signals

Arcing and Corona Together

- Ultrasound teams well with Infrared

Ultrasound Signal

Thermal Image

Ultrasound for Mechanical Inspection

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Mechanical Condition Monitoring

- Rotating and non-rotating equipment
    - Bearings
    - Gearboxes
    - Pumps
    - Motors
    - Compressors
    - Recips
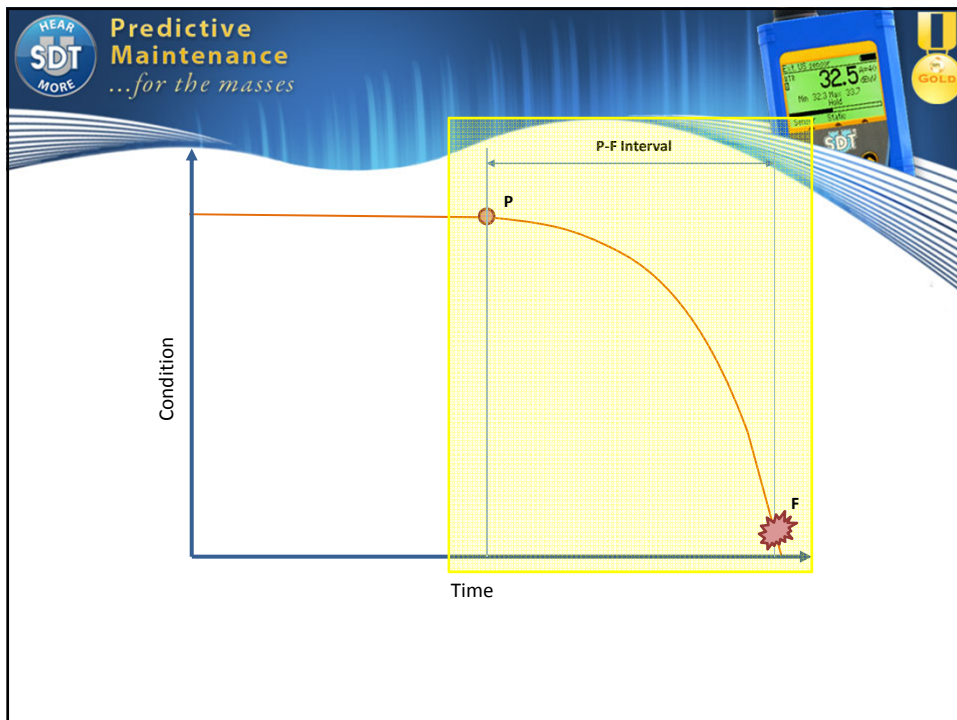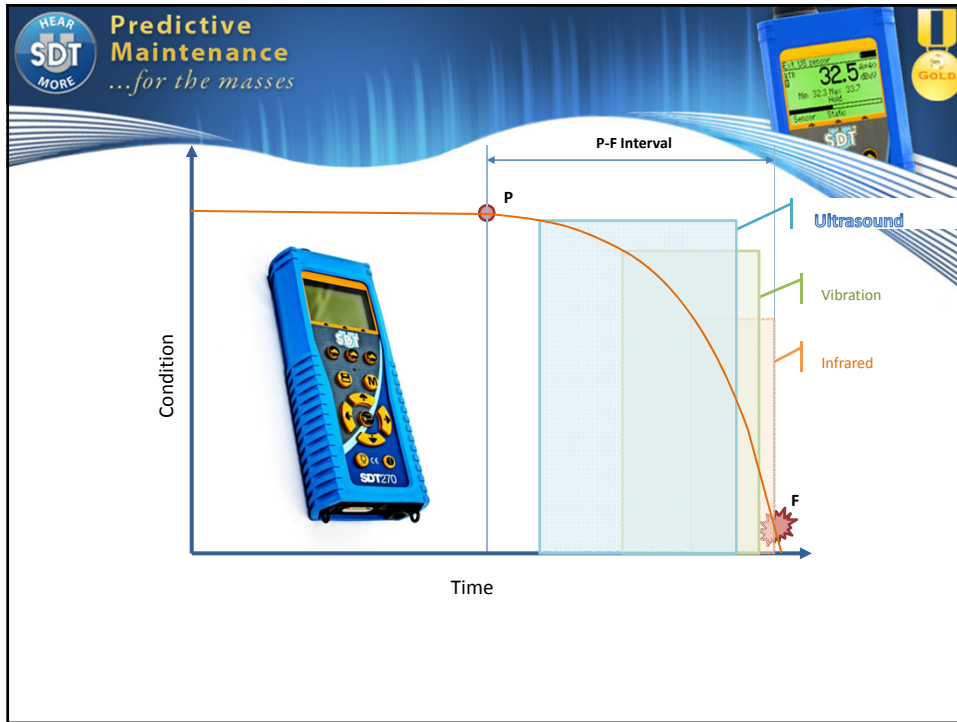
Defect Detection 101

The benefit of ultrasonic is that the energies produced are detectable much <u>earlier in the failure curve</u>.

Time directed tasks

"It wasn't broke, but we fixed it anyway"

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Condition directed tasks

"If it ain't broke, don't fix it"

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Rotating Equipment

NASA Tech Brief Marshall Spaceflight Center

- SDT Recommendation
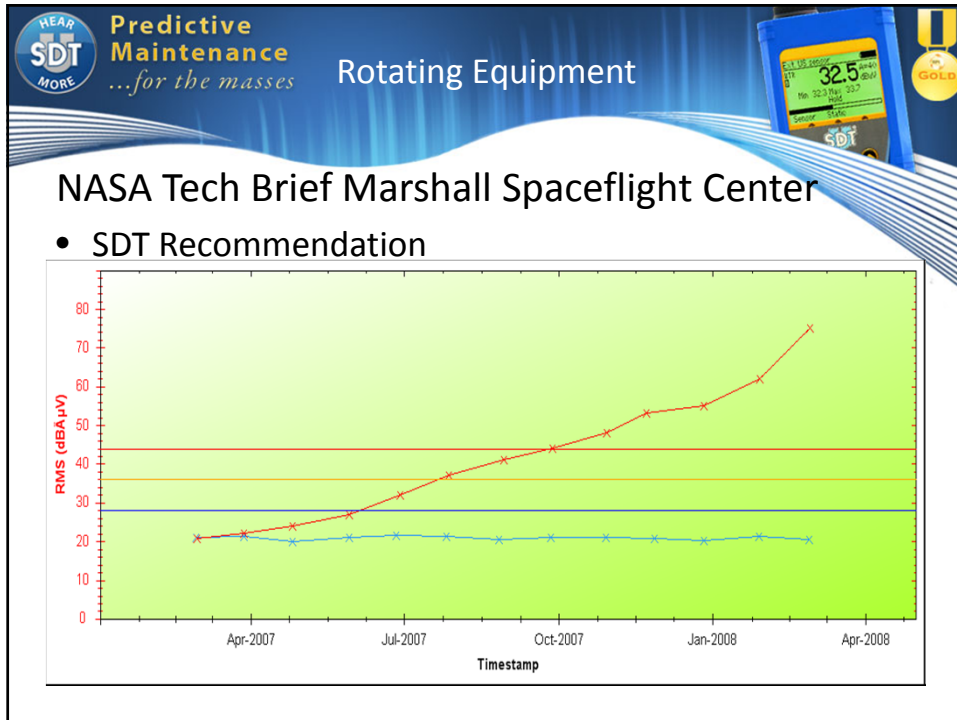
Mechanical Condition Monitoring

- **Three groups**
  - Non-trendable
    - Pass/Fail, couplings, belt drives, some bearings
  - Trendable with static data
    - Most bearings
  - Low energy Identify using dynamic signal analysis
    - Slow speed bearings
    - Gearboxes

Static Condition Indicators

- RMS
- Max RMS
- Peak
- Crest Factor

```
43.5 dBμV RMS
43.6 dBμV Max RMS
56.3 dBμV Peak
4.4 CresFactor
```

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What is RMS?

- Acronym for Root Mean Square
- Reflects the amount of energy present over Acquisition time (Adjustiable)
- Physical unit (we use): dBμV

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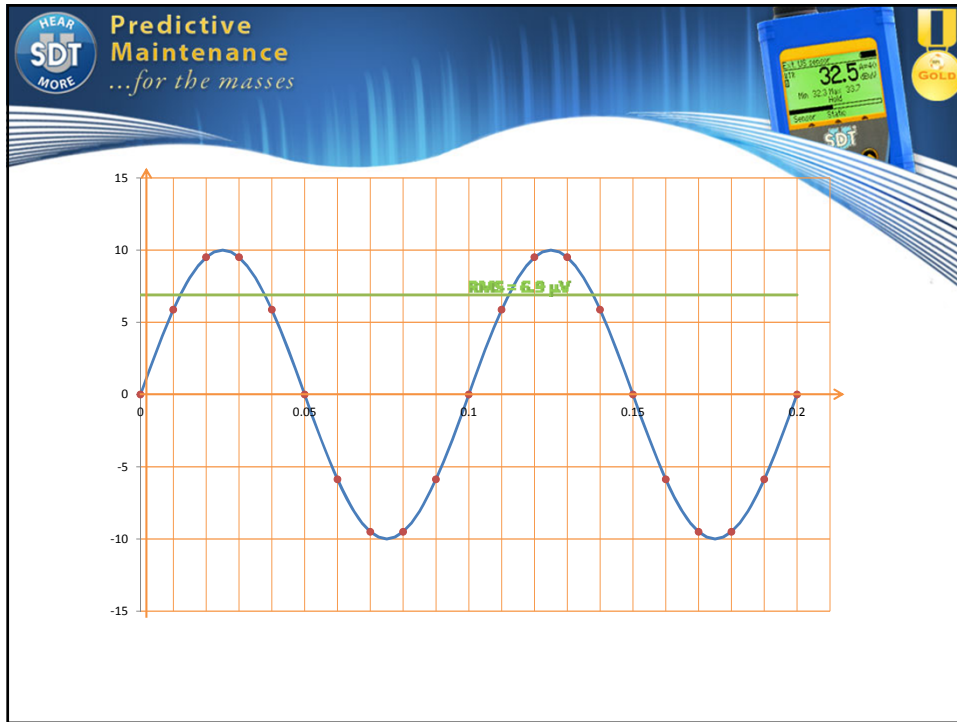
Max RMS & RMS:

Positive:

- Stable
- Repeatable
- Suited for trending

Negative:

- Insensitive to short duration events
- So not suited to early stage impact detection
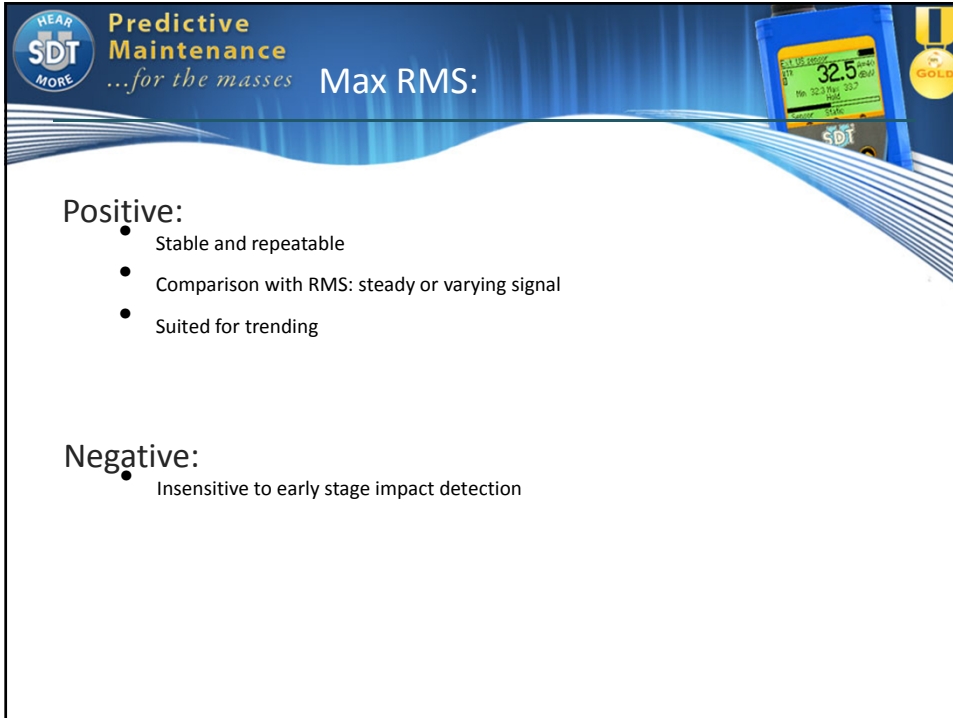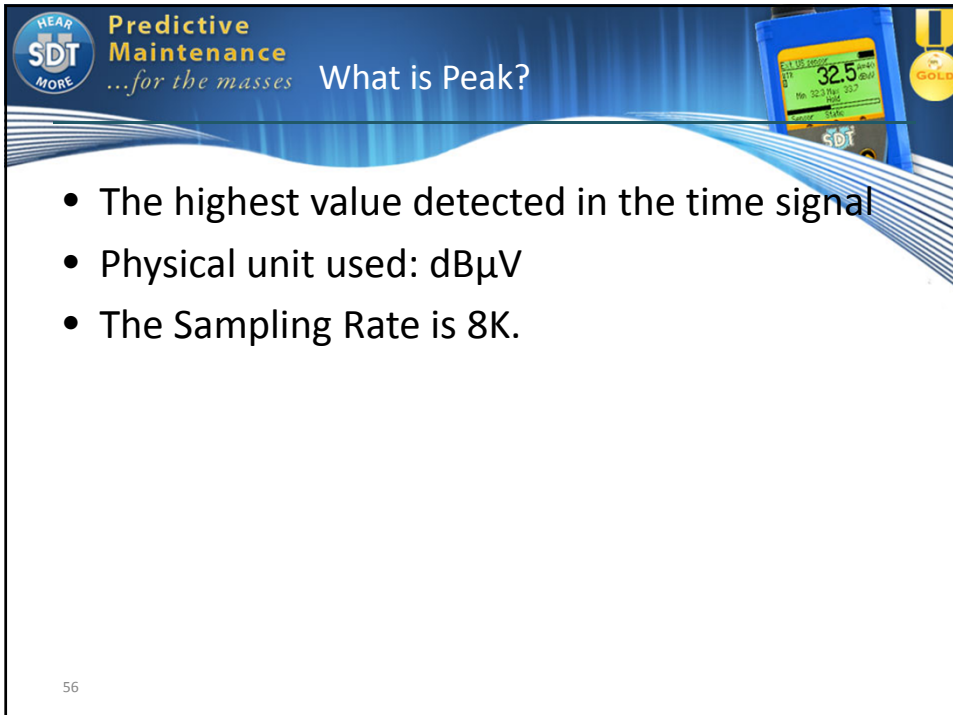
Predictive Maintenance
...for the masses

Max RMS:

Positive:
- Stable and repeatable
- Comparison with RMS: steady or varying signal
- Suited for trending

Negative:
- Insensitive to early stage impact detection

Predictive Maintenance
...for the masses

What is Peak?

- The highest value detected in the time signal
- Physical unit used: dBμV
- The Sampling Rate is 8K.

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Peak :

Positive:
- Very sensitive to any change
- Suited for impact detection

Negative:
- Not going to be repeatable, by the very nature of infrequent transients
- Trends difficult to interpret

What is Crest Factor?

- The Peak-to-RMS ratio
- Crest Factor = Peak / RMS
- No physical unit – it is a numeric ratio
- Indicates how Peaky (impacts) the signal is.

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What is Crest Factor?

- RMS value is 20dBµV
- Peak is 40dBµV
- Crest Factor is expressed in linear numbers
- 40dBµV = 100µV, 20dBµV = 10µV
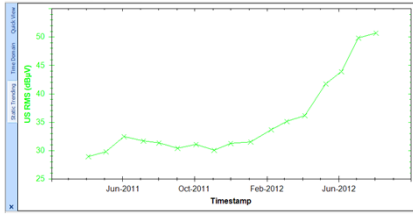 - Crest Factor is 100/10= 10

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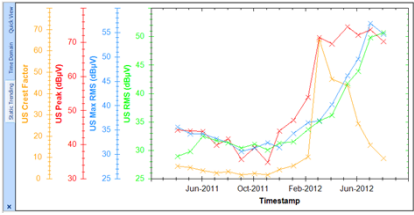
Condition indicators in UAS software :

- Simplicity for those who want
- Elaborate for those who need

Bearing failure example, Time

Healthy bearing:
- RMS = 24.4 dBμV, Peak = 43.1 dBμV, CF = 8.6

Bearing failure example, TW

Defective bearing:
- RMS = 47.7 dBμV, Peak = 75.4 dBμV, CF = 21.9

The Measurement Cycle

3. Check it

1. Find it

2. Fix it
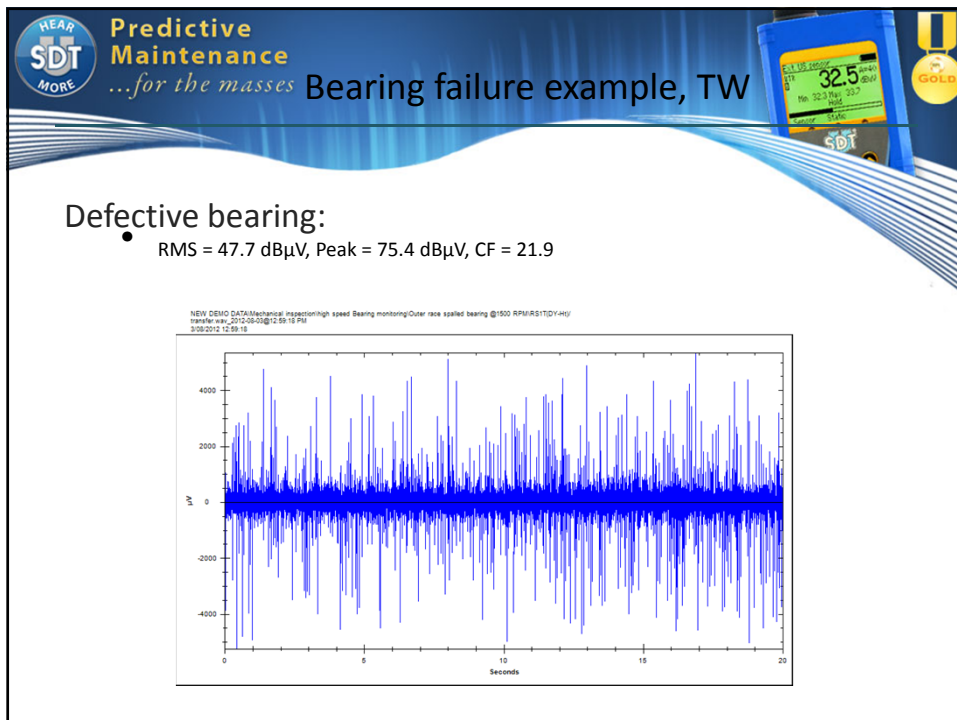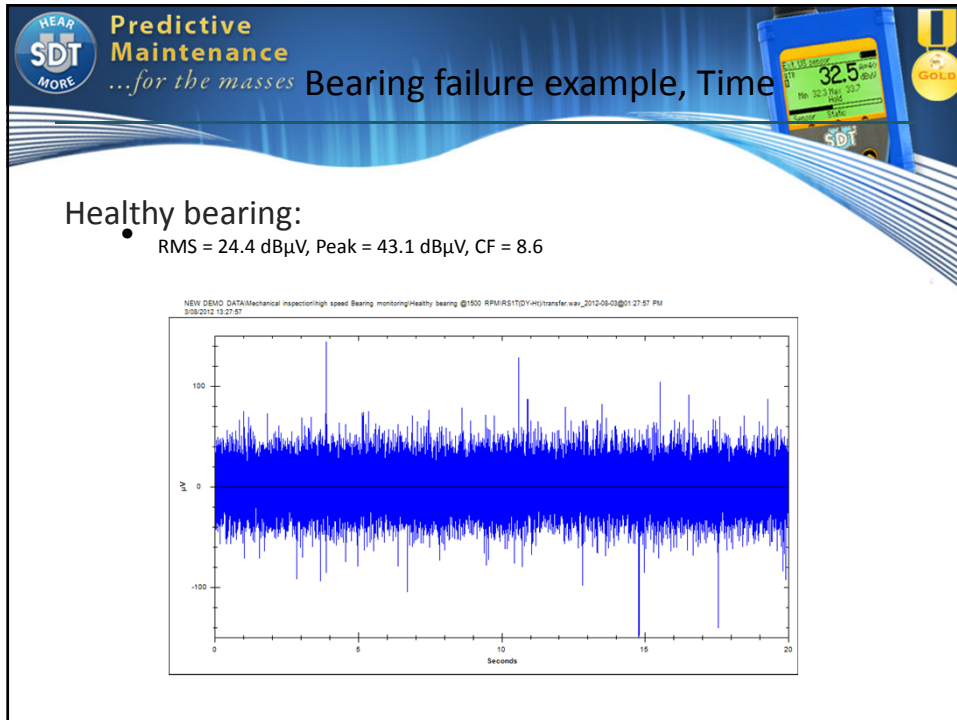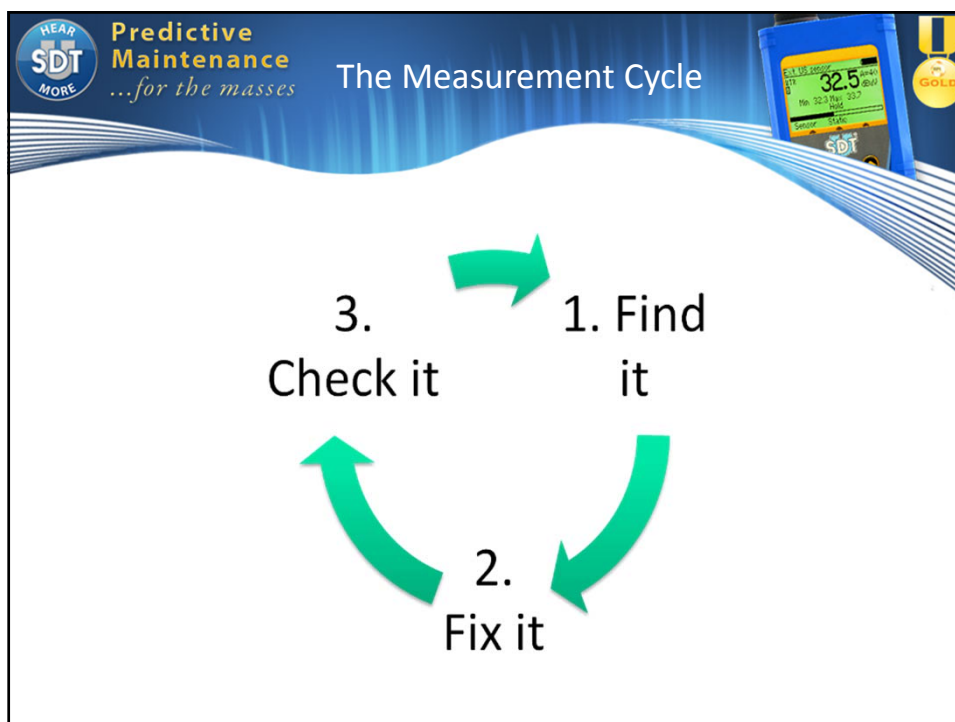
Inspection Methods

A. Comparative

Comparing dBuV readings on similar equipment. Used when no history available and when there are similar equipments.

B. Trending

Monitor increases in dBuV readings over a period of time, making decisions accordingly. Get as much info as possible.

Predictive Maintenance
...for the masses

AVM ™ Acoustic Vibration Monitoring

- **All bearings produce ultrasound**
- **Ultrasonic Monitoring shows lubrication intervals and predicts mechanical failures**

Monitoring Bearing Condition is Easy

1. **Set up a plan to identifying all bearings to be monitored**
2. **Create a Tree Node and Survey**
3. **Trend monthly ultrasound levels**
4. **Record sound wave files to compare month to month readings**

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Predictive Maintenance
...for the masses

Comparative, You Decide

- 1 Feed Pump
- 71.3 decibels/uVolt

- 2 Feed Pump
- 56.6 decibels/uVolt

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Rotating Machinery

- Slow Speed Condition Monitoring
  - Difficult with some technologies
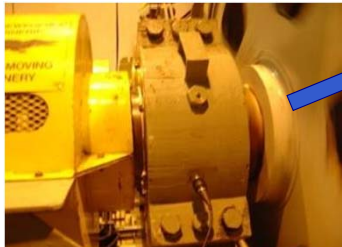   - Ultrasound does not need 1 minute

Singapore Flyer

- Ferris Wheel Feng Shui

- Spindle bearing measurements taken one month after rotational direction changed (Feng Shui)
- 37 minutes for one rotation .0004 RPM
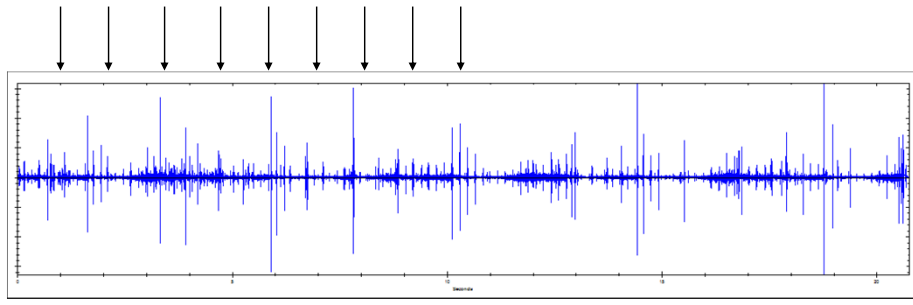
Rotating Machinery

- Special Applications – Hoist Bearing
  - Doesn't operate long enough for some tech.
  - 14 RPM but for 10 or 20 seconds only
  - BPFI expected at 2.88Hz/173CPM

Time Signal

- Time Signal
  - Impacts can be seen clearly
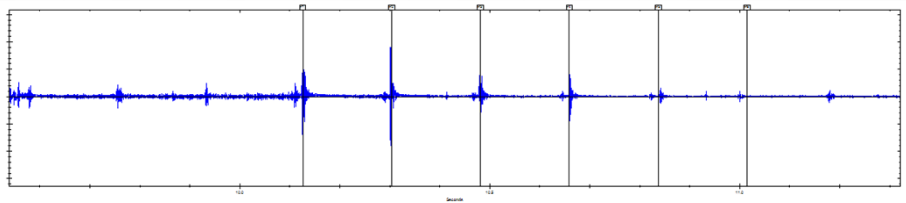
Predictive Maintenance *...for the masses*

Time Signal

- Expand any area of this time signal
- Apply a periodic cusor
    - You get a repetition frequency of 346cpm
    - 2x the inner race defect frequency (173cpm)

Predictive Maintenance *...for the masses*

Rotating Machinery

- Inner Race Defect Discovered
    - Spalling across the length of the raceway

Predictive Maintenance …for the masses Using an accelerometer

Vibration

Motor Current Analysis

Ultrasound

Oil Analysis

Thermal Imaging

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Predictive Maintenance …for the masses Keeping it simple

- The 270 has IR temperature measurement
  - But it is not an IR camera
- The 270 has vibration measurement
  - But it is not a vibration data collector
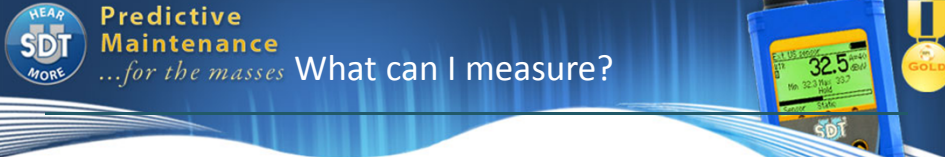 - That's not the intention

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Using an accelerometer

- Adds one extra tool to the powerful Ultrasound
- Means that users can make diagnosis that bit easier
  - Don't need to go back to office to change tools
  - Don't need to ask somebody else to do it

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What can I measure?

- Velocity in ips or mm/s 10-1,000Hz
- Acceleration in g 10-10,000Hz
- RMS and Peak calculated
- Dynamic measurement (Time) of both now possible with the Raw option instead of Ht.
- All options controlled inside Software Options
- Supports 100mV/g ONLY

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Hoist Bearing

- The point
  - NOT that U/S is better than vibe
  - NOT why the 2x defect should be so dominant
  - Ultrasound can measure this difficult vibration measurement in 20-30 seconds
  - Structural vibration is taken out of the equation

Acoustic Lubrication

Lubrication

- Time Based
- Condition Based
- When to Grease
- How Much Grease

  Digital Metering

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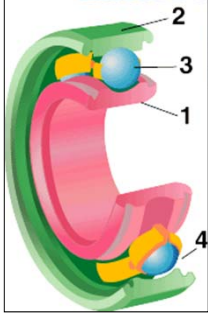
Rolling Element Bearings

(1) Inner Ring - the smaller of the two bearing rings with a groove on its *outside* diameter to form a path for the balls.

(2) Outer Ring - the larger of the two rings. It has a groove on its *inside* diameter to form a pathway for the balls.

(3) The Balls- these are the rolling elements that separate the inner and outer ring and allow the bearing to rotate with minimal friction.

(4) The Cage - the purpose of the cage is to separate the balls, maintaining an even and consistent spacing, to accurately guide the balls in the paths, or *raceways,* during rotation, and to prevent the balls from falling out.

"When lubricating a bearing, how do you know you have enough grease in the bearing"?

"Right when you see the grease starts to appear outside the bearing."

WRONG ANSWER !!!

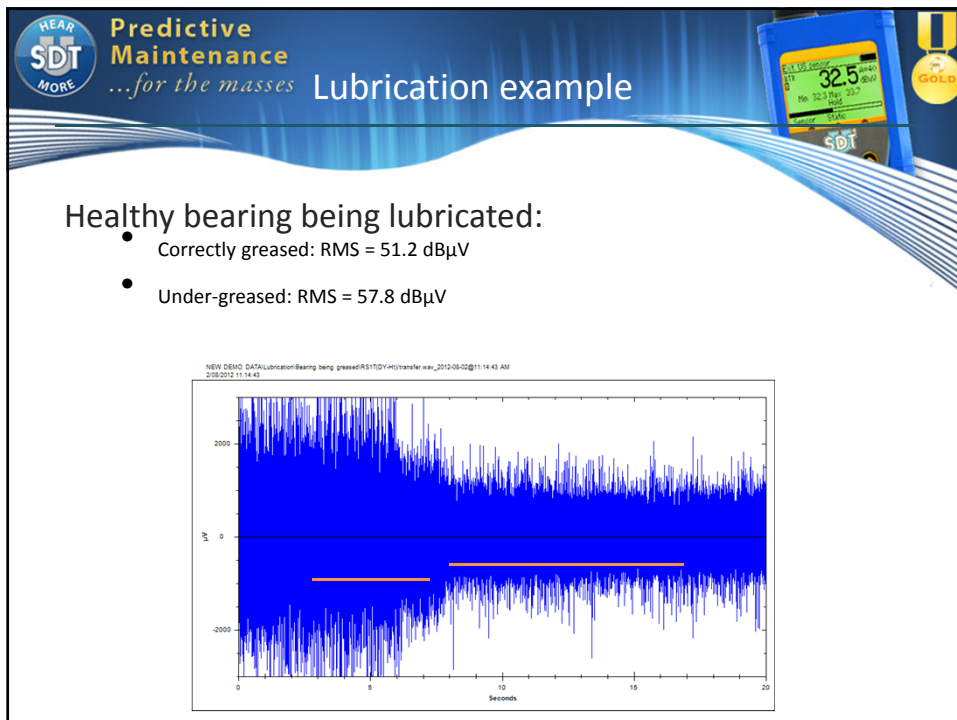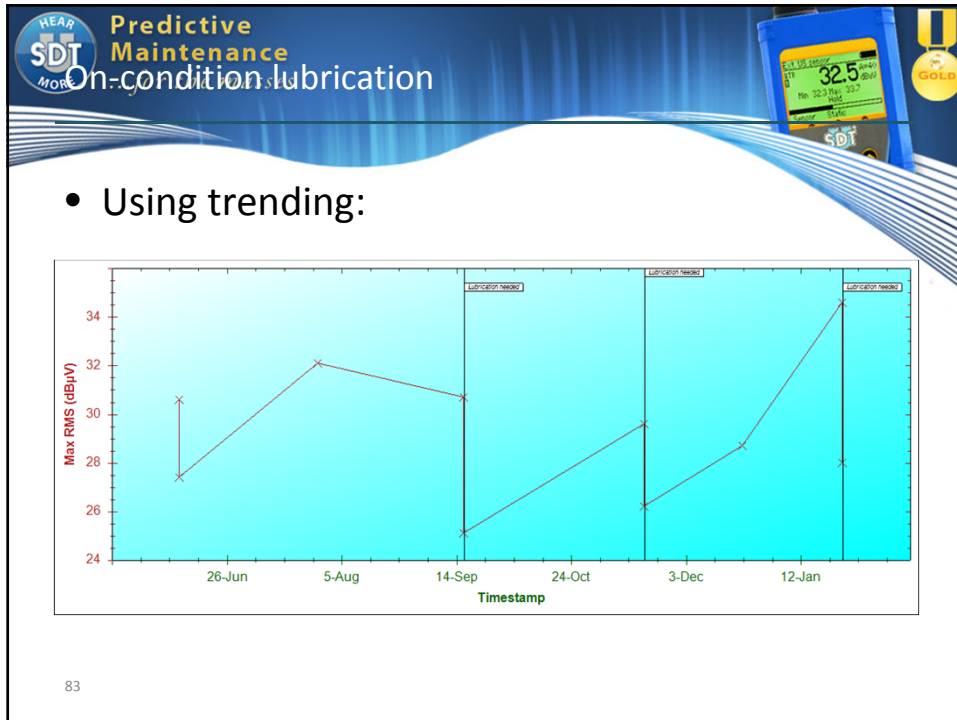**Predictive Maintenance** *...for the masses*

The horror stories

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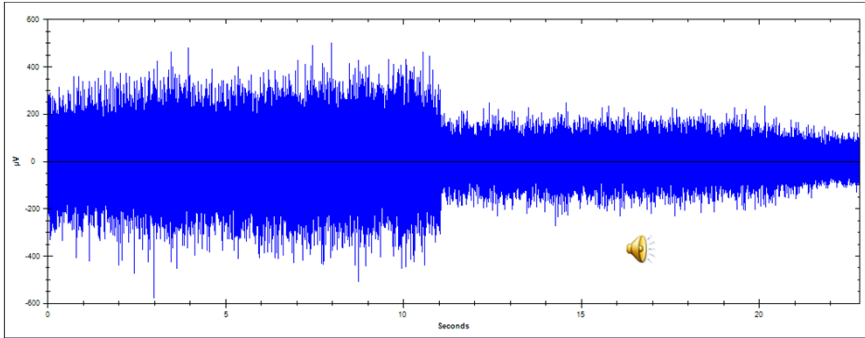**Predictive Maintenance** *...for the masses*

Lubrication

- Time Based
- Condition Based
- When to Grease
- How Much Grease
- Listen Only
- Digital Metering

Before Grease After Grease

55 dBuV   38 dBuV

On-condition lubrication

- Using trending:

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Lubrication example

Healthy bearing being lubricated:

- Correctly greased: RMS = 51.2 dBµV

- Under-greased: RMS = 57.8 dBµV

Predictive Maintenance ...for the masses — On-condition lubrication

- Bearing needed grease:
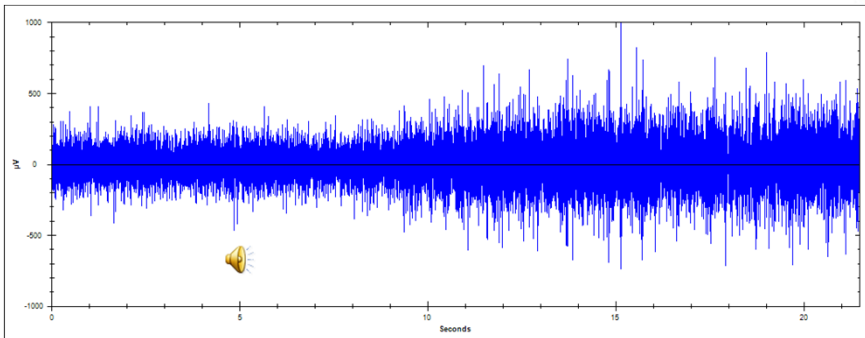
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Predictive Maintenance ...for the masses — On-condition lubrication

- Bearing already overgreased:

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Lubrication

- A picture is worth a thousand words
- What is the value of this picture?

Valve Inspections

1. Do a comparison method before and after the valve.   OR

2. Contact the valve and listen.

Valve Body Inspection

- Checking valve for flow
  - Upstream and downstream
  - Works for any gas or liquid

Valves and Hydraulics

- **Find internal leakage and passing valves**
- **Perform inspections without disassembly**
- **Save hours or even days from complicated repairs**

Ultrasonic Inspection of Hydraulics:
- **Place contact sensor on valve body and wait for system to cycle.**
- **Ultrasound will tell you that the valve is passing or stuck in shut position.**

Predictive Maintenance
...for the masses

- Example
- Multi inspection points in a pump

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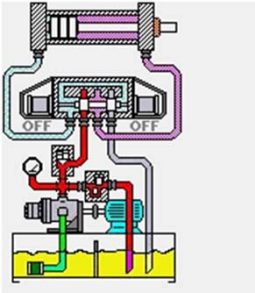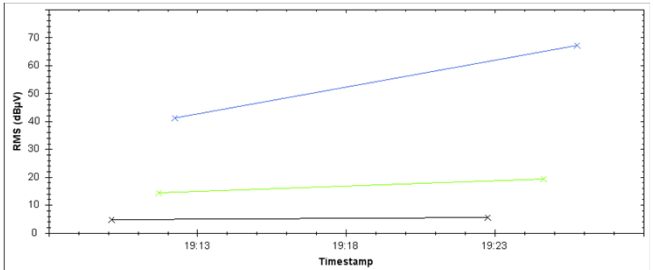
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Predictive Maintenance
...for the masses

Valve inspection

- Passing valves, Blocked valves, Valve cavitation
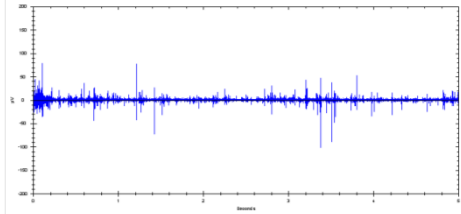- Example of a 60cm bypass valve: 25dBµV difference between closed and 10% open

Valve Inspections

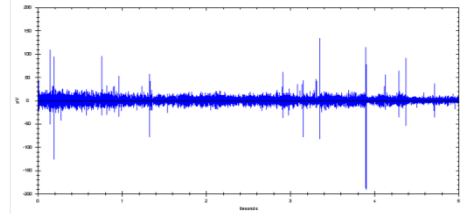- Identify the difference between a closed and 10% open 60cm bypass recycle valve
  - Dynamic measurements captured downstream
  - Time signals identically scaled for comparison

Valve closed

Valve opened 10%

What is a Steam Trap?

- an automatic valve that opens for condensate, air and carbon dioxide (CO_2) and closes for steam.

- operates under the principles of density, temperature or velocity.

Steam Trap Analysis

www.sdtnorthamerica.com

Steam Traps

What is steam?

- it is vaporised water produced by adding heat energy to its boiling point, then more energy is given to change water to steam without further increasing the temperature

+ 142 BTU

+ 970 BTU

1 lb. water
at 70 F

1 lb. water
at 212 F

1 lb. steam
at 212 F

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Properties of saturated steam

Gage Pressure Psig	Absolute Pressure Psia	Steam Temperature F	Heat of Saturated Liquid, Btu/lb	Latent Heat Btu/lb	Total Heat of Steam Btu/lb	Specific Volume cu ft/lb
-5.49	12.00	201.96	169.96	976.60	1146.60	32.40
0.00	14.70	212.00	180.07	970.30	1150.50	26.80
10.30	25.00	240.07	208.42	952.10	1160.60	16.30
50.30	65.00	297.97	267.50	911.60	1179.10	6.66
100.00	114.70	337.90	308.80	880.00	1188.80	4.23
150.30	165.00	365.99	338.53	857.10	1195.60	2.75
200.30	215.00	387.89	361.91	837.40	1199.30	2.13
250.30	265.00	406.11	381.60	820.10	1201.70	1.74

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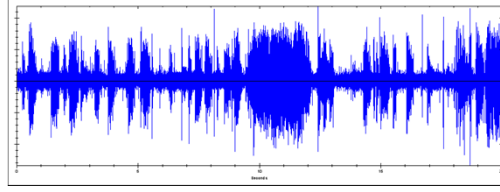
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Ultrasonic inspection

• Allows one to hear inside the trap

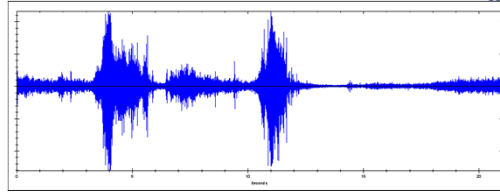Certification Training Level 1 Version 2.0

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- New generation of ultrasound systems can record scalable, comparable time signals
- Now instead of just listening we can compare:
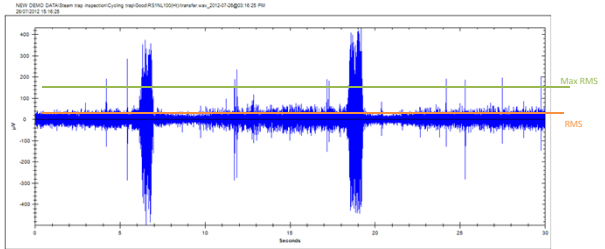
Trap example

Good trap:

Temp 225 F
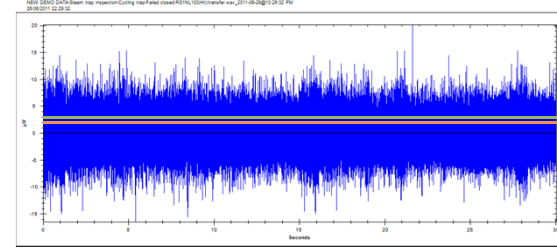
- Max RMS (43.3 dBµV) is higher than RMS (29.7 dBµV) Peak (51.7 dBµV)

Trap example

Failed closed:

- Temp 140 F   RMS is low (9.4 dBμV)

- Max RMS (11.5 dBμV) is close to RMS
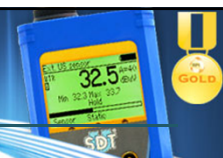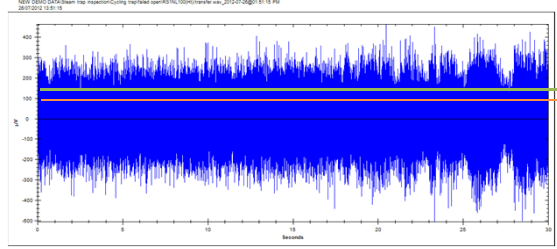
Trap example

Failed open:

- Temp 226 F, RMS is high (39.5 dBμV)

- Max RMS is close to RMS (41.9 dBμV)

Predictive Maintenance *...for the masses*

You Decide
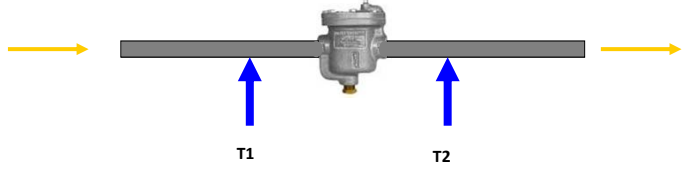
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Predictive Maintenance *...for the masses*

Steam Traps

Thermal inspection

- Upstream and downstream temperature are taken and compared

T1   **T2**

Can be affected by back pressure

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Steam Traps

- The value of a
- steam trap inspection programme

- Promotes efficient heating system
- Save $$$ in chemicals, fuel, material and maintenance costs

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Lots of ifo here

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Predictive Maintenance
...for the masses

Take Upstream Temperature

If Temp is too low

If Temp is normal

- Know the operating pressure of the steam system to determine the system temperature
- Subtract 10% for heat transfer through pipe

Keep Your Trap Shut   Application
Video Tutorial Series

Predictive Maintenance
...for the masses

If Temp is too low

CONFIRM
Is Trap in Service?

NO!

YES!

Diagnosis
Not Possible

Listen to
Ultrasound
Signal

Keep Your Trap Shut   Application
Video Tutorial Series

Predictive
Maintenance
...for the masses

If Temp is too low

Trap is in Service

Listen to
Ultrasound Signal

Signal is
Low & Constant

Trap is Failed in Closed Position

or there is a blockage up or downstream

Keep Your Trap Shut   Application
Video Tutorial Series

Predictive

If Temp is Too Low

Trap is in Service

Ultrasound Signal is Irregular

Record Dynamic Signal

Record Upstream Temperature

Compare data with a good trap to build a
reliable diagnosis and baseline data
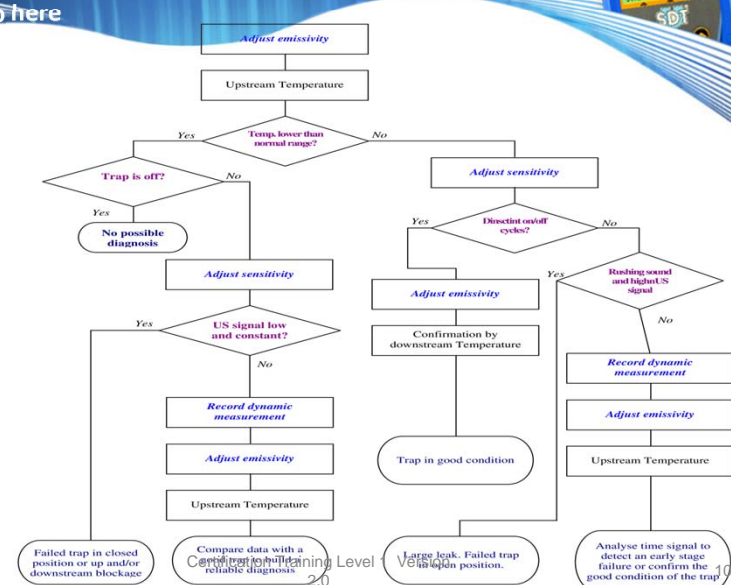
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Video Tutorial Series

Predictive Maintenance
...for the masses

If Temp is Normal

Listen to Ultrasound Signal

Distinct On/Off Cycles

Yes   **No**

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Video Tutorial Series

Predictive Maintenance
...for the masses

Distinct On/Off Cycles

Yes   **No**

Confirm Downstream Temperature

Trap is in good condition

Keep Your Trap Shut   Application
Video Tutorial Series

Distinct On/Off Cycles

Yes | No

Listen to Ultrasound Signal

Rushing Sound and High U/S Signal?

Yes | No

Keep Your Trap Shut   Application
Video Tutorial Series

Rushing Sound and High U/S Signal?

Yes | No

Large Leak, Failed Trap in Open Position

Record Dynamic Measurement

Record Upstream Temperature

Analyze Time Signal to detect an early stage failure or confirm the good condition of the trap
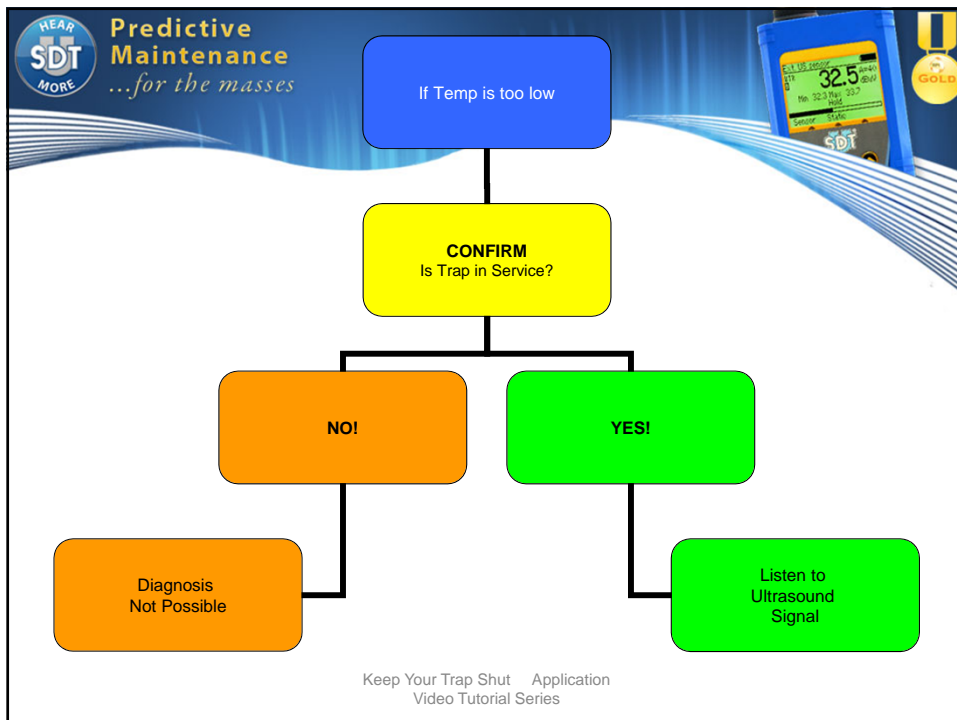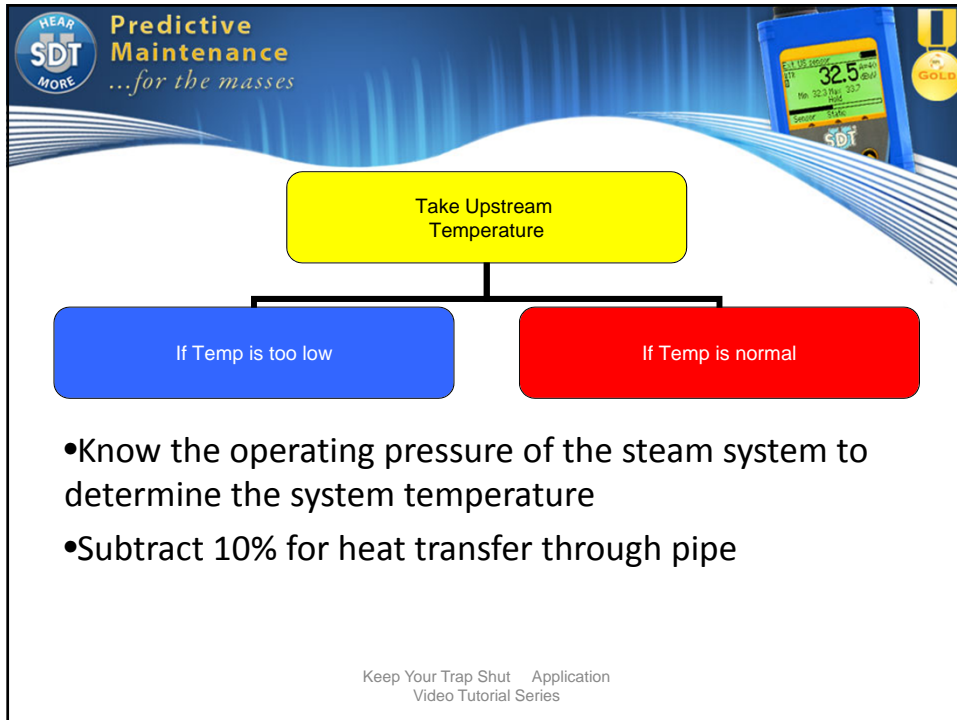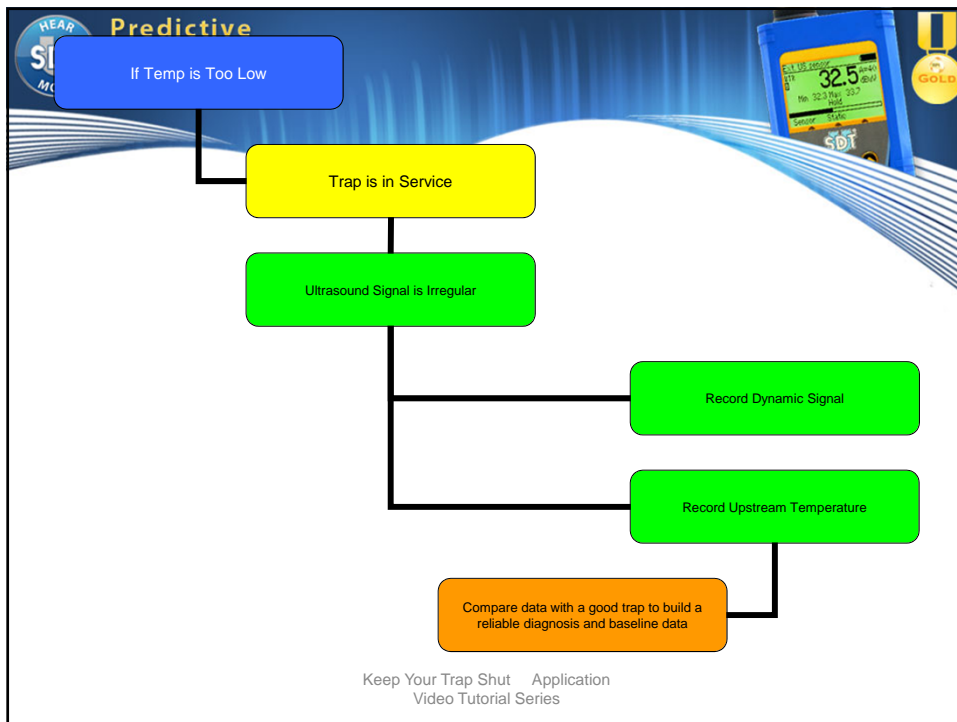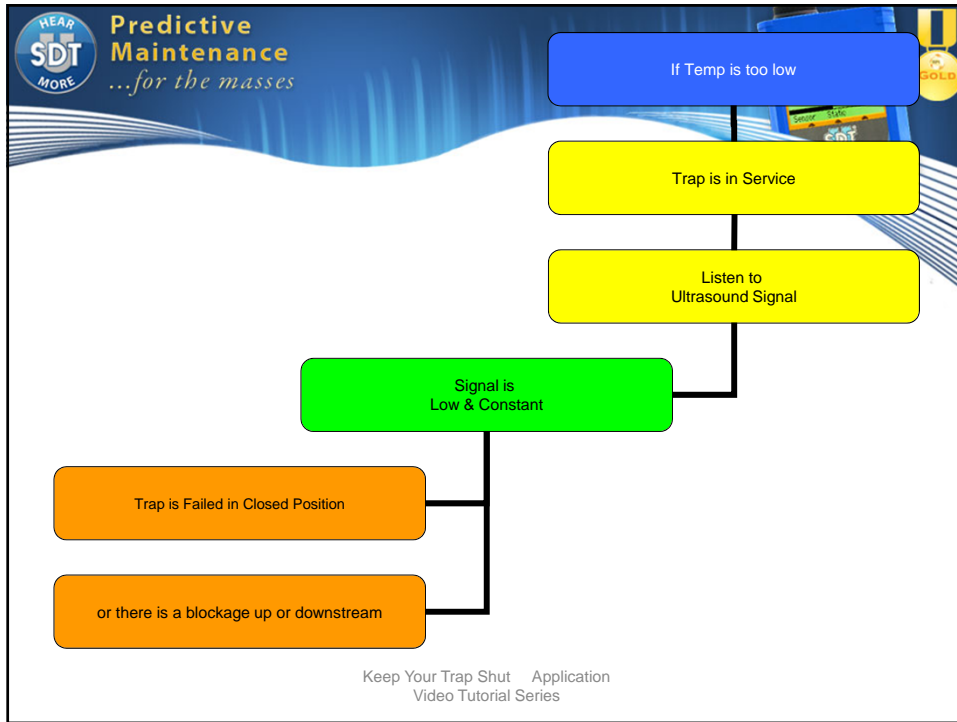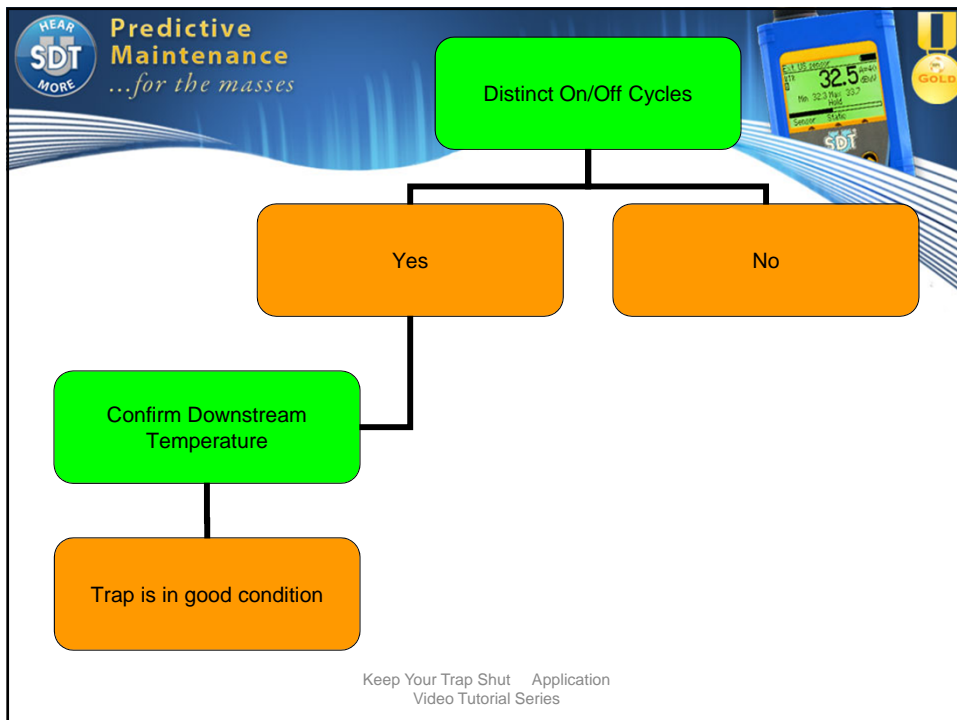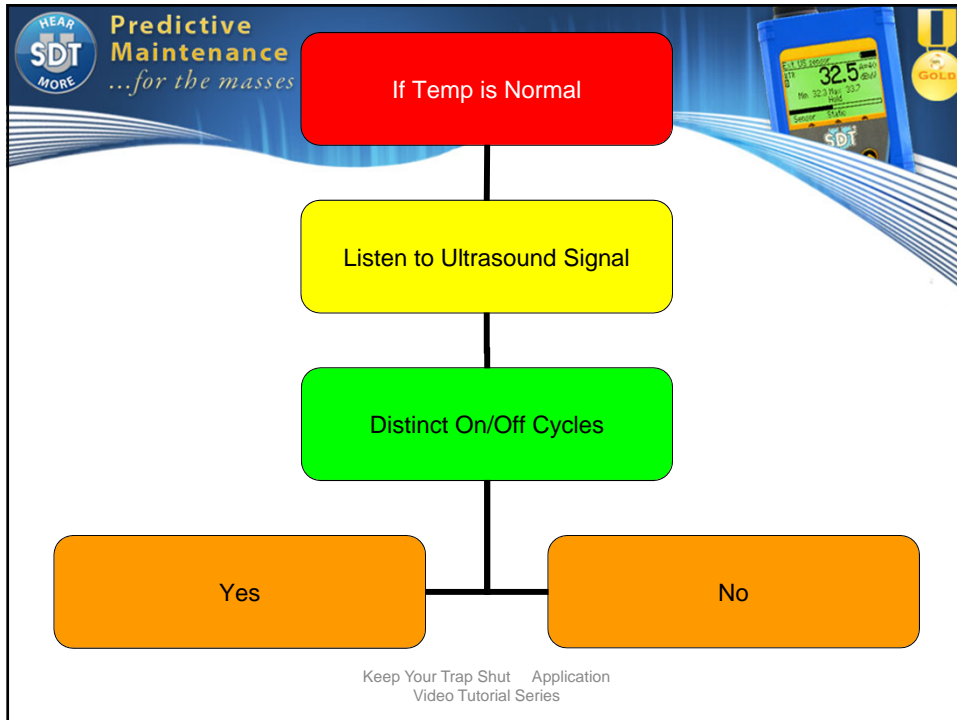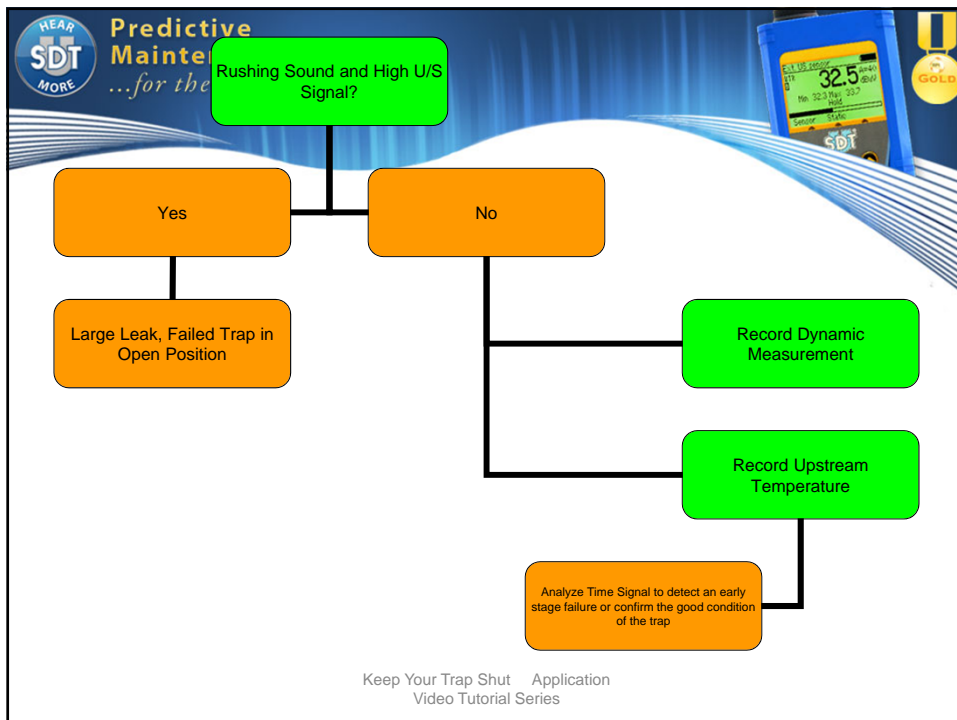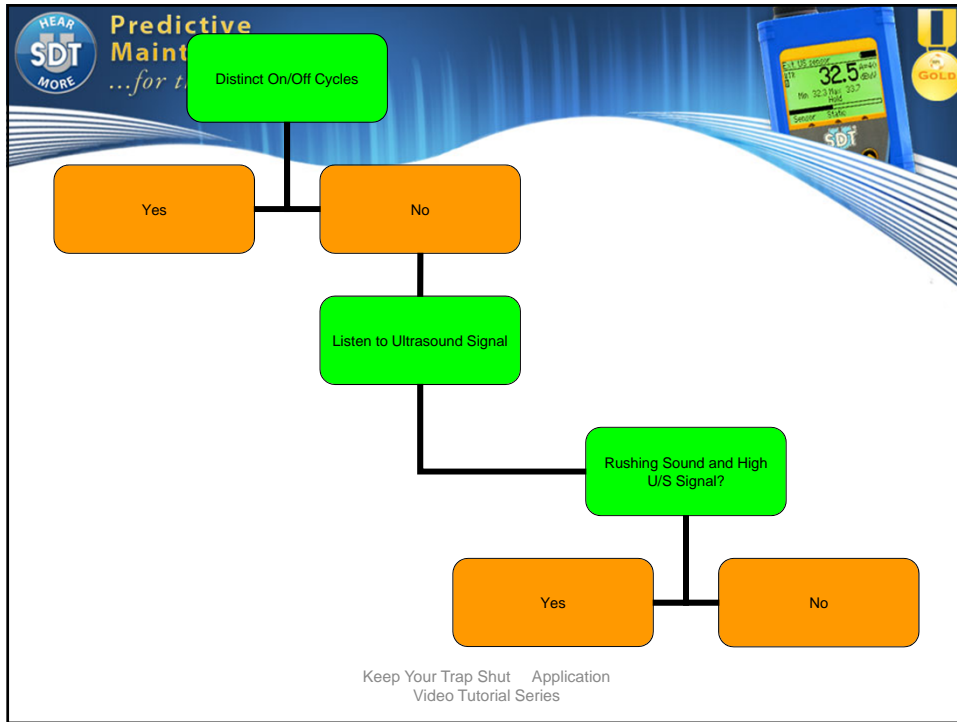
Keep Your Trap Shut   Application
Video Tutorial Series

Steam Systems

- Steam systems don't rotate much
  - No need for PdM there then...

Really??

- Lots of areas where you can work predictively using ultrasound
  - Steam leaks
  - Steam trap testing
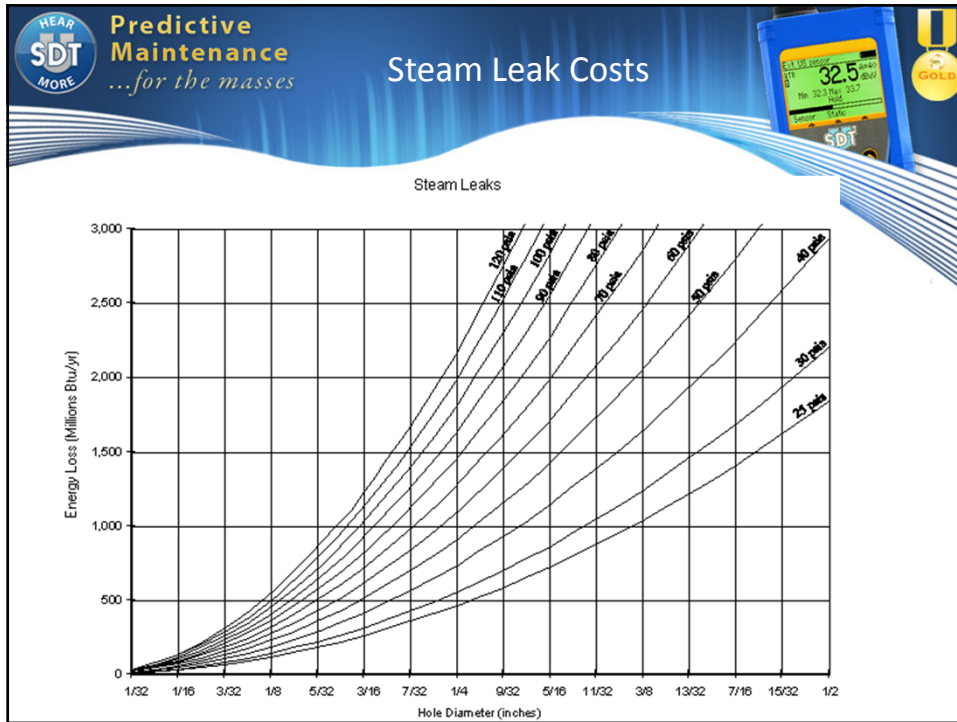 - Valve inspection
  - Tube leaks and shell inspection

Steam Leaks

- HP steam leaks can be deadly
- Old fashioned leak detection: "rag on a stick"
- Much safer way is an ultrasound system with either a flexible sensor or a parabolic dish

Steam Leak Costs

Steam Trap Inspection

- Steam traps keep your steam system healthy
- Steam traps remove
  - Air, Condensate, CO_2
- Steam traps fail either stuck open or stuck shut
- Combining temperature measurement with ultrasound is the industry standard best practice for steam trap inspection
- It is not difficult to do

Heat exchangers

- System leakage
  - Tube cracks
  - Tube sheet
  - Shell
  - Inlet/Outlet ports
  - Steam traps and steam system components

Heat exchangers
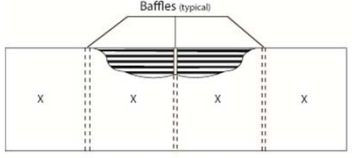
- Opportunities for ultrasound inspectors
  - External tightness inspection
    - Joints, fittings, valves, valve stems, inlets, and connectors
  - Shell tightness inspection
    - Seal of tube sheet
    - Inlet/outlet tightness
  - Tube bundle inspection
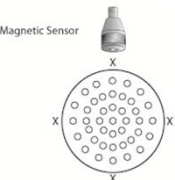   - Online and offline inspections

Heat exchangers

- Ultrasonic detector
- Flexible sensor
- Extended distance sensor
- Parabolic dish (optional for longer distances where the laser sight is advantageous)
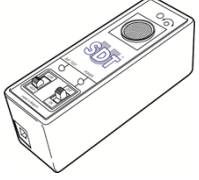- Magnetic or other contact sensor
- Bisonic transmitter

Overview of SDT 270

- Predictive Maintenance Tool
- Easy trending of U/S for failure
- Overall Vibration readings
- Temperature
- RPM
- All trend able is software with alarms.

Name That Sound

Predictive Maintenance *...for the masses*

- What is it?

Predictive Maintenance *...for the masses*

Thank you

Questions…

Comments…

Next Steps…

HEAR MORE