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- CAT III-Certified Ultrasound Analyst

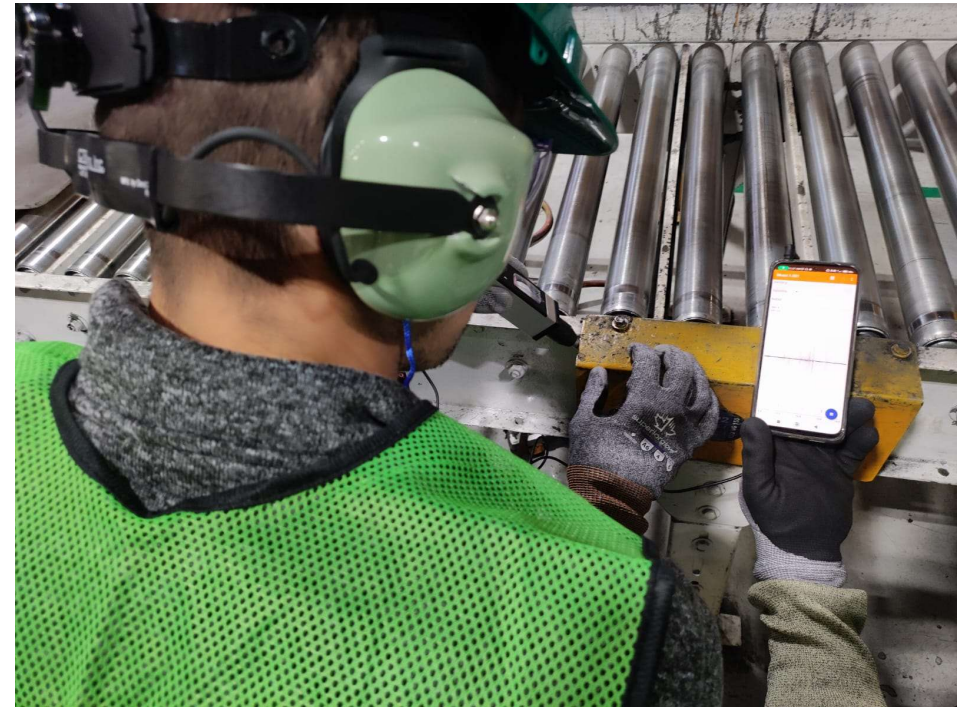


BEARING PRECISION LUBRICATION AND CBM USING VIBRATION MONITORING AND ULTRASOUND DETECTION

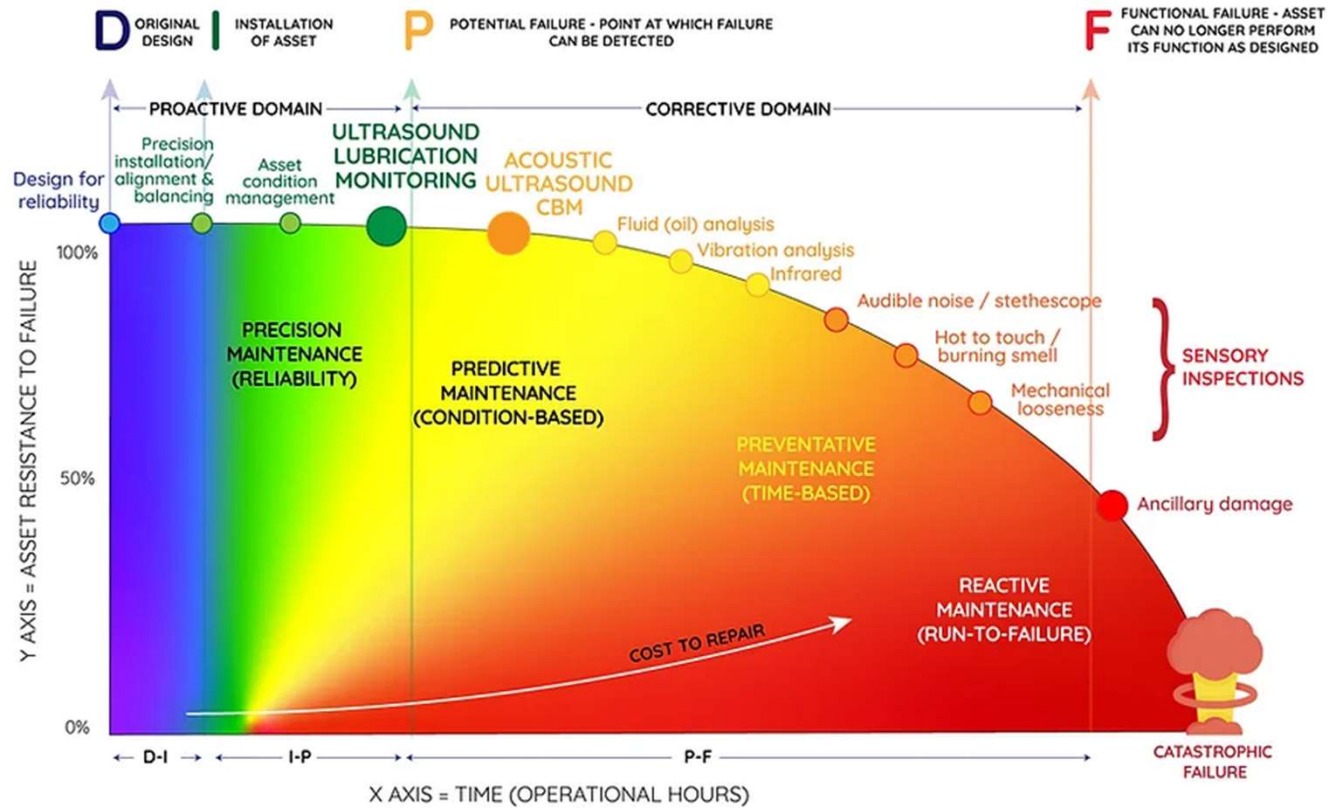


AGENDA

- Condition monitoring
- Ultrasound detection
 - Hearing and understanding your bearings
 - Precision lubrication
 - Hearing bearing faults
- Vibration monitoring
 - Overview
 - Sensing bearing faults



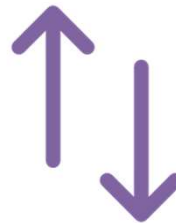
COMPLEMENTARY CONDITION MONITORING TECHNOLOGIES



CONDITION MONITORING VALUE PROPOSITION



Improve safety



Maximize machinery lifetime
and minimize unplanned
downtime



Optimize maintenance
activities and reduce
reactive maintenance

PRECISION LUBRICATION EXTENDS BEARING LIFE, MAXIMIZES MACHINERY LIFETIME

- 50% of bearing damage is due to poor lubrication
- Poor lubrication causes wear, slip grooves, gouges, gall marks and fatigue damage
- The amount of lubricant needed is small, and excessive lubricant is harmful
 - In practice, it is generally dosed more abundantly
 - Time-based lubrication that doesn't account for the bearing's condition can lead to over-lubrication
- Bearing under- and over-lubrication leads to overheating, causing a decrease in the clearance between the bearing and the turning area or even harmful preloads



CONDITION BASED MAINTENANCE AND LUBRICATION

- Bearings and gearboxes
- Under / over lubrication
 - Excess wear
 - RMS / dB levels for tracking, alerts
- FFT available for diagnostics

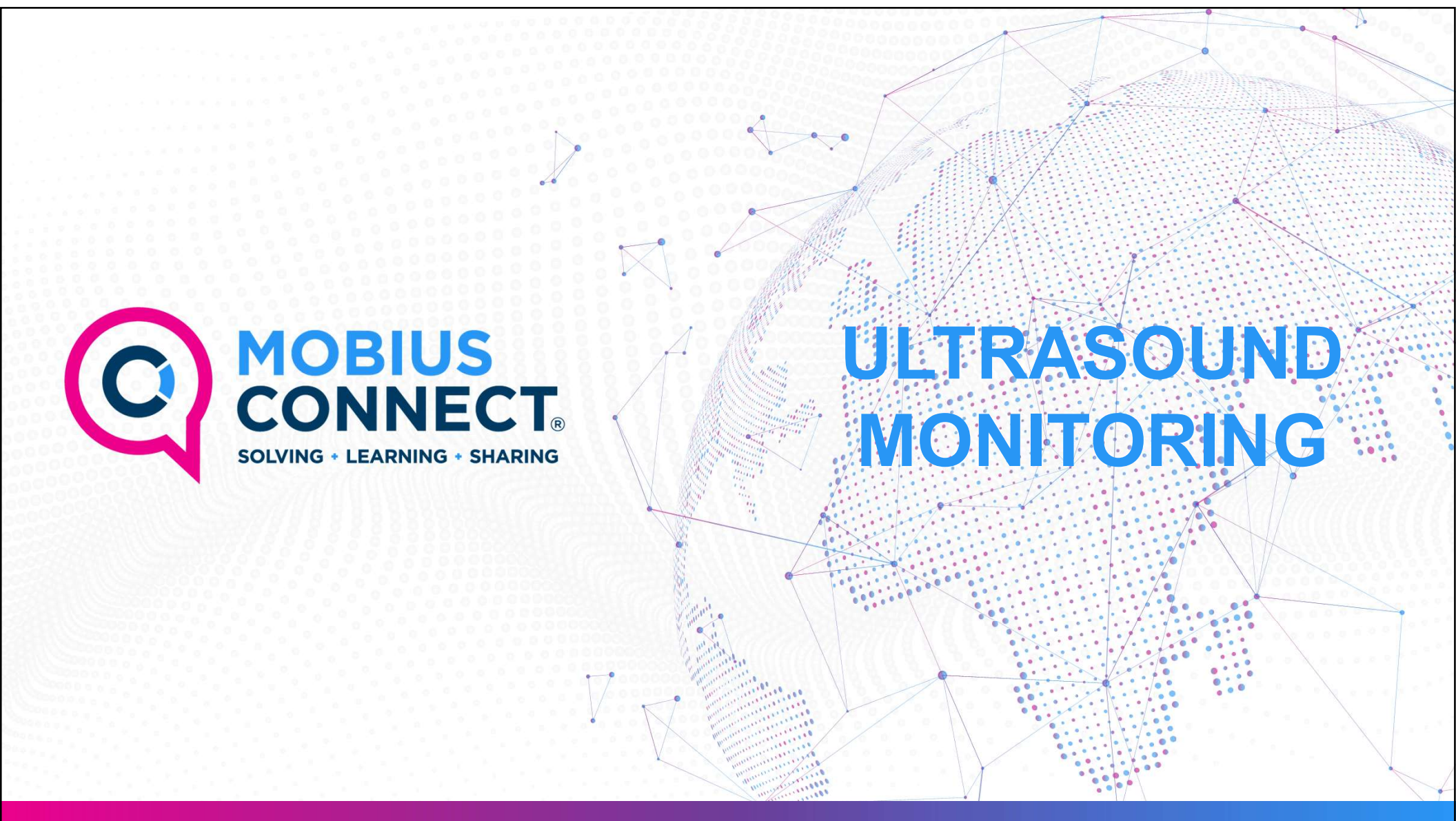


A new ultrasound user discovered a bad bearing on major gearbox. Replacing the bearing before it caused more damage prevented a 22-month rebuild – or worse, replacing the asset after a catastrophic failure. The user achieved 100% ROI the first time they used their ultrasound detection kit.



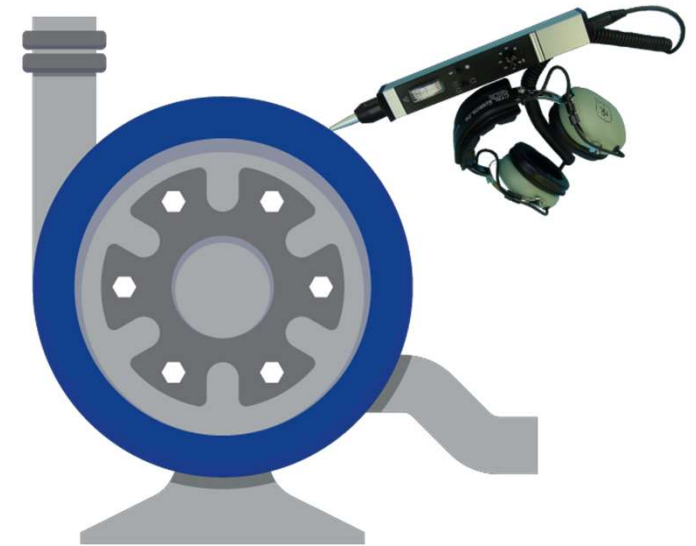
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ULTRASOUND MONITORING



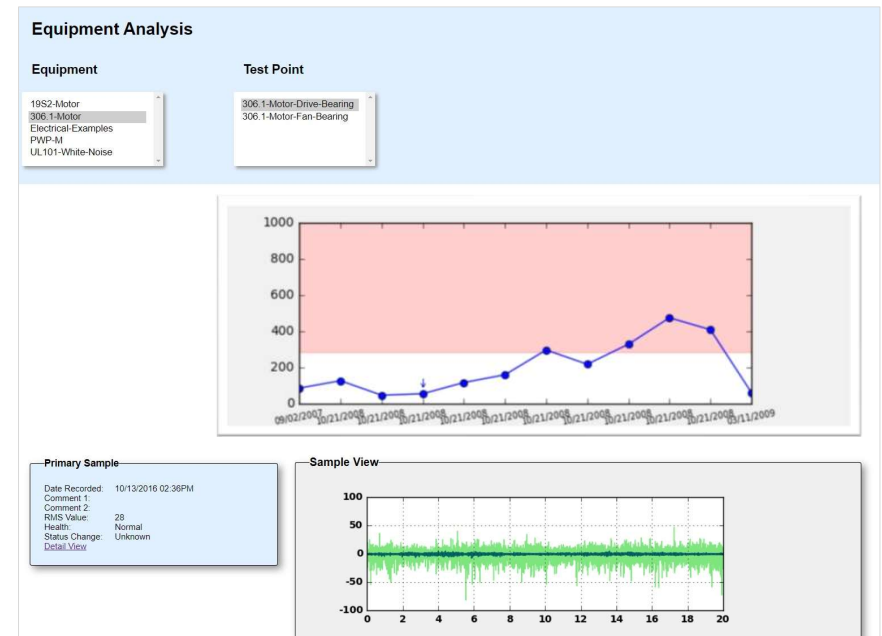
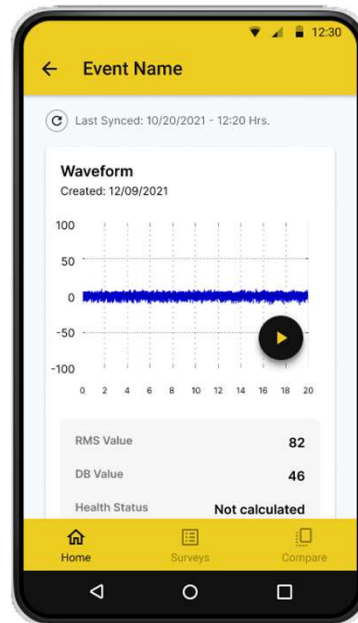
ULTRASOUND TECHNOLOGY

- Ultrasonic (>20 kHz) noise is emitted by mechanical, pneumatic, hydraulic, electrical systems
 - Friction, turbulence, cavitation cause most ultrasonic emissions
- Uses a piezoelectric sensing element (like accelerometers) to receive signals
- Receiver translates high-frequency signal down to audible range to hear through headphones and software
 - Makes bearing under- and over-lubrication audible
 - RMS values, waveforms, historical data, trending available for analysis, fault diagnostics



DATA ACQUISITION WITH CM SOFTWARE ORGANIZES AND ANALYZES AUDIO FILES

- Records analog waveforms that measure real world physical conditions
- Converts the waveforms into digital data for processing.
- Identifies changes in the condition of equipment
- Analyzes significant changes and bearing fault frequencies
- Determines if any action should be taken
- Informs maintenance personnel
- Verifies corrective action was effective

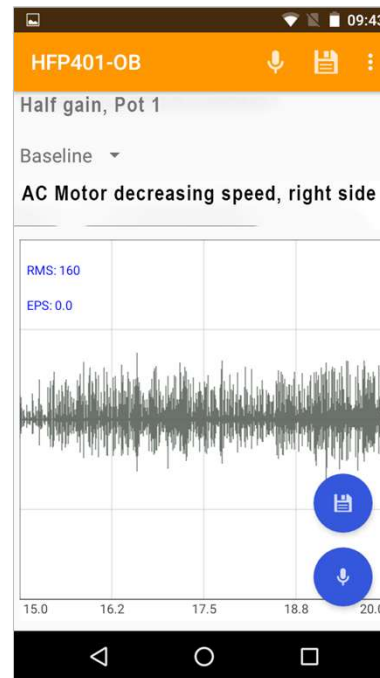


HEARING, SEEING, TRENDING

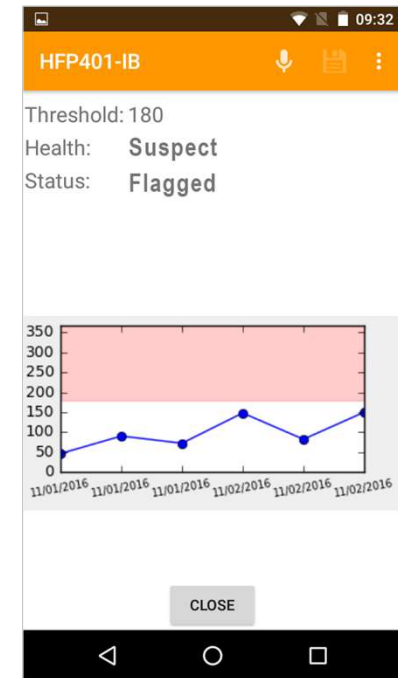
HEARING



SEEING

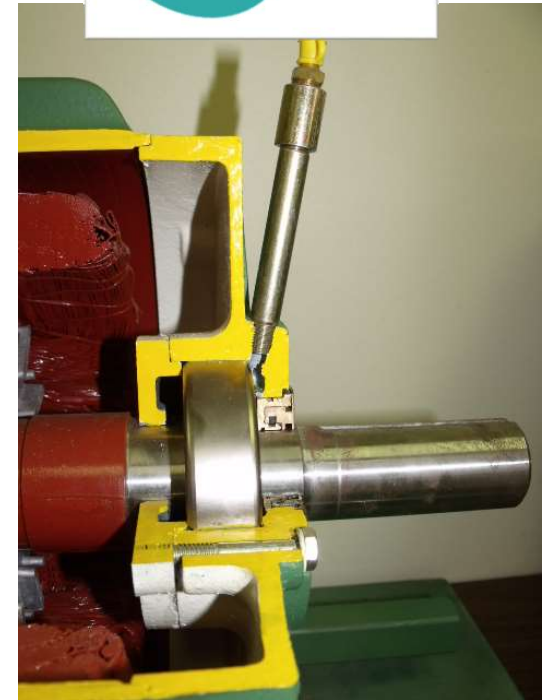
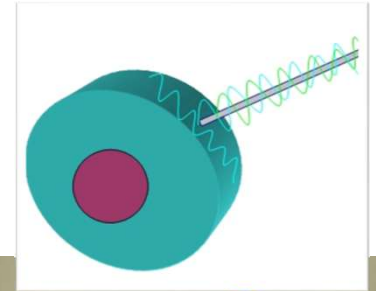


TRENDING



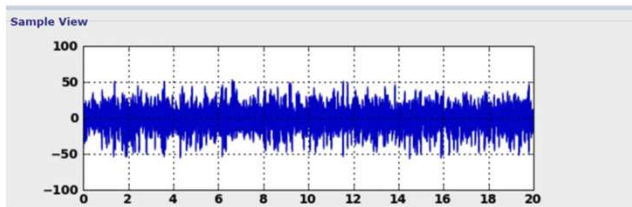
BEARING FRICTION IS A KEY SOURCE OF STRUCTURE-BORNE ULTRASOUND EMISSION

- The biggest factor in loss of efficiency, bearing wear
- A properly lubricated bearing in good condition emits comparatively low-amplitude ultrasound
- An under- or over-lubricated bearing is very obvious compared to the norm
- A failing bearing emits increased ultrasound levels that may indicate the specific fault condition

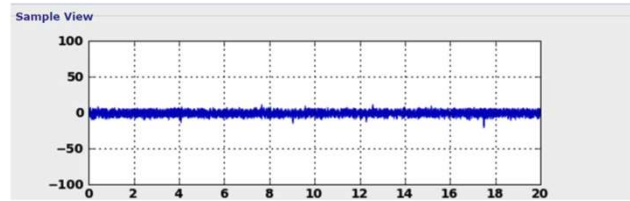


LUBRICATION

UNDER LUBRICATION



NORMAL LUBRICATION



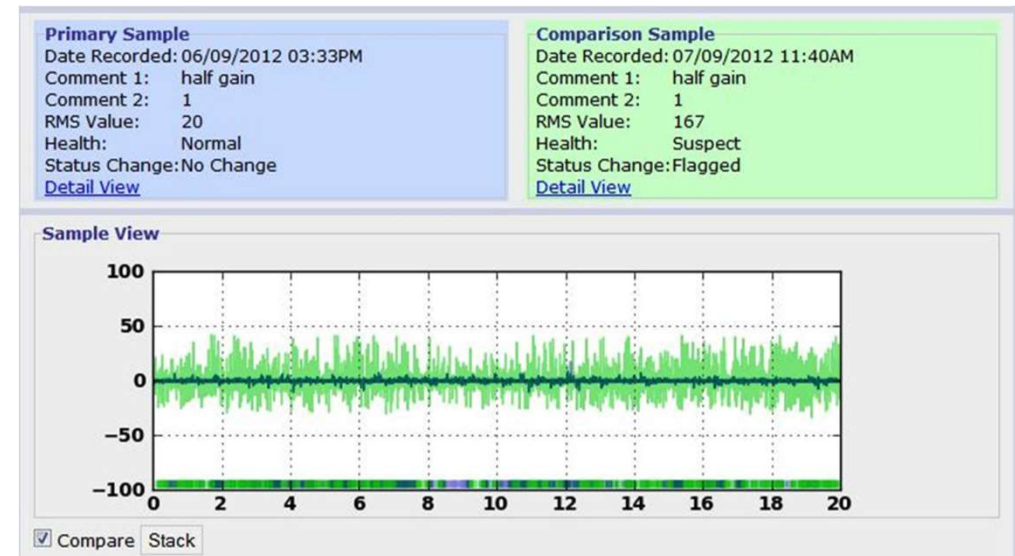
NORMAL TO OVER LUBRICATION



Pre-lubrication, normal bearing

DEFECTIVE BEARINGS

- A normal bearing is quiet and event free
- Intermittent pops are an early indication of bearing damage
- Ultrasound detects the changes to the condition very early
- Vibration analysis and other condition monitoring technologies will diagnose the root cause





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**VIBRATION
MONITORING**

VIBRATION MONITORING OVERVIEW

- Condition monitoring programs using vibration data collection and analysis for machine health monitoring
- Vibration sensors measure vibration levels on rotating machines to detect mechanical faults before equipment failure
- Excessive vibration can indicate potential machine faults including unbalance, misalignment or looseness
- By detecting problems at an early stage, condition monitoring teams can plan repairs, perform maintenance, reduce unplanned downtime, provide advanced warning of component wear, and extend equipment life



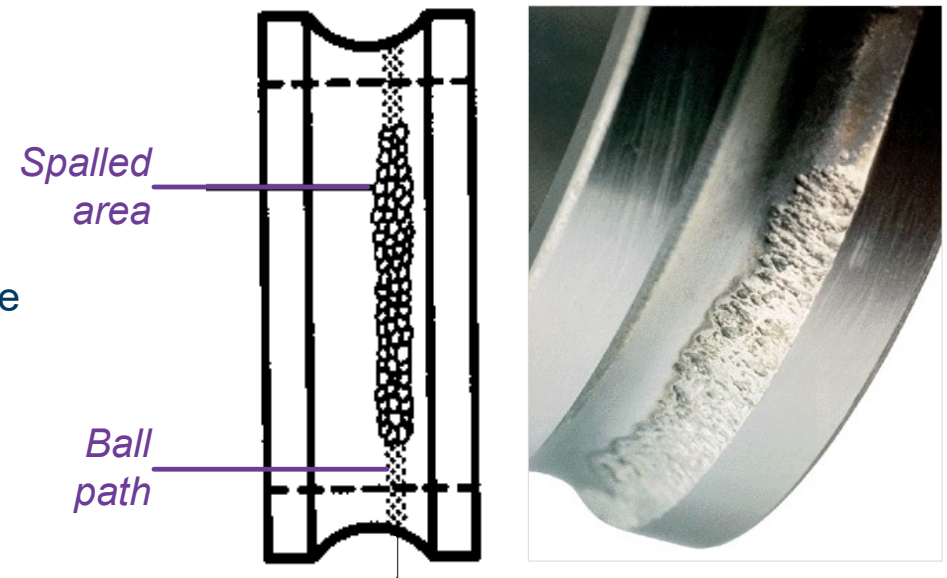
BEARING FAULTS DETECTED WITH VIBRATION ANALYSIS

- Excessive loads
- Overheating
- True brinelling
- False brinelling
- Normal fatigue failure
- Reverse loading
- Contamination
- Lubricant failure
- Corrosion
- Misaligned bearings
- Loose fits
- Tight fits



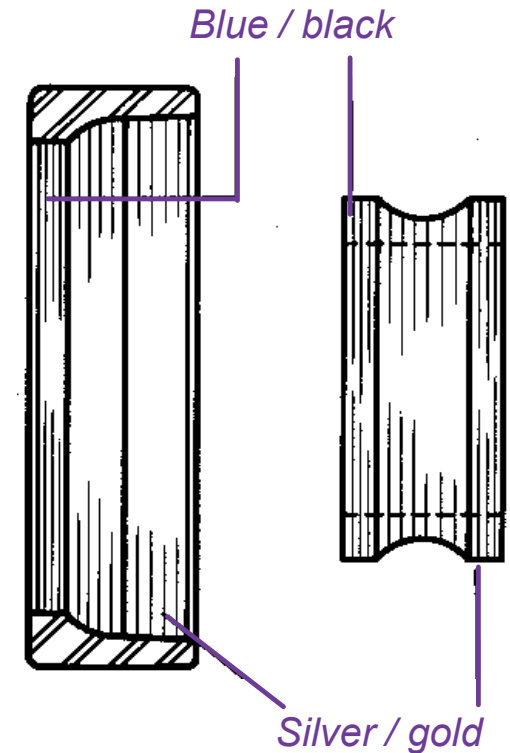
EXCESSIVE LOADS

- Excessive loads cause premature fatigue
- Vibration spectrum: many harmonics with sidebands
- Visual inspection: spalling of the inner and/or outer race
- Corrective action: reduce the load or redesign with a bearing of greater capacity



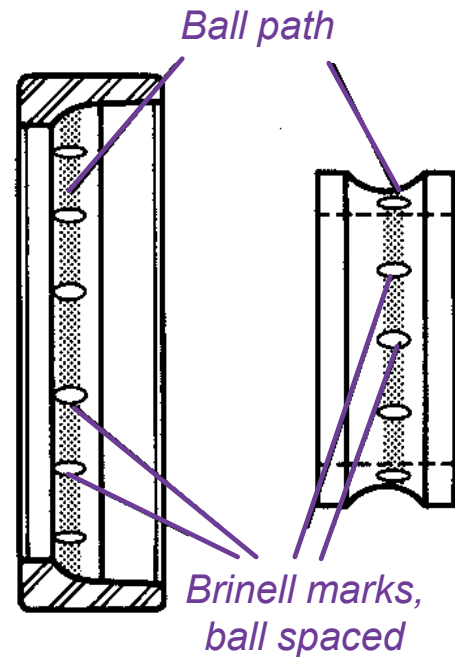
OVERHEATING

- Temperatures $>400^{\circ}$ F can anneal the ring and ball materials and degrade or destroy lubricant, resulting in loss of hardness that reduces the bearing capacity, causing early failure; in extreme cases, balls and rings will deform
- Vibration spectrum: none, but accelerometers with built in temperature probes can help identify this problem.
- Visual inspection: discoloration of the rings, balls and cages from gold and silver to blue and black
- Corrective action: depends on root cause – redesign may be necessary, or consult with suppliers



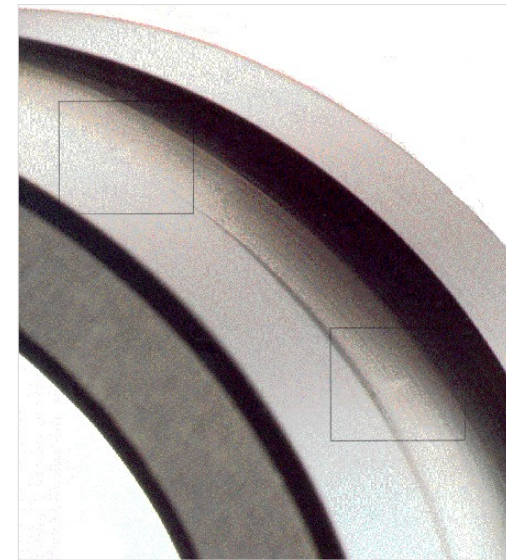
TRUE BRINELLING

- Static overload and severe impacts that exceed the elastic limit of the ring material create Brinell marks
- Vibration spectrum: multiple peaks in the spectrum
- Visual inspection: Brinell marks which show as indentations in both raceways
- Corrective action: avoid shock, high-impact loads



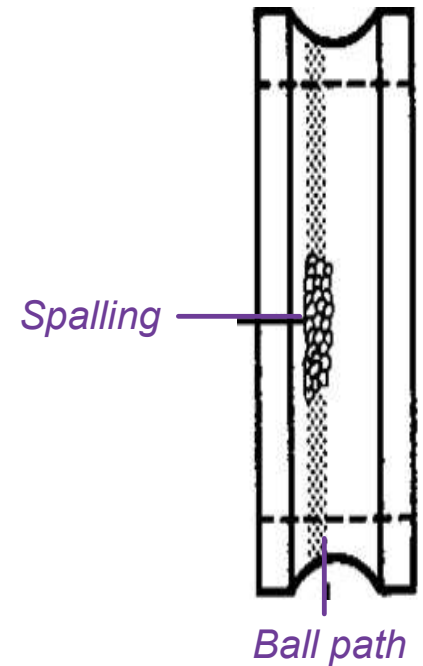
FALSE BRINELLING

- Nearby equipment vibrations that are transmitted to the piece being monitored create excessive external vibration
- Vibration spectrum: very similar to true brinelling, hence the name
- Visual inspection: elliptical wear marks in an axial direction at each ball position with a bright finish and sharp demarcation, often surrounded by a ring of brown debris
- Corrective action: isolate bearings from external vibration, use greases containing anti-wear additives



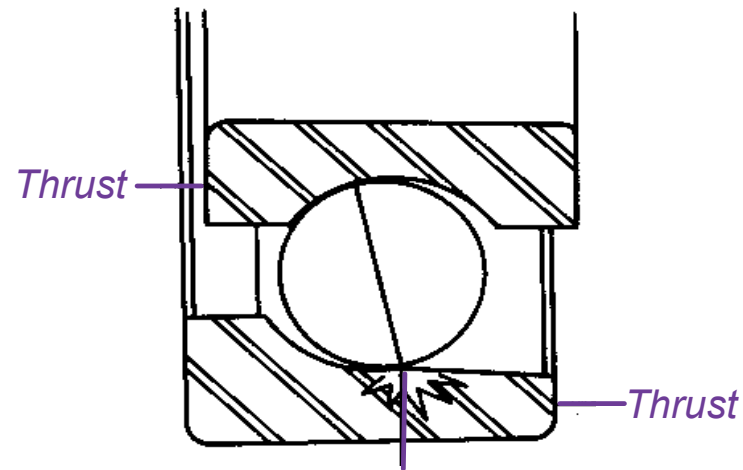
NORMAL FATIGUE FAILURE

- A “progressive” failure that, once initiated, will spread with continued operation, resulting in a fracture of the running surfaces and subsequent removal of small discrete particles of material (also called spalling)
- Vibration spectrum: a marked increase in vibration
- Visual inspection: spalling and wear on the inner ring, outer ring, or balls
- Corrective action: replace the bearing or redesign with a bearing that has a greater calculated fatigue life



REVERSE LOADING

- When angular contact bearings, which are designed to accept an axial load in one direction only, are loaded in the opposite direction, the elliptical contact area on the outer ring is truncated by the low shoulder on that side of the outer ring, resulting in excessive stress and an increase in temperature, followed by increased vibration and early failure
- Vibration spectrum: growth of peaks in the spectrum and increasing temperature
- Visual inspection: ball band visible along roller element
- Corrective action: re-install the bearing correctly

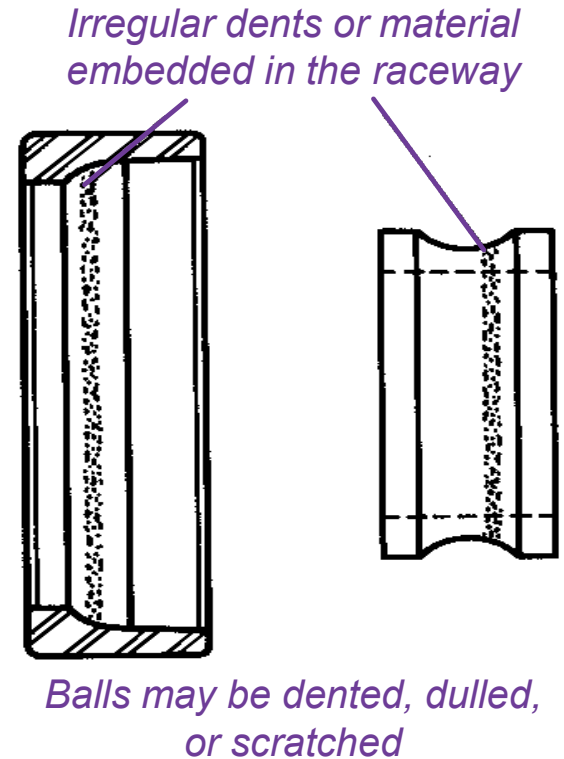


Ball band caused by ball riding over edge of raceway



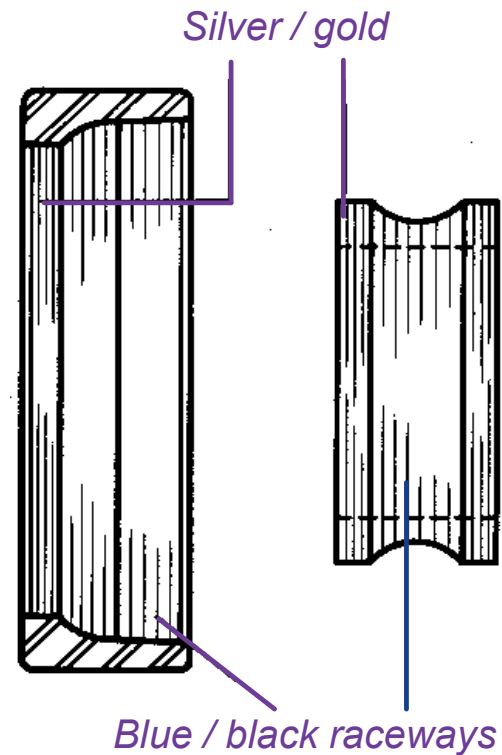
CONTAMINATION

- Contaminants in the bearing housing dent the balls and raceway, resulting in high vibration and excessive wear
- Vibration spectrum: higher frequency peaks with sidebands is an early indication of contamination
- Visual inspection: embedded material or denting of the bearing raceways and balls
- Preventative action: clean work areas, tools, fixtures, hands; keep grinding operations away from bearing assembly areas; keep bearings in their original packaging until installation



LUBRICANT FAILURE

- When lubricant does not provide the smooth barrier between contact surfaces it may result in excessive wear of balls, rings and cages, leading to overheating and subsequent catastrophic failure
- Vibration spectrum: higher frequency peaks caused by metal-to-metal contact
- Visual inspection: discolored (blue/brown) ball tracks and balls
- Preventative action: ultrasound monitoring will indicate lubricant failure earlier than vibration monitoring



CORROSION

- Bearing exposure to corrosive fluids or a corrosive atmosphere can, in extreme cases, initiate early fatigue failures
- Vibration spectrum: peaks indicate the need for inspection
- Visual inspection: red/brown areas on balls, raceway, cages, bands of ball bearings
- Corrective action: divert corrosive fluids away from bearing areas and use integrally sealed bearings

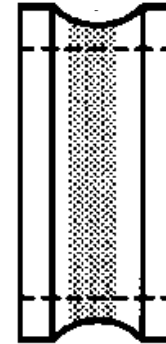


MISALIGNMENT

- Bearing misalignment exceeding 0.001 in./in, will cause abnormal temperature rise in the bearing and/or housing and heavy wear in the cage ball-pockets
- Vibration data: axial vibration measurements, but can be difficult to differentiate without physical inspection
- Visual inspection: ball wear path on the raceway of the non-rotating ring is not parallel to the raceways' edges
- Preventative actions: inspect shafts and housings for runout of shoulders, bearing seats; use single point-turned or ground threads on non hardened shafts, ground threads only on hardened shafts, precision grade locknuts



Wide ball path on inner raceway

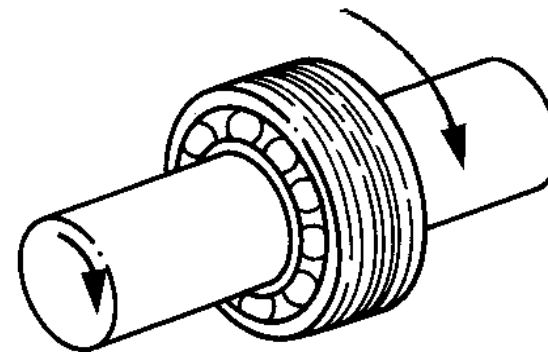


Non-parallel ball path on outer raceway

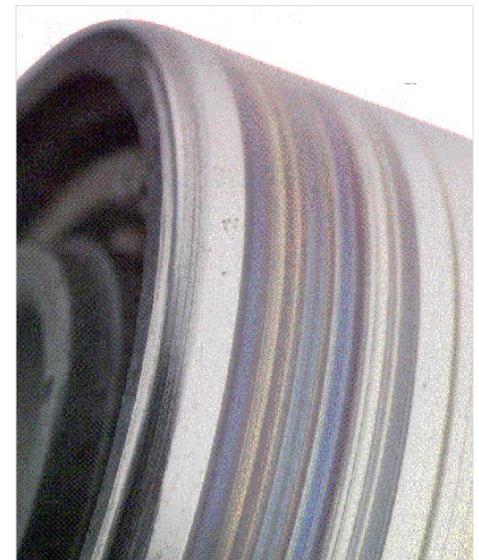


LOOSE FITS

- Relative motion between loosely fit mating parts can cause fretting, the generation of fine metal particles which are abrasive and can aggravate the looseness
- Looseness that allows considerable movement of the inner or outer ring will wear, heat the mounting surfaces (bore, outer diameters, faces), causing noise and runout problems
- Vibration spectrum: multiple harmonics of the running speed
- Visual inspection: distinctive brown color of oxidized particles
- Corrective action: design updates

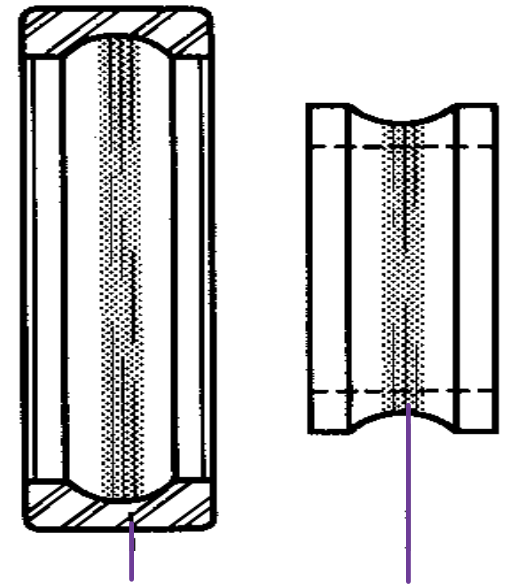


Outer ring slippage caused by improper housing fits



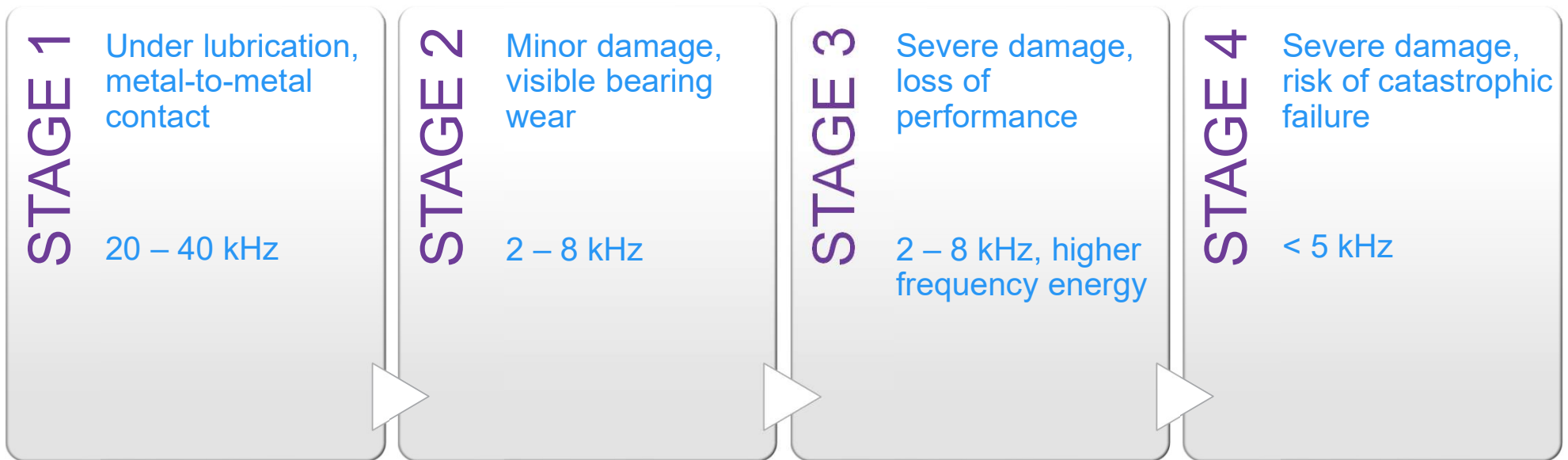
TIGHT FITS

- Where interference fits exceed the radial clearance at operating temperature, the balls will become excessively loaded, resulting in a rapid temperature rise accompanied by high torque; continued operation can lead to rapid wear and fatigue
- Vibration spectrum: a rise in peaks related to the bearing frequencies, temperature measurement will be indicative as well
- Visual inspection: a heavy ball wear path in the bottom of the raceway around the entire circumference of the inner ring and outer ring
- Corrective action: decrease total interference



Discolored, wide ball path at the bottom of raceways

STAGES OF BEARING FAILURE



BENEFITS OF COMBINING ULTRASOUND AND VIBRATION MONITORING

- Ultrasound advantages
 - Early detection
 - Instantaneous across multiple applications
 - Experiential learning
- Vibration monitoring
 - Root cause analysis, specific fault diagnosis
 - Methodical and data-based
 - Versatile
- Both
 - Trending
 - Fast ROI
 - Enhanced by machine learning



THANK YOU! QUESTIONS?



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