Applying Modern Reliability Practices to Aging Research Reactors

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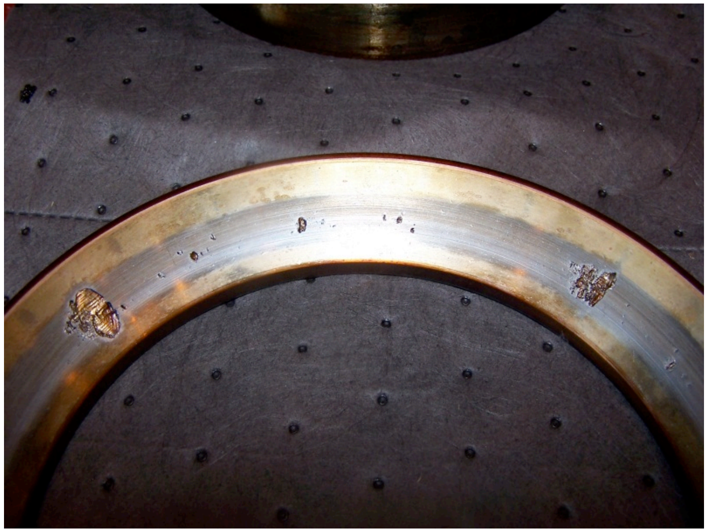
The Fundamentals…

- **Why do I care?**
  - As equipment ages, many failure modes are based on wear which is dependent on time in service
  - Nuclear facilities are not like turning on a light switch… multiple integrated systems and equipment necessary to operate
- **What's the benefit in changing how I do maintenance?**
  - By performing the right maintenance on the right equipment at the right time (condition driven corrective and preventive maintenance), one can:
    - Save money
    - Save resources
    - Reduce work load
    - Improve Reliability/ Availability

Process

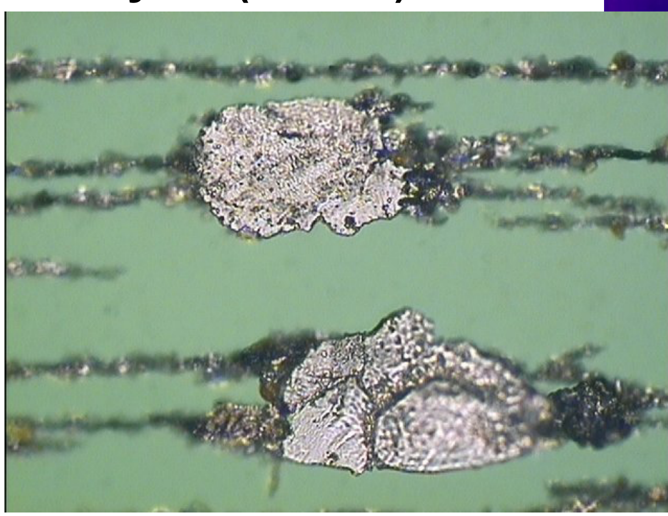
- **All right, I'm interested, but how/ what changes?**
  - **Religiously, routinely apply Condition monitoring**
    - Condition monitoring implies collecting and analyzing data to determine condition
      - Include trending of operating parameters, not just predictive maintenance technologies
    - Don't just collect data, do something with it! Consider collecting less data if it means more realistic chance for thorough analysis and action
      - Consider cooperating with partner higher education facility since many now offer reliability training/ students
    - Now that you have data and the resultant analysis information, make it available to everyone to plan and act on
      - Communication is the key to success!
  - **Take advantage of failure history, industry practice, and applied condition monitoring to review preventive maintenance procedure and frequencies (PM Optimization)**

Condition Monitoring



Vibration Analysis (PU-1A)

Infrared Thermography (Cold Source Control Cabinet)



Lubrication Analysis (Cooling Tower Fan 4A Gearbox)

Communication!

		Vibration						OIL			Thermography	Ultrasonic		
Equipment ID	Equipment Desc.	Reported 430	Reported 429	Reported 428	Reported 427/ Last Report	Sub-Component	Fault Type	Current	Previously Reported	Previously Reported	Current/ Last	Current/ Last	Notes	Method of Resolution
C#21	He Compressor #21	Normal 08/09/2010	Normal 06/18/2010	Normal 05/05/2010	Normal	---	---	Normal	Normal 05/28/2010	Watch 12/22/2009	Normal 11/30/2009	Normal 08/09/2010	**Oil**- sampling periodicity will be every 6 mo. Based on mfg recommendations; high particle count but decreased likely due to sampling equipment	Oil PdM documentation in development
C#22	He Compressor #22	Watch 08/09/2010	Watch 06/18/2010	Watch	Watch 02/22/2010	Compressor	Gear	Normal	Normal 03/15/2010	Watch 12/22/2009	Watch 11/30/2009	Watch 08/09/2010	**Vibration** - Indications of wear on the female lobe of the screw compressor (high amplitude of female rotor turning speed and harmonics)- recommend continue to monitor **Ultrasonics & IR Thermography** - Ultrasonic evaluation has slight gravel noise and IR Thermography shows elevated temperatures (+20F from HE Compressor #21) **Other** - Elevated helium discharge temperatures	Oil PdM documentation in development
C#23	He Compressor #23	Normal 08/09/2010	Normal 06/18/2010	Normal 05/05/2010	Normal 02/22/2010	---	---	Normal	Normal 03/15/2010	Watch	Normal 11/30/2009	Normal 08/09/2010	---	Oil PdM documentation in development
C#24	He Compressor #24	Significant 08/09/2010	Watch 06/18/2010	Watch 05/05/2010	Watch 02/22/2010	Compressor	Bearing	Normal	Normal 03/15/2010	Normal 12/22/2009	Normal 11/30/2009	Watch 08/09/2010	**Vibration** - Significant increase in amplitude: indications of looseness/ clearance on compressor- could be bearing or male to female lobe interaction fault- recommend continue to monitor and plan for eventual replacement (spring long outage?) **Other** - Ultrasonic evaluation has definite gravel noise; notable audible gravel noise present now as well	Oil PdM documentation in development
C#25	He Compressor #25	Normal	Normal	Normal 05/05/2010	Normal 02/22/2010	---	---	Normal	Normal 03/15/2010	Normal 12/22/2009	Normal 11/30/2009	Normal 05/05/2010	---	Oil PdM documentation in development
H2 COMP	Hydrogen Compressor	Normal	Normal	Normal 04/29/2010		---	---	Normal	Normal 03/17/2010				---	---
PU-6A	Sec. Coolant Pump PU-6A	Normal	Normal 06/18/2010	Normal 05/04/2010	Watch	---	---	Watch 07/20/2010	Normal 04/29/2010	Watch 02/11/2010			**Oil** - oil purified EOC 426; upper bearing particle count high; oil change planned EOC430	---
PU-6B	Sec. Coolant Pump PU-6B	Watch 08/09/2010	Watch 06/18/2010	Watch	Watch 02/22/2010	Motor	Bearing	Watch 07/20/2010	Watch 06/10/10	Watch 04/29/2010			**Vibration** - Upper bearing minor bearing wear indications- Continue to Monitor **Oil** - elevated particle count upper bearing reservoir; oil change planned EOC430	---
PU-6C	Sec. Coolant Pump PU-6C	Significant 08/09/2010	Significant	Significant	Significant 02/22/2010	Motor	Bearing	Watch	Watch 06/10/10	Significant 04/29/2010			**Vibration** - Bearing wear on lower bearing- recommended action is to collect oil sample data and plan for inspection; increasing audible noise also observed; Continue to Monitor and plan for replacement **Oil**- Water content addressed; oil filtered and small particle count elevated; planned replacement of oil EOC 430	Work Request Submitted

Condition Monitoring

- **What equipment?**
  - Expert-based, Qualitative Process for examining equipment importance to HFIR mission
    - Including equipment necessary for research facilities- not just the reactor
      - Nuclear safety implications/ Technical Safety Requirements
      - Engineering and Craft resource
      - Lead time for parts/ replacement unit
      - Effect on reactor power
      - Cost
      - External commitments
      - ETC

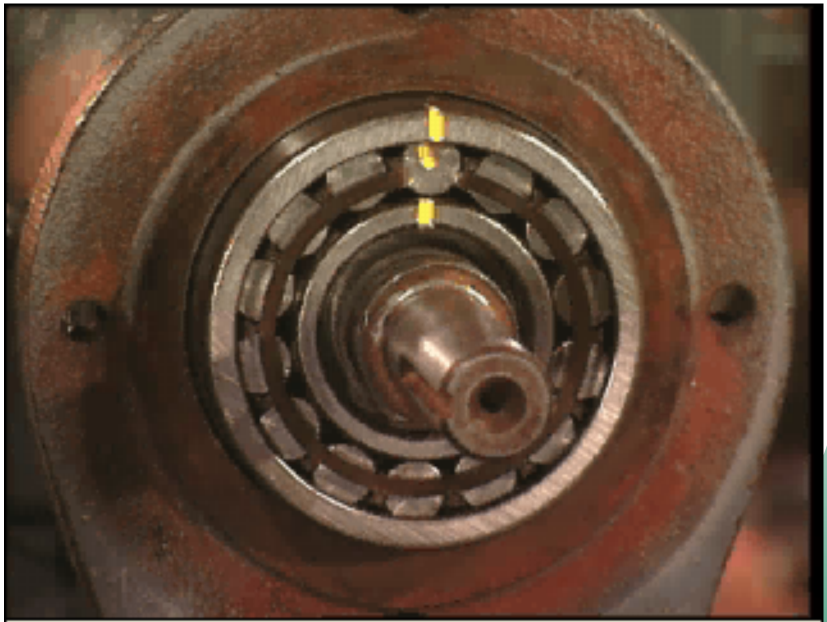
Condition Monitoring

- **How often?**
  - Frequency for condition monitoring data collection as well as preventive maintenance is dependent on many factors:
    - Equipment “importance” characterization
    - Operating environment
    - Operating frequency/ load demands
    - Industrial practice for identical/ similar equipment
    - Manufacturer’s recommendations
    - Failure modes and effects considerations
      - Does not need to be a formal process- Utilize available resources (EPRI, RCM books, other research reactors that have “blazed a path”, etc.)
      - How many ways can it fail? Which ways can be identified in applied condition monitoring activities? How long would it take to fail given the mode? Etc.
    - Equipment failure history

Example- Condition Monitoring

PU-1A Primary Coolant Pump Motor

- Vibration data collected per operating cycle
- Original equipment to reactor commissioning date-'65
- Upper thrust bearing is SKF 29326 (from drawing/mfg)
  - From SKF- Fault frequencies (available via website or call):
    - Defect on Outer Race (BPFO) = 9.46 X TS
    - Defect on Inner Race (BPFI) = 11.51 X TS
    - Defect on Rolling Element (BSF) = 3.57 X TS
    - Defect on Cage (FTF) = 0.45 X TS



inner

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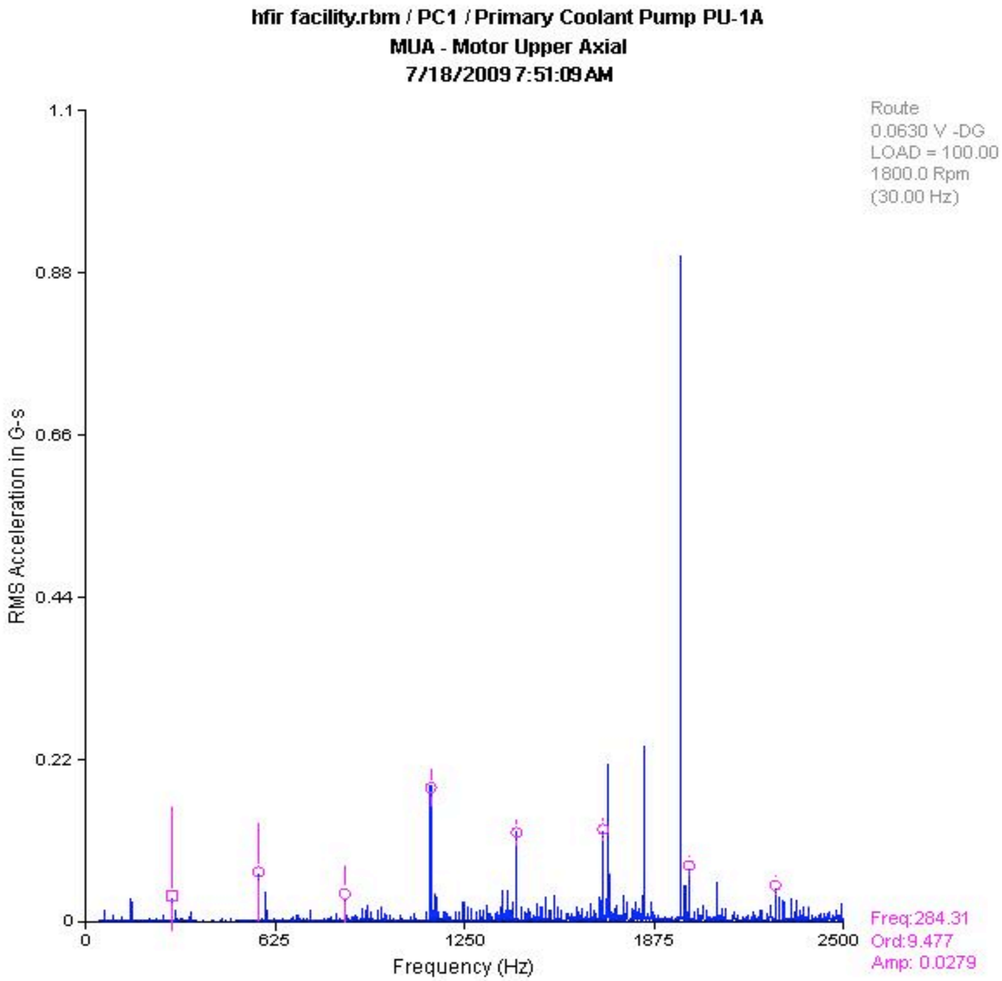
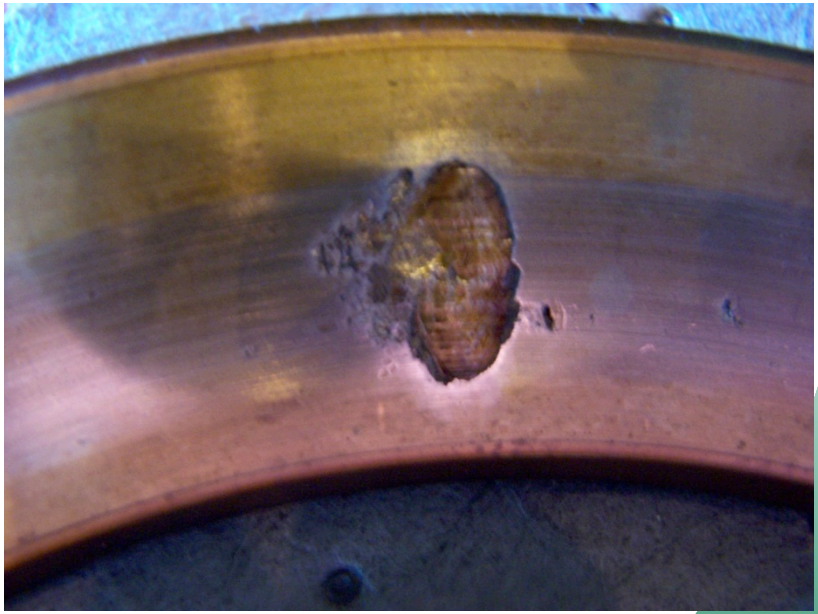
Condition Monitoring Example Cont.



Markers show fundamental defect frequency of BPFO and harmonics

PU-1A Lower (Outer) Race Spalling



Preventive Maintenance Optimization

- **If you've applied the resources to collect and analyze data, why not take advantage of your investment?**
  - Start with equipment with current repetitive maintenance tasks
  - Review task list for a given piece of equipment and compare to likelihood of failure mode, consider risk mitigation by condition monitoring, industrial practice, and failure history
  - Review frequency of task based on equipment "importance", risk mitigation by condition monitoring, industrial practice, and failure history

Example of Optimization:

Motor Control Center "C"

Previous

- 3Y
  - Clean all connections
  - Visibly inspect all terminals, electrical joints, and bus connections
  - Visibly inspect all wiring
  - Check connections tight
  - Cycle breakers and verify operation with multi-meter
  - Inspect and replace insulation
  - Micro-ohm test all connections
  - High voltage test all supply transformer windings and motor loads

Revised

- **Semi-annual:**
  - **Infrared Thermography**
- **Annual:**
  - **Cycle all breakers and verify operation**
  - **High voltage test motor loads**
- 5Y:
  - Clean all connections
  - Visibly inspect all terminals, electrical joints, bus connections, and wiring
  - Micro-ohm test all connections
  - High voltage test all supply transformer windings

Summary

- Condition monitoring can provide detailed condition assessment (right maintenance, right time)
- Resources are readily available
  - Some resources are contractors, partner higher education organizations, industry meetings, etc.
- Implementing condition monitoring can provide information/ justification for reviewing PM frequency (right time)
- Balancing PM resources and condition monitoring can provide positive results on maintenance cost and work load, not to mention the benefit to reliability and availability
  - Communication and thorough analysis are the key
- QUESTIONS????