Failure Progression Modes (FPM)
A Newly Proposed Bearing Failure Mode Identification and Classification System

RBMEC Presentation to
Mechanical Association Railcar Technical Services
September 2005

Presented By:
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Amsted Rail Group (ARG)
RBMEC Membership

• Roller Bearing Manufacturers Engineering Committee (RBMEC)
  – Brenco, Inc.
  – The Timken Corp.
  – SKF
  – General Bearing Corp.
  – FAG Bearings Corp.
  – NTN Bearing Corp. of America
FPM Presentation Outline

• What are the Failure Progression Modes?
• Why are the Failure Progression Modes Better than the Current System?
  – Accurate
  – Reproducible
  – Ease of Analysis
• Summary of Recommended AAR Document Updates
• Bearing Failure Mode Results
What are the FPMs?

- Bearing Failure Mode Identification and Classification System Developed by Bearing Manufacturers at the Request of Railroads to improve the system
- 13 Modes Represent the Typical Bearing Failure Categories
- Primary Symptoms
- Other Symptoms
- Typical Progression
- Additional Criteria
What are the FPMs?

- **(AD) Adapter**
  - Displaced, Worn, Broken, or Wrong Size Adapter
- **(AP) Application Defects**
  - Installation or Assembly Process
- **(BD) Bearing Destroyed**
  - Unknown Cause, Insufficient Evidence
- **(DS) Displaced Seal**
  - Displaced, Cocked, or Loose Seal
- **(LO) Loose Bearing**
  - Loose Bearing Components
- **(LU) Lubrication**
  - Lubrication Breakdown
- **(MD) Manuf./ Reman./ Recond.**
  - Improper Manufacturing, Remanufacturing or Reconditioning
- **(ME) Mechanical**
  - External Abuse on Bearing
- **(NV) Non Verified**
  - No Evidence of Distress Found
- **(SP) Fatigue Spalling**
  - Material Fatigue or Overloading
- **(TR) Truck Related**
  - Negative Truck Influences
- **(WD) Wheel Defect**
  - Cyclic Impacts Cause Cage Failure
- **(WE) Water Etch**
  - Water Ingress and Raceway Etching
Why the FPMs?

• **Accurate** – Less categories and better defined symptoms yield the correct mode being assigned to each

• **Reproducible** – FPM is more consistent among multiple inspectors and more repeatable when reviewed by individual inspectors

• **Ease of Analysis** – Inspected bearings are presorted by the modes to identify performance trends. Additional detailed information easily accessible from MD11A reports.
Why FPMs? - Accurate

**FPM**
- 13 Possible Classifications
- Primary and Other Symptoms Limit Crossovers between Modes
- Classifies Modes Instead of Symptoms

**Fault Tree (Current)**
- 522 Possible Classifications
- Cause of Heat and Initial Defect Qualifiers fit many Failures
- Classifies Symptoms, Not Failure Modes
Why FPMs? - Accurate

Permutations of Initial Defect and Cause of Heat make data analysis confusing. See example below.

Exert from GII 2.7 MD-11 Reporting, Helpful Hints …
”2. Heavily spalled or worn cone raceway or worn rollers will cause heavy damage to seal lips. Grease will leak from bearing and foreign matter will enter.”

<table>
<thead>
<tr>
<th>Initial Defect</th>
<th>Cause of Heat</th>
<th>FPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>CU2</td>
<td>LU1</td>
<td>SP</td>
</tr>
<tr>
<td>CN2</td>
<td>LU3</td>
<td>SP</td>
</tr>
<tr>
<td>RO2</td>
<td>SE4</td>
<td>SP</td>
</tr>
<tr>
<td>CM2</td>
<td>SE4</td>
<td>SP</td>
</tr>
<tr>
<td>others …</td>
<td></td>
<td>SP</td>
</tr>
</tbody>
</table>
Why FPMs? - Reproducible

FPM
• 13 Possible Classifications
• Multiple Inspector Agreement >90%
• Dramatic Improvement w/ Review
• Primary and Other Symptoms Limit Crossovers between Modes

Fault Tree (Current)
• 522 Possible Classifications
• Inspector Agreement <50%
• Little Improvement w/ Review
• Cause of Heat and Initial Defect Qualifiers fit many Failures
Why FPMs? - Reproducible

- Multiple Inspectors
- Agreement Improves with Training
- Transferable Data Throughout Industry
Why FPMs? - Ease of Analysis

FPM
- Categories Include Probable Contributors
- Non Verified FPM for Detector Accuracy
- Characterizes setouts from ALL detector types
- Identifies New Problematic Trends
- Lends itself to Continuous Improvement

Fault Tree (Current)
- Does Not Include Probable Contributors
- Not Hot, Not Reported
- Designed to review Hot Box setouts only
- Only identifies trends known to exist
- Only identifies resultant internal bearing defects.
Why FPMs? - Ease of Analysis

1993 – 2004 Bearing Setouts by FPM

- '93-'94 Setouts
- '03-'04 Setouts

Categories:
- Loose
- Destroyed
- Water Etch
- Mechanical
- Spalling
- Adapter
- Displaced Seal
- Application
- Lubrication
- Wheel Defect
- Truck Related
- Manufacturer
Summary of Recommended AAR Document Updates

- Revised GII P 2.5.4 through 2.7
- Exchange FPM for Helpful Hints and Flow Chart (Figures 2.1-2.6)
- Exchange revised MD-11 form for current MD-11 form (Figure 4.76)
- FPM and Probable Initial Defects / Contributor Key
- Electronic Submission of MD-11 Form
### AAR Detected Roller Bearing Inspection Report

**Car Initial**
- A - Actuated
- D - Disc
- F - Fat
- G - Grape
- H - Hopper
- L - Covered Hopper
- P - Passenger
- R - Refrigerator
- S - Double Stack
- T - Tank
- U - Locomotive
- M - Miscellaneous

**Car Number**

**Position**

**Car Type**
- A - Actuated
- D - Disc
- F - Fat
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**Journal Size**
- 2-3 3/10
- 2-6 x 11
- 3-8 x 12
- 5-3 1/4 x 12
- 6-5 x 7 x 12
- 7-8 x 10
- 8-5 x 8
- 9-3 1/4 x 10
- 10-7 x 9
- 11-7 x 9

**Date of Failure**
- Month
- Day
- Year

**Wheel Tread Defect on**
- Setout Bearing Side

**Why Made Code**
- 07, 70, 73, or 11

**How Detected**
- H - Hot Box
- A - Allowance
- T - Truck Performance
- B - Bearing Trend
- P - Wheel Impact Load Detector

**Journal Burn Off**
- Y - Yes
- N - No

**Elastomer Pad**
- Y - Yes
- N - No
- X - Unknown

**Bearing Distressed - Verified**
- Y - Yes
- N - No

**Sufficient Field Information Supplied**
- Y - Yes
- N - No

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**Bearing Inspection Report - Complete for any Roller Bearings Verified to be Distressed**

**Certificate Number**

**Date Cup Manufactured**
- Month
- Year

**Mounting Information**
- Company Mark
- Shop Code
- Month
- Year

**Last Reconditioning**
- Company Mark
- Shop Code
- Month
- Year

**Times Cup Reconditioned**
- 1-1-2-3-4

**Lubrication**
- NFL or FL

**Screw Seal Ring Present**
- Y - Yes
- N - No

**Seal Manufacturer & Date**
- Company Code
- Month
- Year

**Date Covers Manufactured**
- Month
- Year
- 0 Months
- Year

**Cage Type**
- M - Metallic
- O - Other

**Root Cause of Bearing Distress, Failure Mode Reporting**

**Failure Progression Mode (FPM)**

**Reporting Railroad Mark**

**Investigating Officer**

**Report Must Be Sent to**
- AAR-WABL Committee Coordinator
  - Email: aahf@aar.com
  - Facsimile: 719 585 1896
  - Mail: Transportation Technology Center Inc., P.O. Box 11190, Public, Colorado 81001

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**Mechanical Association Rail Car Technical Services 2005 Program**

**RBMEC**
## Bearing Failure Mode Results from Confirmed Hot Bearings

<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Loose Components</td>
<td>26%</td>
<td>27%</td>
<td>23%</td>
<td>20%</td>
<td>23%</td>
<td>14.8</td>
</tr>
<tr>
<td>Water Etch</td>
<td>13%</td>
<td>20%</td>
<td>18%</td>
<td>25%</td>
<td>20%</td>
<td>12.9</td>
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<tr>
<td>Wheel Defect</td>
<td>16%</td>
<td>13%</td>
<td>13%</td>
<td>13%</td>
<td>13%</td>
<td>9.5</td>
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<tr>
<td>Spalled Components</td>
<td>10%</td>
<td>9%</td>
<td>14%</td>
<td>15%</td>
<td>13%</td>
<td>8.6</td>
</tr>
<tr>
<td>Bearing Destroyed</td>
<td>17%</td>
<td>9%</td>
<td>12%</td>
<td>11%</td>
<td>12%</td>
<td>11.3</td>
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<tr>
<td>Mechanical Damage</td>
<td>7%</td>
<td>9%</td>
<td>7%</td>
<td>4%</td>
<td>6%</td>
<td>9.2</td>
</tr>
<tr>
<td>Lubrication Breakdown</td>
<td>4%</td>
<td>5%</td>
<td>3%</td>
<td>3%</td>
<td>4%</td>
<td>8.3</td>
</tr>
<tr>
<td>Displaced Adapter</td>
<td>4%</td>
<td>5%</td>
<td>3%</td>
<td>5%</td>
<td>4%</td>
<td>7.8</td>
</tr>
<tr>
<td>Displaced Seal</td>
<td>4%</td>
<td>3%</td>
<td>2%</td>
<td>2%</td>
<td>3%</td>
<td>6.5</td>
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<tr>
<td>Truck Related</td>
<td>0%</td>
<td>0%</td>
<td>5%</td>
<td>2%</td>
<td>2%</td>
<td>3.2</td>
</tr>
<tr>
<td>Application Defect</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>1%</td>
<td>0%</td>
<td>5.1</td>
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<tr>
<td>Manufacturer’s Defect</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>1%</td>
<td>0%</td>
<td>2.7</td>
</tr>
</tbody>
</table>
Specific AAR Why Made Codes

Bearing Related Why Made Codes

02 = Broken (including cracked)
03 = Missing
04 = Defective
05 = Bent
08 = Wrong (not standard to car)
31 = Fire or heat damage
32 = Submerged
33 = Derailment damage
**50 = Roller bearing overheated**
92 = Loose or missing cap screws, or other part
93 = Seal loose or cocked out of position
94 = Welding arcing damage
95 = Roller bearing fused due to overheating
97 = Loose backing ring
99 = Damaged seals

Wheel Related Why Made Codes

61 = 80-90 kips wheel as detected by wheel impact detector
65 = High impact wheel as detected by wheel impact detector
67 = Wheel out-of-round detected by gage
75 = Tread shelled
78 = Tread slide flat
Railroad Wheel Set
Typical Bearing Detection
(LO) Loose Bearing Failure: 23%
Hot Bearing Caused by Loose Bearing Components

**Primary Symptom**
- Journal groove ≥ 0.060" deep from a spun cone

**Other Symptoms**
- Loose (or missing) Cap screws (<50% of initial torque on average)
- Loose backing ring
- Journal wear ring groove ≥ .010"
- High Lateral ≥ .030"
- Spun cone (highly polished cone bore)
- Small end roller or raceway spalling
- Cone back face wear ≥ .005"
- Opposite cone from spun cone destroyed (spalling, smearing, etc.)
- O’Rings present
- Inboard wear ring has nose chips on inner diameter

**Typical Progression**
- Low initial clampload, low interference fit, or heavy loading for a long time
- Loss of lateral clampload due to axle flexure, initial oversized cone bore, or undersized journal
- Loss of cone fit; leading to loose cone; leading to point loading of opposite race at small end of the rollers and cup race small end
- Opposite cone and race continue to fatigue – rollers finally skew resulting in obstruction
- Spun cone now takes full load and is destroyed in similar fashion

**Additional Criteria**
Contrary symptoms that may exist:
- Water etch due to displaced seal
- Fragment indentation
- Wheel defects with no broken cage

Despite these contrary symptoms, the preponderance of evidence makes this a loose bearing failure.
Bearing Clamp

LATERAL CLAMP

RADIAL CLAMP
Axle and Thrust Loading
(WE) Water Etch; 20%

Bearing Distress due to Water Ingress and Raceway Etching

Primary Symptom
- Both setout and mate bearing have Condemnable etching on races or rollers (as defined in this mode.)

Other Symptoms
- Should be evidence of Condemnable etching on the rollers or races to be classified a water etch failure.
- Etching to races or rollers is Condemnable if (all should be satisfied):
  - Etch depth can be caught with a 0.010" feeler gage
  - Etch occurs at irregular intervals (less than a roller width apart)
- Rusty bearing parts (cage, spacer, rolling components)
- Bar line water etch spalling (Water etch spalling is often deeper at the edges)
- Water or moisture in grease (grease described as thin or tar like)
- High lateral (≥ 0.030”)
- Severe pitting on cup race edges
- Evidence that cars have been flooded

Typical Progression
- Ingress of moisture and/or contamination
- Roller end scoring
- To race and or roller etching
- To race and or roller spalling
- To cage wear and/or failure
- To skewed rollers
- To race smearing
- To Heat

Additional Criteria
Staining and light etching (no depth) that could have occurred after service should \textbf{NOT} be considered.
Contrary symptoms that may exist:
- Loose stack
- Brinelling of raceways
- Broken cage (not associated with wheel condition)

Despite the presence of these contrary symptoms, the preponderance of evidence makes this a water etch failure.
(WD) Wheel Tread Defect; 13%
Bearing Distress Caused by a Wheel Tread Defect

Primary Symptom
- Out of round (OR) ≥ 0.070” or multiples ≥ 0.050” or wheel impact detection ≥ 90 kips with broken cage

Other Symptoms
- Condemnable Shelling (wm75), tread build up (wm76), out-of-round (wm67), or slid flat (wm78)
- Broken cage
- Skewed rollers
- Smearing races and rollers
- Transfer of roller, race, or cage material

Typical Progression
- Starts with wheel tread defect
- Impacts cause cage to break
- Rollers become skewed
- Smearing of races and rollers begins
- Transfer of material
- To seized bearing or excessive heat

Additional Criteria
Contrary symptoms that may exist:
- Average cap screw torque ≤ 50%
- Cone back face wear ≥ 0.005
- Water etch
- Light brinelling
Despite these contrary symptoms, the majority of evidence points to a wheel tread defect failure.
Cage Impact Loads

- Cone supports upper rollers
- Side rollers vertically supported by cage bars only
- Rollers support cage but get "wedged" into pockets
- Wheel impacts create high roller loads that cage must support
- Cup supports lower rollers
- Cup gives some support to cage large end
- No support provided to cage small end
Steel Cage Failures Resulting From Wheel Impact Loads
Polyamide Cage Failures Resulting From Wheel Impact Loads
(SP) Fatigue Spalling; 13%

Bearing Distress Caused by Material Fatigue Spalling

**Primary Symptom**
- None

**Other Symptoms**
- Bearing geometry appears to be good
- Cyclical fatigue spalling of rollers or races
- Component with significant service life
- No water etch, impact or other bar line spalls present
- No point loading from worn, displaced, or wrong adapter
- Raceway that shows fatigue has repaired spalls
- Raceway that shows fatigue has been reground
- HAL (heavy axle loading) Car, 286,000+ lbs on Class F bearing
- Repaired spall that has propagated

**Typical Progression**
- Intermittent spalls of various sizes around roll track or race
- Spalls appear to originate near center of either race or roller
- Spalls propagate
- Race and/or rollers smear
- Heat

**Additional Criteria**
As defined by this Mode, fatigue spalling does **NOT** originate from:
- Water etch
- Impact brinells
- Uneven loading (from loose components, adapter, or truck
- Lubrication loss or breakdown

Fatigue spalling **CAN** originate from:
- Defects in the steel
- Severe or heavy loading (stresses exceeding the strength of the material)
- Reground or repaired raceways
$L_{10}$ Life / Fatigue Spalling
Fragment Indentation Resulting from Spalled Components
(BD) Bearing Destroyed, Undetermined; 12%
Obviously Distressed Bearing with Unknown Cause

Primary Symptom
- Bearing should be considered a Destroyed/Undetermined if there is NO definitive indication in the mate or hot bearing as to the cause of failure.

Other Symptoms
- Bearing destroyed, no evidence in mate or hot
- Fused to journal (no pull) no evidence in mate

Typical Progression
- Unknown source of heat
- Heat destroys bearing components
- Bearing components fuse to one another or journal

Indicators for common Failure Modes of destroyed bearings
(For pulled, no-pull, or burn off destroyed bearings, satisfaction of any one criteria lead to the failure mode listed. Note that the failure is not limited to the modes listed, any Failure Mode can be assigned to a burn off or destroyed bearing given proper evidence.)

(LO) Loose
- Cone seat groove on the setout side is > 0.060”
  (even if wheel defects are present)
- Spun inboard wear ring on setout bearing
- Setout or mate display 3 or more indications of loose bearing
  - average cap screw torque < 50%
  - cone back face wear > 0.005”
  - loose backing ring
  - turned cone (journal grooved < 0.060”)
  - seal cap o-rings present
- Mate or setout journal is undersized, no wheel defect is found and the bearing has been in service longer than 4 years (from mount date)
- Bearing can only be partially pulled from journal (1-3”), suggesting that a cone has dropped into a turned journal seat.

(WD) Wheel Defect
- Wheel defects are present, (flat spot out of round wheel) > .070”, multiples greater than 0.050”, or wheel impact detection ≥ 90 kips on the setout side

(WE) Water Etch
- Mate bearing has water damage (e.g. heavy rust in EC, BR or WR, water etch on races or rollers, etc.)

(ME) Mechanical
- Mate bearing has heavy brinelling (condemnable)
- Mate bearing or wheel has other evidence of derailment or impact damage

(TR) Truck Related
- Mate bearing shows symptoms of overloading from truck
- Opposite truck wheelset is available and shows signs of overloading from truck
(ME) Mechanical; 6%

Bearing Distress Caused by External Abuse

Primary Symptom
- None

Other Symptoms
- AAR condemnable Brinelling of raceways (use AAR brinell gage)
- External heat (thaw shed, torch, etc.)
- Cup fractures that occurred in service (not caused in wheel garden after service)
- Evidence of minor/ major derailment damage
- Fluting or electrical arcing
- Foreign substances wrapped around or pulled into bearing
- Damaged or dented seals (not from adapter)
- Impact Spalling

Typical Progression
- Physical abuse to bearing
- Seal damage
- Loss of lube
- Heat generation
  - Rough car handling
  - Brinelling of roll tracks (cup and/or cones)
  - Spalling originating from brinells (impact spalling)
  - Spalls propagate
  - Heat generation

Additional Criteria
Any external source of abuse that leads to bearing distress.
(LU) Lubrication; 4%

Bearing Distress Due to Lubrication Break Down

Primary Symptom
- None

Other Symptoms
- Loss of grease noted, without other defects
- Grease is thin and runny or tar like (dramatic change in consistency)
- Roller end scoring
- Races and rollers blue in color (evidence of heat)
- Race and roller smearing, peeling
- Build up of moist road grime on the end cap/ backing ring
- Polished races
- "Burnt" smell to grease
- Pocket bars heavily worn (possibly broken)
- Spalling of cone back rib (no other evidence of spalling)

Typical Progression
- Lubrication breaks down (Thinning)
- Leads to lubrication loss of base oil (Thickening)
- Leads to roller end scoring
- Polishing of races
- To race and or roller heat (blue race and rollers)
- To race and or roller smearing/ peeling
- To cage wear or breakage
- To skewed rollers
- To more heat

Additional Criteria
Lubrication failure mode is normally not associated with spalling. At any point in the progression process this bearing could produce enough heat to be flagged and setout.
Adapter (AD: 4%)  
Worn, Displaced, Broken, or Wrong Size
(AD) Adapter (Displaced, Worn, Wrong Size, or Broken); 4%

Bearing Distress Caused by Displaced or, Worn, Wrong Size, or Broken Adapter

Primary Symptom
- None

Other Symptoms
- Adapter should be determined to be displaced, worn, wrong size, or broken during external inspection in order to be AD failure
- Adapter rubbing on end cap, backing ring, or seal case
- Point loading (evidence on cup outer diameter and corresponding cup race)
- Damaged or dented seal case
- Cracked and/or broken cup counterbore

Typical Progression
- Displaced adapter or wrong adapter size (noted at external inspection)
- Point loading
- To localized point loaded spalling on races
- To race and roller smearing
- To accelerated spalling
- To heat
- Displaced adapter (noted at external inspection)
- Rubs end cap or backing ring generating heat

Additional Criteria
Contrary Symptoms that may be present:
- Displaced seal (and associated damage)
- Race spalling
- Grease contamination

Despite the presence of these contrary symptoms, the preponderance of evidence points to a defective adapter condition.

Very strong visual evidence should be present during external inspection to make this notation if adapter is not with bearing.
(DS) Displaced Seal; 3%

Bearing Distress due to Displaced, Cocked, or Loose Seal

Primary Symptom
- None

Other Symptoms
- Loose seal (rotating in counterbore)
- Displaced or cocked seal (seal bead sheared off)
- Presence of free water in the bearing
- Seal components rubbing together (HDL, LL or Thin Gap)
- Seal rubbing end cap or backing ring
- Uneven seal lip wear
- Loss of lubrication

Typical Progression
- Seal becomes dislodged without obvious influences
- Seal components rubbing against each other (Thin Gap, LL or HDL) or rubbing on backing ring / end cap
- To loss of lube and ingress of water
- To race and or roller smearing
- To race and or roller spalling
- To heat

Additional Criteria
Most cases involve the seal becoming dislodged due to another mode:
- Adapter pinching cup (AD)
- Improper mounting (AP)
- Loose bearing components or debris from inside the bearing (LO, SP, WE, etc.)
- Seal being contacted by adapter or external force (signs of brinelling) (ME)
- Cup counterbore out of specification (MD)

This failure mode only pertains when there is NO clear reason why the seal became loose or displaced.
Truck Related Damage (TR: 2%)
(TR) Truck Related Failure; 2%
Bearing Distress Caused by Uneven Loading from the Truck Components

Primary Symptom
Primary – none

Other Symptoms
- Heavily worn cone raceways (typically inboard)
- Spalling in cup, matched to heavily worn cone race
- Heavily worn rollers, matched to heavily worn cone race
- Cage rubbing race (smearing)
- Fine metal particle content in grease (large quantities)
- Cup outer diameter worn over opposite races of the setout and mate bearing

Typical Progression
- Bolster splays due to HAL and high mileage
- Side frames toe inward
- Inboard races/rollers take more of the bearing load (adapter pinched axially)
- Cone race begins to spall and wear
- Associated cup race and rollers wear and spall
- Cage begins to rub race and smear
- Load is transferred to outboard race and spalling occurs there as well (elliptical at first)

Additional Criteria
Uneven loading caused by abnormal performance of the Truck assembly (sideframe, bolster, spring group, snubber, side bearing, elastomeric pad, etc.) is classified a truck related failure. Additional conditions in the bearing could be noted from these types of failures.

Typically this type of failure will be repeated among a car set or even a car type running in a common service.
(AP) Application Defects; 0%
Bearing Distress Caused by Installation or Assembly Process

Primary Symptom
- None

Other Symptoms
- Bearing should be \( \leq 4 \) years old (from mount date) to be considered an application defect failure.
- Undersized or oversized journal \( \geq 0.0003" \) out of range by second hand axle tolerances
- Out of spec. lateral \( \geq 0.030" \) or Zero - not free turning
- Displaced seal
- Handling/ Mounting damage to bearing
- Journal gauling during mounting

Typical Progressions
- Misalignment of mounting press
- Gouging of journal by IB wear ring
- To displaced IB seal
- To seal damage
- To heat from seal damage
- Undersized journal, reduced radial clamp
- Cone(s) spin during service
- Progresses as loose bearing failure

Additional Criteria
Contrary symptoms that may exist:
- Water ingress due to a displaced seal
- Journal grooving due to turned cone
Despite these contrary symptoms, the short life of bearing and supporting evidence points to a mounting problem.
(MD) Manufacturer/ Remanufacturer/ Reconditioner Defect; 0%

Bearing Distress Caused by Improper Manufacturing, Remanufacturing, or Reconditioning of the Bearing

Primary Symptom

Primary – none

Other Symptoms

- Mixed raceway components
- Components that do not meet with AAR acceptable dimensions
- Test products or experimental components
- Product included in AAR recalls
- Bearing assembly defects
  - Missing components
  - Improper bench lateral
  - Excessive or inadequate grease charge
- Remanufactured/ reconditioned components that do not meet with AAR accepted practices
- Manufacturing or processing defects (ex. seamed roller)

Typical Progression

- Assembly defect
- Bearing fails prematurely
- Oversized Cone
- Progresses as Loose Failure

Additional Criteria

Some symptoms are similar to those found in with Application Defect (AP) failures. This mode includes all failures that are attributed to the improper manufacturing, remanufacturing, or reconditioning of a bearing as well as test/ experimental product that offers a unique failure that cannot be characterized by another mode.

Typically this type of failure will be repeated among product supplied from a manufacturer/ remanufacturer/ reconditioner during a certain time frame.
# Bearing Failure Mode Results from Confirmed Hot Bearings

<table>
<thead>
<tr>
<th>Failure Mode</th>
<th>Ave.</th>
<th>Yrs.</th>
</tr>
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<tbody>
<tr>
<td>Loose Components</td>
<td>23%</td>
<td>14.8</td>
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<td>Water Etch</td>
<td>20%</td>
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</tr>
<tr>
<td>Wheel Defect</td>
<td>13%</td>
<td>9.5</td>
</tr>
<tr>
<td>Spalled Components</td>
<td>13%</td>
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<td>12%</td>
<td>11.3</td>
</tr>
<tr>
<td>Mechanical Damage</td>
<td>6%</td>
<td>9.2</td>
</tr>
<tr>
<td>Lubrication Breakdown</td>
<td>4%</td>
<td>8.3</td>
</tr>
<tr>
<td>Displaced Adapter</td>
<td>4%</td>
<td>7.8</td>
</tr>
<tr>
<td>Displaced Seal</td>
<td>3%</td>
<td>6.5</td>
</tr>
<tr>
<td>Truck Related</td>
<td>2%</td>
<td>3.2</td>
</tr>
<tr>
<td>Application Defect</td>
<td>0%</td>
<td>5.1</td>
</tr>
<tr>
<td>Manufacturer’s Defect</td>
<td>0%</td>
<td>2.7</td>
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</table>
# Bearing Failure Mode Results from Confirmed Hot Bearings

<table>
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<th>Failure Mode</th>
<th>Ave.</th>
<th>Yrs.</th>
<th>OEM</th>
<th>RECON</th>
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<tr>
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<td>11.6</td>
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<td>13.3</td>
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</tr>
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<td>12%</td>
<td>11.3</td>
<td>15.2</td>
<td>9.7</td>
</tr>
<tr>
<td>Mechanical Damage</td>
<td>6%</td>
<td>9.2</td>
<td>13.5</td>
<td>7.3</td>
</tr>
<tr>
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<td>4%</td>
<td>8.3</td>
<td>11.2</td>
<td>7.2</td>
</tr>
<tr>
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<td>7.8</td>
<td>11.0</td>
<td>6.9</td>
</tr>
<tr>
<td>Displaced Seal</td>
<td>3%</td>
<td>6.5</td>
<td>9.8</td>
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<tr>
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</tr>
<tr>
<td>Application Defect</td>
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<td>10.0</td>
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<tr>
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<td><strong>Total</strong></td>
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FPM Timeline

- Developed by Brenco & Timken in 2002 with BNSF
- Implemented by RBMEC in 2003 – Dual Reporting
- Proposed to AAR (WABL) in March 2003
- TTCI Analytical Use in 2004
- Now Spearheaded by CN for Adoption
Questions