

# Contents

Preface — VII

Acknowledgments — IX

List of illustrations — XIX

Introduction — XXIII

## PART A: Bearings and optimally applying lubricant

### Examining rolling element bearings and traditional lubrication

#### Chapter 1

**Making the case for upgrading — 5**

- 1.1 Management digest — 5
- 1.2 What causes lubricants to degrade — 5
- 1.3 Cost-justifying upgrades — 6

#### Chapter 2

**Fundamentals of rolling element bearings and lubricant application — 9**

- 2.1 Management digest — 9
  - 2.1.1 Pumps used as examples — 9
- 2.2 Failure distribution — 14
  - 2.2.1 Pump failure distribution — 14
  - 2.2.2 Causes of bearing failures — 15
  - 2.2.3 Employee motivation matters — 16
  - 2.2.4 Plant size is not a factor — 16
  - 2.2.5 Reliability-focus versus repair-focus — 16
- 2.3 Even elusive failures have causes — 17
  - 2.3.1 True keys to asset performance — 19
- 2.4 Only two root causes of failure exist — 19
  - 2.4.1 Repeat failures — 19
    - 2.4.2 Bearing checklist — 20
- 2.5 What to upgrade in process pump bearing housings — 22
  - 2.5.1 Generics tell the story — 22
  - 2.5.2 Black oil — 23
- 2.6 “FRET” – force, reactive environment, time, temperature — 24
  - 2.6.1 Bearing housing protector shortcomings — 24
- 2.7 DN-number points to oil level preferences in bearing housings — 24

2.7.1	Oil rings, general —	24
2.7.2	Bearing and shaft velocity constraints —	26
2.7.3	Oil levels in bearing housings with different size bearings —	27
2.8	Oil rings have serious limitations —	29
2.8.1	More on test stand versus field experience —	29
2.9	DN number concerns re-emphasized and summarized —	30
2.9.1	Shaft horizontality and oil level —	31
2.10	Constant level lubricators —	32
2.10.1	Making informed choices —	34
2.10.2	Why use only pressure-balanced constant level lubricators —	34
2.10.3	Disseminating information relating to lubricators —	35
2.11	Needed: a better choice than oil rings and constant level lubricators —	36
2.11.1	Rebuilding and upgrading are urgently needed —	38
2.11.2	Test the pump rebuild shop's lubrication knowledge —	38
2.12	Why avoid low-cost lubricants and lube delivery methods —	39
2.12.1	Experience-based rankings for general guidance —	40
2.13	Understanding elusive bearing lubrication issues —	40
2.13.1	Bearing housings with or without oil rings —	42
2.13.2	Attempts to improve on troublesome oil ring lubrication —	42
2.14	Black oil and bearing protector seals —	43
2.14.1	The story of "black oil" in pump bearing housings —	43
2.14.2	More on the issue of darkened oil —	44
2.14.3	Oil level and oil application concerns must be addressed —	45
2.15	Needed: a better choice than oil rings —	45
2.15.1	Contemplating ideal lube applications —	46
2.15.2	Accountability —	47
2.15.3	Oil mist provides more than just lubrication —	48
2.15.4	Highlights and summary – 25 lubrication-related issues —	48

### **Chapter 3**

#### **General applicability ranges for oils and greases — 55**

3.1	Management digest —	55
3.2	Oil lubrication categories —	55
3.2.1	Synthetic lubricants —	55
3.2.2	Where synthetic lubes become important problem solvers —	56

### **Chapter 4**

#### **Grease lubrication — 59**

4.1	Management digest —	59
4.1.1	Grease relubrication intervals —	60
4.1.2	Shields versus no shields in electric motor bearings —	61

**Chapter 5****Examining reliability-compromised process pumps — 67**

- 5.1 Management digest — 67
  - 5.1.1 Revisiting “dn” — 67
  - 5.1.2 Vendor response — 68
  - 5.1.3 Prior art considered — 70
- 5.2 Why pump users should request lube delivery upgrades — 72
  - 5.2.1 Slow progress in obtaining lube delivery upgrades — 74
  - 5.2.2 The gear pump meeting — 75
  - 5.2.3 Pursuing regenerative pumps — 76
  - 5.2.4 The 26 pump lube improvement opportunity — 76
  - 5.2.5 Implementing an immediate upgrade in the Western United States — 78

**Part B: Fundamentals of oil mist technology****How equipment outdoor preservation later becomes full standby protection****Chapter 6****Oil mist technology and its role in optimally protecting standby (standstill) equipment — 85**

- 6.1 Management digest — 85
- 6.2 Brief overview — 85
  - 6.2.1 Coalescing action — 88
  - 6.2.2 Lubrication volume and reclassifier sizes — 90
- 6.3 Oil mist technology and its role in optimally protecting equipment — 92
  - 6.3.1 “Mothballing” and how it works — 92
  - 6.3.2 No downsides, only advantages — 93
  - 6.3.3 Fifty years of oil mist lubrication and why oil mist excels — 98
  - 6.3.4 Primary advantages over conventional lubrication summarized — 100
  - 6.3.5 Closed oil mist systems — 100
  - 6.3.6 Operational parameters and simplified parts list — 103
  - 6.3.7 Oil mist for plain bearings — 104
  - 6.3.8 Temperature limits for oil mist lubrication — 105
  - 6.3.9 Hot bearings — 106
  - 6.3.10 Old-style open- and new-style closed-oil mist systems — 107
  - 6.3.11 Quality of air needed for oil mist — 110
  - 6.3.12 Modern bearing housing protector seals used with oil mist — 111

## **Chapter 7**

### **Oil mist history and reliability experience — 115**

- 7.1 Management digest — **115**
- 7.2 Scope of overview — **115**
- 7.3 Why oil mist is a mature technology — **115**
- 7.3.1 Few maintenance tasks with oil mist — **117**
- 7.4 Relating oil mist experiences — **117**
- 7.5 Case histories: Oil mist application beyond process pumps — **121**
- 7.5.1 Northeast oil refinery – a 2018 experience involving a four-cell cooling tower — **121**
- 7.5.2 Case history: rapid payback from modern oil mist systems at an oil refinery in Texas — **124**
- 7.5.3 Updates always confirm earlier findings — **125**
- 7.5.4 Fewer shutdowns on record — **126**
- 7.5.5 What can shut down an oil mist system? — **127**
- 7.5.6 Installed spare modules (mixing chamber reservoir) options — **128**
- 7.5.7 Thoughtful layout saves money — **128**
- 7.6 Warehoused spares — **129**
- 7.7 Oil mist is the ultimate filter — **129**
- 7.8 Why oil mist terminations with low melting point alloys can be fire monitors — **130**
- 7.9 Using and supervising your own workforces to implement large-scale oil mist systems — **131**

## **Part C: Full equipment standstill/standby protection**

## **Chapter 8**

### **Outdoor equipment storage and preservation yards — 135**

- 8.1 Management digest — **135**
- 8.2 Overview and principles of storage yards — **135**
- 8.3 Modifying new equipment upon arrival at a storage yard — **135**
- 8.4 Preservation statistics and cost data — **140**
- 8.5 Preview of alternative outdoor storage protection methods — **143**

## **Chapter 9**

### **Storage protection use often followed by permanent installation — 147**

- 9.1 Management digest — **147**
- 9.1.1 Important dual purpose of oil mist equipment — **147**
- 9.2 N<sub>2</sub> blanketing and/or nitrogen sweeping — **148**
- 9.3 Oil mist blanketing and/or oil mist sweeping — **149**
- 9.4 Oil mist intrusion into electric motors — **150**

**Chapter 10****Why storage preservation as an afterthought will fail — 153**

- 10.1 Management digest — 153
- 10.2 When it is too late for storage preservation — 153
- 10.2.1 How degradation progresses — 153
- 10.3 The flushing option — 154

**Chapter 11****CAPEX for best available technology — 157**

- 11.1 Management digest — 157
- 11.2 Questions on funding — 157
- 11.3 Costs for small outdoor storage yard using a pre-owned OMG — 158
- 11.4 Costs for future large outdoor storage yards with factory-new OMGs — 160
- 11.5 Budgeting oil mist preservation — 161
- 11.6 Why context matters — 161
- 11.7 Thorough cost justifications require study of statistical information — 162
- 11.8 Summary of findings and how data are validated — 163

**Chapter 12****Can field trials be bypassed? — 171**

- 12.1 Management digest — 171
- 12.2 No field trials needed for oil mist — 171
- 12.3 Field trials for conventional storage preservation — 171
- 12.4 Definition of deliverables — 172

**Chapter 13****Vapor-related and old-style conventional storage protection methods — 173**

- 13.1 Management digest — 173
- 13.2 Examining vapor phase and vapor space inhibitors — 173
- 13.3 Opting for conventional storage preservation and selecting products — 174
- 13.4 Properties of product A — 174
- 13.5 Properties of product B — 175
- 13.6 Properties of product C — 176

**Chapter 14****Machine-specific storage preservation steps — 179**

- 14.1 Management digest — 179
- 14.2 Small motors and similar machines — 179
- 14.2.1 Relating bearing construction to “leave alone” strategies — 180

- 14.3 Large electric motors — **181**
- 14.4 Steam turbines — **181**
- 14.5 Gas turbines and hot gas turboexpanders — **182**
- 14.6 Gearboxes — **182**
- 14.7 Centrifugal (dynamic) plant air compressors and blowers — **182**
- 14.8 Lube and seal oil consoles and circulating oil systems — **183**
- 14.9 Reciprocating compressors — **183**
- 14.10 Hydraulic units — **183**

## **Chapter 15**

### **Strategy for short-term equipment storage preservation — 185**

- 15.1 Management digest — **185**
- 15.2 Shaft rotation requirements (applicable to short-term equipment storage) — **185**
  - 15.2.1 Visual inspection (refers only to short-term equipment storage) — **186**
  - 15.2.2 Draining of condensate (for short-term equipment storage) — **186**
- 15.3 Bearings (for short-term equipment storage) — **186**
- 15.4 Electric motors (for short-term equipment storage) — **186**
- 15.5 Steam turbines (for short-term equipment storage) — **186**
- 15.6 Gears (for short-term equipment storage) — **187**
- 15.7 Compressors (for short-term equipment storage) — **187**
- 15.8 Using oil mist for short-term equipment preservation — **187**
  - 15.8.1 Other considerations for short-term equipment storage — **188**
  - 15.8.2 Storage preservation mentioned in industry standards — **188**
  - 15.8.3 Protection of mechanical seal components in nonoperating fluid machines — **190**
  - 15.8.4 Pumps and fluid machines where no fluid is present — **190**
  - 15.8.5 Pumps and fluid machines where fluid is present — **191**
- 15.9 Case history involving EPC contractor — **191**

## **Chapter 16**

### **Preparing stored equipment for re-commissioning (re-start after long periods of preservation) — 193**

- 16.1 Management digest — **193**
- 16.2 Steps before removing machine — **193**
  - 16.2.1 The process pump example — **194**
  - 16.2.2 Inert gas purge versus the oil mist preference — **194**

**Chapter 17**

**Summary and conclusions — 195**

- 17.1 Management digest — 195
- 17.2 Other points worth recalling — 195
- 17.3 Taking reliability engineering up a notch — 196
- 17.4 Be mindful of the bottom line — 197

**Appendix I: Damage terms, damage prevention, and the corrosion mechanism — 199**

**Appendix II: A new development: “ADIOS” — 207**

**Appendix III: Jobsite receiving and protection — 213**

**References — 221**

**Index — 225**

**About the author — 231**