

# **Rotating Machinery Health Management and Rotating Equipment Maintenance and Reliability Training Course Content**

## 4-Day Rotating Machinery Excellence Introductory and Advanced Course Content

### **Course Content**

#### **Day 1 - Machinery Health and Reliability Excellence - Introduction**

##### **COURSE OVERVIEW**

First day – Cause of Rotating Machinery failures

Second day – Standards, condition monitoring and top-class maintenance

Third day – Shafts, bearings and seals for reliability excellence, Maintenance for reliability

Fourth day – Improving machinery reliability, reducing maintenance cost, sustaining RE integrity

What is 'Rotating Machinery Excellence'?

##### **PLANT AND MACHINERY DOWNTIME COSTS**

The True Cost of Failure

Where Profit is Lost in Business Processes

The Purpose of Business

Maintenance is an Economic Decision

Impact of Defects and Failures

Defect and Failure True (DAFT) Costs go Company-wide

Failure Costs Surge thru the Company

Separate the True Downtime Costs so you can see them for what they are

Calculating the True Downtime Costs

##### **MACHINERY RISK MANAGEMENT**

Understanding Risk and Its Consequences

Risk Calculations

The Shape of Risk

Risk Relationships

What Risk Means

Determine Your Acceptable Failure Domain

Maintenance is Used to Manage Risk

Benefits of Reducing Operating Risk

##### **VARIATION, DEFECTS AND FAILURES**

Defects and Failures Enter Your Business Everyday

Normal Ways to Control Defects and Failures

Preventing Defects and Failures

The Trouble with Accepting a Defect

Defects Lead to Failures and High Costs

Act to Control the Defects and Risks

Problems, Defects and Failures start with Variation

Effects of Process Condition Disruptions

Special and Common Cause Variation

Preventing Process Condition Disruptions

##### **MACHINERY DESIGN ISSUES**

The Unforgiving Nature of Machine Design

Activity 1 - Design Shaft Rotor and Material Selection

The Slow Destroyers

Good Process Control Prevents Rapid Internal Equipment Changes

Supporting Structure and Foundation Strength and Rigidity

Vibration Basics

# **Rotating Machinery Health Management and Rotating Equipment Maintenance and Reliability Training Course Content**

## 4-Day Rotating Machinery Excellence Introductory and Advanced Course Content

### **Course Content Continued**

Forced Vibration  
Natural Frequency  
Attenuation of Vibration  
Dissipating Loads and Forces  
Preventing Equipment Deformation  
Preventing Deformation from Pipe Stress  
Activity 2 - Soft Foot Case Study  
Soft Foot Case Study  
Soft Foot Distorts Motor Armature Air Gap

### **ROTATING MACHINERY PARTS FAILURE**

Causes of Shaft Failures  
Causes of Roller Bearing Failures  
Calculating L10 Lifetime  
Effects of Fluctuating Loads and Forces  
Lubrication Contamination  
Lubrication Contamination Control  
Tell-tale Bearing Failure Signs  
Causes of Contact Shaft Seal Failures

### **ROTATING MACHINERY RELIABILITY**

The Payoff is Reliability, Availability, Maintainability, Safety (RAMS)  
Equipment Degradation Cycle  
Equipment Life Extension  
Valuable Precision Maintenance  
Rotating Equipment Precision Maintenance  
Precision Maintenance of Rotating Equipment is ...  
Accuracy Controlled Enterprise (ACE) Procedures  
Activity 3 - Develop an ACE procedure

## **Day 2 - Machinery Health and Reliability Excellence - Introduction**

### **MECHANICAL EQUIPMENT AND MACHINERY STANDARDS**

6 Mechanical Equipment Care Standards to Set, Use and Keep Using  
Balanced Rotors and Balancing Standards  
Rotating Equipment Balancing  
Shaft Coupling Problems  
Appropriate Key Length for Assembly  
Coupling Bolts and Washers  
Specification for Coupling Assembly  
Burred Shaft  
Either on end or next to bearing face  
Activity 1 Balancing Case Study  
Effects of Shaft Misalignment  
Causes of Shaft Misalignment  
Coupling Flexing Points Locations  
Accuracy and Limits for Alignment  
Precision Alignment Practice  
. Pre-Alignment Checks  
. Rough-In Alignment  
. Precision Alignment

# **Rotating Machinery Health Management and Rotating Equipment Maintenance and Reliability Training Course Content**

## 4-Day Rotating Machinery Excellence Introductory and Advanced Course Content

### **Course Content Continued**

. Alignment Records  
Off-line to Running (OL2R) Machine Movement  
Case Study 2 – Important Factors when Doing Shaft Alignments

#### **CONDITION MONITORING METHODS FOR ROTATING MACHINERY**

Range and Choice of Condition Monitoring Methods  
Condition Monitoring Degradation  
Selecting Condition Monitoring using the Three Point Inspection Frequency  
Machine Shape Deflection

#### **VIBRATION ANALYSIS**

Rotating Machinery Vibration  
Causes of Vibration  
Bearing Vibration Causes  
ISO Standards for Vibration Evaluation  
Allowable Vibration Severity  
Vibratory Condition Based Monitoring  
Rotating Shaft Vibration Measurement  
The Value of a Baseline Vibration Signature  
Rotating Bearing Vibration Displays

#### **TRIBIOLOGY AND LUBRICATION ANALYSIS**

Wear Particle Analysis  
Analysing Properties of Lubricants  
Sustaining Lubricant Health  
Lubricant Management Programs

#### **THERMOGRAPHY**

#### **ROTATING EQUIPMENT NON-DESTRUCTIVE TESTING**

Radiography (X-Ray, Gamma Ray)  
Magnetic Particle Inspections  
Dye Penetrant Procedures  
Ultrasonic Scanning (thickness, cracks, inclusions, etc)  
Visual Inspections (human eyes, borescope, etc)  
Performance Monitoring (human senses, temperature, pressure, pH, etc)

#### **RELIABILITY AND MAINTENANCE STRATEGY MIX**

The Six Purposes of Maintenance  
Equipment Availability as a Function of Maintenance Costs  
Asset Management & Business Performance  
Reliability and Maintenance Best Practice Assessment  
Plant and Equipment Life Cycle  
When Operating Costs are Committed  
Component & System Reliability Modelling  
Reliability of Parts and Components  
Reliability of Systems of Parts and Components (i.e. Machines)  
Equipment Reliability Strategies  
Failure Mode and Effects Analysis (FMEA)  
Equipment Criticality

# **Rotating Machinery Health Management and Rotating Equipment Maintenance and Reliability Training Course Content**

## **4-Day Rotating Machinery Excellence Introductory and Advanced Course Content**

### **Course Content Continued**

Rotating Equipment Maintenance Strategy PM - PdM - Replace - Breakdown Mix  
Operator Driven Reliability  
A Strategy for Equipment Reliability  
Maintenance KPIs and Outcomes  
Maintenance Quality Improvement  
Use Visual Management for Feed Forward Control of Performance  
Activity 4 – RE Life-Cycle Reliability Strategy

### **Day 3 - Machinery Health and Reliability Excellence - Advanced**

#### **LUBRICATION SELECTION**

Physics of Lubrication  
Properties Of Lubricants and Additives  
Purpose Of Grease Additives  
Use Grease or Oil?  
Dry Lubricant  
Lubricant Operating Environment for Oils and Greases  
Wear Debris Analysis  
Lubricant Life-extension with Lubrication Management

#### **PROCESS CONTAINMENT SEALS**

Methods, Types, Designs, Process Effects  
Process Containment Seal Design Overview  
Sliding Lip Seals  
Seal Failure Modes  
Long-life Seal Conditions  
Seal Selection Issues

#### **TRANSMITTED VIBRATION PREVENTION AND ISOLATION**

Basics of spring/damper systems  
Forced Frequency and Natural Frequency  
Passive Machinery Vibration Isolation  
Activity 1 – Vibration Isolation Calculation

#### **STRENGTH OF MATERIALS FOR SHAFTS AND ROTORS**

Metallurgy - Stress and Stress Raisers  
Stress Concentration Effect  
Metal Fatigue  
Metal Fatigue Control  
Bending and Deflection of Shafts  
Horizontal and Vertical Shaft Design  
Combined Axial, Radial and Torsional Loads  
Controlling Axial, Radial, Torsional Loads  
Shaft & Equipment Assembly Considerations  
Shaft Manufacture, Diameter and Tolerance  
Activity 2 – Life Considerations for a Shaft and Bearing Assembly

#### **BEARING DESIGN AND SELECTION - RADIAL AND AXIAL**

Roller Bearing Loads – Max and Min

# **Rotating Machinery Health Management and Rotating Equipment Maintenance and Reliability Training Course Content**

## **4-Day Rotating Machinery Excellence Introductory and Advanced Course Content**

Bearing Overload

### **Course Content Continued**

Roller Bearings and Plain Bearings – Uses and Limitations of Each  
Bearing Lubrication Selection and Use  
Value of Better Bearing Sealing  
Bearing Housings and Construction  
Activity 3 – Select a Roller Bearing for the Shaft

### **PRECISION MAINTENANCE**

Explaining Precision Maintenance  
Precision is a Serious Opportunity  
Precision Standards to Set, Use and Keep  
What we Know about the Business Benefits of Precision Maintenance  
Journey to 6 Sigma – Minimizing Variability  
The Solution starts when Management set standards, then promote and enforce them  
Typical Precision Maintenance Program Content

- . Accurate Fits and Tolerance at Operating Temperature
- . Impeccably Clean, Contaminant-Free Lubricant Life-long
- . Distortion-Free Equipment for its Entire Life
- . Forces and Loads into Rigid Mounts and Supports
- . Laser Accurate Alignment of Shafts at Operating Temperature
- . High Quality Balancing of Rotating Parts
- . Low Machine Vibration
- . Correct Torques and Tensions in all Components
- . Correct Tools in the Condition to do the Task Precisely
- . Only In-specification Parts
- . Failure Cause Removal to Increase Reliability
- . A documented system to standardize work and use standards in a successful way

Improve Lubricant Condition  
Alignment Tolerance Recommendation  
Define Allowable Vibration Severity  
Replace Unbalance with Balance  
Correct Shaft and Hole Fits  
Soft Foot  
Using Precision Maintenance

- . Creative Disassembly
- . Creative Disassembly – Pre-shutdown of Equipment
- . Creative Disassembly – At Shutdown
- . Creative Disassembly – At Strip-down

Tell-tale Bearing Failure Signs  
Set Standards for Condition and Use of Tools and Equipment  
Typical Standards for Precision Maintenance Program  
Developing Precision Skills  
3Ts of Failure Prevention  
The Accuracy Controlled Enterprise

### **Day 4 - Machinery Health and Reliability Excellence - Advanced**

#### **RISK REDUCTION STRATEGIES IN ROTATING MACHINERY DESIGN AND OPERATION**

Understanding and Measuring Risk  
Chance vs. Consequence Risk Reduction Methods  
Applying Risk Reduction During Design  
Understanding and Measuring Risk

# **Rotating Machinery Health Management and Rotating Equipment Maintenance and Reliability Training Course Content**

## 4-Day Rotating Machinery Excellence Introductory and Advanced Course Content

### **Course Content Continued**

What is a High Potential Incident?  
Similarity between Safety Incidents and Equipment Failures  
Applying Risk Reduction  
Which Risk Reduction Methods are Best?  
Risk Management Process

### **DESIGN AND OPERATING COST TOTALLY OPTIMISED RISK**

Life Cycle Operating Cost  
Failure Cost Impact Calculations  
Design and Operating Costs Totally Optimised Risk (DOCTOR)  
Life Cycle Risk Management Strategy

### **LIFTING LIFETIME RELIABILITY**

Failure Mechanisms  
Equipment Reliability Overview  
Reliability Mathematics  
Measuring Reliability for Components – Weibull Plot  
Calculating the Reliability of Systems  
Reliability of Series Systems (i.e. Machines)  
Reliability of Parallel Systems (i.e. Machines)  
Crow – AMSAA Reliability Growth Plotting  
Reliability Implications for Maintenance  
Failure Mode Effects Analysis (FMEA) Fundamentals  
Failure Mode Effects Analysis  
Reliability Centred Maintenance fundamentals  
The RCM Process and Method  
Choosing of Maintenance Type - Simplified RCM Method  
Activity 1 – FMEA exercise

### **ROOT CAUSE FAILURE ANALYSIS (RCFA)**

Root Cause Failure Analysis Process  
. RCFA fundamentals  
. Finding the Evidence and Proof  
. Applying RCFA in the Workplace  
How RCFA Contributes To Improvement  
RCFA is Fundamentally about Finding the Cause Behind the Cause  
Cause Behind the Cause - Latent Thoughts  
The Real Cause?... Latent Values  
The RCFA Process  
Data Gathering Following an Incident  
Data Analysis to Release Information  
Extra Clues for Causes  
Developing and Implementing Solutions  
Operating and Maintenance Records for Reliability Improvement  
Importance of Keeping Accurate Records and History  
Making RCFA 'Live' in the Workplace  
Cross-functional Teams  
For the Shopfloor – The 5 Whys method  
Operator and Maintainer Buy-in for Improvement  
Activity 2 - RCFA Exercise

# **Rotating Machinery Health Management and Rotating Equipment Maintenance and Reliability Training Course Content**

4-Day Rotating Machinery Excellence Introductory and Advanced Course Content

## **Course Content Continued**

### **MANAGING ASSET INTEGRITY**

Asset Management in a Nutshell  
Rotating Equipment Asset Integrity  
Control of Asset Integrity  
Asset Integrity Means...  
  . Design Integrity  
  . Technical Integrity (mechanical integrity)  
  . Operating Integrity  
Threats to Technical Integrity  
Commonly Reported Areas of Inadequate Process Safety Programs  
Rotating Equipment Start-up Delays  
Technical Integrity Assurance  
Taking Integrity into Operations  
Use Effective Asset Integrity Processes  
Use Structured Review Audits  
Structured Review Audit Objectives  
Measuring and Rating Objectives  
Machine Integrity Inspection Guide Notes  
Example Model for a Plant Tour  
Reciprocating Compressor Example  
No Equipment Management Oversight  
Activity 3 - Plans and Actions to Improve Rotating Machinery Reliability