Key Steps to Implementing Condition-Based Maintenance

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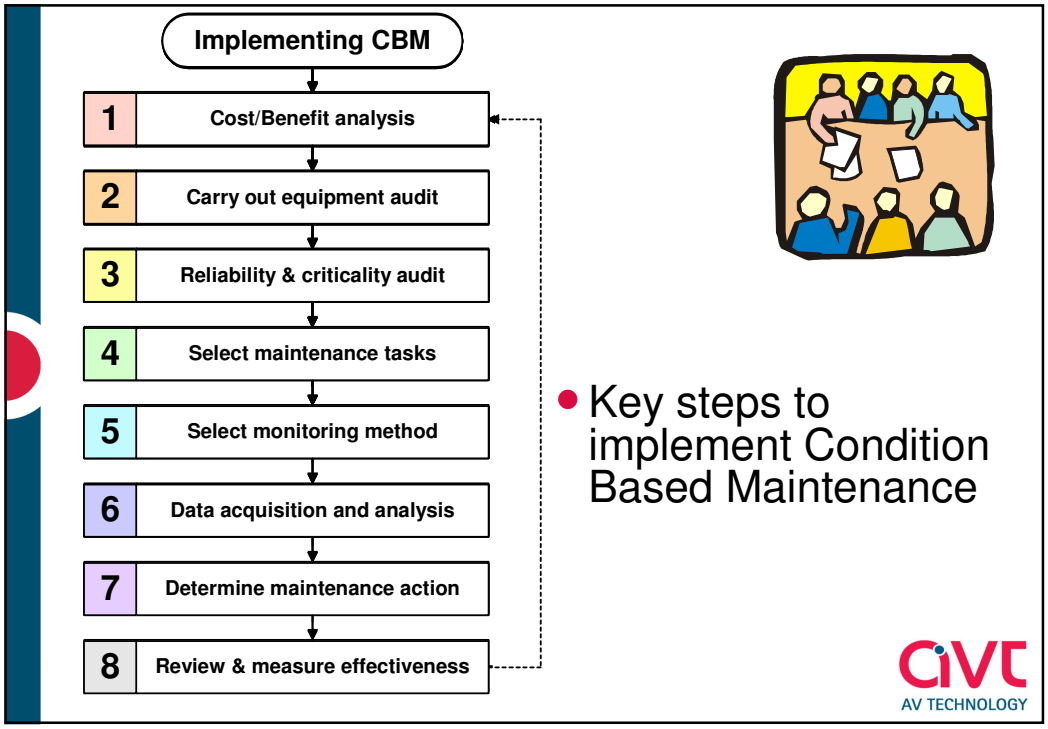
Introduction

- Effective maintenance management depends on applying the appropriate maintenance techniques
- Factors such as fault and failure modes, criticality and cost-effectiveness need to be considered
- Using the wrong maintenance technique can waste time, money and resources, often with no effect on improving or maintaining availability
- This seminar is based on ISO 17359: Condition Monitoring and Diagnostics – General Guidelines



Cost Benefit Analysis

Typical Condition-Based Maintenance Set-up			Phase			
Step		Detail	Set up	Routine	KPI	Optimise
1		**Cost benefit analysis**				
	1.1	Return on investment analysis	y			y
	1.2	Life cycle cost	y			y
	1.3	Cost of failure / secondary damage	y			y
	1.4	What is the available budget	y			y

- This will highlight where Condition Based Maintenance will reduce costs
  - Do we have life cycle cost info?
  - What is cost of failures?
  - What is cost benefit of avoiding failure?

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Carry out equipment audit

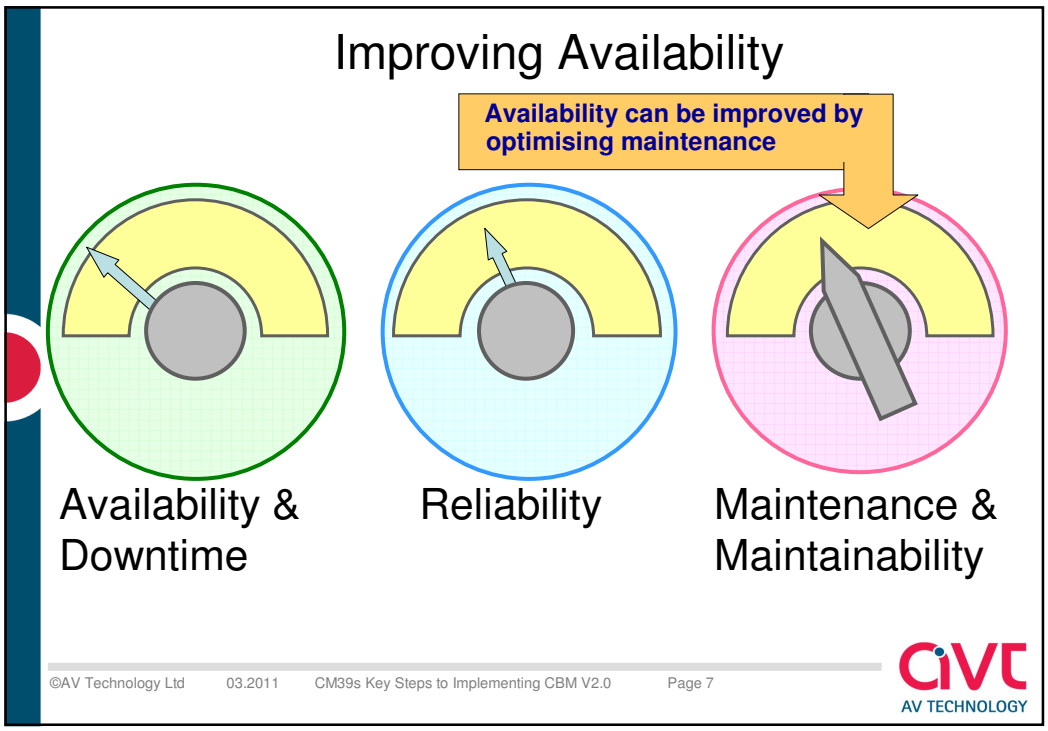
Typical Condition-Based Maintenance Set-up			Phase			
Step		Detail	Set up	Routine	KPI	Optimise
2		**Carry out equipment audit**				
	2.1	Identify assets & sub-assets	y			y
	2.2	Create & test asset codes	y			y
	2.3	Label assets & sub-assets	y	y		y
	2.4	Update database	y	y		y

- Make sure we have accurate databases with assets clearly identified and labelled
  - The importance of this step is often overlooked
  - Without clear identification of assets most activities are compromised

Reliability & criticality audit

Typical Condition-Based Maintenance Set-up			Phase			
Step		Detail	Set up	Routine	KPI	Optimise
3		**Carry out reliability & criticality audit**				
	3.1	Estimated availability & reliability	y			y
	3.2	FMECA, FMEA, FTA, Root cause failure analysis	y			y
	3.3	Maintenance history, pareto analysis, reliability databases	y			y

- Carrying out this means we can target the most important assets and apply the correct maintenance regime
- What Availability & Reliability does the business need?
  - MTTR – Mean Time to Repair
  - MTBF – Mean Time Between Failure
- FMEA – Failure Modes & Effects


Improving Availability
Availability can be improved by optimising maintenance
Availability & Downtime
Reliability
Maintenance & Maintainability
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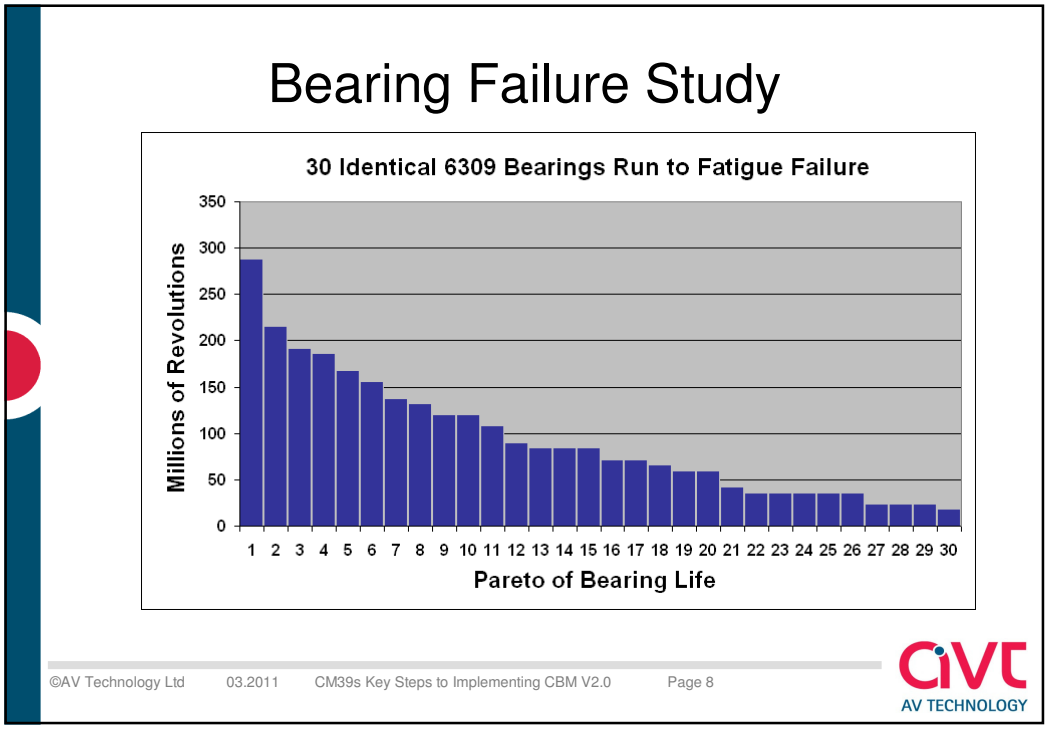
AV TECHNOLOGY


Bearing Failure Study
30 Identical 6309 Bearings Run to Fatigue Failure
Millions of Revolutions
0
50
100
150
200
250
300
350
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Pareto of Bearing Life
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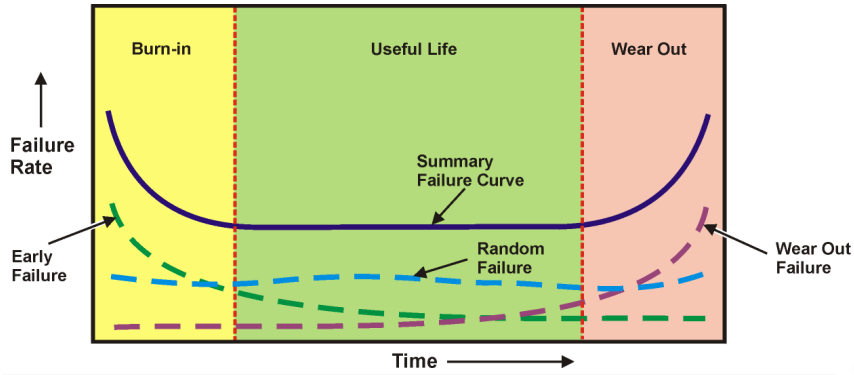
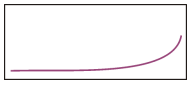
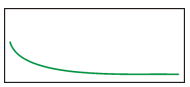
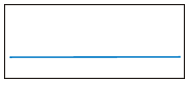
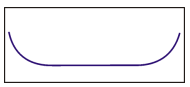
Failure Rates

- In practice the bathtub failure mode curves may be a summary of underlying mixtures of failure profiles



Matching Failure Rate Profiles to Maintenance Strategies

Ref	Type	Failure rates versus time profiles	Criticality	Applicable Strategy				
				Burn In	On-failure	Time-based	CBM	Design Out
1.1	**Wear out** 2% [Nowlan & Heap, 78] 17% [USN, 73]		Low		✓	✓	✓	
			High			✓	✓	✓
1.2	**Infant mortality** 68% [Nowlan & Heap, 78] 29% [USN, 73]		Low	✓	✓		✓	
			High	✓			✓	✓
1.3	**Random** 14% [Nowlan & Heap, 78] 42% [USN, 73]		Low		✓		✓	
			High				✓	✓
1.4	**Bathtub** 4% [Nowlan & Heap, 78] 3% [USN, 73]		Low	✓	✓	✓	✓	
			High	✓		✓	✓	✓

Select Appropriate Maintenance Strategy

Typical Condition-Based Maintenance Set-up				Phase			
Step			Detail	Set up	Routine	KPI	Optimise
4			**Select maintenance strategy**				
	4.1		Condition monitoring task	y			y
	4.2		Inspection task	y			y
	4.3		Preventive maintenance task	y			y
	4.4		Corrective maintenance task	y			y
	4.5		Re-design	y			y

- Selecting the appropriate combination of maintenance tasks depends on the failure history
  - Initially the results from Step 3,
  - Later on from feedback and analysis from Steps 6 – 8

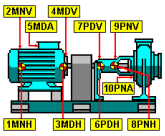
Selecting Maintenance Strategies

Equipment / Component	Failure Mode	Maintenance Strategy			
		On-Failure	Fixed Time	CBM	Design Out
AHU Filter	*Filter blockage*		✓	✓	
Pump Bearing	*Misaligned on installation*			✓	✓
Turbo-generator bearing	*Plain bearing wear due to number of starts*		✓	✓	
Vehicle Engine	*Degradation of oil due to adverse operating conditions*		✓	✓	
Vehicle Wheel	*Tyre tread wear*			✓	
Vehicle Lamp	*Lamp element failure*	✓			

Select monitoring method

Typical Condition-Based Maintenance Set-up			Phase			
Step		Detail	Set up	Routine	KPI	Optimise
5		**Select monitoring method**				
	5.1	Identify parameters to be measured	y	y		y
	5.2	Select measurement technique	y	y		y
	5.3	Select measurement locations	y	y		y
	5.4	Set or review alert/alarm criteria	y	y		y

- We need to identify the best parameters to be measured to detect faults
- Fault and failure characteristics linked to measurable parameters and symptoms allow us to do this (Output from FMEA in step 3)
- We can then select the best measurement technique and then select the appropriate transducers and condition monitoring system



Task 4 – Selecting Techniques – Pump

Ref: ISO 17359

Machine type: Pump	Symptom or Parameter Change									
Fault	Fluid leakage	Length measurement	Power	Pressure or vacuum	Speed	Vibration	Temperature	Coast Down Time	Oil Debris	Oil Leakage
Damaged impeller		✓	✓	✓	✓	✓	✓	✓	✓	
Damaged seals	✓	✓		✓	✓	✓				✓
Eccentric impeller			✓	✓	✓	✓	✓	✓		
Bearing damage		✓	✓		✓	✓	✓	✓	✓	✓
Bearing wear		✓				✓	✓	✓	✓	
Mounting fault						✓				
Unbalance						✓				
Misalignment		✓				✓				
✓	indicates symptom may occur or parameter may change if fault occurs									

Examples of CBM Techniques

	Selected CBM Techniques
1	Human Senses / Inspections
2	Performance Monitoring
3	Thermal Monitoring
4	Vibration Monitoring
5	Ultrasonics
6	Acoustic Monitoring
7	Partial Discharge
8	Current Monitoring
9	Oil Monitoring







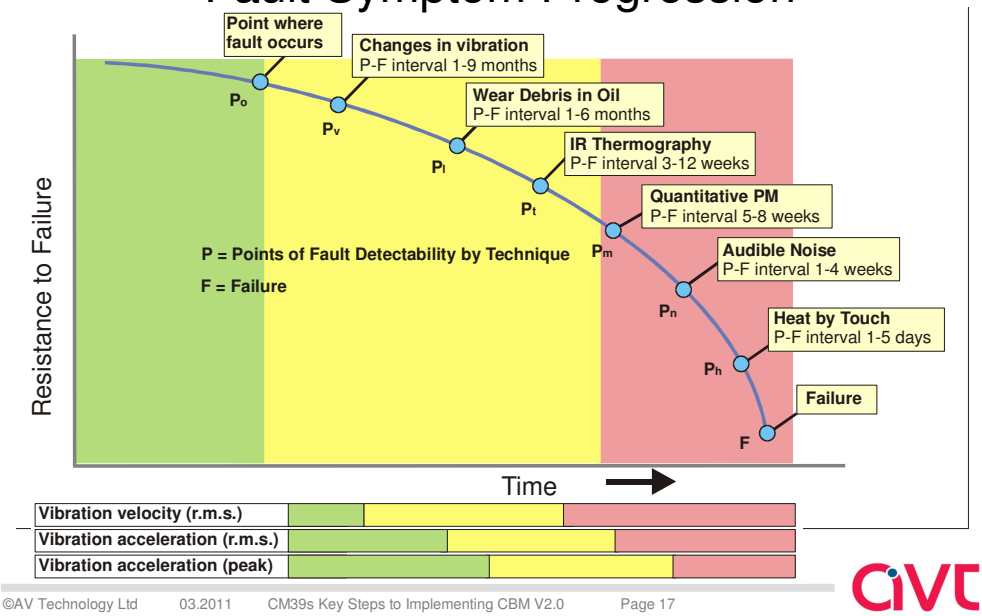


Data acquisition and analysis

Typical Condition-Based Maintenance Set-up			Phase			
Step		Detail	Set up	Routine	KPI	Optimise
6		**Data acquisition and analysis**				
	6.1	Take measurements and trend readings		y		y
	6.2	Compare with alert/alarm criteria		y		y
	6.3	Diagnose, prognosis and assessment		y		y
	6.4	Identify root cause failure mode		y		y

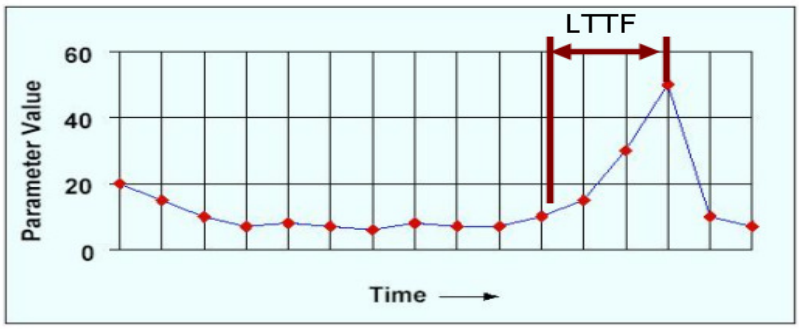
- Quality of Measurements OK?
- Possible errors come from
  - poor readings, transducer faults or adjacent machines.
- If confidence in readings low:
  - take more readings or apply other types of CM
- Review symptoms, rules etc

Fault Symptom Progression



Lead Time to Failure (LTTF)

- Also known as Estimated Time to Failure (ETTF)



Matching monitoring frequencies to LTTF

Factor	Monitoring Frequency					
LTTF	Q	M	2W	W	D	On Line
> 1 year	✓	✓	✓	✓	✓	✓
6m – 1y		✓	✓	✓	✓	✓
2m – 6m			✓	✓	✓	✓
1m – 2m				✓	✓	✓
1w – 1m					✓	✓
any						✓

Key: Q = quarterly, M = monthly, 2W = 2 weekly, W = weekly, D = Daily

Determine maintenance action

Typical Condition-Based Maintenance Set-up				Phase			
Step			Detail	Set up	Routine	KPI	Optimise
7			**Determine maintenance action**				
	7.1		Recommend appropriate maintenance action		y		y
	7.2		Carry out maintenance action		y		y
	7.3		Confirm diagnosis after maintenance actions		y		y
	7.4		Feedback to history records		y		y

- The key output of a CM program is recommended maintenance actions
- Poor feedback allows valuable information to leak away

Condition Based Maintenance Reporting

- Action Report Containing:
  - Asset ID, Date, Current Alarm Status, Fault, Action, Priority
- Missed Measurement Report listing:
  - Asset ID, Date and reason measurements missed
- Typical Action/Advisory Priorities:-

Action	Priority	Description	Comment	Typical Response
1	High	Immediate	Safety Related, Immediate Attention	Immediate – 1 day
2	Medium	Urgent	Urgent Attention Required	Within 1 week
3	Low	Routine	At Next Routine Service	Within 1 month
4	None	None	No Action – Continue Routine Monitoring	No action

Typical Action Report

Asset Code	Description	Reported Status	Fault / Comment	Action	Prty
Area:	**CONVEYORS**				
CONV-1	CONVEYOR 1	W 19/09/07	Chain impacts picked up on far end bearings	**Lubricate bearings**	3
CONV-2	CONVEYOR 2	A 19/09/07	Gear harmonics increasing indicating gearbox wear.	**Inspect gearbox**	2
Area:	**AIR CON**				
AC-EFN1	EXH FAN 1	W 19/09/07	Fan non drive end bearing noisy	**Lubricate fan bearings**	3
AC-EFN3	EXH FAN 3	N 19/09/07	Drive belts broken	**Replace drive belts**	1
AC-SFN2	SUPP FAN 2	W 19/09/07	Noted, alarms adjusted	No action recommended Continue monitoring	4
AC-SFN6	SUPP FAN 6	A 19/09/07	Fan bearings very noisy	**Replace fan bearings**	1
AC-SFN8	SUPP FAN 8	A 19/09/07	Fan unbalance increasing	**Balance iaw ISO 1940 to balance grade G6.3**	2

Measuring Effectiveness

Typical Condition-Based Maintenance Set-up			Phase			
Step		Detail	Set up	Routine	KPI	Optimise
8		**Review & measure effectiveness**				
	8.1	Review alert/alarm criteria			y	y
	8.2	Availability & reliability			y	y
	8.3	Failure rate, MTBF, MTTR, Downtime			y	y
	8.4	Review available CM techniques			y	y

- Managing CBM is a continuous process
- Technology & Techniques change
- Periodic reviewing the process is an important step

Examples of Equipment suitable for Condition Based Maintenance

- Electric Motors
  - AC fixed and variable speed
- Fans
  - Supply, Exhaust, Air Handling Units
- Pumps
  - Vacuum, Water, product
- Compressors
  - Centrifugal, Screw, Scroll, Reciprocating
- Generators
  - Diesel
- Gearboxes
  - Helical, Epicyclic, Worm Drive
- Mixers
  - Screw, orbital, ribbon

Conclusions

- Benefits
  - Applies to all failure profiles
  - Detect faults before failure
  - Work can be planned
  - Production rate can be modified
  - Can avoid secondary damage
- Remember
  - Review the cost benefits
  - Target the failure mode
  - Needs to be reasonable Lead Time to Failure

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