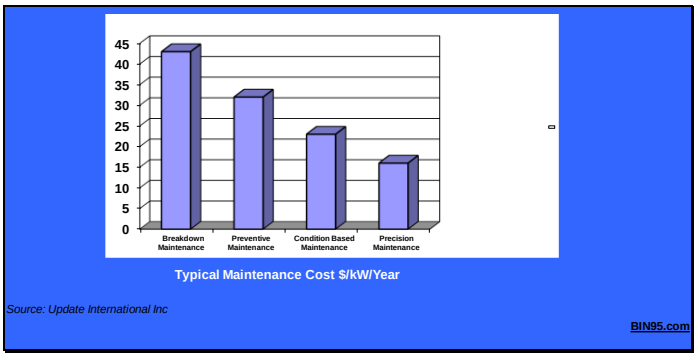
Precision Maintenance Training

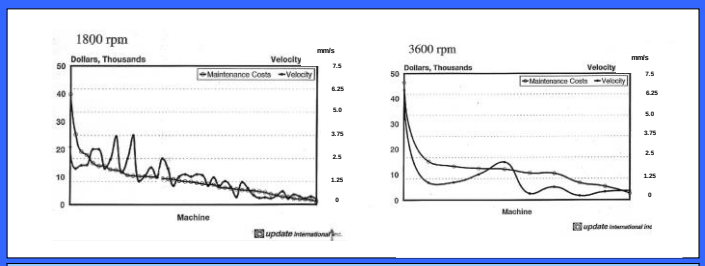
This PDF is the precision maintenance training section of the [rotating machinery reliability course](). For world-class machinery reliability, understanding what is precision maintenance, is critical.

A Powerful Business Case



The graph above shows the relative costs of the maintenance strategies currently available to industry. Precision maintenance cost the least of them all.

Precision is a Serious Opportunity



Machine Vibration to Maintenance Cost

Machine Type	Highest Velocity mm/s	Dollars Spent Last Year	Lowest Velocity mm/s	Dollars Spent Last Year
Single Stage Pumps	5.6	$3,200	2.0	$650
Multi Stage Pumps	4.8	$6,100	1.5	$1,100
Major Fans & Blowers	9.0	$900	2.8	0
Single Stage Turbines	3.8	$8,200	1.0	$2,000
Other Machines	7.8	$11,850	3.0	$3,700

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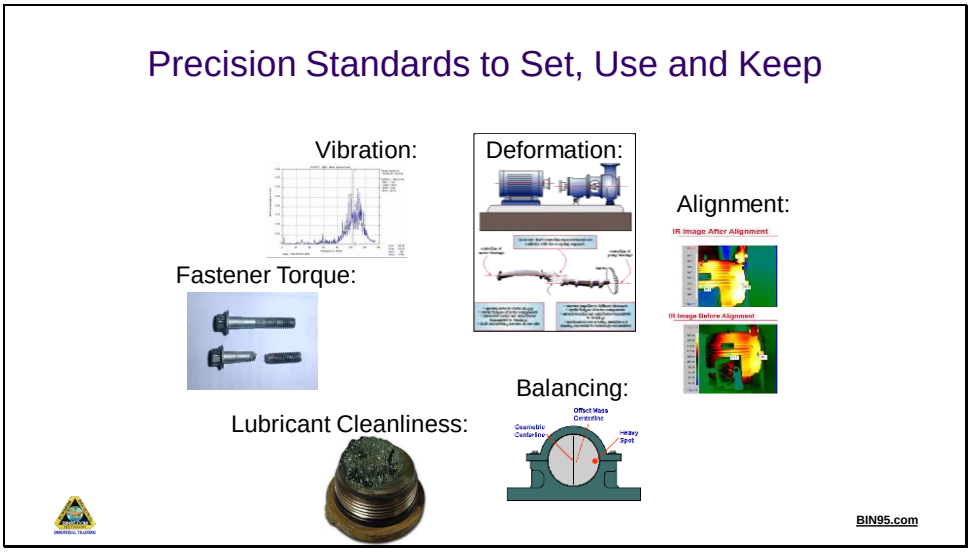
Precision Maintenance means working to high accuracy. The charts show how the cost of maintenance falls as the vibration levels on a machine falls. They show equipment vibration verses their maintenance costs. They tell a remarkable story – when machine vibration levels fall, so do the maintenance costs; dramatically at first, then gradually and continually, as precision skills and use improve. That means that **your machinery is not breaking down.** It is running brilliantly for longer. Your plant availability, throughput and productivity are maximised when precision maintenance and precision operation are used. You have more time to make more product, at less cost, to sell for more profit.

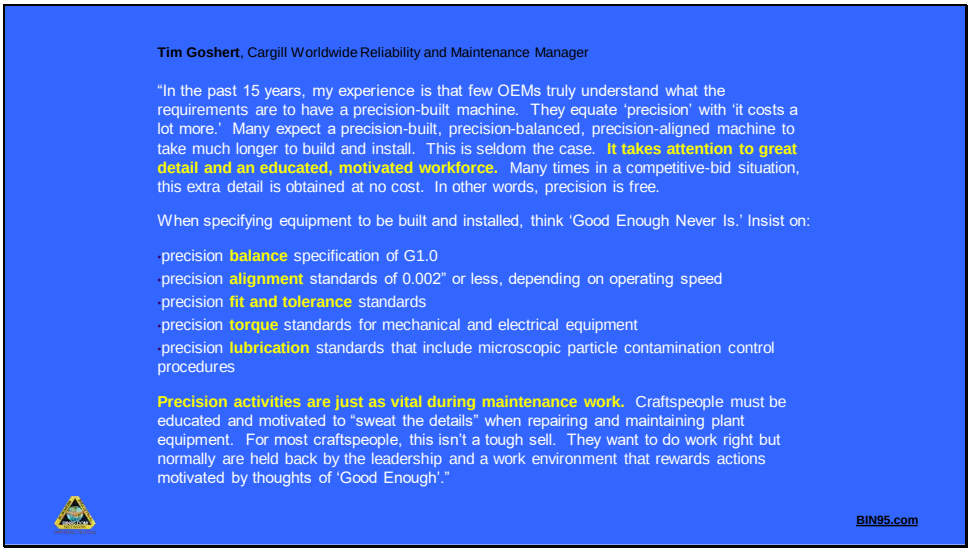
The table shows results of an equipment vibration survey in a large industrial facility. Vibration levels of equipment in the operation were measured and the maintenance costs for the same items of plant were collected. The table shows that maintenance costs for equipment with low vibration levels was about 75-100% of that for machines that ran rough. The message is clear – getting great reliability is possible if you set and work towards high standards. Insist on:

- precision balance specification of G1.0
- precision alignment standards of 0.002” or less, depending on operating speed.
- precision fit and tolerance standards
- precision torque standards for mechanical and electrical equipment
- precision lubrication standards that include microscopic particle contamination control procedures

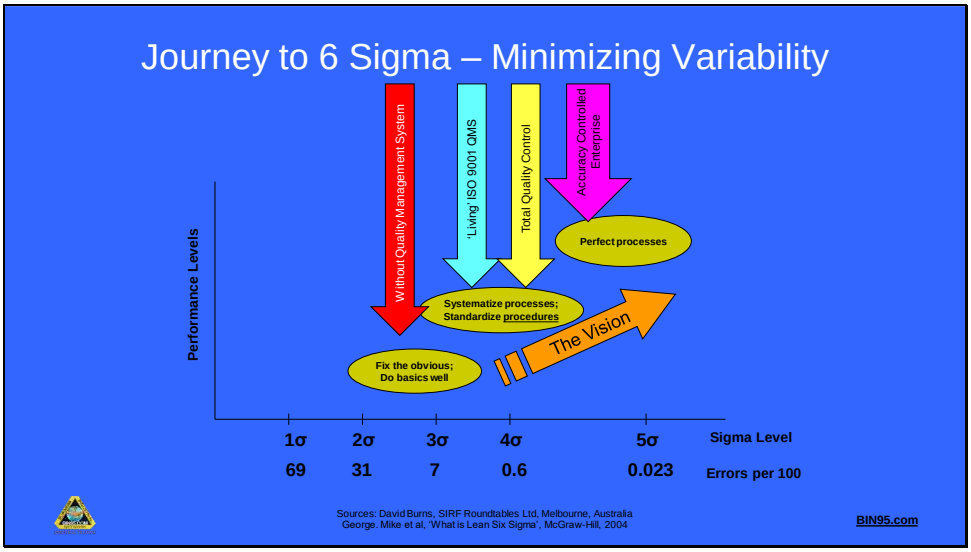


When it comes to mechanical equipment the 6 critical standards listed in the picture above must be set and kept. It is necessary to spend the effort in researching and specifying them for your operation. Once they are determined, communicate them to the engineering and maintenance staff company wide. Start using them in all situations, and for all subcontractors. If necessary, buy or subcontract with providers whatever equipment is required to meet them and train your people in how to achieve the standards in everything they do. If you want top class reliability from mechanical equipment you have no choice but to get very, very good at continually meeting those standards.

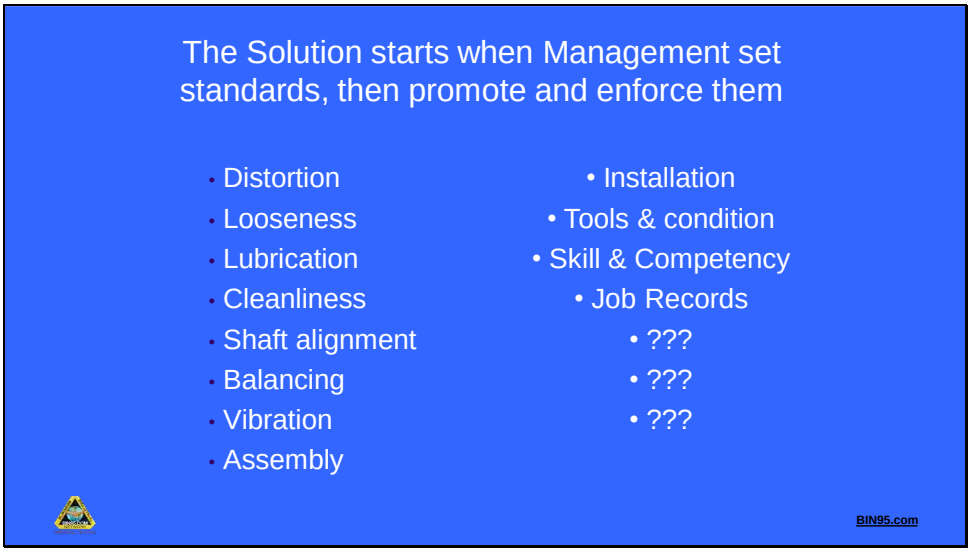
Again, precision maintenance not only saves money, but at the same time enables more production output as the machines considerably increase their run time before failure.



Summary: Remember, 'Good Enough Never Is.' Insist on precision balance, alignment, fit and tolerance, torque, and lubrication. Maintenance workers should 'sweat the details'.



The graph above illustrates the change in processes needed to reach 6 Sigma by minimizing variability. David sums it up nicely, do basic well, standardize procedures and perfect the process.



You need to set the standards first. Then you train to become that good.

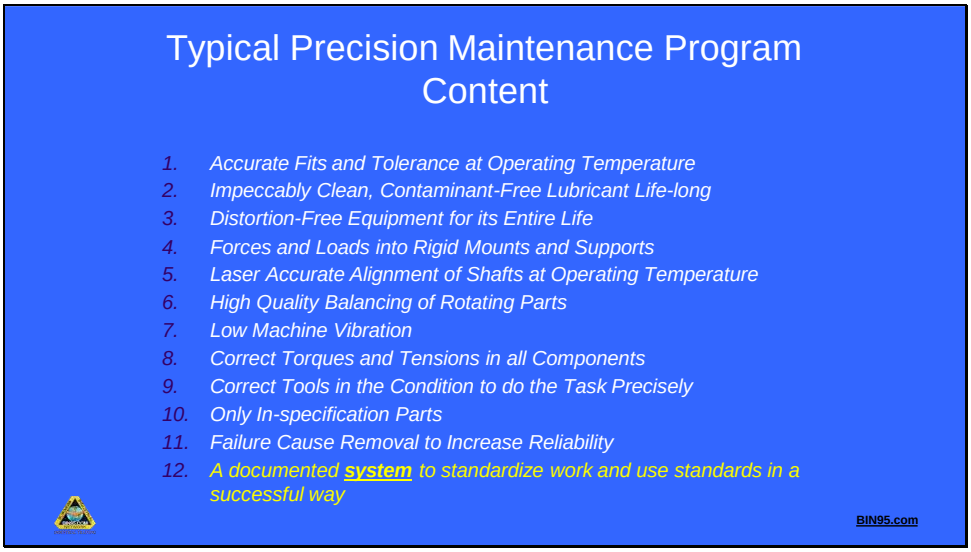
Standards are used to provide clear direction and instruction in how to do a task so that the required outcome results. They are intended to remove uncertainty and variation from performance. If done correctly, to the standard, the result will be suitable for the needs of the situation.

Standards serve a second purpose of setting the benchmark of acceptance. Anything less than the standard is unacceptable. Until the standard is reached development and training continues.

The third purpose of a standard is to provide a baseline against which audits can be compared. Reliability improvement standards are aimed at achieving near-perfection results. With standards set for such issues as those listed on the slide, the aim becomes to always be better. In doing so equipment operates in a near-perfect environment within near-perfect tolerances. This gives plant and equipment maximum chance of operating correctly without failure.

A fourth benefit of working to standards is they can be tightened to set a new level of performance. In this way you can instigate continuous improvement.

You must set the standards for the issues listed in the picture above and then ensure they are known organisation-wide and are applied and practiced by the workforce.



The contents of a Precision Maintenance Program (shown above) require high standards encompassing all the factors impacting the entire operating life of plant and equipment.

Alan has a question...

Bill, what do you mean by a system to deliver precision maintenance?

A system is a documented method to produce a selected outcome. You follow the system and it delivers you the outcome that it is designed to produce. When precision maintenance is put into a system, and the system is used the way that it should be used, you get precision results.

So we can build a system to deliver whatever outcome we want?

Yes! In fact you won't get the outcome you want without a system. If you do get the right result then it was just good luck, not good management. The Japanese learnt the secret from Deming – standardise and then systematise!

I can see where this heading Bill. A lot more documentation and a lot more checking.

And a lot more right answers and lot more good choices that will make our plant and equipment operate at world-class performance.

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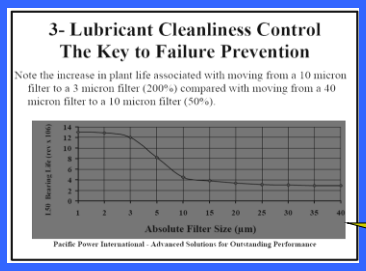
Improve Lubricant Condition



Water % in oil	% Bearing life remaining
0.01	100
0.05	38
0.15	20

Precision Maintenance

ISO 4406 Scale Number	Particles per milliliter More Than	Less Than
22	20000	40000
21	10000	20000
20	5000	10000
19	2500	5000
18	1300	2500
17	640	1300
16	320	640
15	160	320
14	80	160
13	40	80
12	20	40
11	10	20
10	5	10
9	2.5	5
8	1.25	2.5

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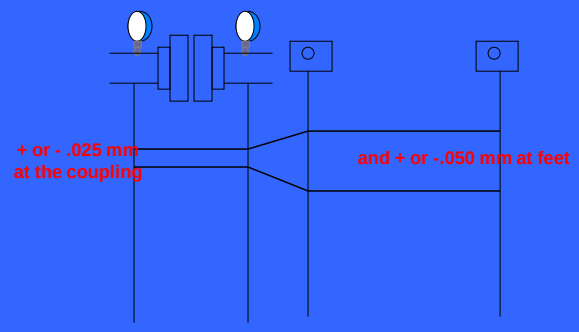
Update International Machinery Improvement Alignment Tolerance Recommendation



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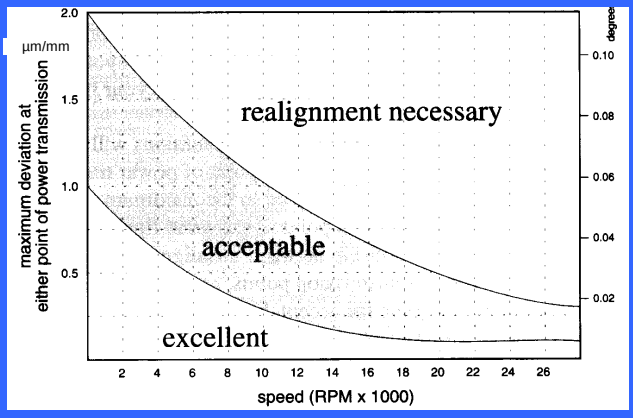
Misalignment Tolerance Guide

By John Piotrowski



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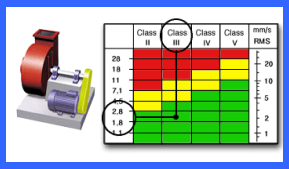
Define Allowable Vibration Severity

ISO 7919 – measuring vibration of rotating elements
ISO 10816 – measuring vibration of non-rotating parts
ISO 13373 – vibration condition monitoring

RANGES OF VIBRATION SEVERITY	QUALITY JUDGEMENTS			
RMS Velocity (mm/s RMS)	I	II	III	IV
0.28	A	A	A	A
0.45				
0.71				
1.12	B			
1.80		B		
2.80	C		B	
4.50		C		B
7.10	D		C	
11.2		D		C
18.0			D	
28				D
45				



Measure 'base line' vibration at start-up for two reasons;
1 Trending future changes
2 Monitoring assembly and installation quality

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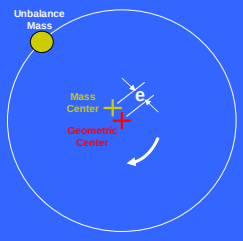
Replace Unbalance with Balance

Unbalance is "the unequal distribution of the weight of a rotor about its rotating Centerline" resulting in the eccentricity 'e'
The balancing standard ISO 1940 gives the recommended eccentricity to achieve optimum machine life



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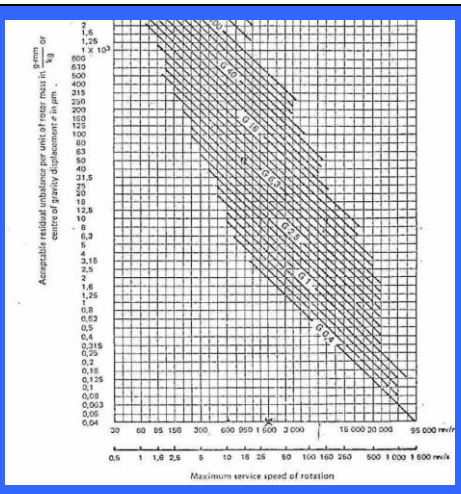

Extract from ISO 1940 showing relationship of rotor eccentricity against service speed to give balance quality.

For optimum results use G1.0

Note; API uses equivalent of G 0.8

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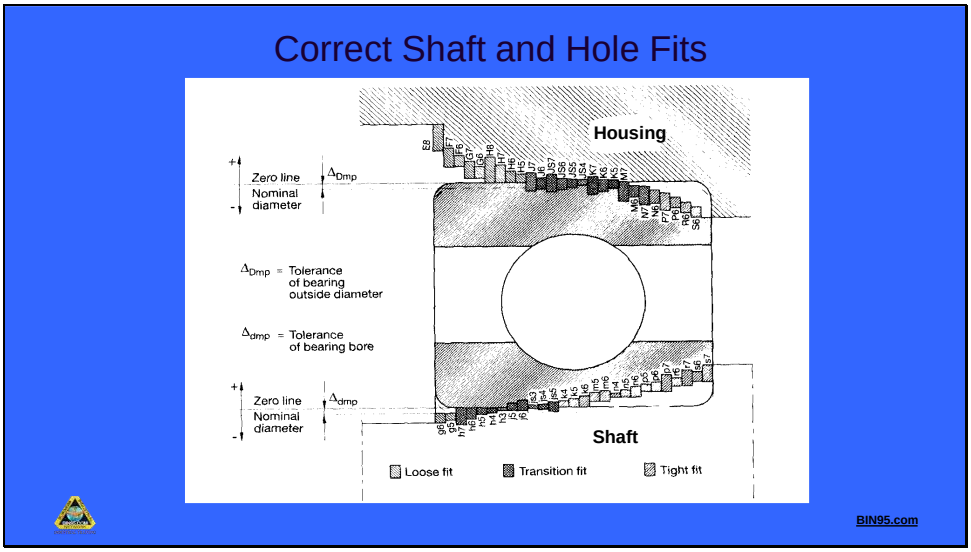
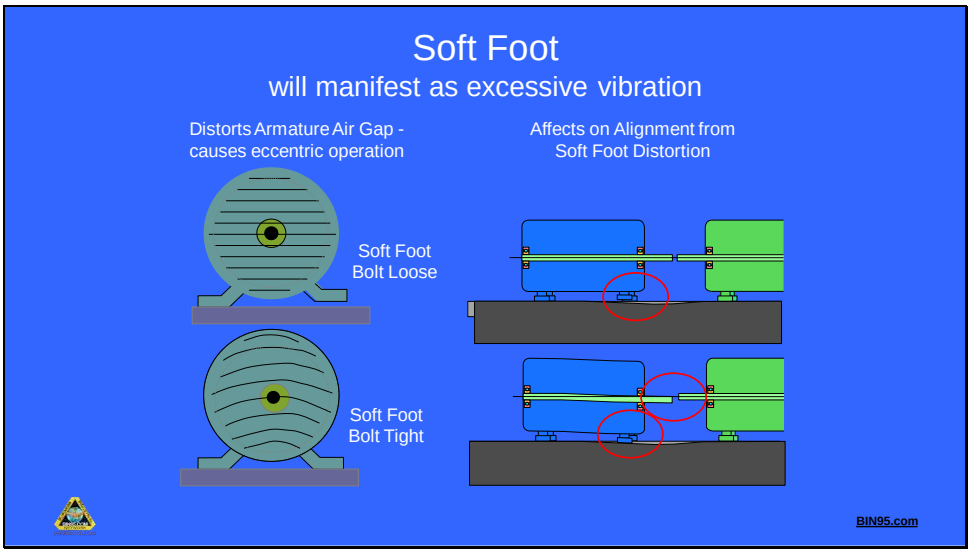
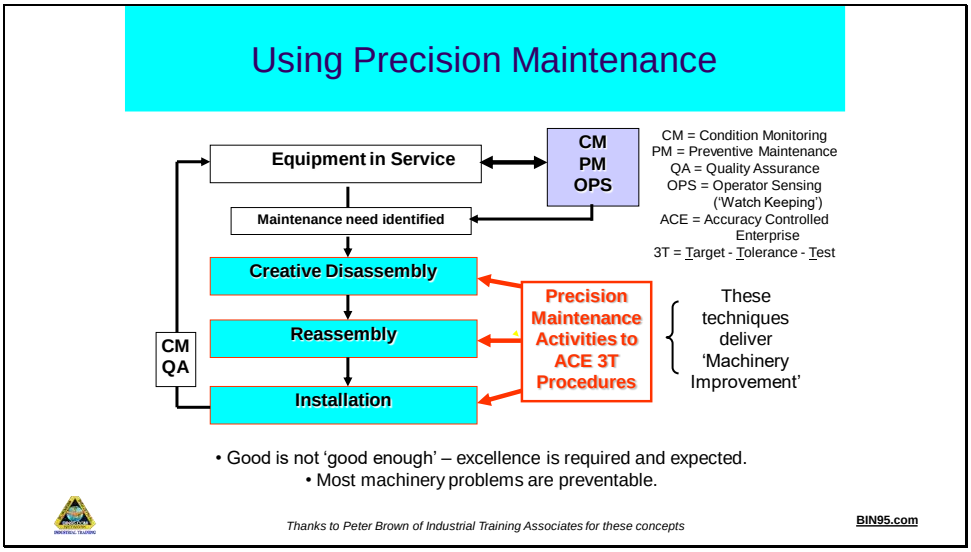
 Sample from the **rotating machinery reliability course**



Our modern industrial society depends on international and readily available standards for measuring, interchangeable part manufacture, and mass production manufacturing. Today, most manufacturing, including that of rolling bearings, is done to the ISO System of Limits and Fits.



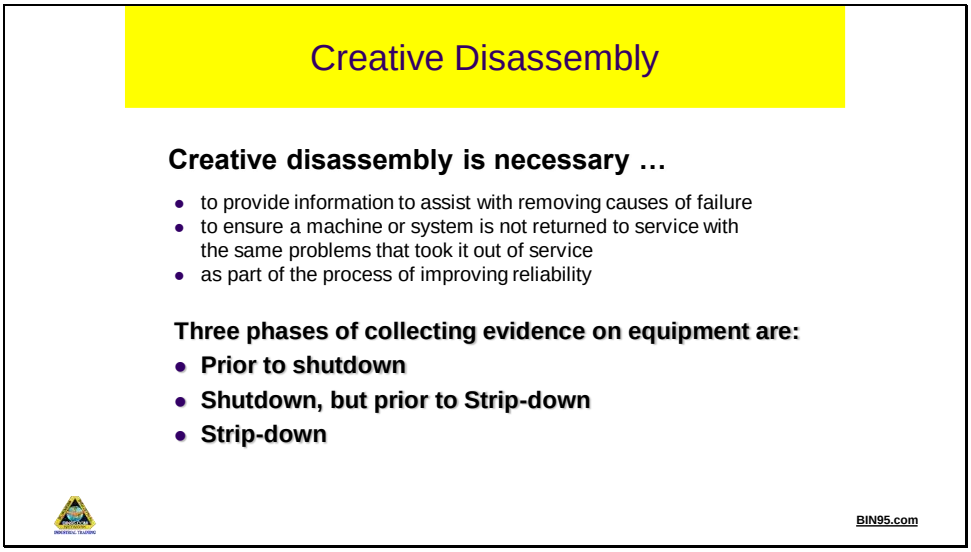


Precision skills come into play –

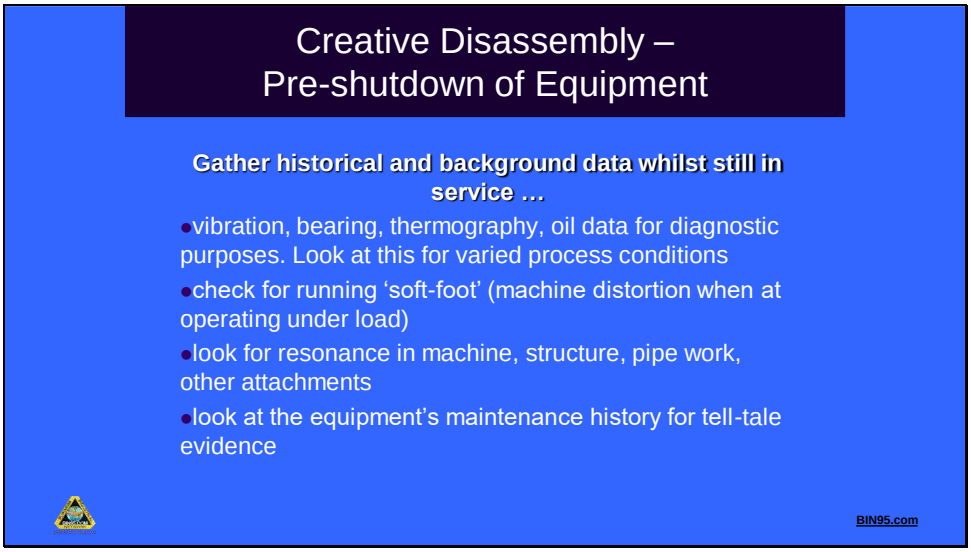
• in the disassembly of equipment for maintenance and corrective work. It is when the information is gathered to identify the root causes of failure and to provide feedback information contributing to redesign to eliminate failure and unnecessary maintenance.
• during reassembly and repair of equipment to ensure quality work takes place; attention to fits and tolerances, fitting of bearings and other components etc.
-during installation to ensure foundations and substructures are sound and highest alignment standards are met.

The process of moving **Toward Improved Plant Reliability** through **Precision Skills** requires a significant change in attitude and thinking at all levels in the maintenance organisation.

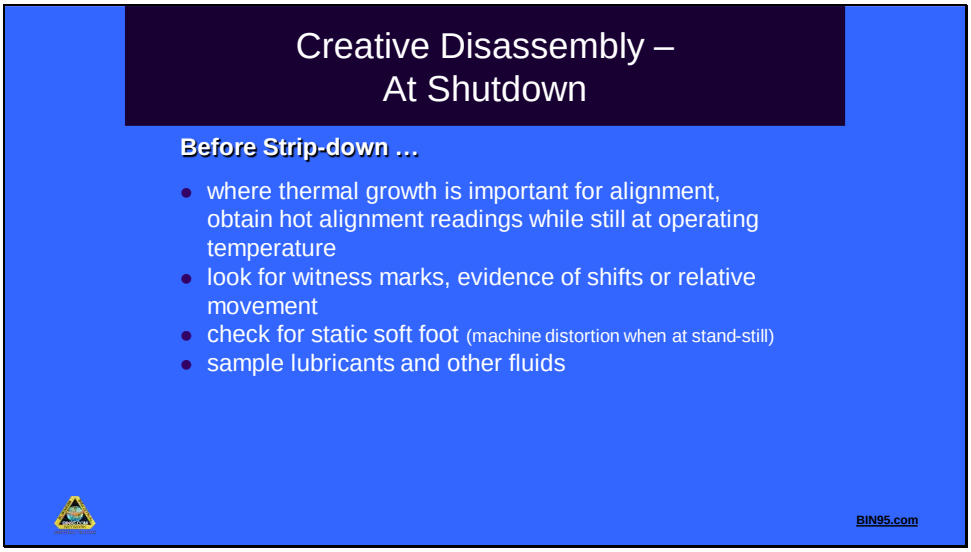
- A Change in Philosophy
- FROM detecting problems and fixing them, which is REACTIVE.
- TO prevent failures from happening in the first place, which is PROACTIVE.
- Good is no longer good enough – excellence is to be expected.
- Most machinery problems are preventable.
- Everyone in the organization has a role.



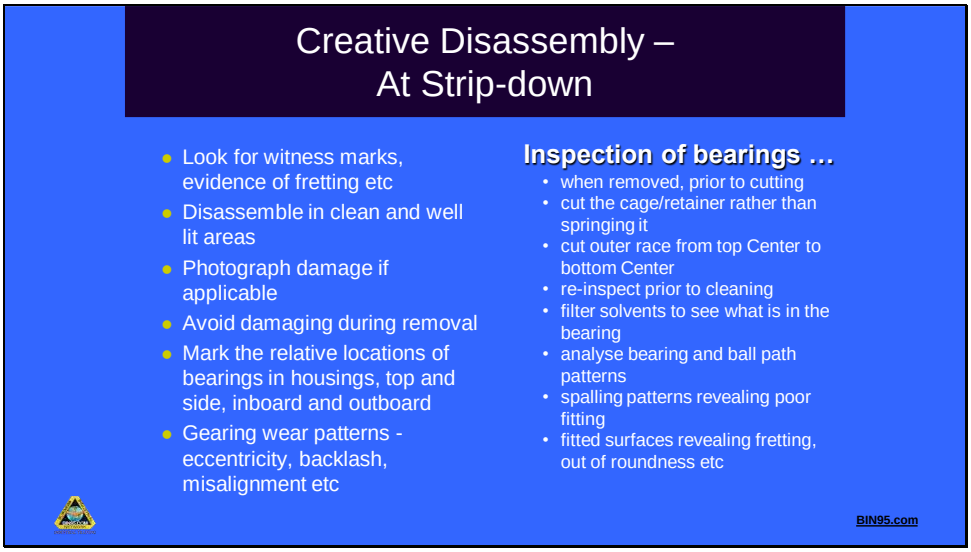
The Precision Maintenance mind set makes it necessary to remove the causes of failure as part of doing a repair. The process to adopt is known as 'Creative Disassembly'. The equipment parts provide the evidence of their demise. From the failure evidence, an analysis is conducted to identify the causes. Once the causes are known they are permanently corrected. Creative Disassembly follows a three-step process in which evidence is carefully collected to be sure the real cause(s) are found.



Improving machinery reliability starts with knowing where its current problems are. That information can be found from the equipment's history and by collecting evidence of its poor performance and condition while it is running.



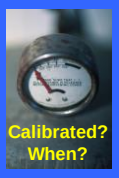
When the equipment is shutdown look for evidence of abnormal operation and condition.



As the machine is stripped down look for evidence in its parts and assemblies for signs of what has been happening to it during use. Every part 'tells' us the story of its life; if we look for it.

Each of these pictures of failed bearings tell the story of what caused its demise. When bearings are removed look at the 'story they tell' before throwing them into the bin. You will very likely be able to find the cause of the failure and fix it while doing the job.

Set Standards for Condition and Use of Tools and Equipment



Calibrated? When?

Rounded Nuts OK?

A Precision Tool?

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Typical Standards for Precision Maintenance Program

1. *Accurate Fits and Tolerance* – ISO/ANSI Shaft/Hole Tolerance Tables
2. *Clean, Contaminant-Free Lubricant* – ISO 4406
3. *Distortion-Free Equipment* – Shaft Alignment Handbook - Piotrowski
4. *Forces and Loads into Supports* - Shaft Alignment Handbook
5. *Accurate Alignment of Shafts* – Shaft Alignment Handbook
6. *High Quality Balancing of Rotating Parts* – ISO 1940
7. *Machine Vibration* – ISO 10816
8. *Correct Torques and Tensions* – ISO/ASME Bolt, Stud and Nut Standards
9. *Correct Tools in Condition* – 'As-New specification'
10. *Only In-specification Parts* – OEM specifications, Machinery Handbook
11. *Failure Cause Removal* – '5 Why' ; RCFA
12. *A **system** to use the standards successfully* – ACE 3T Procedures

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Developing Precision Skills

- In-house precision skills training
(coaching on-the-job; maximum skill and knowledge transfer)

- Third-party training providers *(classroom training needs to be supported with practice bench)*

- Center of Excellence *(The 'Precision Room' is a place to practice doing everything in perfection)*

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3Ts of Failure Prevention

Target ..... Tolerance ..... Test

The Standard The Degree of Accuracy Proof of Precision

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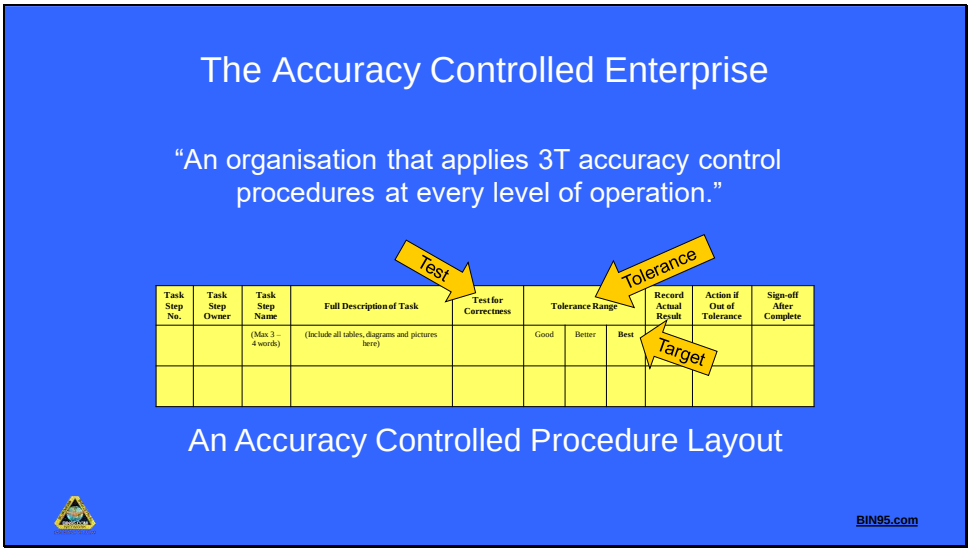
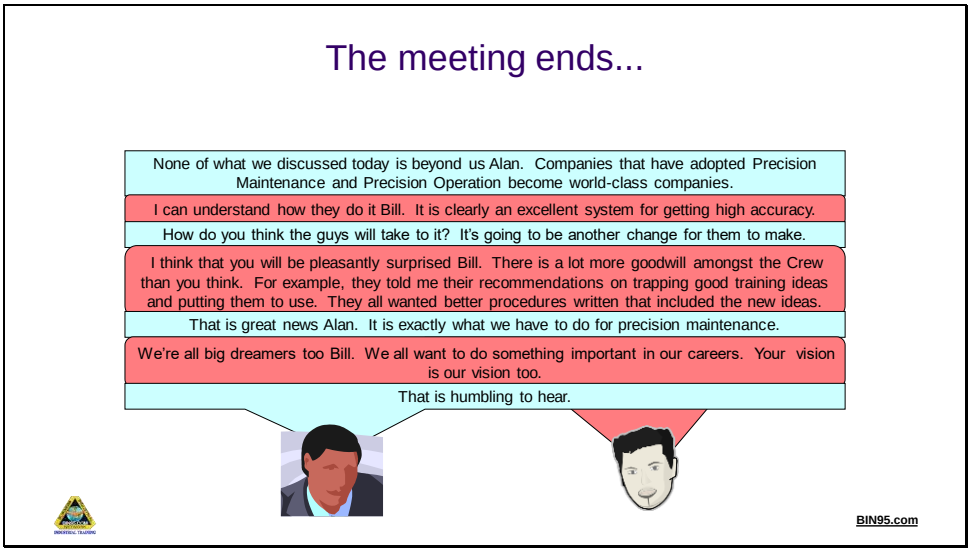


The way we write our procedures needs to change to the layout shown in the slide. This layout makes it clear to users exactly what they must achieve in every task. Each task has a boundary and test to confirm compliance. The only 'rule' is that no new task is started until the previous task is proven to be done right.

With the ACE 3T layout you still use your current procedures' text. The one new requirement is to incorporate the 3Ts to provide the statistical control needed to ensure task accuracy.



We hope you enjoyed this precision maintenance section of the reliability course.

To download the entire **Rotating Machinery Reliability Course** **<< click link**