Chapter 17: Precision Maintenance Skills and Standards

Precision maintenance is the strict adherence to exacting machinery quality standards. It improves machines and equipment condition to a level at which no equipment attributable quality or reliability problems occur. Precision maintenance sustains plant and equipment at the specifications that eliminate the part defects and failures that cause breakdowns and ruin production. Consequently, it saves large amounts of money for the companies that use it.

Using highly reliable equipment with exceptional uptime that delivers unfailingly high production of top-quality product is a sure strategy for operational success. Precision maintenance brings high operating profit for the following reasons:

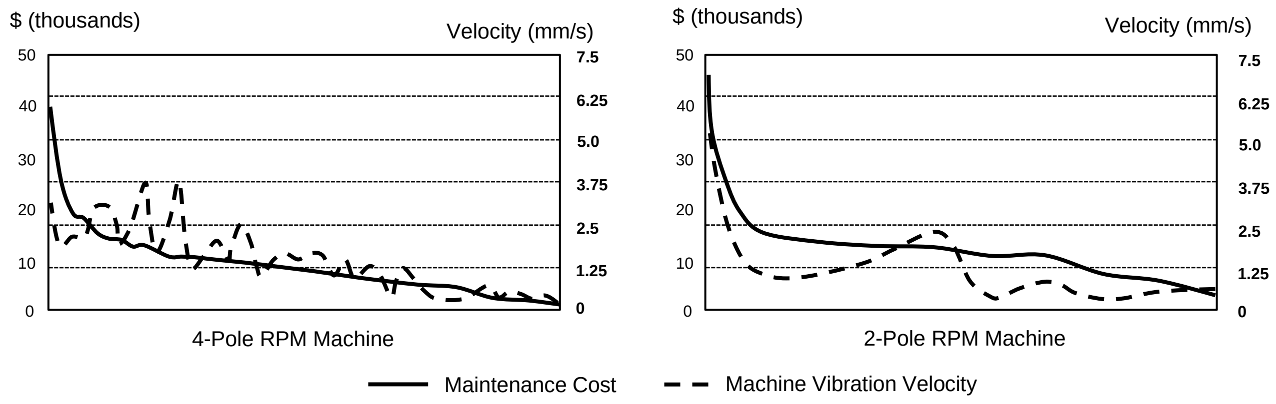
- Machines and equipment are built not to fail
- There is reduced need for maintenance because parts don’t wear out as quickly
- It maximizes quality production and stops scrap because machines work properly
- There are far fewer stoppages and slowdowns
- Fewer spares are used because machines don’t need them
- Plant availability and productivity are maximized with highly reliable machines
- Safety incidents dramatically fall because machines don’t need to be touched
- Environmental incidents dramatically fall because process chemicals don’t leak out

Realizing remarkable machinery reliability through Precision Maintenance has been practiced by progressive, proactive organizations since the mid-1980s, achieving both the most outstanding production performance and maintenance cost reductions of all maintenance strategies.

Financial and Operating Benefits of Precision Maintenance

The two graphs in Figure 17.1 tell a remarkable story: when machine vibration levels fall, so do maintenance costs—dramatically at first, then gradually and continually as the use of precision practices improves.[1] That means machinery does not break down. It runs for longer, and plant availability, throughput, and utilization are at their maximum. Thus, there is more time to make more product, at less cost, to sell for more profit using fewer people.

First a rapid fall in maintenance costs as machine problems are fixed . . .



. . . then costs continually decline as machines are improved

Figure 17.1—Maintenance Costs Fall When Overall Machine Vibration Levels Fall

Table 17.1 shows the results of a vibration survey in a large industrial facility for two- and four-pole electric speed machines. It records bearing vibration levels taken while the equipment is operating, along with the previous year's maintenance costs for the machines. Very low vibration for such equipment is 1 millimeter per second (mm/s) to 1.5 mm/s. If you touched the machine with your fingertips, its motion would feel like a tingling sensation. At 8 mm/s, a machine is running very rough. If you touched it, you would feel the machine shaking. At higher vibration levels, the machine would shake itself apart. The costs for equipment with low vibration are 70%

to 80% less than machines running rough. Compared with any other maintenance strategy, you will always reap the largest financial benefits when you apply precision maintenance on your machines.

Machine Type	Highest Velocity (mm/s)	Dollars Spent Last Year	Lowest Velocity (mm/s)	Dollars Spent Last Year	Savings with Precision
Single-Stage Pumps	5.6	$3,250	2.0	$650	80%
Multistage Pumps	4.8	$6,100	1.5	$1,100	82%
Major Fans and Blowers	9.0	$900	2.8	$0	100%
Single-Stage Turbines	3.8	$8,250	1.0	$2,000	76%
Other Machines	7.8	$11,850	3.0	$3,700	69%

Table 17.1—Maintenance Costs versus Machine Vibration

It is no mystery why precision maintenance lets you make more, ship more, sell more, and profit more while doing it all at less cost: it improves the operating conditions of parts within machinery and reduces their microstructure distress levels. When equipment is built to fine standards that prevent distortion and provide healthy internal conditions, it runs smoother, and its parts suffer substantially less stress, fatigue, and degradation. Your maintenance people make your machines run better. This is how maintenance contributes to operating profit—by making machines run precisely so that failures don't happen, and repairs aren't needed.

The Importance of Precision Standards for Machine Reliability

Exceptional equipment reliability requires a very narrow zone of high precision quality. This level of quality puts machine parts into the "precision quality zone," where you get a massive improvement in the machine's reliability. The difference can be 5 to 10 times fewer failures over the same period, with commensurate savings in operating and maintenance costs.

Example 17.1: No One Knew How Badly the Lubricant Was Contaminated

A case study from a mineral processing refinery illustrates why quality standards are vital for machinery reliability. The refinery's worst "bad actor" machine had been a production headache for 40 years. It was critical piece of hydraulically driven equipment that stopped production every time it failed. It was so important to the business that the company paid a specialist subcontractor to be on-call to maintain the asset. Regular hydraulic oil samples were sent to the laboratory for chemical analysis. Eventually, the poor reliability of the equipment could no longer be tolerated, and the company began an investigation to improve its uptime.

The laboratory oil condition report showed an ISO 4406 wear particle count of 23/22/19 (see Chapter 3, Table 3.4 for the range of solid particles in each value). This amount of solids contamination in hydraulic oil is so bad it is unbelievable it could get to that point. The oil was as black as pitch. If you rubbed a drop of it between your fingers, you would feel the wear particles grinding across your skin. It is no surprise that the asset had been unreliable for 40 years with oil so badly polluted. One must wonder how such a disastrous situation was tolerated for so long.

The investigation turned to the engineering procedures, which showed that no quality standard had ever been set for oil contamination. No one in the operation, nor the specialist contractor, knew that a 23/22/19 wear particle count was such a high contamination of solids that it ensured breakdowns on a regular basis. Next, the manufacturer's maintenance manual was consulted, and it, too, specified no upper limit for solids contamination in the hydraulic oil. There was one way to find out where the manufacturer might have specified an allowable ISO 4406 count. The make and model of the hydraulic pump subassembly was tracked down, and the pump manufacturer's maintenance manual was located on the Internet. The manual specified a maximum solids contamination of 18/16/13. The hydraulic oil in the circuit was contaminated more than 30 times the amount allowed by the pump maker. Forty years of equipment failures had occurred because there was no engineering standard set for maximum solids contamination. Without a standard to test against, the laboratory analysis meant nothing to the people who were reading the report. As soon as the manufacturer's oil contamination limits were known, the cause of those never-ending breakdowns was obvious.

Example 17.2: Shaft Quality Control Gets Rolling Bearing Reliability

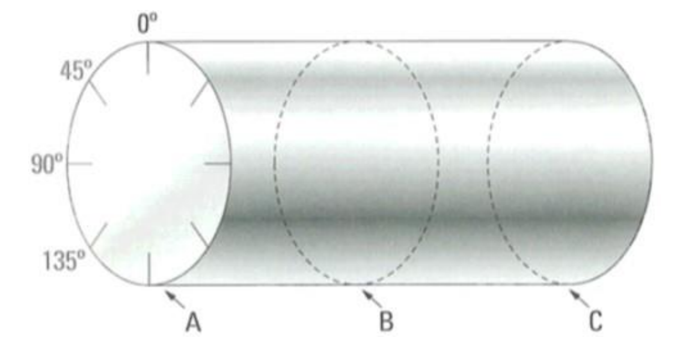
After years of suffering monthly spherical roller bearing failures on a head pulley at a steel mill, the maintenance manager brought in the bearing manufacturer to investigate why the bearing on a 150 mm diameter shaft never lasted for more than four weeks in service. The production downtime had become unacceptable, and an investigation was started to address the problem. Wisely, the bearing manufacturer was asked to be involved with the root cause analysis.

Spherical roller bearings of the design used come with a tapered support sleeve that sits on the shaft journal and carries the inner ring of the bearing. The pulley drove a critical mill conveyor that stopped the operation when it failed. To prevent failure during production, the conveyor was handed over to the maintenance crew every three weeks to replace the bearing. This went on for years. Roller bearing service life is measured in thousands of hours of failure-free operation, so when a roller bearing gets only weeks of service life, something is happening to the bearing to make it fail. First, the manufacturer asked the maintenance group for the tolerance and form values of the shaft under the bearing. The measurements were not known, and it was agreed they would be recorded at the next bearing replacement.

Tolerance affects the tightness of fit between a bearing and its shaft and a bearing and its housing. A loose fit permits oscillation and vibration, while an overly tight fit squeezes the bearing's parts together and stresses the contacting surfaces. To ensure the right fit is made for roller bearings, manufacturers publish the allowed fit and tolerance for the housing and shaft that each bearing model requires to get a full-service life.

The form indicates the shape of the shaft in the region under the bearing. The shaft must be sufficiently cylindrical, sufficiently round, and sufficiently straight so that the bearing inner ring is supported at enough contact points with the shaft to keep its structural integrity and shape during rotation under maximum load-carrying service.

Both the correct tolerance and form must be present for a bearing to reach its designed operating lifetime. When the bearing was next changed, the journal dimensions were taken with a micrometer and checked against the manufacturer's requirements. Table 17.2 lists the shaft tolerances and form shape that must be met for full bearing service life. The 150 mm shaft diameter needs to be h9 tolerance—a permitted maximum size of exactly 150.0 mm and a minimum size of 149.9 mm—and IT5 form—from Plane A to Plane C the straightness, roundness and cylindricity are all within an 18-micron annulus—under the bearing. The shaft diameter values measured at Planes A, B, and C are recorded in Table 17.3.



Shaft Diameter (mm)		**Tolerance h9 (µm)**		**Form IT5 (µm)**	**Form IT7 (µm)**
Over	Incl	High	Low	Max	Max
22	30	0	-52	9	21
30	50	0	-62	11	25
50	80	0	-74	13	30
80	120	0	-87	15	35
120	220	0	-100	18	40
220	250	0	-115	20	46
250	315	0	-130	23	62

Table 17.2—Spherical Bearing Manufacturer Shaft Dimensions

	0º	45º	90º	135º	Required Tolerance h9
Plane A	149.98	149.99	149.98	149.99	> 149.900 < 150.000
Plane B	149.97	149.94	149.98	149.95	
Plane C	149.98	149.98	149.95	149.99	

Table 17.3—Measured Shaft Dimensions

Tolerance Evaluation

All journal dimensions were inside the required h9 tolerance. But there was still the mandatory IT5 form shape to be proven. In Tables 17.4 and 17.5, the problem with the shaft's shape is identified.

Cylindricity Evaluation

The maximum amount that the shaft is allowed to deviate from a perfect cylinder is no more than 18 microns (μm) on the diameter at any point in the region under the bearing. Table 17.4 shows that the difference between the maximum and minimum measurements along the 0-degree line on top of the shaft at Planes A, B, and C were within 10 μm—well inside the maximum 18 μm tolerance. But that was not the case for the corresponding three points along the 45-, 90-, and 135-degree lines. Along those positions, the form is well outside of tolerance, and the shaft is not cylindrical. The measurements prove that the shaft beneath the bearing was undulating in many places and could not fully support the inner ring. There were gaps between the shaft surface and the sleeve supporting the inner ring that allow the ring to move up and down as load-carrying rolling elements move over the cavities. The flexing of the inner ring rapidly fatigues the metal, and the bearing failed as a result.

	0º	45º	90º	135º	Plane Average	Required IT Grade 5	IT Grade 7
Plane A	149.98	149.99	149.98	149.99			
Plane B	149.97	149.94	149.98	149.95		< 0.018	0.040
Plane C	149.98	149.98	149.95	149.99			
Max-Min	**0.01**	**0.05**	**0.03**	**0.04**			

Table 17.4—Shaft Cylindricity

Roundness Evaluation

The form requirement for shaft roundness can also be identified from the measured values. Table 17.5 indicates that the shaft at Plane A was out-of-round by 10 μm, at Plane B by 40 μm, and at Plane C also by 40 μm. Planes B and C were out-of-round by more than twice the manufacturer's worst allowance.

	0º	45º	90º	135º	Plane Max-Min	Required IT Grade 5	IT Grade 7
Plane A	149.98	149.99	149.98	149.99	**0.01**		
Plane B	149.97	149.94	149.98	149.95	**0.04**	< 0.018	0.040
Plane C	149.98	149.98	149.95	149.99	**0.04**		

Table 17.5—Shaft Roundness

The shaft passed on tolerance but failed on form shape—it was not cylindrical enough, it was not round enough, and it tapered toward the center. The roller bearing could not reach full-service life because the journal was badly misshapen. The shaft under the bearing mounting sleeve did not support the bearing sufficiently to prevent flexing from the load of the rollers. Figure 17.2 exaggerates the problem to help explain what was wrong with the shaft.

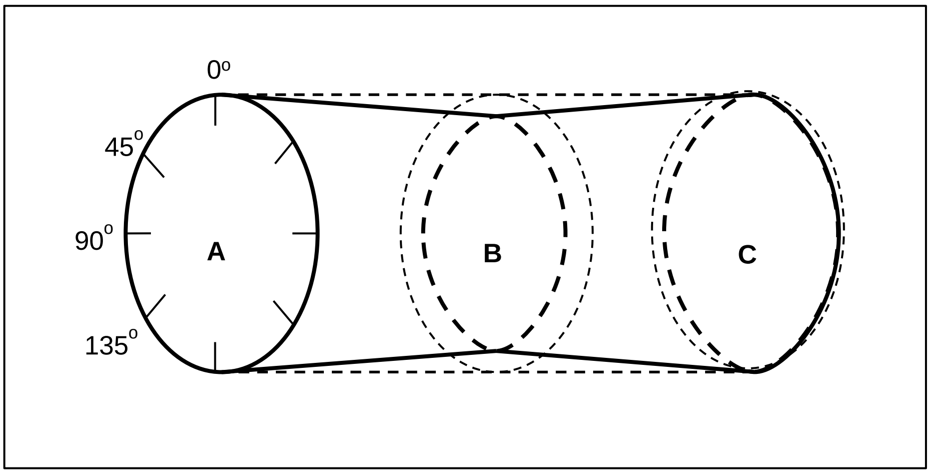


Figure 17.2—Roller Bearing Reliability Compromised by the Shaft Condition

The shaft condition became evident once the right quality assurance checks were done. The bearing manufacturer's standards for shaft form were not being met, but no one in the steel mill knew that because it was not a required maintenance inspection. The form shape checks immediately found the problem, and its solution was clear: replace the defective shaft with a new one machined to within the required tolerance and form.

The tolerance and form values for roller bearings have been published for generations. The information that would have exposed the defective shaft has always been available, but it was not a part of the repair procedure, and the shaft was never checked for its actual shape. Had the shaft tolerance and form check been included as a quality characteristic inspection every time the bearing was replaced, the maintainers would have spotted the problem and replaced the shaft many years earlier, and each time the journal wear became excessive.

Your machinery parts must always be in a least stress, contaminant-free environment, or else high reliability is impossible to achieve. It is necessary to know all the vital factors that affect a machinery part's reliability and the exact values for the quality standards needed to put a part into its precision zone. Setting those values is the foundation of enterprise asset management success because with those values, you have a target at which to aim your asset management system and its life-cycle processes. They are published in your ACE 3T engineering, operating, and maintenance procedures, and your people use them to prove that equipment health and operating conditions meet the level of quality that produces the intended reliability. If a required standard is not met, you and your people immediately know there is a defect and can act to solve its causes.

The ISO vibration limits for machinery is given in ISO 10816 and its subparts. Each subpart of the standard is specific to a particular type of machine and a range of service duties. ISO 10816-3 relates to general industrial machinery, such as gearboxes, electric motors, and bearing housing. It provides warning and alarm vibration velocity values for working equipment. Table 17.6 is compiled from ISO 10816-3.

ISO 10816-3	**Medium-Sized Machines**		**Large Machines**	
Machine Type	Group 2		Group 1	
	15 kW–300 kW		300 kW–50 MW	
	Motor Shaft Centre 160 mm–315 mm		Motor Shaft Centre Above 315 mm	
Foundation	Rigid	Flexible	Rigid	Flexible
Velocity mm/s rms		**Machine Damaged**		
11.0				
7.1				
4.5		**Restricted Operation**		
3.5				
2.8		**Unrestricted Operation**		
2.3				
1.4				
0.7		**New Machine**		
0.0				

Table 17.6—ISO 10816-3 General Machinery Vibration Levels

Most companies take the vibration level values literally and base maintenance interventions on the vibration range that damages equipment. They set warning limits at the restricted operation value and action limits at the pre-failure level. As a result, they guarantee they will have occasional breakdowns and that their mechanical plant and equipment regularly undergo randomly scheduled maintenance and suffer higher maintenance costs. Because the maintenance philosophy is to wait until the machine condition is poor and needs to be rectified, these companies incur greater equipment damage, with shorter time between failures and higher production costs. In a Plant Wellness Way site, you adopt the wise adage, "a stich in time saves nine" and use a proactive approach so that vibration levels never get beyond new machine condition values.

In order to get machine vibration values below 1.5 mm/s, it is necessary to first guarantee that you have only miniscule misalignment between equipment components and assemblies; that there is barely detectable imbalance; that there is no body or frame distortion when mounting the equipment; that frame and body expansion or contraction do not distort internal components; that all parts have precision flatness, precision straightness, precision roundness, precision squareness, precision form, and are precisely located; that the equipment is fixed on substantial, strong mountings to which it is correctly and accurately fastened; that shaft revolutions per minute are not at resonating speeds; that bearings are selected to carry the correct load so rolling elements roll properly and do not skate over the lubricant; that journals are sized and in tolerance to get the correct bearing clearance at operating duty without looseness or causing oil whirl; that housings are rightly sized and in tolerance; and the lubricant is impeccably clean and its chemical composition remains at specification. Once you have all that right, there are no vibration problems. It's a daunting list of precision requirements that must be achieved. Starting from the design phase of the life cycle and extending into the operating phase it is necessary to control dozens of failure mechanisms. But until you control the outcomes of all the issues listed above, there will regularly be machinery vibration problems and no certainty of reliability.

In the Plant Wellness Way, because the causes of machine vibration are removed or prevented, you do not need to monitor vibration levels, and the predictive maintenance program would only consist of lubricant analysis where it was financially justifiable. Instead, you monitor the variables that cause the established quality conditions to change. You observe the operation of the machine and process conditions for circumstances that will produce vibration if not corrected—such as the causes of material build-up on rotating equipment that would unbalance the rotor, process conditions that attack or corrode microstructures, severe speed and momentum changes, abnormal temperatures causing expansion and contraction of components and the subsequent misalignment of shafts and other internal parts, pressure "hammer" in pipework, along with monitoring all other applicable Physics of Failure cause mechanisms—then immediately correct the situation back to the stable design envelope quality range. The Plant Wellness Way gives you incredibly low maintenance costs and outstandingly high uptime because your machinery is always kept in precise, good-as new condition. The combined maintenance and operating strategies create and sustain the precision quality needed to produce plant and equipment parts health and wellness for the whole service life of the machine.

In 2002, I visited a Sumitomo Chemical process plant in Japan on behalf of my employer. The host took me on a tour of the operation, and as we passed a pumping station, I could hear the rumbling sound of centrifugal pump cavitation. The process used hot caustic soda solution at elevated temperatures near the chemical's boiling point. The chance of pump cavitation is high at such temperatures, and it takes only a small blockage in the suction pipe to lower the pressure enough to make the pump cavitate.

At the conclusion of the hour-long tour, we went past the pumping station again. A maintenance technician was packing up his tools after swapping out the cavitating pump with a replacement. Curious to learn about the predictive maintenance employed on site, I asked my host, "What type of condition monitoring technology is used on the pump?" His answer surprised me.

Apart from the operator using his physical senses to observe pump performance, the pump was never condition monitored. The plant employed precision maintenance for all rebuilds, and its machines were installed in perfect condition. When the pump cavitated, it was caused by the process, not by poor maintenance work quality or component degradation. Putting the pump into a condition monitoring program was pointless because it would never prevent the cavitation. There was nothing more to be gained by instigating a condition monitoring program for the pump. His explanation was technically sound and financially sensible. It also made clear to me how precision maintenance brings worth and profit to an industrial operation that uses it.

Precision Maintenance Program

The following list includes the important requirements for a successful precision maintenance program:

1. Accurate fit and tolerance at operating temperature
2. Impeccably clean, contaminant-free, chemically correct lubricant lifelong
3. Distortion-free equipment for the entire lifetime
4. Shafts, couplings, and bearings running true to center
5. Forces and loads into rigid mounts and supports
6. Exact alignment of shafts at operating temperature
7. High-quality balancing of rotating parts
8. Low total machine vibration
9. Correct tension in all fasteners
10. Correct tools and test equipment in the condition to do the task precisely

11. Only in-specification parts installed
12. Application of precision skills and techniques
13. Creative disassembly to find and remove defects and failure causes
14. Proof tests that precision is being achieved
15. Business processes to consistently apply these requirements successfully

There is nothing in this list that should not already be standard practice in every industrial operation. But that hardly ever happens. The exacting standards required to deliver excellent equipment health that produces failure-free operation are not specified in many company quality systems. They are not taught to managers and engineers or to operators and maintainers. Worst of all, they are not seen as important to those supervising work quality, and they are of no interest to those people running industrial companies, despite the fortunes in operating profits that are made with the achievement of precision quality targets. Without precise standards everyone works to their own degree of accuracy, which, as a result of misunderstanding and confusion, introduces wide variation in work performance that causes inaccuracy and creates errors. Thus, defects are generated all the time, eventually triggering operating problems and equipment failures. The cause-and-effect sequence is as predictable as night following day. But it does not need to be that way.

Creative Disassembly and Defect Removal

For the thousands of defects existing within plant and equipment waiting to become failures, your maintenance and operations people use creative disassembly to fix them.[2]

Creative disassembly requires the identification of flaws in machinery and their immediate correction. It operates at the equipment part level and strikes at the heart of the thousands of defects making up the base of the equipment failure pyramid (see Chapter 12). By reducing the number of defects in machinery, fewer opportunities present themselves for catastrophic failure. The plant operator and maintenance technician become the root cause analysts for their operating plant and equipment. Instead of operators only running the plant and maintainers only replacing parts and doing maintenance, they team up and become responsible for finding the cause of a failure and correcting its root cause. They are given the authority to follow through and do all of the necessary work, including scheduling production outages to do the precision maintenance needed to prevent repetition of a problem.

There are three phases to creative disassembly analysis: before shutdown, before strip-down, and during strip-down. As the work is done, comparisons are made against specified ACE 3T precision standards. When defects are detected, they are removed or corrected during rebuild, and the equipment is returned to the right precision standards for high reliability.

Pre-shutdown data collection

Before an item of equipment is worked on, its history, information, and service condition are checked for telltale signs of potential trouble.

- Collect records from the CMMS, parts usage, repetitive maintenance, and operating problems
- Collect condition monitoring data such as vibration and bearing characteristics, thermography, oil analysiss, etc.
- Check for running soft foot and machine distortion while operating; identify resonance problems and poor supporting and hold-down structures

1. Measurements and detailed observations taken at shutdown but before strip-down

Once you’ve got safe assess, look over the equipment in detail, noting what is there, what is not there, and what should be present. This is when engineering, technical, and operating quality control standards are valuable for comparing real conditions against design requirements.

- Where thermal growth occurs, collect hot growth and alignment readings
- Identify witness marks showing relative movement between parts
- Notice the presence of unusual deposits from wearing parts such as drive belts and couplings
- Take lubricant samples for analysis and patch testing of wear particle count while still hot
- Check for static soft foot distortion problems

2. Strip-down measurements and investigative observations

As the equipment comes apart, inspect for evidence of both poor and good operation. Take important measurements of components and compare them with the manufacture’s limits to identify problems.

- Look for witness marks and telltale evidence of incorrect operation and behavior
- Mark relative positions of bearings to confirm correct location
- Inspect bearing wear patterns for evidence of spalling and other failure modes
- Note incorrect roller or race motion, cage damage, fretting corrosion, out-of-roundness, shaft straightness, etc.

- Inspect for damage and wear patterns on moving parts such as gear teeth, pulleys, belts, etc.

Take time to do the job of creative disassembly and precision rebuilding well. It will lead to world-class equipment performance as more and more defects are removed from your plant and machinery.

Introducing a Precision Maintenance Program

Once maintenance, operations, and production managers learn of precision maintenance, they acknowledge that it is a great concept and totally valid—although few implement it. Yet there is no other way to get lasting world-class industrial plant and equipment reliability.

Becoming a precision-focused organization starts by determining and setting 3T quality standards for every aspect of plant and equipment operation and care. Each standard is set to prevent or control the Physics of Failure mechanisms that affect the equipment. These standards should push your people to become better and your business to become a world-class performer. Every aspect of operating machine life gets measurable values to define its precision zones. Equipment is then run within the specified precision zones. Maintenance is done so that parts function within their precision zones. Rebuilding machines is done to precision specifications. You make sure your business processes deliver equipment that meets the precise standards that will always produce outstanding production success.

One way to start a precision maintenance program is to introduce precision requirements into everyday workplace practices. Everything that relates to plant and equipment health will need to meet those standards. For the organization, the symbiotic reality is that eventually its influence needs to extend controlling the quality from the original equipment manufacturers, setting the project engineering and design specifications, ensuring parts reliability in procurement and storage, quality assuring plant and equipment installation, operation, maintenance, and all its outsourced subcontract work. It requires confirming that the accuracy of the work performed is to precision standards. You will start keeping maintenance records, measurements, and photographs to prove how well equipment was built and rebuilt, what was used to build it, the exact conditions in which it was built, and how it was operated and maintained during its service life. You keep and use health condition records to prove components are well and fine and need no further work to be done on them. You monitor operating variables for trends and changes as evidence that your production processes are in control or that they are not. Nothing during the life cycle affecting the health and wellness of your equipment is left to chance. Every critical part on every machine and every piece of equipment needs to meet engineering, maintenance and operating standards that guarantee they are in great condition. When those standards are not being met you want to know why, and what will be done to return the parts back to health. The standards are measurable: they define the "engineering numbers" that are proof of compliance with requirements. With measurements to prove that the ideal conditions are present, you have the best chance of getting top-quality machinery. You can be confident that the work done on your plant is right and that your equipment will run precisely because the parts are operating in their precision zones.

All critical parts in your machines, whether they be mechanical, electrical, control system, or structural, need quality standards addressing all vital health requirements:

- Distortion
- Looseness
- Lubrication
- Cleanliness
- Shaft alignment
- Balancing
- Temperature range
- Vibration

- Manufacturing accuracy
- Surface finish
- Installation accuracy
- Tools and their condition for use
- Skills and the necessary competency
- Job history records to keep
- Calibration accuracy of test equipment
- And everything else your equipment parts need for a lifetime of low stress, health, and wellness

The original equipment manufacturer's standards spell out the minimum quality you must achieve. But they are not world-class standards. Precision maintenance standards are typically a magnitude better than what the manufacturer gives you. You need to research and agree on the precision zone quality values for your equipment because those values will be exacting of your people and service providers. Their continual achievement requires a different approach to doing work than what was done in the past. The following is a short list of some of the necessary mechanical quality controls that should be set in a precision maintenance program. Each one must have a value that can be tested so that workplace results can be proven to either meet, exceed, or fail the standard.

- Correct tension for every fastener
- Most and least number of threads protruding from a tightened nut
- Maximum size and amounts of contamination that are acceptable in lubricant
- Position along a shaft from a datum to place a component
- Size, dimensional tolerance, and shaft form at a bearing location
- Amount of damage to a part that is acceptable before it is replaced
- Distortion in a gearbox case before misaligned holes are re-bored
- Flatness of a baseplate to ensure there is no soft foot
- Exact alignment accuracy between shafts in a drive train
- Cleanliness of workshop benchtops and atmosphere so that parts are not contaminated

- And everything else your equipment parts need for a lifetime of low stress, health, and wellness

To those who are uninitiated in precision maintenance, the task of setting up a program seems enormous. It is not so. Many standards are universal, and the necessary standards that produce outstanding reliability are already known. What needs to be done is straightforward and methodical. Training and practice in precision techniques is required, but even that is readily available.

Successfully applying precision maintenance requires competence in best-practice precision skills, supported in the workplace with the correct tools and measuring devices, along with a top-class engineering body of knowledge about the necessary machinery and maintenance standards. If you want equipment in your operation at consistently high reliability, your maintenance and operations people need to develop the higher work skills and quality practices that produce that reliability. They may not yet have such expertise and proficiency. Getting those skills requires setting high levels of excellence and then training people to meet them. Many managers, operators, and craftspeople will not believe they need such high skills in their operation. This, of course, is a fundamental error in their thinking, and it explains why many businesses undertaking reliability improvement efforts still suffer poor availability and breakdowns. They do not realize that reliability results from meeting precision quality standards. If the work processes in use are incapable of delivering that quality, they must be changed to those processes that naturally produce the required precision. Every practice and technique you use can only deliver the accuracy it can produce. You cannot use imprecise practices and expect precise outcomes every time. That is impossible. Companies will always fail in their improvement efforts until they change to practices that naturally guarantee success every time they are used.

Setting Precision Quality Standards for Your Equipment

The solution to equipment reliability problems starts with setting reliability standards that bring sure reliability. The standards you need already exist and have existed for decades. Your challenge is to make them standard practices achieved all the time in your operation. The following list is an example of some of the books and international publications where you can find the necessary information and guidance.

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 by John Piotrowski*
4. Shafts, couplings, and bearings running true to center—*Shaft Alignment Handbook*
5. Forces and loads into supports—*Shaft Alignment Handbook*
6. Accurate alignment of shafts—*Shaft Alignment Handbook*
7. High-quality balancing of rotating equipment—*ISO 1940 and Parts*
8. Machine vibration—*ISO 10816 and Parts*
9. Correct torques and tensions—*ISO/ASME Bolt, Stud, and Nut Standards*
10. Correct tools in correct condition—*"As-New Specification"*
11. Only in-specification parts—*OEM specifications, Machinery Handbook*
12. Application of precision skills and techniques—*Precision Skills Training and Practice*
13. Failure cause removal—*POF based Creative Disassembly*
14. Proof test—*Precision Measuring Tools; Condition Monitoring Technologies*
15. A system to use the standards successfully—*ACE 3T*

This list of publications and techniques may be incomplete for your operation's needs, and you may have to look for additional standards. Note that the benchmarks used in international standards are usually not of sufficient quality for a precision maintenance program. The quality parameters in international standards are minimum requirements that can be used to set the “good” boundary on quality performance in your ACE 3T procedures. But they are not world-class standards. When you set the “best” 3T standard, use the most demanding recommendations of subject matter experts in their field. When a documented world class best standard cannot be found, then set your best quality at a value a factor of ten (i.e., one magnitude) finer than the 3T good tolerance.

Accuracy-Controlled Maintenance Quality System

Item 15 in the list of key precision maintenance requirements is the glue that keeps the rest together. It requires installing a work quality management process to ensure that the other requirements are delivered to every machine and equipment in your operation. In the Plant Wellness Way, you use Accuracy-Controlled Enterprise procedures to drive equipment reliability and production results by making precision quality your company’s standard practice. You solve equipment performance problems forever because ACE procedures contain exactly the information you need to produce outstanding reliability. More importantly, ACE quality standards let you make precision maintenance a habit throughout your operation. The beauty of the ACE methodology is you set the “good” band value at what your people can do today. It lets everyone start from where they are right now and move upward toward the excellent performance you set in the “best” quality target. Within your ACE 3T procedures is a realistic step-by-step plan for achieving the world-class quality that brings outstanding reliability and Operational Excellence.

In a nutshell, introducing a precision maintenance program consists of the following:

1. Corporate approval to implement precision maintenance and precision practices

2. Agreement across the operation on the plant and equipment to be precision maintained
3. Agreement across the operation on the precision standards to meet
4. Agreement across the operation on the best practices to be applied to meet the standards
5. Agreement across the operation on the measurement methods to prove compliance with standards
6. Written ACE procedures for all operating, maintenance, and inspection activities on the selected plant and equipment
7. Necessary test equipment, specialist tools, and facilities
8. New skills learned through on-the-job training and expert support
9. ACE procedures applied and refined
10. Monitoring of the effect of the program on plant performance and operating profits
11. Continual improvement in the use of precision skills and practices
12. Extension of the program to other plant, equipment, and operating sites

You will only have done the job of introducing precision maintenance well when you've done the following:

- Published precision standards for equipment operation and maintenance company-wide
- Held seminars to explain and discuss them with all the people who need to know and use them
- Purchased the measuring and testing equipment needed to prove compliance
- Written ACE procedures for all activities related to achieving needed precision quality
- Trained people to the standards, and ensured that they can achieve them competently
- Deployed a document and record management system to collect all important information about the equipment that allows everyone fast access to the knowledge they need to make right decisions

Too few companies are that good, but this is what the Plant Wellness Way is designed to do for organizations that adopt it as their reliability creation methodology.

Engaging the Workforce

What matters most in achieving reliability success is the skills and knowledge of the shop floor people working on your plant and equipment. If you want reliability, you need to bring the engineering knowledge and maintenance work practices of the crew and subcontractors maintaining the equipment up to a level at which they can deliver world-class machinery performance. For precision maintenance to work, it needs maintenance crews and their supervision to want it and to master the necessary new skills. It requires the right engineering know-how and hand-skill competence to be used by the maintenance technician. Precision maintenance knowledge is needed, but precision maintenance skills are tactile, and people must work on machines in the right ways to get highly reliable operation from them. It requires procedures to be used in a very specific way to get statistical quality control of maintenance work. When done properly, your precision maintenance program will maximize production from the efforts of highly skilled craftspeople for the least maintenance cost.

Although your shop floor people deliver precision maintenance, it is maintenance and operations managers who start the change, sustain it, and keep improving it. The great problem for industry is to find a reliable way to introduce the necessary changes in working practices so that precision thinking becomes the natural way to work. Climbing to the heights of precision maintenance success needs a safe, sound, and encouraging method to change the way people work. There needs to be a safe approach for equipment maintainers to gain understanding of precision maintenance—its work quality requirements, the skills needed, and the procedural methods to put and keep parts in their precision zones of operation.

Starting a precision maintenance program requires a well-thought-out and structured change management process that will help your people to learn and work to new, higher-skilled practices. You do this with the “Change to Win” change management team process explained in the accompanying workbook downloaded online. The Change to Win program gets engineers, the maintenance crew, and maintenance supervision together in setting higher quality standards and helps the organization to recognize the need to upskill to meet those standards.

Precision Maintenance Results the Plant Wellness Way

For rapid success with precision maintenance, the approach recommended in the Plant Wellness Way is to develop a core team of specialists who undertake the development and delivery of a precision maintenance program. These people do the precision maintenance tasks and create highly reliable equipment. The rest of the maintenance crew and the equipment operators sustain the new level of performance. This is the simplest and quickest way to deliver the most operating profit from a precision maintenance program. Few people have the capability to be naturally great precision maintainers. It takes a great deal of training to get the needed skills and continual practice to keep them top class. It is fastest to concentrate training efforts on the few people who will become specialists rather than trying to train the whole crew and getting mediocre results. As well as doing the precision maintenance work, the specialist team introduces precision methods to the rest of the maintenance crew, the operating crews, the engineering group, and the supply chain vendors that service or support your plant and equipment. These precision maintainers write procedures, deliver on-the-job training to people on how to do precision work, ensure work quality assurance, and work with the operations teams to monitor the stability of equipment and process conditions to ensure that component materials of construction have long, trouble-free lives.

FOOTNOTES

1. Ralph T. Buscarello, "Vibration and Its Impact on Reliability and Costs" presentation, Update International, Lakewood, CO, 1990, http://www.tappi.org/content/events/10pirm/paper/buscarello.pdf., accessed August 22, 2015

2. Peter Brown and Max Wishaw, "Precision Maintenance for Engineers" course book, Industrial Training Associates, Perth, Australia, 2000.

3. Solomon Associates, Maintenance Practice Analysis, circa 2002.