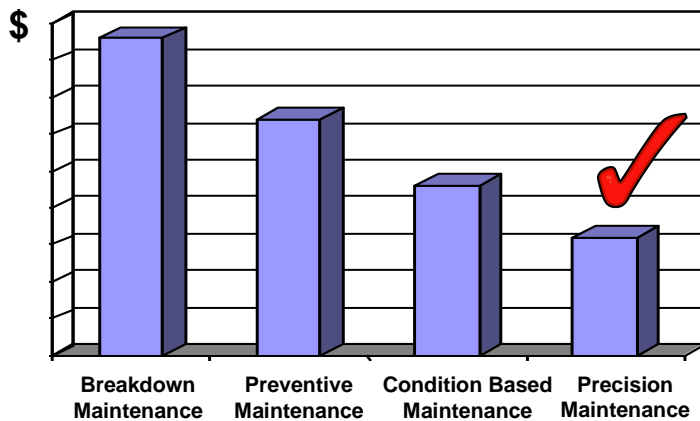


Summary Report on Using and Introducing Precision Maintenance



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Realizing remarkable machinery reliability through precision maintenance is not new; progressive, proactive organisations have practiced it since the mid-1980s; achieving both outstanding production performance and the best maintenance cost reductions of all maintenance strategies. Maintenance, Operations and Production Managers acknowledge that it is a great concept and totally valid – but few implement it!

Solve the stumbling blocks and remove the difficulties so you can put Precision Maintenance reliability into your operation. This summary report explains Precision Maintenance and the essential ingredients for its success. You'll learn of the new, easy, low-cost Accuracy Controlled Enterprise method of implanting precision maintenance habits into your organisation using the 'Change To Win' Program.

Precision Maintenance Skills and Standards

Eliminating defects and preventing failure is a necessary strategy to control the causes of variation. Variation is any deviation from an agreed standard. When variations occur they cause problems because they do not meet the requirements for the process. A variation is waste because it was not what was wanted.

Precision maintenance was created to ensure plant and equipment was maintained to the finest specification so that variations which caused defects and failures were eliminated as the maintenance work was done. Precision maintenance rebuilds machines and equipment to the highest standards so that fewer problems occur during operation. Precision Maintenance is a matter of systematically ensuring the important things for equipment and machinery health are done right and done accurately first time.

Financial and Operating Benefits of Precision Maintenance

Table 1 shows results of equipment vibration survey in a large industrial facility. Vibration levels of operating equipment were measured and the maintenance costs for the items of plant were collected. The annual maintenance costs for equipment with low vibration levels was 70% - 80% less than for machines that ran rough. Precision definitely pays well. (By the way, this is how maintenance makes a profit – you make your machines run better, your costs fall, you keep the money as profits.)

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	\$3,200	2.0	\$650	80%
Multi Stage Pumps	4.8	\$6,100	1.5	\$1,100	82%
Major Fans & Blowers	9.0	\$900	2.8	0	100%
Single Stage Turbines	3.8	\$8,200	1.0	\$2,000	76%
Other Machines	7.8	\$11,850	3.0	\$3,700	69%

Table 1 - Machine Vibration to Maintenance Cost

The two graphs in Figure 1 tell a remarkable story – when machine vibration levels fall, so do the maintenance costs; dramatically at first, then gradually and continually, as precision practices and their use improves. That means that your machinery does not breakdown. It runs brilliantly for longer. Plant availability, throughput and productivity are maximised. And, naturally, you get more time to make more product, at less cost, to sell for more operating profit, using fewer people.

There is no mystery why Precision Maintenance lets you make more, ship more, sell more and profit more, while doing it all at less cost - Precision Maintenance improves your machinery. Quite literally, your people make your machines run better.

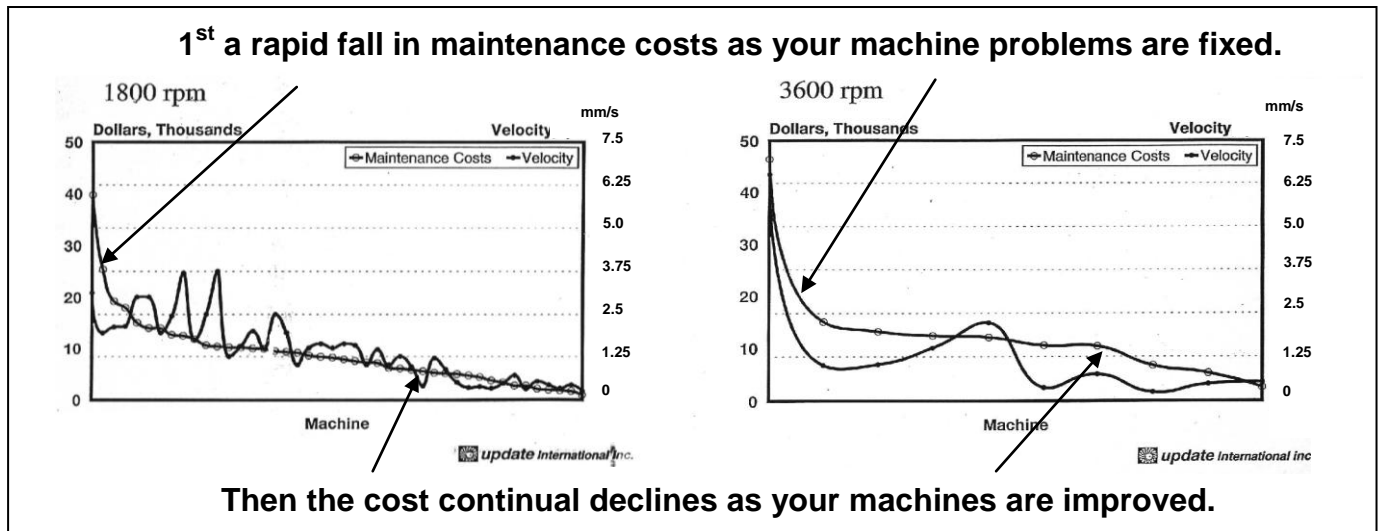


Figure 1 - Maintenance Costs Fall When Machine Vibration Levels Fall

Precision Maintenance is the strict adherence to exacting machinery health standards. It saves amazing amounts of money for the companies that use it because:

- their machines and equipment are rebuilt not to fail
- they reduce the need to use subcontract maintenance people
- they maximise first-pass quality production and stop scrap
- they have vastly fewer stoppages and slowdowns
- fewer spares are used since their machines don't need them
- plant availability and productivity is totally maximised

Here is the list of thirteen key requirements for a precision maintenance program:

1. Accurate fits and tolerance at operating temperature
2. Impeccably clean, contaminant-free lubricant life-long
3. Distortion-free equipment for its entire life
4. Forces and loads into rigid mounts and supports
5. Laser accurate alignment of shafts at operating temperature
6. High quality balancing of rotating parts
7. Low total machine vibration
8. Correct torques and tensions in all components
9. Correct tools in the condition to do the task precisely
10. Only in-specification parts installed
11. Failure cause removal to increase reliability
12. Proof-test for precision
13. **A system to apply the standards in a successful way**

You can see that there is nothing in that list that should not already be standard practice in every industrial operation. But it hardly ever seems to happen. The reason is that no one sets the exact equipment condition standards to be met, and so everyone works to their own standards. This leads to variation, confusion and inaccuracy that, in time, cause you the operating problems and equipment failures you live with. It is as predictable as night following day. But it does not need to be that way.

Here are the standards that you must determine and set for every piece of equipment, every nut and bolt, every electrical connection, every motor base plate, every gearbox,... everything in your plant and equipment.

- Distortion
- Looseness
- Lubrication
- Cleanliness
- Shaft alignment
- Balancing
- Temperature
- Vibration
- Assembly accuracy
- Installation accuracy
- Tools & condition
- Skills & their competency
- Job History Records
- ??? Anything else your equipment parts require for a lifetime of health and wellness

In your standards are 'the numbers' that are to be physically measured and recorded as proof of compliance to standard.

- Like the exact turn from snug to tighten a nut so the torque is correct (*you could use a torque wrench and state newton-meters of torque, but the up-to 25% error in using a tension wrench may not be accurate enough for you*);
- The number of threads protruding from a tightened nut
- the maximum size and amounts of contamination you will accept in your lubricant;
- the exact gap between parts that you can test with feeler gauges;
- the size and dimensional tolerance you will accept for a shaft at a bearing location before you replace the shaft
- the amount of distortion you will accept on a part before you replace it with new
- the exact distance along a shaft from a datum to mount a disc;
- the exact alignment accuracy between drive shafts that you can measure with a laser or by twin reverse dial indicators,

...and so on for everything on every machine and piece of equipment in your operation.

Once you have standards to work to, you can prove if a thing is right or not. Once you measure and prove 'the numbers' (which are your minimum standards) then you know (almost without question) you are within requirements. You are virtually certain that the job is done right and the equipment is running precisely and operating under precision conditions! What uncertainty remains would be due to the risk of using out-of-calibration test equipment that gave a false reading. But your quality management system would have stopped that from happening. (You do have a quality management system controlling the quality of your maintenance tools?)

The great problem for industry is to find a reliable way of introducing the necessary changes in working practices so that Precision Maintenance becomes the natural way work is done. That has now been overcome with new procedural tools and change

management methods that lets your own people introduce Precision Maintenance into your operation.

Starting a Precision Maintenance Program

When you start a precision maintenance program your intention is to introduce the twelve precision requirements listed previously into your everyday practices.

Everything that everyone does which is related to your plant and equipment will need to meet the new precision standards you set for those requirements. Eventually that will include what is done by original equipment manufacturers, operations and maintenance managers, project and design engineers, procurement people, plant and all equipment operators and maintenance crews (including all subcontract work you send out).

Nothing is left to chance - nothing! And if you do leave things for chance to decide, you can be sure that most times it will go badly for you.

Item twelve in the list of key requirements is the glue that keeps the rest together. Item twelve says that you need to install a business process that ensures all the other eleven requirements are actually met for every machine in your operation. That includes recording the dates that the precision standards were met and, if necessary, later checked. You will have records for every piece of equipment, for its entire operating life, of the exact conditions it was built to and it was operated under.

Introducing Precision Maintenance requires training in maintenance best-practice precision skills supported by a top-class engineering and maintenance standards 'body of knowledge' in the workplace so that the plant and equipment in your operation is built to be consistently high reliability.

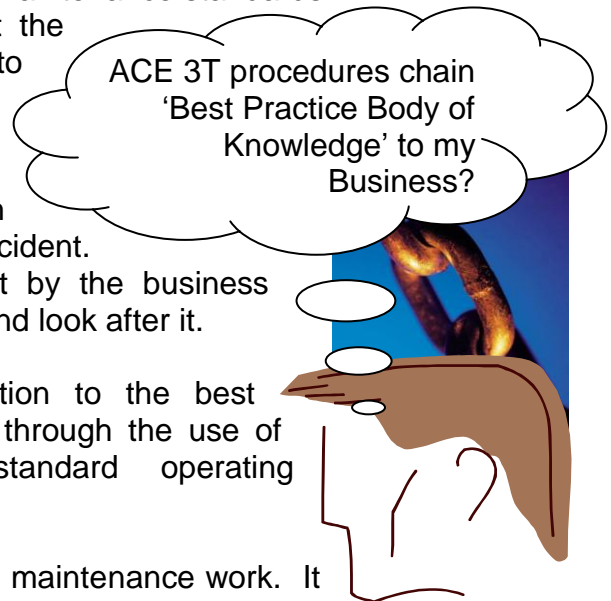
Outstandingly reliable equipment, with exceptional uptime, that delivers unfailingly high production of top quality product, is no accident. These characteristics are built into equipment by the business systems that design it, select it, install it, use it and look after it.

Precision Maintenance connects your operation to the best practices known to deliver world-class results through the use of Accuracy Controlled Enterprise (ACE) standard operating procedures.

An ACE introduces statistical quality control into maintenance work. It concentrates on failure prevention and defect elimination in every task performed by the operations and maintenance people. With ACE in place you have the tool to drive amazing equipment reliability and production results in your business. You start solving equipment performance problems forever. And, more importantly, it lets you make Precision Maintenance a habit throughout your operation.

In a nutshell introducing a Precision Maintenance Program consists of:

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 use for the plant and equipment
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 that will prove compliance to standards
6. Writing ACE 3T procedures for all maintenance and inspection activities on the selected plant and equipment
7. Conducting a gap analysis to identify necessary test equipment, specialist tools and facilities
8. Identify any needed skills to be learnt by on-the-job training and support
9. Applying the ACE 3T procedures and refining their use
10. Monitoring the effect of the program on plant performance
11. Continually improving the use of precision skills and practices
12. Expanding the program to other plant, equipment and sites

Setting Precision Quality Standards for Your Equipment

The solution starts when management set standards, then promote them, train to them and enforce them. Where do the standards come from? The list below is an example. They already exist, and have existed for decades. Your challenge is to bring them alive in your operation.

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 Excellent Condition – *'As-New specification'*
10. Only In-specification Parts – *OEM specifications, Machinery Handbook*
11. Failure Cause Removal – *'5 Why'; RCFA, Creative Disassembly*
12. Proof-Test for Precision – *ACE 3T Precision Operating Procedures*
13. A system to use the standards successfully – *ISO 9001 Quality System*

You may have to look for additional standards to those listed above. The list maybe incomplete for your operation, but it is a good start. Note that there are not always international standards for every standard you will have to set. In that case use the recommendations of experts in their field.

When it comes to equipment distortion and shaft alignment you can start by using the advice in John Piotrowski's 'Shaft Alignment Handbook' (the 3rd Edition is very comprehensive) until you need to set a higher standard. At that point you maybe the world-leader in a field of expertise and you will be setting your own standards to work to, which one day we will all follow.

You will only have done the job of introducing precision maintenance well when:

- you have written and published the specific precision details company-wide for all equipment in the operation;
- you have held seminars to explain and discuss them with all the people that need to know and use them;
- you have purchased the measuring and testing equipment you need to prove compliance;
- you have written ACE 3T procedures for all activities;
- you have trained people to the standards and they can achieve them competently, and
- you have a document management system that records all important equipment information over its life and allows everyone fast access to the information they need to make right decisions.

Too few companies are that good. But it does not need to be that way.

A Precision Maintenance Success Example

A dairy in New Zealand was suffering excessive failures of their centrifugal pumps. Regularly mechanical seals were failing and bearings needed replacing. Their mechanical maintenance technicians had recently completed a training program in Precision Maintenance skills and it was decided to use that knowledge to address the pump failures.

A set of seven pumps were selected for trialling the use of precision maintenance skills. During the next schedule shutdown these pumps were to be handed over to one of the trained fitters to completely strip each installation and rebuild it. A plan was developed to properly install the pumps and correct any deformation and distortion faults. Standards were researched and adopted for foundation rigidity, base plate stiffness and flatness, shaft alignment, bearing fits and clearances, shaft straightness, journal roundness, fastener tensions, oil cleanliness, parts specifications, rotor balance and total machine vibration. The precision standards were incorporated into detailed procedures covering the overhaul of the pumps and their re-installation in-situ.

By setting the standards it became clear that the foundations were too flimsy and were removed and replaced with foundations of greater mass and of better quality concrete. The base plates were found not to be structurally rigid and deflected excessively under load. They were redesigned and manufactured new. The redesigned base plates incorporated jacking bolts for ease of precision movement during equipment shaft alignment.

Each pump was stripped using creative disassembly techniques to identify faults and the defects were addressed and corrected during their overhaul and rebuild. The rotating assemblies of each pump set were sent for balancing to G1 requirements. Meticulous care was taken to ensure the balance standard was retained during the rebuild and reassembly on-site.

The seven pumps were precision installed and measurements were taken to prove all components and assemblies were rebuilt and reinstalled to fine tolerances. The pump set was precision aligned using reverse dial indicators and alignment graph paper to world-best practice standards. Upon start-up each pump's vibration was measured at below 1mm/s. Seven years later the history records of each pump was reviewed. During the seven years not one pump had failed.

Engaging the Workforce is Critical to Success

The international benchmarking group Solomon Associates discovered some years ago that - "Maintenance success is (ultimately) determined by decisions of craftsmen and supervisors." (Extract from *Solomon Associates Maintenance Practice Analyses*.) The Solomon Associates survey found that in the end what matters most in achieving maintenance and operations success is the skills and knowledge of the shopfloor people doing maintenance on your plant and equipment.

If you want precision maintenance reliability you will need to bring your peoples' machinery skills and knowledge right-up to the level where they can deliver world-class machinery performance. This is what the ACE procedural tool does for you.

For Precision Maintenance to work it needs your shopfloor people and maintenance supervision to want it and to learn the necessary new skills. It requires the right engineering know-how and knowledge in the workforce, it requires procedures to be used in a very specific way to provide statistical quality control of maintenance work. When it is done properly you will maximise production, in less time, and for less cost.

Though your shopfloor people deliver Precision Maintenance, it is Maintenance and Operations Managers who start the change, sustain it and keep improving it.

The journey to Precision Maintenance success needs a sound, safe and encouraging method to change the way people work. There needs to be a safe way for your people to gain understanding of Precision Maintenance - the work quality requirements, the skills needed, and the procedural method that make Precision Maintenance work for you and your operation.

Starting Precision Maintenance requires a well thought-out and structured change management process that gets your people to want to introduce, and work to, new higher-skilled precision practices. This is done by using the 'Change to Win' change management team process.

Change Management – Helping People Take Positive Action

Making 'change' happen is hard. Change hardly ever works if it is forced onto people. People don't like being forced to do anything. It's the way we are made. We need to be given the opportunity to come around to it by ourselves.

You have to work with human nature, not against it. That means you have to find ways to let people discover the good and better ways for themselves. Once they find-out how to do a thing better for themselves, and are encouraged by their managers and supervisors to use the better practices, they will be highly likely to adopt the 'change' and make it a natural part of doing their work. You want them to welcome the 'change' and positively support it.

'Push the Limit' Concept

Figure 2 shows the 'push the limit' method of continual progress and improvement. It is the remedy that world-class companies use to protect themselves from turning into low performers. They intentionally force themselves out of their comfort zone by setting higher targets and standards to reach. They set higher standards to meet, and then look for ways to reach them. Pushing-the-limit is a world-class improvement strategy.

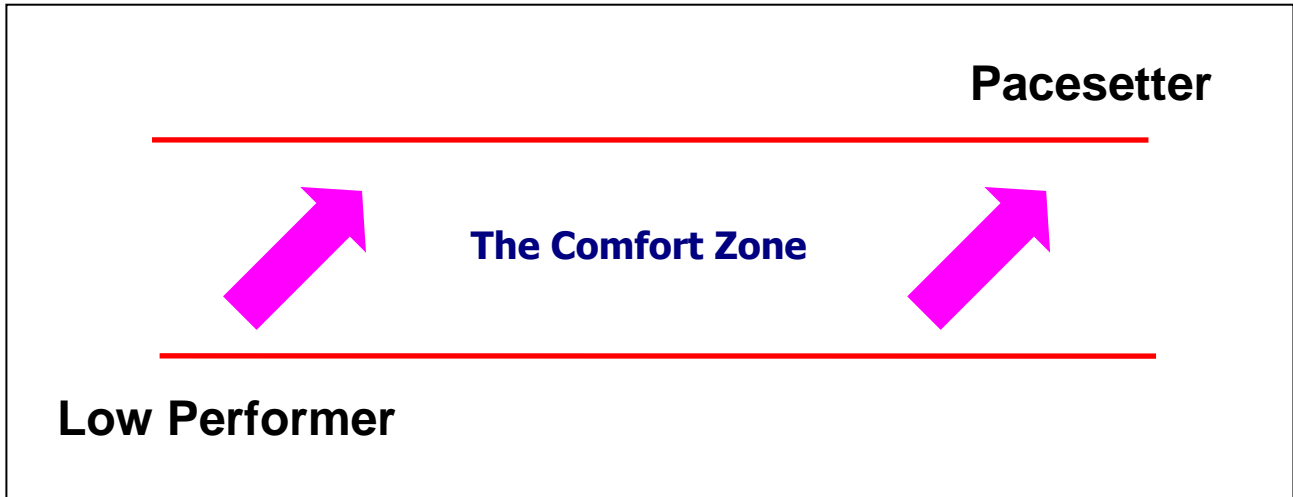


Figure 2 – Push the Limit - The Path to Higher Performance

This is the path your operation will also need to take - the same path that world-class organisations follow.

The 'Change To Win' Program

'Change To Win' is a structured change management program used to introduce needed changes, best practices and innovative improvements into an organisation.

The 'Change To Win' program uses a team-based process for helping people to learn of better ways and best practices which they then include into what they do. The 'Change To Win' teams identify the higher standards that the organization needs to work too so that current worrisome problems are overcome. They find ways to 'push the limit' and bring them into the organization. It lets people from the workplace find and apply best-practice solutions for themselves.

A 'Change To Win' team consisting of the managers, supervisors and people in the workplace is assembled to find best-practice solutions. It is responsible to plan how the organisation will adopt the solutions and what changes need to be made to trial them and then implement them into standard practice.

The 'Change To Win' process is not used for problem solving, though it can be adapted to do so. Solving problems is done with 'Root Cause Failure Analysis', Creative Disassembly or the '5 Whys'. The 'Change To Win' process is a behaviour change process that improves business performance by introducing and integrating higher standards of performance into business processes. It is used to change the way things are done in an organisation by introducing better practices into the workplace.

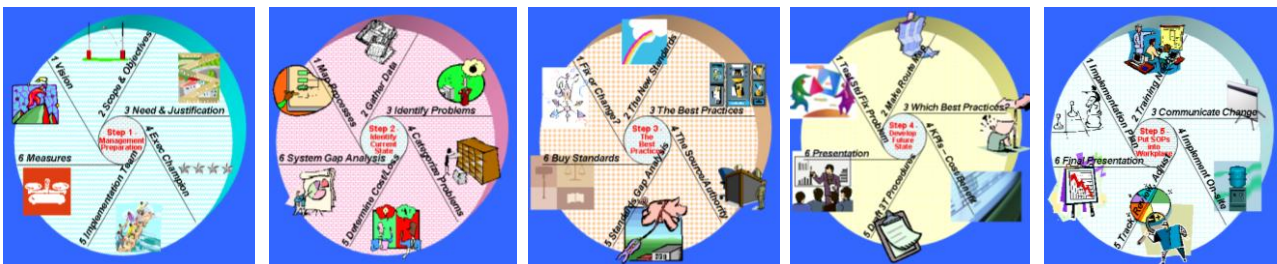
You use the 'Change To Win' program to bring best practices into your organisation. Examples are introducing TPM (Total Productive Maintenance) into Operations; introducing Lean Manufacturing into a manufacturer; introducing a new software system into a business; introducing an ISO9001 quality system into a company, introducing a 5S good workplace habits program into a factory or office, and introducing Precision Maintenance into the workforce.

The 'Change To Win' Workbook

Though your shopfloor people deliver Precision Maintenance, it is Maintenance and Operations Managers that need to start the change, sustain it and keep improving it.

The journey to Precision Maintenance success needs a sound, safe and encouraging method to change the way people work. Starting Precision Maintenance requires a well thought-out and structured change management process that gets your people to want to introduce, and work to, new higher-skilled precision practices. This is done by using the 'Change to Win' 100-day programme.

You need to prove the worth of Precision Maintenance in your own operation with a trial project. You will need to show senior people just how good it is, because they will not accept change in current practices without evidence. Once the 'experimental' project is a success you have real evidence from within your own business that Precision Maintenance works. That proof is critically important. And 100 days is short enough for people to wait for evidence, yet long enough to do the project very, very well. Then you keep rolling-out more 100-day projects until Precision Maintenance is used by everyone on all your operating plant and equipment.



The 5 Wheels of Change in the 'Change to Win' 100-Days Program

Instead of risking that your Precision Maintenance project becomes another failed management fad, you need a believable process that lets people buy into change with 'head, heart and soul'!

The 'Change To Win' program is introduced to the workforce as a simple workbook that each team follows over a 100-day period. It is a friendly, low-risk, low-cost strategy to introduce precision maintenance into your operation. The teams just start at the front of the workbook and each week they progress on agreed tasks. At weekly meetings the team reviews progress and develops action plans until the workbook is complete. When the workbook is finished the 100-day program is done and the proof is there for all to see.

The 'Change To Win' workbook contains the complete change management process you need to apply. It requires a team facilitator who is trained for a day on using the workbook and the change process it contains. The workbook is self-explanatory and the team facilitators help teams to work their way through it and apply the process. The facilitator keeps the team on-track and on-schedule. Like everything that people do, the more often

we do it the better we become. Once each facilitator uses the 'Change To Win' program with two or three teams it will have become second nature to them.

Introducing Precision Maintenance 100-Day Program

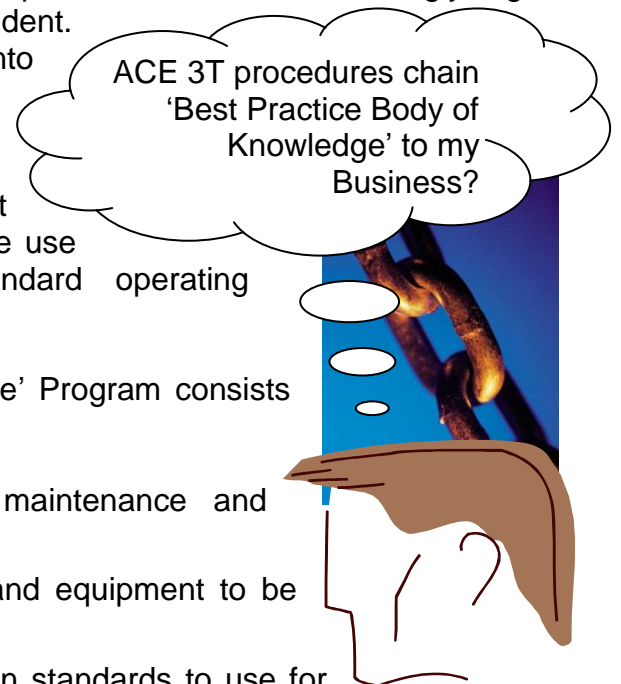
The 'Introducing Precision Maintenance' Program brings maintenance best-practice precision skills and a top-class engineering and maintenance standards 'body of knowledge' to the workplace so that the plant and equipment in your operation is made to be consistently highly reliable.

Outstandingly reliable equipment with exceptional uptime, that delivers unfailingly high production output of top quality product, is no accident. These production characteristics are built into equipment by the business systems that design it, select it, install it, use it and look after it. The 'Introducing Precision Maintenance' Program connects your operation to the best practices that are known to deliver world-class results through the use of Accuracy Controlled Enterprise (ACE) standard operating procedures.

In a nutshell the 'Introducing Precision Maintenance' Program consists of:

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 use for the plant and equipment
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 that will prove compliance to standards
6. Writing ACE 3T procedures for all maintenance and inspection activities on the selected plant and equipment
7. Conducting a gap analysis to identify necessary test equipment, specialist tools and facilities
8. Identify any needed skills to be learnt by on-the-job training and support
9. Applying the ACE 3T procedures and refining their use
10. Monitoring the effect of the program on plant performance
11. Continually improving the use of precision skills and practices
12. Expanding the program to other plant, equipment and sites

Over the page you will find a summary of the activities in the 'Introducing Precision Maintenance' 100-Day Program.



Introducing Precision Maintenance Activities Summary

Wk	CEO, Executive Team, Operation & Maintenance Managers	Operations and Maintenance Managers, Supervisors and Team Leaders	Maintenance Manager, Supervisor and Team Leaders, Maintenance Teams	Outputs	Comments
Pre	Scope and Targets of Project; Communication Plan			Organisational Communication, KPIs	
1	Explain Scope to Supervisors and Team Leaders	Introduce Precision Maintenance; ACE 3T Procedures; Select Plant and Equipment to be Precision Maintained & Monitoring KPIs		Select Plant and Equipment for Precision Maintenance	Introduction
2		Set Standards; Select Authorities, Agree on Best Practices to meet; Select Project Team, Identify needed resources; Set meeting times		Set Standards to Achieve; Acquire Authorities	Plan
3	Explain Scope to Shopfloor Teams		Introduce Precision Maintenance; ACE 3T Procedures, Team duties; Project Plan, Match Equipment and Standards; Identify Procedures for ACE 3T	Business Systems Changes	Plan
4			Identify and bridge gaps between current practices and new Standards; Draft first procedure into standard ACE 3T format	Business Systems Changes	Plan
5	Commit to Agreed Standards		Draft procedures into standard ACE 3T format	Business Systems Changes	Do
6			Review and continue to draft procedures into standard ACE 3T format	Business Systems Changes	Do
7			Review and continue to draft procedures into standard ACE 3T format; Identify test equipment, tools and in-the-field support and training for implementation	Business Systems Changes; Get additional help and resources	Do
8	Review progress and provide support		Review and sign-off on new 3T Procedures	Business Systems Changes	Do
9			Implement Procedures on selected equipment and additional support	Use, Learn, Adjust	Do
10			Implement Procedures on selected equipment and additional support	Use, Learn, Adjust	Do
11			Review implementation and identify necessary adjustments to procedures, practices and support; Review KPIs; Include adjustments and improvements into procedures; Continue with implementation	Use, Learn, Adjust	Check
12			Implement Procedures on selected equipment and additional support	Use, Learn, Adjust	Act
13	Review progress, review KPIs, Celebrate and extend program		Review progress, review KPIs, Celebrate and extend program	Use, Learn, Adjust	Act

Project Team Structure and Duties			
Position	Primary Duty	Secondary Duties	Name
Team Leader	Organizes and leads meetings, develops agenda, encourages participation by all; Coordinates resources throughout the Company	Reviewing procedures	Maintenance Manager
Assistant Team Leader	Writes action sheets, maintains action plan, and relieves for Team Leader if not available	Reviewing procedures	Maintenance Supervisor
Researcher 1	Gathers best practice methods from Authorities.	Writing procedures	Engineer or Technical Officer
Researcher 2	Gathers best practice methods from Authorities.	Writing procedures	Engineer or Technical Officer
Procedure Writer 1	Drafts procedures into ACE 3T format	Reviewing procedures	Trades
Procedure Writer 2	Drafts procedures into ACE 3T format	Reviewing procedures	Trades
Procedure Writer 3	Drafts procedures into ACE 3T format	Reviewing procedures	Trades
Reviewer 1	Reviews draft procedures and works with Writer to refine	Updates communication board with progress fortnightly	Trades
Reviewer 2	Reviews draft procedures and works with Writer to refine	Collects KPI Measures and graphs them	Trades
Reviewer 3	Reviews draft procedures and works with Writer to refine	Collates project documents from all others into project folder/files	Trades
Facilitator	Helps and coaches team through the process, provides support to the Team Leader	Acts as catalyst for change and assists team to challenge the status quo	Outside third party

If you want more information on becoming an ACE, or using the 'Change To Win' process, please contact the undersigned.

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