

# **Maintenance Planning and Scheduling for World Class Reliability and Maintenance Performance**

## **3-Day Training Course**

### **Day 2 Maintenance Planning Slides with Complete Explanations**

# **The Maintenance Planning and Scheduling for World Class Reliability and Maintenance Performance Training Course Textbook 2**

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## 1. Introduction

Welcome to Day 2 of the Maintenance Planning and Scheduling for World Class Reliability and Maintenance Performance 3-Day Training Course. I hope that you enjoyed Day 1 and found the maintenance and reliability concepts it contained useful.

Day 1 covered the vital concepts of industrial asset management and maintenance that a Maintenance Planner needs to be aware of so they can align their duties and output with the aims of the enterprise. If you work in the Maintenance discipline you need to know the strategies that deliver equipment reliability and best production equipment performance. A Maintenance Planner needs to understand those concepts and how their role uses them to produce good maintenance results.

Day 2 and part of Day 3 focus on the methods, routines and techniques of maintenance planning. You learn about setting up the necessary work system, processes and practices for doing great maintenance planning. We will cover the equivalent requirements for maintenance scheduling during Day 3 of the course.

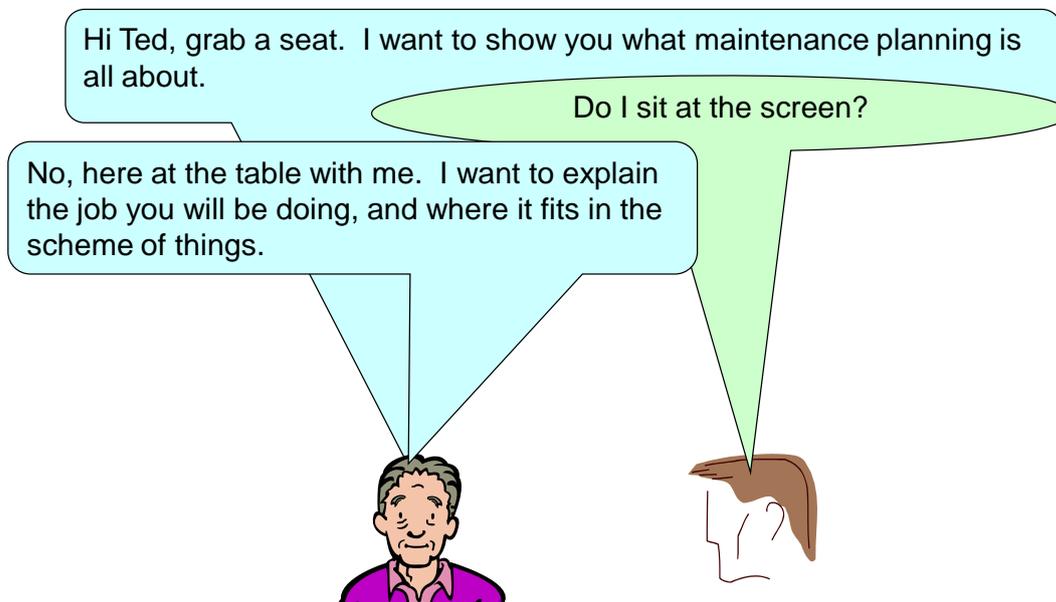
It is wise to remember what the sage Confucius said about planning over 2500 year ago, *“In all things success depends on previous preparation, and without such preparation there is sure to be failure.”* Confucius warns us that thorough planning is an important element in every success.

As you do the Maintenance Planning role remember that you are part of a business that wants to build a great company. Maintenance Planning is a foundation requirement to ensure maintenance work is done successfully, right first time. A Maintenance Planner’s role is to prepare work packs in a timely manner for the effective, efficient and safe performance of maintenance work. World class Maintenance Planners build planning systems that deliver world class results in every job. Their work helps everyone on the maintenance crew to be successful.

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November 2011

## Day 2 Content

- Planning Systems – for office and information management
- Parts Purchasing and Management
- Specifying Work Quality Standards for Reliability
- Project Management – plan/prioritize/control activity
- Work Planning Process – Plan/Prepare/Do/Check/Act
- Shutdowns – Management philosophy for shutdown control



At the following meeting ...

Today we start into maintenance planning. The first day laid the foundations of maintenance and reliability so that you will better understand where maintenance planning adds value to the reliability growth process.

I try not to emphasize the word ‘maintenance’, when talking about maintenance planning because what every person who does planning really does is to remove risks in doing a job and improve the chance of delivering good work outcomes. Maintenance is merely using ‘planning’ to control work activities and work quality in order to reduce the likelihood of future equipment failure. Planning maintenance helps maintenance work go right and get done right.

Successful maintenance planning requires developing office systems to collect and distribute information accurately and quickly. It has nothing to do with being a good equipment maintainer. You need to be a good organiser and project manager. You can read more about the duties and requirements of the Maintenance Planner below.

### ***What is a Maintenance Planner expected to do?***

Maintenance planning has two connotations. The first is of a strategic nature involving the selection of maintenance strategies from among alternative courses of action, for the enterprise as a whole. It is, in effect, deciding in advance what maintenance types to use to manage the various operating risks of the organisation. Planning at this level assumes that rational processes can be used to nominate resources and define appropriate future action which will produce the desired outcomes ([www.unisa.edu.au/pas/qap/planning/glossary.asp](http://www.unisa.edu.au/pas/qap/planning/glossary.asp)). To me this is what the Maintenance Manager is responsible to do.

The second view of maintenance planning is tactical in nature. It takes a project management perspective and is the process of establishing the sequence and relationship of a series of actions and requirements prior to maintenance work commencing, along with procuring and providing the parts and resources needed to deliver the work plan. This is the meaning of maintenance planning that I use when I talk about a maintenance planner’s duties.

This definition ties-in very well with the primary purpose of maintenance planning, which is to maximise ‘tool time’ of the maintenance crew. (Keep the maintenance guys on the move straight from one job to the next.) This tactical work connects to the strategic work of the first definition by ensuring that the maintenance work performed delivers the organisation’s desired outcomes. Hence the secondary purpose of maintenance planning is to ensure the trades do quality work by providing all the parts, tools, information, procedures and check testing needed to deliver a quality job.

Scheduling is not planning. It is the setting of order and time for planned events. Scheduling involves taking decisions regarding the allocation of available capacity or resources (equipment, labour and space) to jobs, activities and tasks over time. Scheduling thus results in a time-phased plan, or schedule of activities. The schedule indicates what is to be done, when, by whom and with what equipment. Scheduling seeks to achieve several conflicting objectives: high efficiency, low inventories and good customer service ([src.ncsu.edu/public/DEFINITIONS/S.html](http://src.ncsu.edu/public/DEFINITIONS/S.html)).

### **What is a Work Order Backlog and how do you manage it?**

A ‘backlog’ is a build-up of work to be completed. Hence a Work Order Backlog is a list of all maintenance work orders not yet complete. Some work orders will be resourced and in progress, some will be scheduled to start on a future date, some will be planned waiting scheduling, others will be unplanned.

A maintenance backlog is a slippery beast to tame because production priorities are always changing. To successfully manage the backlog requires Operations and Maintenance to work as a team so that equipment, parts and resources are made available at the same time to do the maintenance work. This can only be accomplished by people from each group and operations process affected sitting down in a well-structured meeting and deciding what work to do, when to do it, and committing to its accomplishment. Once everyone at the meeting is agreed the job is then classified as ‘scheduled’.

Until agreement is reached at the meeting the job is classified as ‘planned’ or ‘unplanned’. These meetings must be DAILY and people attending must act as professionals working to a well structured and timed agenda. The scheduling meeting should be over and done in 30 minutes (don’t do planning during this meeting, the planning for a work order is done separate to this meeting). Weekly meetings never work because too much will have changed during the week and there is not enough time in a weekly meeting to discuss all that must be discussed.

To aid in decision making each work order has a means to indicate its importance or priority to the operation. Usually this is based on the equipment criticality, which depends on the size of risk to the operation if an item of equipment fails or suffers downtime. To ensure the low priority jobs are not left sitting on the backlog for years due to the higher priority jobs always taking precedence, their priority is gradually increased as time goes by so they rise to the top of the backlog and must be done.

### **What sort of reports is a Maintenance Planner expected to present at the Weekly Planning and Scheduling meetings?**

Typically you report various performances related to planning and doing quality maintenance work.

Since the Maintenance Planner is responsible for planning work orders this is one of the details reported – ‘Number and/or proportion of work orders fully planned in the total backlog’ (This reflects how well the Planner’s prime duty is being achieved), ‘Work Orders Completed as Planned’ (this indicates effectiveness of preparation work), ‘Work Orders Right First Time’ (indicates workmanship and skills quality for further development). A variation on the last one could be ‘Frequency of Repeating Work Orders’ (indicates work quality or parts reliability problems).

Other information in reports could include: ‘Size of backlog’ (is it growing, reducing, steady?), ‘Uncompleted Work Orders by Required Date’ (is the work getting done in good time?), ‘Work Orders Overdue from Scheduled Date’ (are Operations providing access? are resources available on-time?), ‘Operating Risk Level Represented by Work Orders’ (are we living with high risk problems or are we controlling our risks?), ‘Work Orders Complete by Trade Type’ ( are there problems in the maintenance workforce?). There will be other appropriate information that you want to report.

You should also ask Operations what they want to know and present that information at the meetings.

### ***Maintenance Planning Work Process***

There are five distinct phases in executing Maintenance Work.

#### **1) Identify the Work**

**Resp: All**

- From PM’s
- Adhoc Job Requests / Work Requests eg repaint lines on workshop floor
- Equipment Breakdowns
- Equipment Maintenance Strategy Analysis e.g. FMECA/RCM/DOCTOR/RGCA

#### **2) Plan the Work**

**Resp: Maintenance Planner**

- Planner identifies work, resources and materials required on jobs that can be planned.

#### **3) Schedule the Work when Planned**

**Resp: Maintenance Scheduler**

- Planner/Scheduler schedules the work for the following week with Production.

#### 4) Execute the Work

#### Resp: Maint Sup'r or Leading Hand

- Maintenance Superintendent or Leading Hand allocates labour to execute scheduled jobs.
- Confirms with Production that plant is available and isolations will be ready.
- Confirms all materials and resources are available when required.
- Follows-up to ensure work is done.

#### 5) Close out and record history

#### Resp: Maintenance Technician

- The maintenance technician is trained in CMMS data entry and does the job close-up and job history, as they are the people who actually executed the job.
- In leau of the maintenance technician should be the Leading Hand but usually defaults to the Maintenance Planner. Essential that the maintenance technician writes on the CMMS maintenance job history sheet what was found and what was done.

### ***Role of the Maintenance Planner/Scheduler***

#### 1) Plan the Work

- Reviews the backlog (all uncompleted work) and identifies priority work and equipment.
- Planner identifies the extent of work required
- Identifies tasks required for the job.
- Planner identifies Resources and Materials required.
- Ascertains stock item and non-stock item material requirements.
- Places orders for non-stock items and materials.
- Reserves stocked items and materials for the job.
- Confirms sub-contracted services availability and cost.
- Identifies best-practice engineering standards applying to the job.
- Planner prepares equipment specific documentation e.g. special assemble instructions, past modifications, data sheets, calibration requirements, manufacturer's design info, etc
- Planner prepares ACE 3T specific work procedures.
- Produces a cost estimate and time estimate to do the work.
- Assembles complete work pack
- If repetitive job, i.e. likely to occur again, then saves job as a template in CMMS.

#### 2) Schedule the work when Planned

- Planner/Scheduler schedules the jobs for the following week to match available labour.
- PM's have first priority on available labour.
- Training and breakdown load are taken into account i.e. currently only schedule 50% of day labour and 20% of shift labour.
- Only schedule planned jobs or those jobs that require labour only.
- As breakdowns fall or scheduled jobs are reliably completed then increase schedule loading.

**3) Prepare the Weekly Schedule Book.**

- Confirm next week’s Maintenance Schedule with Production at weekly planning meeting.
- Planner/Scheduler develops bar chart for all scheduled work orders.
- Print out CMMS work order sheets, PM sheets and any other relevant information for all scheduled jobs for the following week and clip them into the respective day in the weekly schedule book.
- Expedite any non-stock items for next week’s jobs.
- Print and distribute copies of the Weekly Maintenance Schedule to the Production Superintendent, Production Team Leaders, and Ops Manager.
- Issue copy of the weekly schedule book to the Maintenance Sup’r or Leading Hand.

***Job Description for a Maintenance Planner***

This job description details the attributes, skills and knowledge required for a person to competently do the duties of a maintenance planner.

<b>Maintenance Planner Duties</b>	
Scope the full extent of maintenance work needed to conduct the relevant repair / preventive / predictive / design-out activities on the organization’s plant and equipment	
Develop cost estimates of planned maintenance work to within 10% of final job cost	
Purchase all necessary parts, equipment, services and documentation to perform the maintenance work	
Write applicable maintenance procedures that promote defect-free work quality	
Responsible for up-keep of maintenance history database	
Responsible for up-keep of technical information on plant and equipment	
Appreciation of how maintenance strategy is converted into workplace activities	
Able and competent in root cause failure analysis leadership and investigations	
Apply good stores management practices to ensure parts and equipment retain full reliability while stored	
<b>Personality</b>	
Able to explain their position and justify it respectfully to persons from all organisational levels	
Pleasing demeanor that encourages and supports discussion, interaction and problem resolution	
Well dressed and groomed, looking like a professional	
Prepared to listen to others views on a topic without being judgmental or offensive	
<b>Education and Skills</b>	
Fully certified to perform relevant maintenance activities e.g. applicable licenses, permits and qualifications	
Sound and correct understanding of equipment reliability concepts	
Solid appreciation of risk management strategy and practices related to plant and equipment	
Solid appreciation of quality management methods and practices related to plant and equipment	

# *The Purpose of Planning Maintenance*

1. Maximum trade 'tool time' (*Efficient use of workforce*)
2. Quality work done 'right-first-time' (*Effective use of resources*)

# *The Purpose of Scheduling Maintenance*

1. Make sure maintenance is done so failure is prevented
2. Least production disruption
3. Right resources and people to the job on-time

These are the most important goals to work towards as a Planner, and as a Scheduler.



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Operations can delay preventive maintenance (PM) because they are focused on getting production out. We know that unnecessary, costly production failures will occur if PM is never done. If there is no specific strategy within Production to allow its equipment maintenance to be planned, it is almost bound to be neglected in a busy factory, which is just when it is most needed. So to control the risk of production neglecting their own equipment because they are too busy, the maintenance work must be planned and scheduled by the maintenance group.

In this course we focus on the only two aspects of maintenance planning that are truly important for a business—the efficient use of limited resources and the delivery of highly reliable plant and equipment. Unless maintenance work is efficient and is done right so that it adds value to a company, it is destroying value through wasted effort and pointless rework.

Tool time is when technicians and artisans are contributing their knowledge and expertise to the upkeep and improvement of the business. Right-first-time means their work is done expertly, using quality craftsmen skills, to deliver highly reliable machinery with long, long periods between problems. The Planners job is to help their maintenance people maximise tool time and maximise quality workmanship.

Maintainers contribute most value to the operation when they are performing maintenance. There is no value from them if they need to stand at the store waiting for parts, they can offer no value if they are waiting for the right information to do a job. If you want maximum value from your maintenance crew, you must develop systems and methods that keep them working on keeping the operation running at full capacity and maximum reliability.

When men are not contributing to making a company run better they are wasting its energy and money and destroying their own self-worth.

# Purpose and Role of Maintenance Planning and Scheduling

## PRIMARY PURPOSE

“The point of instituting the Planning and Scheduling process is to gain greater work utilization from the rest of the maintenance mechanics.”

*Alan Warmack, Marshall Institute*

## ROLE of MAINTENANCE PLANNING

Develop and collate detailed work plans covering information, procedures and standards. Assemble the correct components and parts. Ensure repairs and maintenance are executed correctly, accurately, safely, quickly, and without interruption with the least production disruption.



**Planners  
turn the  
maze into  
a map**



5

# Purpose and Role of Maintenance Planning and Scheduling

## ROLE of MAINTENANCE SCHEDULING

Coordinate with Production for the time and methods to access plant and equipment. Ensure repairs and maintenance are done safely and correctly in the time provided to return components and equipment to design reliability and proper operating condition, with the least production disruption.



**Schedulers  
turn the  
map into  
the trip**



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The primary purpose of maintenance planning is to maximise ‘tool time’ of the maintenance crew. (Keep the maintenance guys on the move straight from one job to the next.) Maintenance

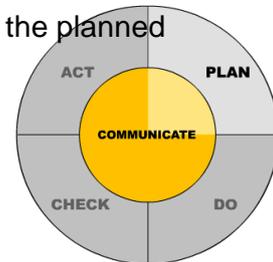
planning aims to ensure the trades do quality work by providing all the parts, tools, information, procedures and check testing needed to deliver a quality job, done in a timely manner.

Scheduling is not planning. It is the setting of order and time for planned events. Scheduling involves taking decisions regarding the allocation of available capacity or resources (equipment, labour and space) to jobs, activities and tasks over time. Scheduling thus results in a time-phased plan, or schedule of activities. The schedule indicates what is to be done, when, by whom and with what equipment. Scheduling seeks to achieve several conflicting objectives: high efficiency, low inventories and good customer service (*from srcr.ncsu.edu/public/DEFINITIONS/S.html*).

## What Planned Maintenance Looks Like

- **A Planned Maintenance System is the most effective method to improve the maintaining function.**
- ***To be successful, the Planned Maintenance System must include:***
  1. A work order system used to make assignments to craftsmen/ technicians and to accumulate maintenance data.
  2. Maintenance personnel dedicated to the task of planned and scheduled maintenance including predictive and preventive activities.
  3. Methods of formal planning and scheduling.
  4. Measurement of Planning and Scheduling Results.
  5. A means of sharing planning and scheduling information with production personnel and business teams.
  6. Regulated Inspections and Repairs – Procedural documentation.
  7. Systematic, continuous review, revision and refinement of the planned maintenance system.

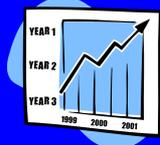
Source: Maximising Operational Efficiency , 2004 E. I. du Pont de Nemours and Company



Companies that do maintenance planning and scheduling (MPS) well have a distinctive look and feel about their planning systems. They work in certain ways when they do MPS.

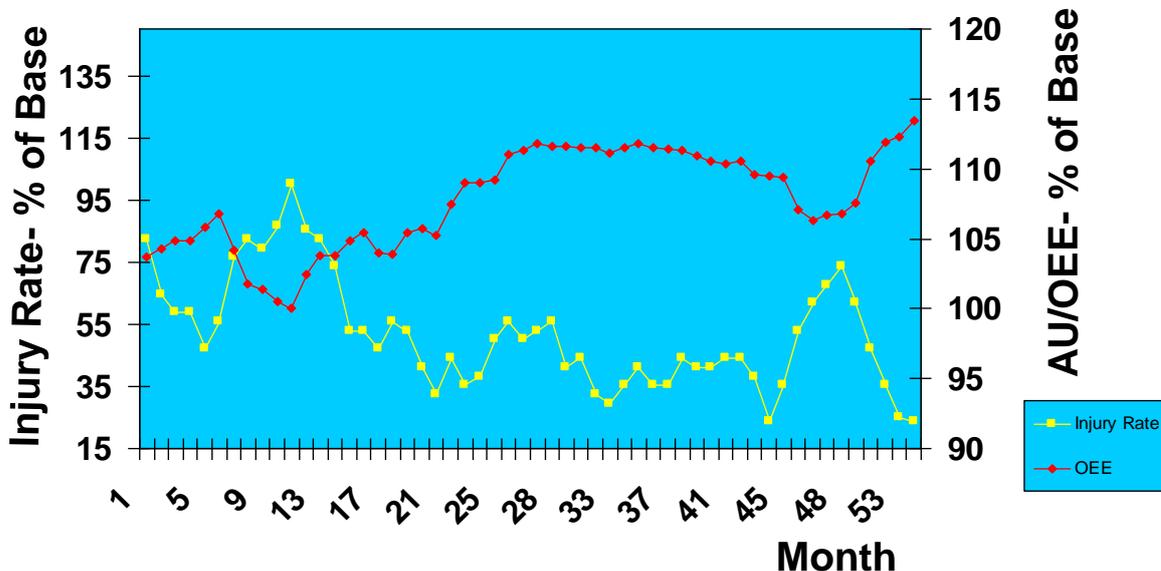
# Maintenance Planning Brings Benefits

- Increase maintenance work performed by up to 100% above reactive
- ‘Tool time’ can rise to 50% of maintainer’s day (Palmer, MPS Handbook, Second Edn)
- Planned work is 4 – 12 times more efficient than reactive
- Needs 1/3 the labour of unplanned work (B. Peterson, SAMI, 1998)
- Planned work is 3 – 9 times less expensive than reactive
- On larger jobs each hour of planning saves 3 – 5 hours execution time
- Up to 90% of your work can be planned (Maximising Operational Efficiency, Du Pont, 2004)
- Up to 95% of planned work can be done when first scheduled
- 7 times safer than reactive (USA Construction Industry report)



Research of literature on the value of maintenance planning highlights many positive benefits. These benefits arise because planned work is safer, more efficient and jobs are done quicker.

## Safety Driven Companies Ought to be Reliability Driven Companies



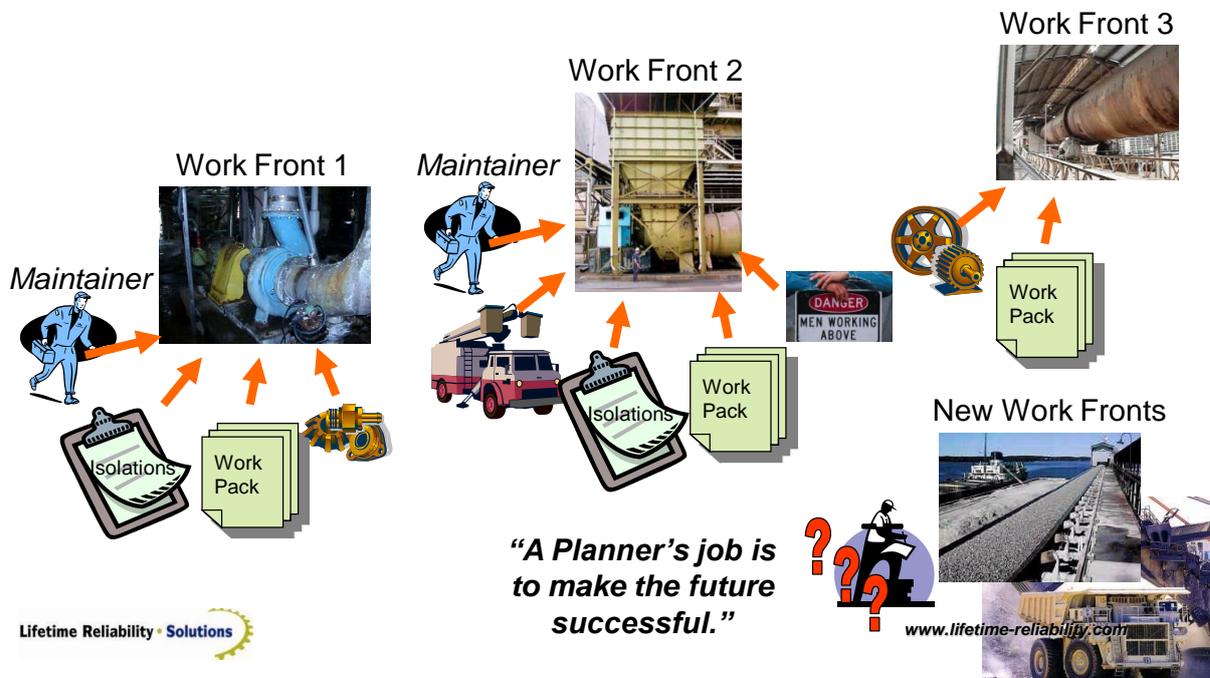
The RM Group, Inc. Knoxville, TN Source: Making Common Sense Common Practice, Elsevier Butterworth-Heinemann Books, Boston, MA, & London, England. Used with permission

Companies that are safety driven should also be reliability driven because reliability delivers greater safety. In the slide the injury rate falls when OEE rises, and rises when OEE falls.

Overall Equipment Effectiveness = Availability x Production Rate x Quality Rate.

In an OEE key performance indicator the amount of Availability is a direct relationship to equipment reliability. Hence the slide connects equipment reliability with plant safety performance. There is a direct inverse correlation between higher reliability and improved safety – the more reliable the equipment, the fewer the reasons to interact with it, and as a consequence the lower the number of accidents.

“ ...to gain greater work utilization from the rest of the maintenance mechanics.”

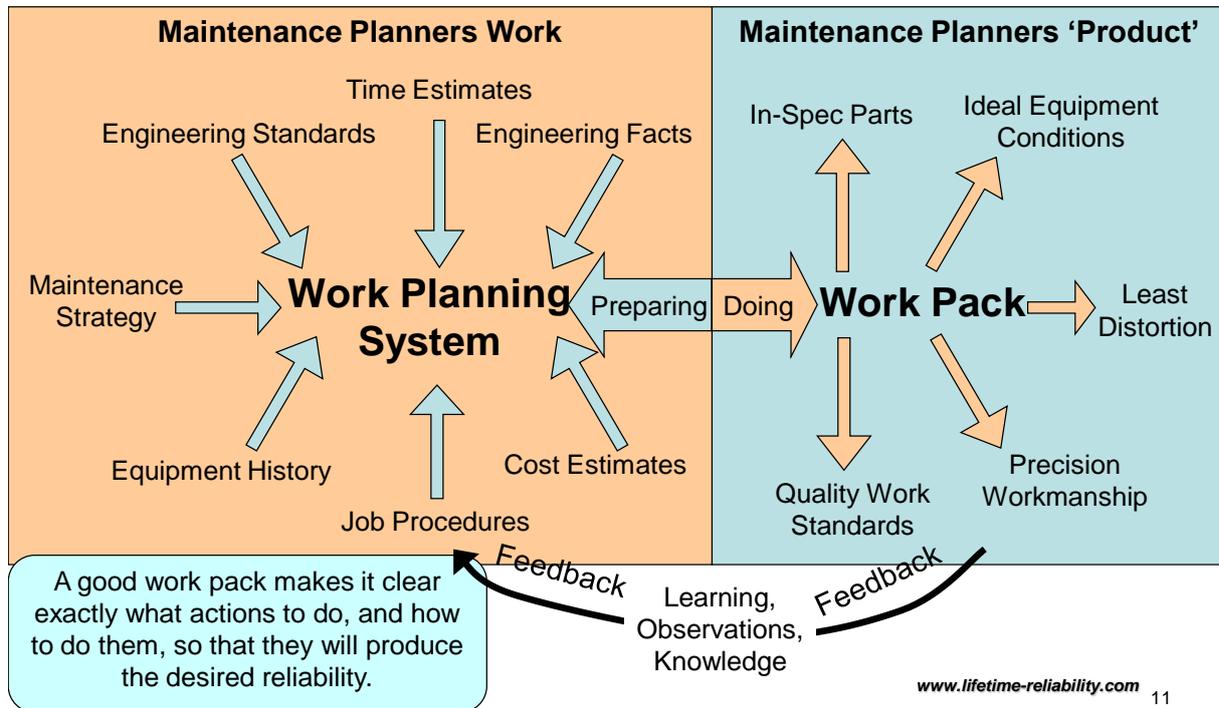


This slide explains/gives you a vision of what it is to be efficient in maintenance, which is one of the two prime purposes of the Maintenance Planner working “to make efficient and effective use of the maintenance workforce”.

We see the tradesman moving from one work front to the next, at each job everything is provided and ready for him to start the work and to do it well. The Planner is ahead of the tradesman planning future work fronts and preparing all that is necessary to do those jobs perfectly (i.e. to the required standards).

The Planner needs to be well ahead of the Maintainers with the preparation of the work fronts. They must be planning work two to three weeks, and more, ahead of it being done. Planners are responsible to make the future successful and so they must be preparing the future work so it can be done successfully. Planners must not be dragged back to today’s problems. Once a Planner is caught up in today’s work orders they are wasted. Today’s problems must be addressed by the Supervisor and the crew. Leave the Planner alone preparing and organising work to be done in the coming weeks, at least that way there is some chance that the future will be better.

## Planning is a System to Get Right Work Actions



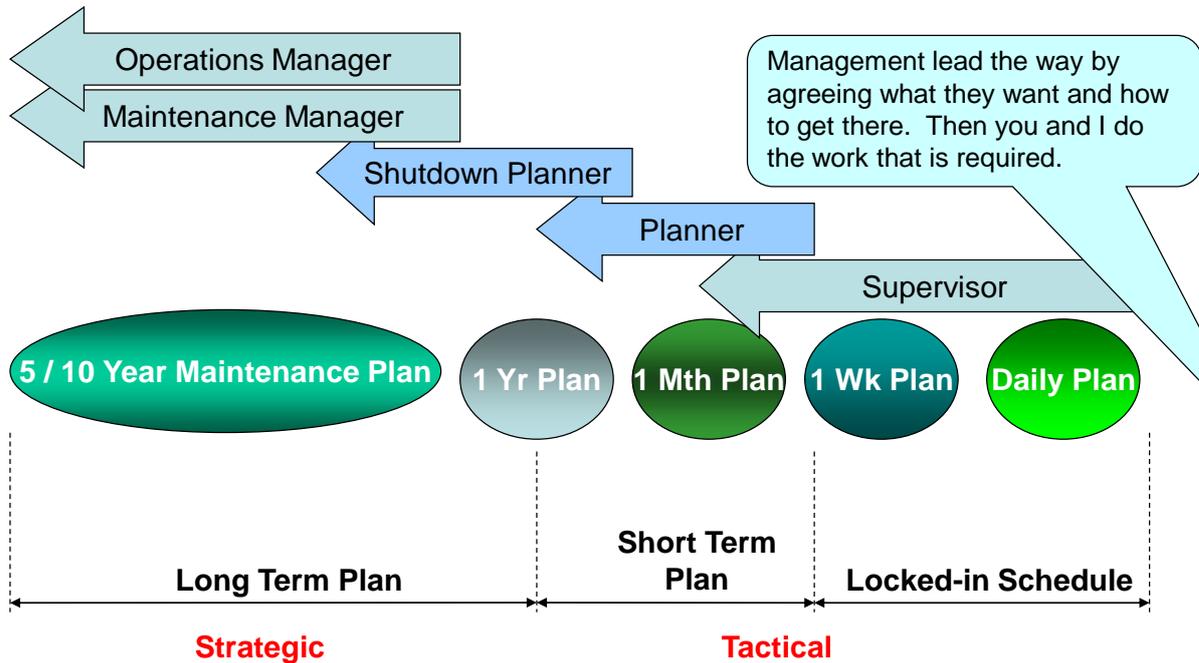
Planning is only useful if the plan is followed. The plan is only useful if it delivers the necessary results and outcomes. A good plan makes it clear exactly what actions to do, and how to do them, so that they will produce the desired results. All that information is in the work pack that the maintenance planner is responsible to produce.

A Maintenance Planner needs a systematic approach so they can quickly compile the correct parts, tools and information needed to do the maintenance to high quality standards. This necessitates the Planner to develop specific information management systems for the quick identification and collation of large amounts of engineering facts, equipment history, job procedures, work standards, time estimates and cost estimates while ensuring the maintenance strategies are actually put into place.

Every company needs planning systems if they want to maximize performance and results from using their resources. The Maintenance Planner owns and is responsible for the maintenance planning system which they use to build and produce their 'product'—a work pack for every job.

When the planning system is used the work packs are complete, correct and highly reliable for delivering the quality work needed for world class plant availability.

# Maintenance Planning Horizons



The long-term maintenance plan cascaded down into the annual plan, which in turn is separated into the monthly plan. The monthly planned work feeds into the weekly schedule, which is set and is not altered.

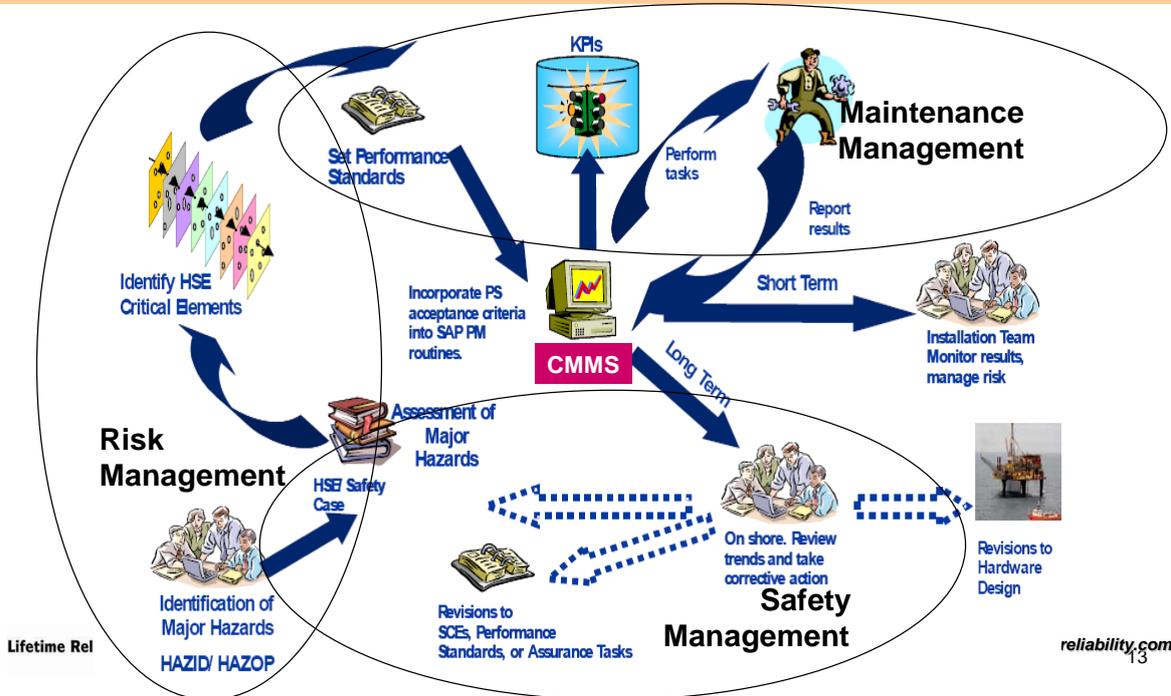
The slide also shows the focus and time jurisdictions that people in the maintenance functions are responsible for.

Maintenance planning has two connotations. The first is of a strategic nature involving the selection of maintenance strategies from among alternative courses of action, for the enterprise as a whole. It is, in effect, deciding in advance what maintenance types to use to manage the various operating risks of the organisation. Planning at this level assumes that rational processes can be used to nominate resources and define appropriate future action which will produce the desired outcomes (*from [www.unisa.edu.au/pas/gap/planning/glossary.asp](http://www.unisa.edu.au/pas/gap/planning/glossary.asp)*). To me this is what the Maintenance Manager is responsible to do.

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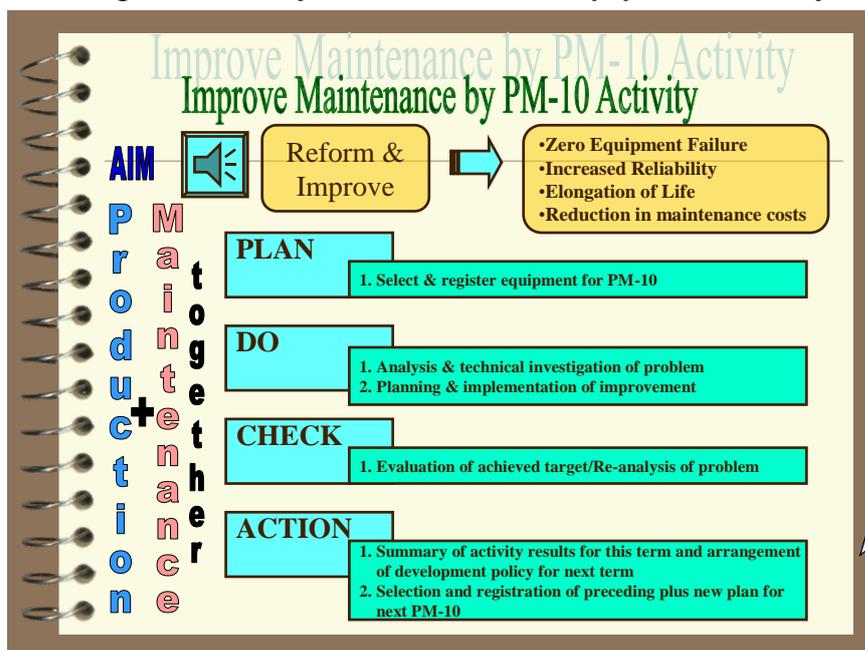
# Maintenance Arises from Operating Risk Management and Safety Strategy



Much of the work that becomes the computer maintenance management system (CMMS) generated work orders, rounds and routines is developed out of the strategies put into place to control the risks that prevent achievement of the business operating and production objectives.

## The Strategy Behind Maintenance Planning

*Planning offers us a systematic method of equipment reliability improvement*



Solving production problems and improving equipment drives the reliability growth strategy. The goal is to build high production process reliability, which you see as high equipment availability in the operation. Those strategies become maintenance actions the Planner develops and puts into place.



By doing it that way it allows the effect of historical equipment problems to be put in perspective. If the faults have continued to occur their impact on the operation can be seen and a decision can be made to address the problem in some suitable fashion.

If modifications and changes done in the past were successful then the problem can be seen to have disappeared. By reviewing past history and its impact on the operation it would be easy to justify which issues to transfer into the PM-10 process.

This table is more than a plan! It is a strategy! A strategy to reduce the known production stoppages and to focus the maintenance effort.

Can you see how this would work? You know what has gone wrong with the equipment over the last eight years, it's listed right there in front of you. You can see how effective the past practices, methods and solutions have been. From that you can wisely decide what to do over the next two years to prevent reoccurrence of problems.

Instead of writing the usual 'blue sky' 5 or 10 year maintenance plan that no one believes anyway, you only plan for the believable two years ahead. You write down exactly what can really be done in the foreseeable future to reduce or prevent the real problems.

The plan for the next two years would include proposed modifications, equipment replacements, new condition monitoring plans, etc.

Now that is a great way to make next year's maintenance plan! It would be one that is totally defensible and fully justifiable to upper management because it is well thought out, rooted in getting the best return for your money and based on the important business requirements to continue in operation.

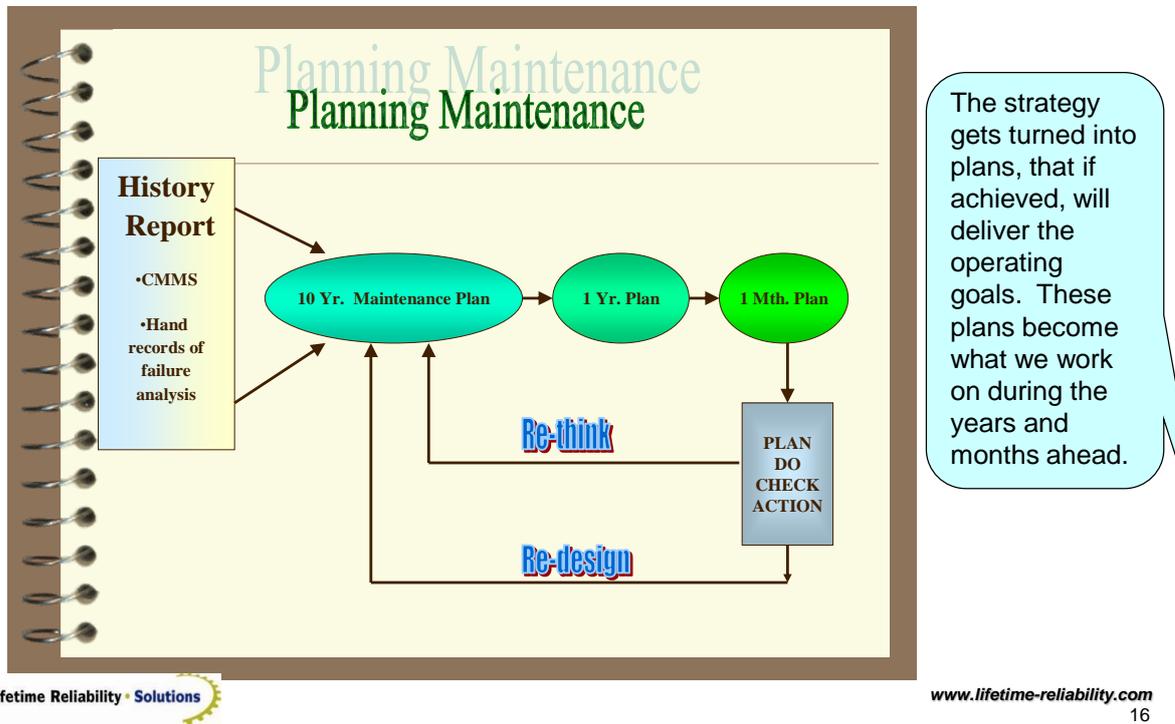
My suggestion to cover the period beyond the next two or three years (and only if it is necessary in your company), is to use the spreadsheet to make forecasts. Project ahead based on what you plan to do in the coming two to three years to fix the current problems. If you aren't going to fix the problems then don't assume less maintenance in the future. Remember that a forecast is not a plan! A forecast is a best-guess suggestion, often known as 'blue sky dreaming'. A plan is a set of action steps that in time produce a desired result. They are totally different to each other.

The great benefit of a PM-10 table is how it ensures that you never forget the past. All the failure history of each item of equipment is always right-in-your-face. If there has been too many failures the truth cannot be evaded. But most importantly the PM010 table lets you change the future. Because in it you can put your plans and actions to create a better future.

On the PM-10 table you show when and what will be done to fix the problems. It provides a visual indicator that drives resource planning, capital expenditure, and maintenance planning activities.

If I were you I would extend the PM-10 into the future for five years and not just two years ahead. I would then include the complete replacement of machines that are at the end of their lives. This would signal to upper management to put money aside in the relevant years to renew the old plant before it starts failing too often. You would have to regularly make the plan public at joint operations and maintenance meetings to get discussion going and to remind those managers present to put moneys into the forecast capital budgets. But proactive communication and foresight is part of a Maintenance Planners job.

# Putting Maintenance Strategy into Action

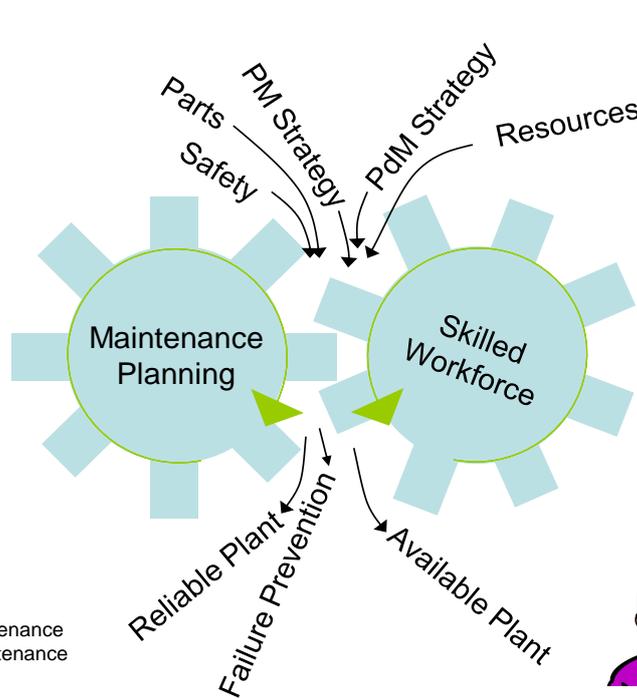


The long-term maintenance plan is a compilation from several sources. These include the PM-10 improvement activities, the computerised maintenance management system (CMMS) preventative maintenance work orders and decisions from equipment failure analyses conducted after equipment failures.

The long-term plan cascades down into the annual plan, which in turn is separated into the monthly plan. The monthly planned work is performed and the self-improvement 'Plan-Do-Check-Action' process is applied to feed improved methods and ideas back into the long-term plan.

# Turn the Planning of Maintenance into a Standardised Business Process

Like maintenance itself, maintenance planning is a risk management strategy used to increase the likelihood of production success, and must be done if you want to reduce equipment failures and maximise business profits.



PM = Preventive Maintenance  
 PdM = Predictive Maintenance

Confucius said, "In all things, success depends on previous preparation, and without such preparation there is sure to be failure."  
 (Analects)

Even 2500 years ago the importance of planning was known to be the major difference between operational success and failure.



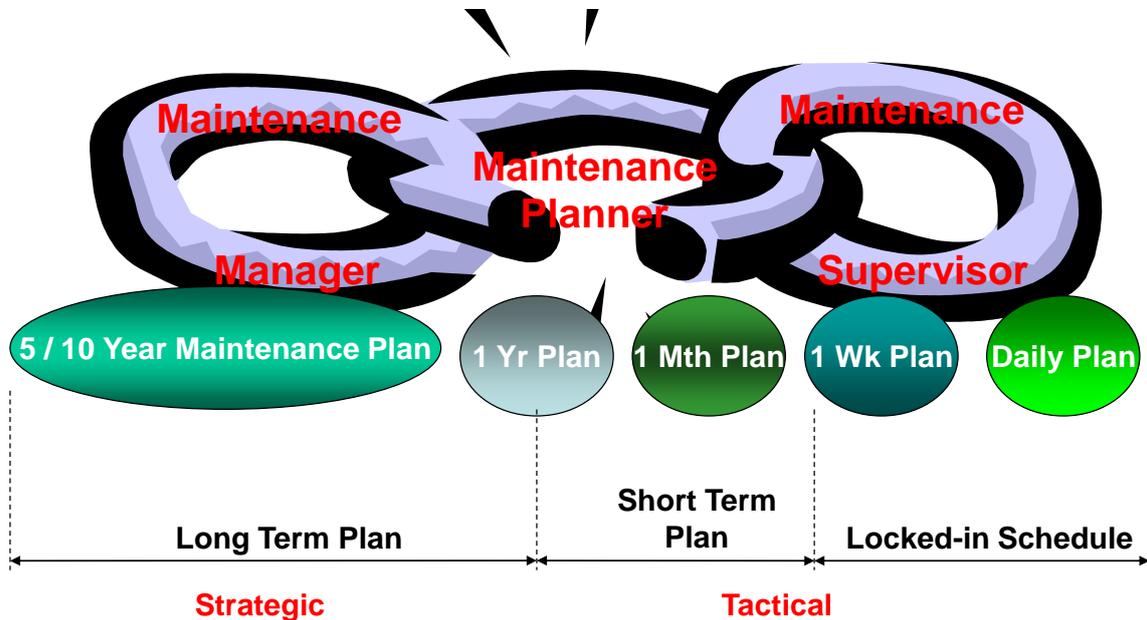
Maintenance Planning performs the service of preparing a business' people and resources to perform maintenance work effectively (doing the right work, rightly) and efficiently (doing the work quickly and accurately).

The success of a job is directly related to how well it was planned and prepared. Follow the 2500 year old advice of Confucius – "In all things success depends on previous preparation, and without such preparation there will be failure."

Planning maintenance is a 'mechanical' process involving standard duties and practices that when performed applies an organisation's asset management strategy to deliver high operating plant and equipment performance. It can be seen as a 'machine like process' that turns the company's asset management strategy, resources and systems into well operating, highly reliable plant and equipment.

In order to foster and support this sort of thinking it is necessary that senior management first approve and condone the resulting necessary actions by writing an appropriate policy and publicly stating their intention and support for it.

## Maintenance Planners covert strategy into actions that the crew does to deliver the objective



The Maintenance Planner is the link between corporate asset life-cycle management strategy and the workforce. They are the person responsible to convert plans into actions that people use to deliver the objectives.

No one tells you that the **real role of the Maintenance Planner** is to put the maintenance strategy into practice.

How's that Joe?

The person who does Maintenance Planning has to ensure that the maintenance strategy is turned into the right actions at the workforce. They are the link between what the organization wants done and what will actually happen to the machinery. **Maintenance success is (ultimately) determined by decisions of maintainers and supervisors.** The Planner ensures the right information and methods are used to make the right decisions.

Now, ... do you remember what the other key purpose was for the Maintenance Planning role?

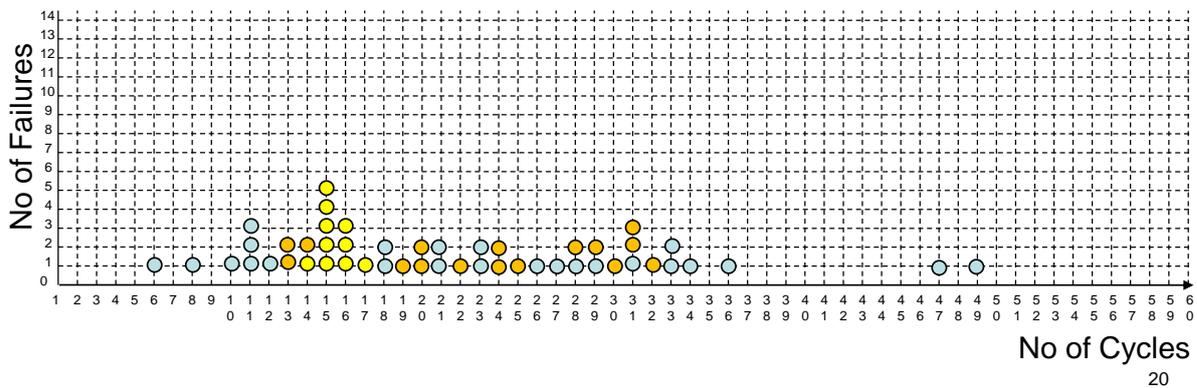
It's burnt into my memory – least 'tool time'!

So you were paying attention.

## Activity: Paper Clip Failure Distribution



- 1) Each person works a paper clip and counts the number of full cycles until it breaks (*from start point and back again is a cycle*).
- 2) Develop a distribution for the group of the cycles to failure counts
- 3) Under the Instructors direction repeat the paper clip failure exercise and plot the new distribution



This activity involves letting people break a 33mm long paper clip, like the one in the slide. The activity has several purposes. One is to show people what a distribution looks like. Second is to talk to the audience about variation. Third is to explain metal fatigue and how it happens (after all, machines are made of parts constructed from metal, and what happens to the paper clip is also what happens to machine parts). Fourth is to get people discussing the use and value of standardised processes and procedures.

The activity starts by getting everyone in the audience to break a paper clip by cold working it until it snaps. They count how many fatigue cycles it takes them to snap their clip and each person's count is plotted on the chart. The blue dots are used to show each value from the first failure tests. The range of values forms a wide distribution.

Next the Instructor bends and breaks several clips for the audience to see. The Instructor applies only bending action to the clip in a standardised way. Because they break the clips using the same method every time they create a narrow distribution. The yellow dots are used to show the Instructor's distribution.

The audience are again asked to break another paper clip but this time to do it in exactly the same way as was done by the Instructor. The orange dots are used to show the new distribution from the audience.

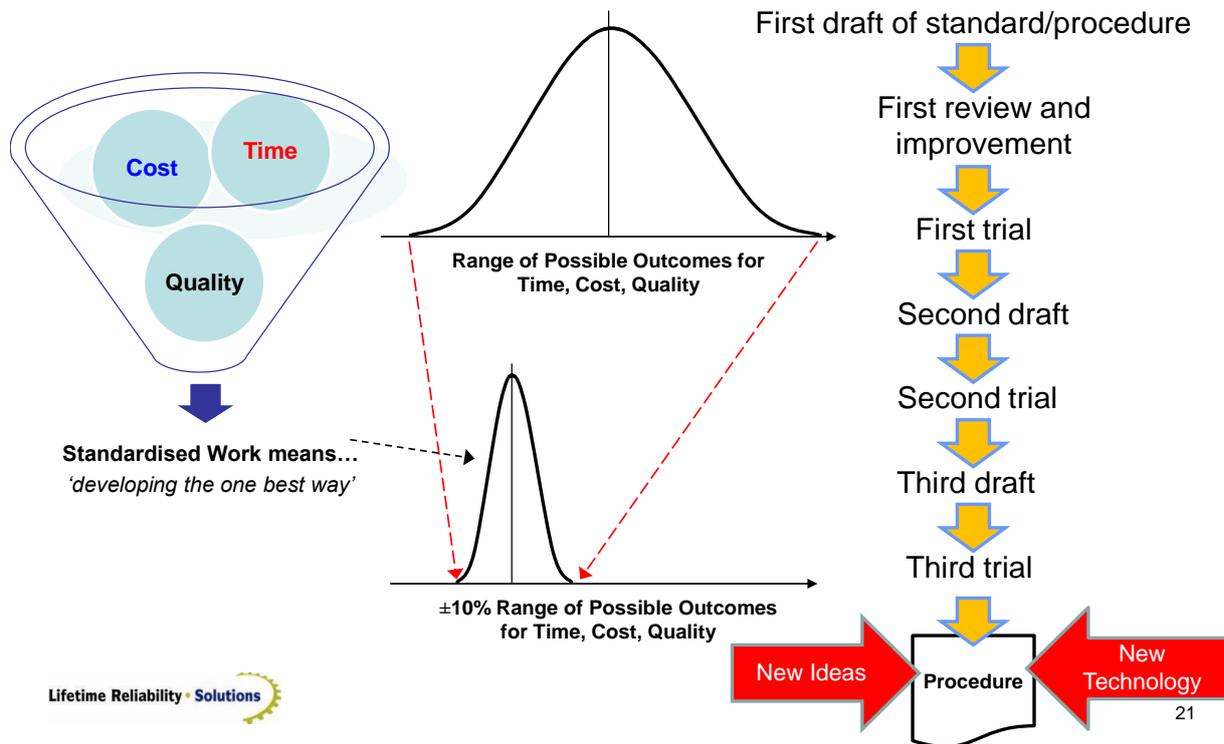
Discussion is initiated by the Instructor as to what happened in each case that caused the three different distributions.

The important take-away from the activity is that the distribution of results is malleable by the use of specific instructions that are exactly followed by the people using them. It is vital when a company wants to control an outcome that there are specific instructions on how that outcome is

achieved, and that the people doing it are trained and well practiced in exactly how to do the instructions correctly.

When you have complete and clear instructions that will produce a certain outcome, it is easy to identify that a problem exists when the result is not within the distribution that the instructions are known to produce. If the outcome is outside the expected result it must be because the instructions were not done correctly. Once you see an outlier (the name for points falling outside the expected distribution) you have reason to investigate the cause and correct it.

## Standardised Work Limits Variability



You want to do work in a standard way that removes variation and creates a narrow distribution of results. When you do that you put the work into a controlled and controllable environment. Once you find that ‘best way’ of doing the job you want to make sure that it is always done the same way every time by everyone that does it. By standardising work you aim to produce a repeatable outcome every time it is done regardless of who does the task.

As soon as there is work to be done the question that arises is ‘How to do it quickly and well?’ Time and quality are important, but equally important is the cost to do the work. You know from the Value Stream Concept that we only want to do activities that add value. We also know that removing ‘waste’ activities reduces the cost because time is not spent doing them. To have least cost work, done in the least time and at the right quality requires you to find the very best way to do the job that gives you all three.

The first time any instruction is written it can never be perfect. We will do our best to ensure that it is right, even to the point of getting a competent, independent person to review it and improve it. But the first draft is just what it is—our first attempt to explain what needs to be done. It is only by using it and improving it through use that it will eventually become a brilliant document that always delivers the right result every time it is used.

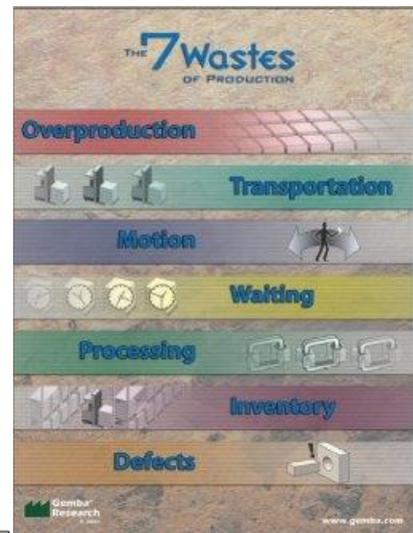
Output variation is either the natural result of using a particular process (called common cause variation because it was inherent, common, to a process) or caused by factors external of the process changing its performance (special cause variation because they were identifiable as a particular problem special to a situation). The extent of the output spread is dependent on the amount of volatility permitted in a process. If many methods of work were allowed, each introduces its own effects. Each new method causes the final process output to be slightly different to that of the other methods. But when one standard method is used the outputs are less variable. The difference in output distribution between a standardised method and the use of any method is shown in the Figure. Standardisation reduced variation.

## Standardise the Work to Get Control

Purpose of Standardised Work is to **eliminate person-to-person variability** and follow 'one best practice' way to do each job.

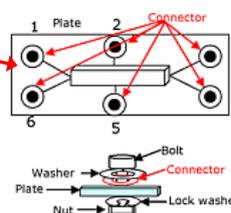
Have a **precise description of each work activity** specifying task accuracy, cycle time, the work sequence of specific tasks, the parts on-hand and tools needed to conduct the activity expertly.

- Find the **best-practice method** of doing work (individual job, jobs in a team, jobs in a process)
- Have everyone doing jobs **do them in the same standard way** (take the variability out of the person-to-person aspect of each job)
- Ask people to help **continuously improve** how all jobs are done (seek higher quality and productivity)



**YOU STANDARDISE WORK WITH DETAILED PROCEDURES**

*"This is the best way we have found to do this job right every time!"*



Your Job Procedures must have only one way to do a thing – the standard way and no other way.

Your procedures and work instructions must be complete in detail so that there is no guess work required of its users. That does not mean that you are stuck with them the way they are presently written. Standardized Work is all about finding better, faster, cheaper ways of doing the same job. Standardized Work is making continuous improvement real. It is about getting rid of the unnecessary and refining work to just those activities that deliver the right outcome as quickly as possible. Once a method is standardised, the use of any other method is an external special cause factor, easily identified and corrected by training if it produces volatility, and gladly accepted into standardised practice if it reduces volatility. Standardisation is about making quality outcomes 'the way that we do things around here'.

# The Value Stream Concept

**Waste when Mounting a Part on a Truck Chassis**

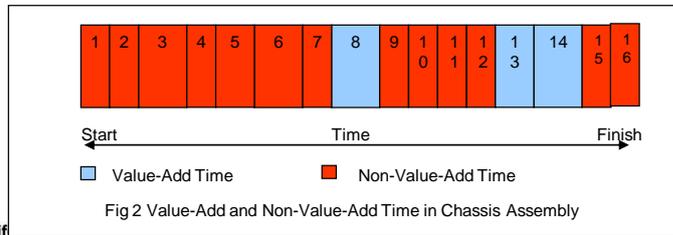
1 Drop carton of components at assembly line	Start
2 Walk 8 meters to pick-up components	10 sec
3 Remove carton wrap to expose components	60 sec
4 Reach into carton and grab components	20 sec
5 Orient components so they can be picked up	60 sec
6 Pick up bolts for component	15 sec
7 Walk 8 meters to the chassis on the assembly line	10 sec
8 <b>Position components on the chassis</b>	<b>20 sec</b>
9 Walk to power tool	5 sec
10 Reach for power tool	5 sec
11 Walk and pull tool to component on the chassis	10 sec
12 Bring power tool down to component	5 sec
13 <b>Place bolts in the component</b>	<b>20 sec</b>
14 <b>Tighten bolts to the chassis with power tool</b>	<b>15 sec</b>
15 Place power tool on bench	10 sec
16 Walk 8 meters to pick-up next components	10 sec
	275 sec

Fig 1 Waste in a Truck Chassis Assembly Process

**“Would the Customer be less satisfied with the product if this step were left out?”**

## The 7 LEAN Wastes

- 1 Overproduction:** Producing items for which there are no orders.
- 2 Waiting Time:** Employees standing about. Inventory at stand-still.
- 3 Unnecessary Transport:** Moving material unnecessarily or long distances.
- 4 Over-processing:** Using more steps to produce a product than necessary.
- 5 Excess Inventory:** Retaining unnecessary inventory between process steps.
- 6 Unnecessary Movement:** Any wasted motion by man or machine.
- 7 Defect:** Making incorrect product.



Awareness of value-adding and non-value-adding is important in Maintenance Planning. After all, the Maintenance Planner’s prime roles is to use the maintenance crew effectively to get through the work quickly while doing it well; very, very well.

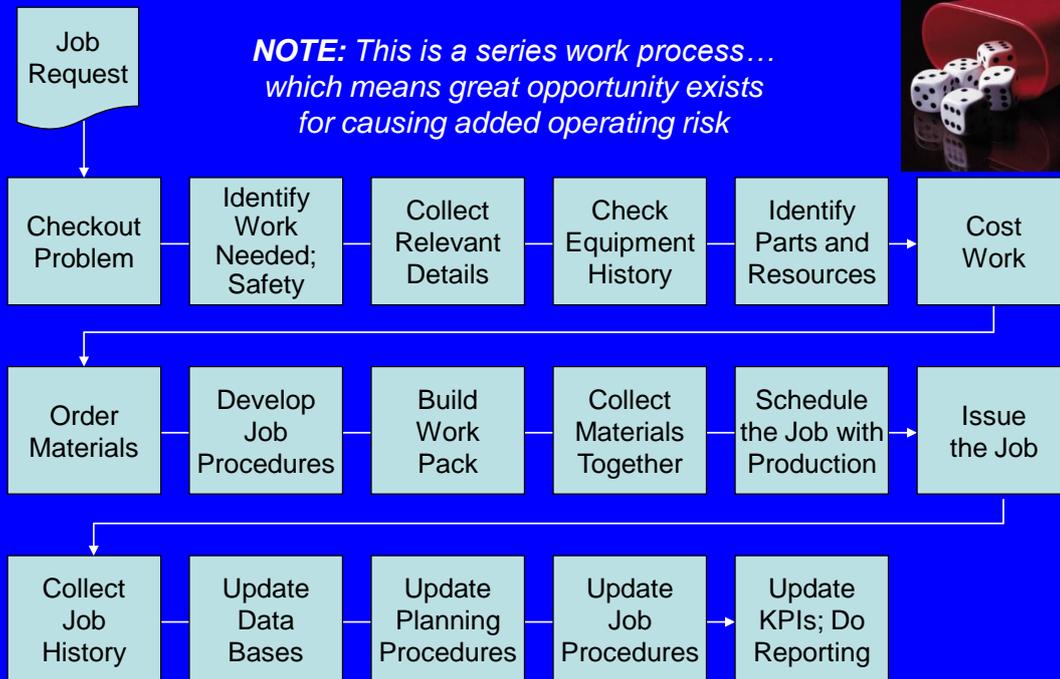
Put simply, the Value Stream Concept is about recognising what adds worth and what is waste, and then removing as much waste as possible.

The slide shows ‘standing in the circle’ observations of a person working on building a truck chassis. If you watched this person they would be very busy. They would be over here, over there, going from one thing to another, always on the move. Unfortunately that movement and energy does not build the truck. Only three activities out of the entire list, 55 seconds out of nearly five minutes of work, builds the truck—the rest is wasted time, movement and cost.

Value is from the customer’s perspective, the customer being the person who uses the output. Value-adding actions and resources are those which create value for the customer. Non-value-adding is everything done in the process which contributes no value for the customer but which they are forced to pay for when they buy the product or service. Figures 1 and 2 shows a situation in a truck chassis assembly process where value is added and lost for the customer. Necessary non-value-adding are those actions in a process that must be done to make the product but create no value for the customer. Unnecessary non-value-adding is removed and necessary non-value-adding is minimised to the least possible.

Maintenance work is renowned for its huge proportion of wasted time and inefficient activities. The world class Maintenance Planner understands what Value Adding means and is always striving to remove waste from the maintenance delivery and workplace processes.

# The Planning/Scheduling Workflow Process

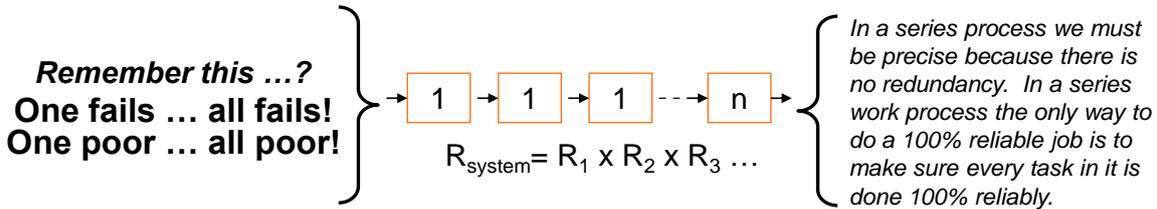


This slide summarizes the Maintenance Planning/Scheduling process. It is obvious that planning is a series work process. It must be managed and controlled if you want to prevent variation from increasing the operating risk.

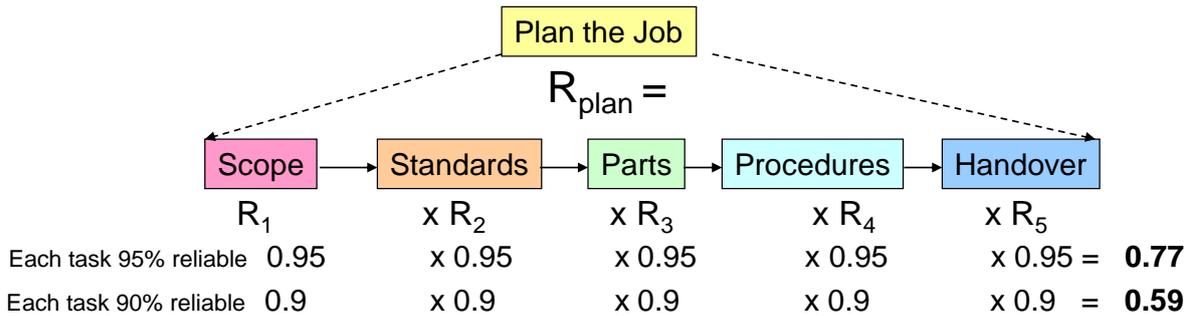
Without a detailed planning process flowcharted and fully described in a planning procedure there will be too many variations in how the planning is done. If there is no procedure people will make-up their own, which will not be complete, or thorough enough, to ensure good quality work is done on the plant and equipment. Once you have a procedure you can look closely at it and strip-out all the non-value adding actions, to make it streamlined, quick and effective.

With one 'standard way' to do planning every planner in an operation focuses on how to improve it. Instead of having every planner doing planning as they think is right, but in fact producing more and more variations, you have every planner thinking how to do the one way faster and better. With one planning procedure you 'trap' the best ideas for everyone to use.

# Planning is a Process and needs Control



## Planning is a series process.



Because planning is a series process, the task variability problem needs a work system that standardizes what to do, and how to do it. This makes planning repeatable and reliable. **The 'planning system' comprises the accumulated planning procedures.**

The slide breaks an imaginary planning job down into five tasks. The tasks form a sequential process. In a sequential process the overall reliability is the multiplication of the individual step reliabilities. If the reliability (the chance of it working right) in one step is low, then the entire process' reliability is low. When maintenance planners do their work they are completing a series of sequential steps. Any wrongly performed step makes the whole job wrong. This is reason why it is important to plan work carefully and fully using a planning procedure and then train people to do their work precisely – so that the reliability of all planning tasks is 100% and hence the maintenance job outcome is given 100% chance of being done right

Measurement of the chance of business or job success requires probability. Probability maths can get very involved, but we require only a simple level of math to measure the chance of getting business processes and jobs right. If a Task has a 100% chance of perfect work its probability of success is 1. If it is done right 50% of the time, then has a 0.5 probability of success. Equation 1.1 is used to calculate the job reliability, which is the chance of doing our five-step process successfully. The underscore below the 'R' acts to differentiate the modelling of work process reliability from component or system reliability (which does not use the underscore).

$$\underline{R}_{job} = \underline{R}_1 \times \underline{R}_2 \times \underline{R}_3 \times \underline{R}_4 \times \underline{R}_5 \quad Eq. 1.1$$

Even at 90% certainty for each task, the chance that the job is right is a poor 59%. The job goes wrong 41 times out of every 100 times it is done. If this job were twelve tasks in length, its reliability would be 0.28. In other words, it would go wrong 72 times for every 100 times it was done. For the sake of the example, say every task is perfect except Task 3, which is correct 60% of the time. The reliability of the job now is:

$$R_{job} = 1 \times 1 \times 0.6 \times 1 \times 1 = 0.6 \text{ (or 60\%)}$$

The chance of doing the whole job right is just 60%. The chance of a job being done right is never more than that of the worst performed task. To do a job properly needs every task to be 100% perfect. In a series process, if one step is wrong, the whole process is wrong; if one step is poor, the whole process is poor. This applies to every series arrangement, including production processes, machines, supply chains, jobs, businesses and maintenance planning. It explains why production plants have so many problems – it only takes one part to fail in one machine and the whole plant stops.

## Planning System Necessities

You need to build information management and inventory systems that let you bring all the details together fast. Turn the bullet points in this list into the standardised procedures that you follow.



- Standardised Planning Work Process
- Information Database Management System *(can be computerised)*
- Purchasing Specifications
- Inventory Management
- Job Plans and Job Procedures
- Work Order Costing
- Plant and Equipment Information
- Planning Documents and their Control
- Equipment Records and their Control
- Job History Records and their Control
- Equipment Performance Trending
- Job Performance Trending
- Track Planning Performance & Benefits
- Job, Work and Personnel Safety
- Planning System Maintenance

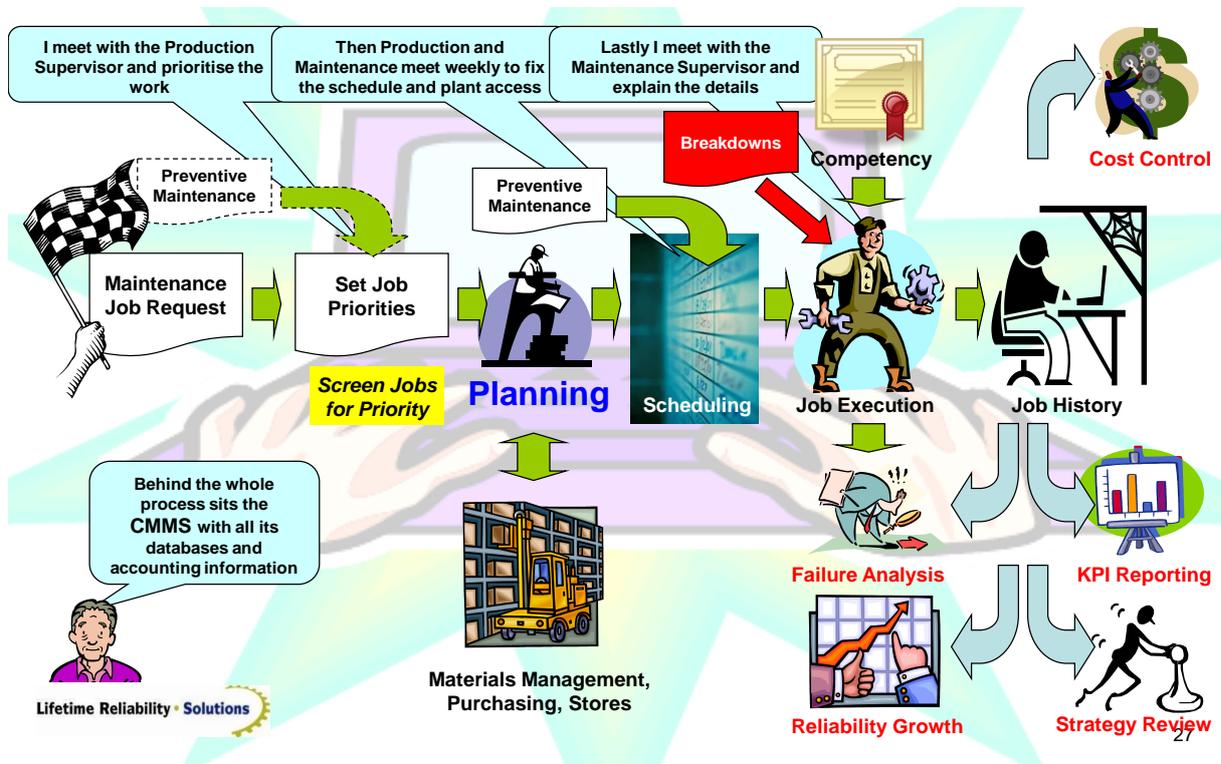
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This slide summarizes the processes Maintenance Planners need at their disposal in a maintenance planning systems. Each part of the system will need to contain full and accurate details that can be instantly put to use. These system requirements may take several months to develop as information is added from numerous and various planning tasks the Planner will conduct. In time, the system will be highly valuable to the organization and to all the planners that follow.

Each system requirement listed will need to have a written procedure explaining in detail what it contains, how it works and how to use it. Unless you have written procedures to explain the system to people they will do what they think is best and eventually the planning system will fail and become unusable because there will be so many variations. Always have a comprehensive ‘user guide’ (i.e. full content and well written procedures) so you can train people how to do things rightly.

You only have a usable system when you have solid procedures that explains it to everyone else.

## Standardised Maintenance Work Management Process



Work Management is standardising your processes so that there is only one system used to handle all maintenance work. This prevents multiple methods developing, causing confusion and waste. Because maintenance is a timely activity, where time is of the essence using limited resources, it is particularly important that a systematic approach be developed and adopted by everyone.

Maintenance workflow management needs to be designed to give total consistency and uniformity in how the work process is done, and to provide some measurement points along the way for monitoring. The first task is to establish a shared need in the operation to have a simple, common approach to doing maintenance, and to agree on the goals and key elements of the Work Management process. The slide highlights the key components and requirements of a typical maintenance work process.

The aim being to always do maintenance in a controlled way for sustainable improvement in equipment reliability. Some of the elements of the diagram are listed below.

- Maintenance Request comes into the system
- Prioritise the Maintenance Job Request
- Notification approval
- Planning Jobs
- PM Work Order initiation (Will it go straight to scheduling, or will the Planner review each PM? Remember, you want 'right-first-time'.)
- Scheduling Jobs
- Execution & History Collection
- Breakdown Management
- Performance Management (using the data collected)
  - KPI reporting

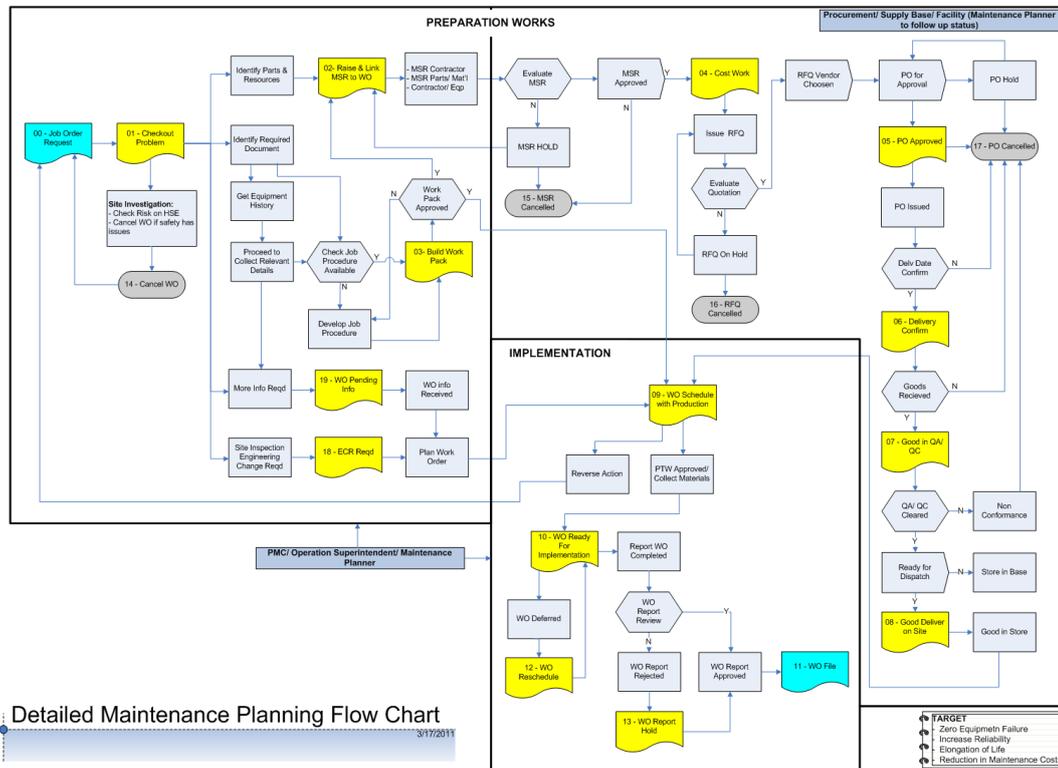
- Failure Analysis
- Maintenance Strategy Review
- Budgeting and Cost Control

Underneath the overall diagram there are more detailed documents defining the system and each step, along with training and competency assessment systems.

The slide is really about your own planning process and not about getting work orders completed. As a Planner you must also follow a designed process to do your work. Exactly how will you go about building a full and thorough work pack? That is the real purpose of having a documented process.

In terms of how that fits with the overall Work Management Process, you need to create a specific procedure and flow chart that covers just how to do the Planning of maintenance work and not anything else (one each for weekly planning and for shutdown planning).

## A Maintenance Planning Process Flowchart



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What you explain in your flow charts and procedures is the standardised way to do planning in your operation. You need to cover such things as: what you do for work order planning from scope out, through to job plan creation, trades selection and setting activity times, work plan reviews, through to purchasing services/components, the storage of parts and materials awaiting work allocation, allocating parts to jobs, etc. Since your 'product' is the work pack you need to design and describe what must be done to properly produce that work pack.

The planning procedure becomes it part of your company's document management system.

By the way, yes, you are responsible to make your system work better and if that means training people and teaching them what they need to know and do well, then it falls to you to do that.

## Scoping-out a Job

1. Start with a written work request
2. Check the details on the request are correct
3. Talk to the Requester and get their version of events
4. Go to the job site and view for yourself (or send an experienced technician)
5. Scope the job as if you will be doing it
6. Use a standard scope-out form that uses keywords to trigger thoughts, enquiries and information needs
7. Collect together engineering data, drawings and equipment history to review for critical information
8. Is there Opportunity Maintenance to be done?
9. Write necessary job details into the Work Order
10. Set the standards and develop the Job Procedure for the work



To scope a job means to investigate and consider how it will be done safely and timely. Scope-out is the responsibility of the Planner and ideally the Planner does the scope, which means they need to be highly knowledgeable of the equipment construction and the production process it is used in. If the Planner cannot do the scope then someone else knowledgeable in the plant and process does the scope-out on their behalf.

## Activity 5 – *Standardise Your Maintenance Planning Process from the Start*

Develop Scope-out guidewords to capture all necessary details for individual job tasks and their associated requirements

### *Review and Discussion of Activity 5*

The activity involves developing a job scope-out check sheet for the maintenance of a piece of equipment. People are to write two or three word titles that represent all the issues that they would need to consider and address when compiling a work pack to pass to the maintainers.

This Activity is intended to achieve two purposes. The first is to set a base line from which to measure the completeness and effectiveness of the work scope-out process.

The second purpose is to draw out all the fine details that should be included in the work pack. The aim being to recognise the need to have fully detailed, clear and accurate work packs, and to recognise the need to set-up processes that will allow planners to quickly gather together all necessary job details to develop complete and well-costed work packs that their maintenance people will need to do the job properly.

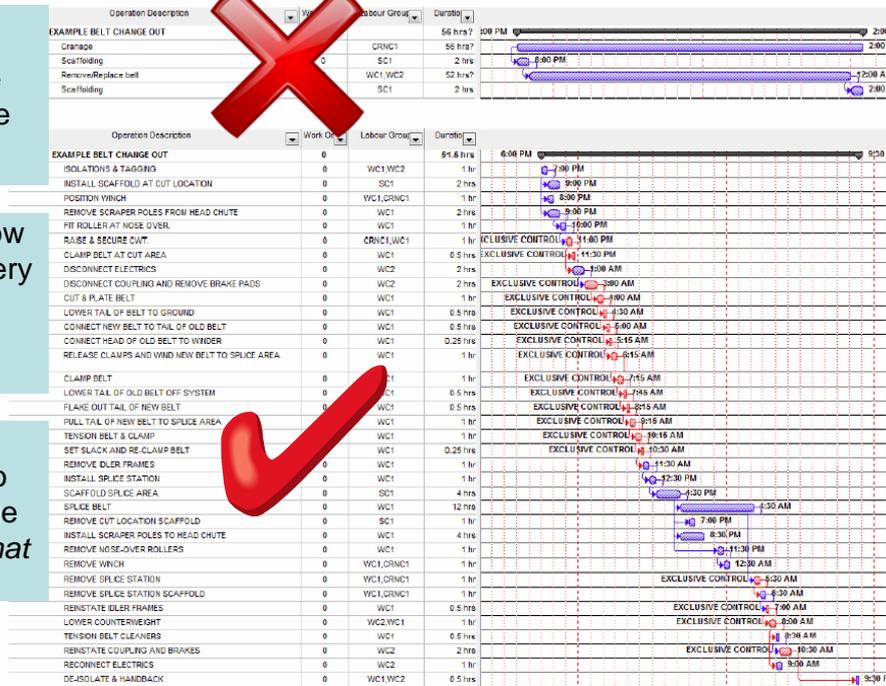


# A Maintenance Job Plan Lists Every Job Task along with Every Milestone Activity

You cannot have a 52 hour long maintenance task—nor can you have a one hour long task.

Everyone needs to know what will happen at every step during a job, no matter if the job is one hour or 52 hours long.

Use a maximum of 30 minute long activities so maintainers self-manage to deadlines—and so that they can be managed!



To get the degree of control needed when doing maintenance work you need a job planned out step-by-step in no more than 30 minute intervals—15 minute intervals would be better.

List every task down on the job plan in the sequence the work will flow. For each task list all its milestone activities. If necessary invent suitable milestones so that there are benchmark performance measures against which to track progress.

This will prevent you from skipping over what seems to be simple and unimportant information that you think others should already know. Your plan is the only time that someone will think through the job in great detail, and if you miss anything important there is a very good chance that the job will go badly when it is done because the work plan does not work.

With a job plan that has tasks and activities which are no longer than 30 minute intervals you can walk out to the work face and see how the job is going. As soon as you check progress against the plan you immediately know its completion status. If at the time of your visit the job is running late—i.e. it is behind where it is scheduled to be—you know it straight away and can act to address the problem.

Analyse the repair time recorded on maintenance work orders (also known as Mean Time To Repair – MTTR). Long repair times mean equipment was not available for production. Where the average times to do a job varies greatly, an investigation and analysis of the work order times will identify problems and allow people to propose solutions for issues affecting the work. It is always useful to meet after a job goes particularly well, or particularly poorly, to learn its lessons and include them into the work procedure and then do necessary training.

## Job Plan to ±10% Cost and Time Accuracy

*(Detailed in full in the Planning Procedure with process flow diagrams and descriptions)*

To control a maintenance job, you need to remove the risk of things going wrong and encourage those outcomes that need to be done right. This needs a detailed job plan.

	Task	Time minutes Best/Worst	By	Cost Best/Worst	Comments
<b>Job: Replace Impeller on Process Chemical Pump R987</b>					
<b>Line of Sight Map from Start to End</b>	Plan and prepare work pack	60/90	Planner	\$150/\$225	
	Materials in Store rack Bin 3C day prior	30/45	Storeman	\$1,500	Parts listed on WO M2435
	Pick-up parts from Store Bin 3C	15/25	Tech	\$30/40	Check all parts against WO
	Local Hazard Analysis (Process Plant Pump)	15/20	Tech	\$30/40	'Take 5' in Work Pack
	Bunting, floor protection, rubbish bin	15/20	Tech	\$30/40	Store provides in Bin 3C
	Isolations (6 valves, 2 power supplies)	30/40	Operator	\$60/80	Procedure I26 in Work Pack, Tags by Control Rm Super
	Drain pump and piping	20/30	Op & Tech	\$40/50	Acid PPE
	Handover	10/15	Op & Tech	\$15/20	Permit by Control Rm Super
	Undo suction flange	15/20	Tech	\$30/40	Procedure F03 in Work Pack
	Lifetime Reli:	Etc, Etc, Etc			

A job plan lists the milestones to complete a job from start to finish. It must be detailed enough to provide a line-of-sight map/plan to get through all the work in the correct way and proper order. Each maintenance job requires planning in detail to identify possible problems and put into place the actions and responsibilities needed to ensure the work goes right.

The way I do job plans is different because my job plans show and cost all the resources needed to turn a job request into a completed job. That includes putting down the Planner's time to collate the work pack, Operator time for isolations and handover, Storeman time to get parts together for the job, along with the time and cost needed for all manpower resources used in doing the work order.

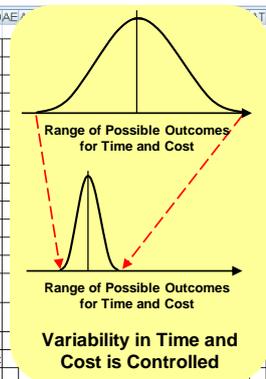
This is the correct way to think about planning work. A business will pay for all costs. The work plan has to reflect with ±10% accuracy in costs and time how the job will be completed. It must show what needs to be done by which resources at what time and for what duration. Every action and every cost needs to be known for each and every task and activity in a job.

I disagree wholeheartedly with only using a single time estimate for an activity. No job will ever be done exactly on time, to the minute. It is more meaningful to know the spread of times from worst outcome to best outcome. Once you see the distribution you recognize if a task is highly variable. Those tasks with wide distributions must be looked at more closely because the size of the distribution indicates complexity and risk of unknown problems. The Planner's role is to reduce the uncertainty so that at the end of the whole job it is completed to within ±30 minutes of schedule.

Once time estimates are accurate to within ±30 minutes then budgeted job costs can be accurate to within ±10% of actual costs.

# Provide enough details so the Job ends within $\pm 30$ minutes of scheduled completion

Task ID	Task	By	Time (30 minute increments)
<b>Day 1</b>			
<b>REMOVE</b>			
P10-1	Isolation Permits	Operator	6am Isolation Permits
P10-2	Check Isolations and Handover	Pump Tech	6am Isolations and Handover
P10-3	Job Safety Analysis	Pump Tech	6.30am Job Safety Analysis
P10-4	Rack-out pump at MCC	Electrician	6.30am Rack-out pump
P10-5	Disconnect power cable at motor	Electrician	6.30am Disconnect power cable
P10-6	Pre-removal inspection of pump set and base, record as found condition	Pump Tech	7am Pre-removal inspection
P10-7	Remove pumpset off plinth and take to workshop	Pump Tech	7.30am Remove pumpset off plinth
<b>RESTORE condition</b>			
P10-8	Separate major assemblies, record as-found condition	Pump Tech	8.30am Separate major assemblies
P10-9	Strip bearing housing, refurbish as-new, record as-found condition, record as-built condition	Pump Tech	9.30am Strip bearing housing
P10-10	Strip wet end, refurbish as-new, record as-found condition, record as-built condition	Pump Tech	11am Strip wet end
P10-11	Test motor electrical condition, record as-found condition	Electrician	11am Test motor electrical condition
P10-12	Reassemble pump set on base	Pump Tech	1.30pm Reassemble pump set
<b>REPLACE</b>			
P10-13	Replace pump set on plinth	Pump Tech	2.30pm Replace pump set on plinth
<b>Day 2</b>			
P10-14	Align pump and motor	Pump Tech	6am Align pump and motor
P10-15	Reconnect power cable to motor	Electrician	9pm Reconnect power
P10-16	Power at MCC	Electrician	9.30am Power at MCC
P10-17	Bump-test motor direction	Electrician	9.30am Bump-test motor direction
P10-18	Remove Isolations	Pump Tech	10am Remove Isolations
P10-19	Handback, complete permits	Pump Tech	10am Handback, complete permits
P10-20	Recommission to commissioning plan, record performance data	Operator	10.30am Recommision
P10-21	Base-line bearing vibration readings, record VA data	CM Tech	11.30am Base-line bearing vibration
P10-22	Operator accept plant back	Operator	11.30am Operator accept plant back
P10-23	Complete work order close-out and records	Pump Tech	11.30am Complete work order



**Now you know exactly how the job is meant to run, how long it will take, and when it is in trouble...**



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A job schedule itself is a timeline of the tasks involved in doing a job from the first minute of job preparation to the last minute of the record completion. The job schedule lists the detail necessary to track the job progress and makes clear the responsibilities of the persons involved. Full details of each task is in the work pack documentation.

The Job Schedule is laid out into three broad sections – REMOVE, RESTORE, REPLACE. The value of this is that the progress of a job can be quickly categorised. If many jobs are being tracked their progress can all be identified on a bar chart by advising the category which each job is currently at.

Colour coding trades and resources helps to quickly appraise the workface situation and identify discrepancies. Once problems are found the role of supervision is to address the issues and get the work back on schedule.

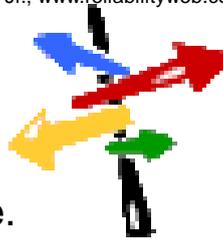
Without better than  $\pm 30$  minute accuracy on each work order completion it will be impossible to control the allocation of people to do work or to schedule work for each day with a high degree of certainty that it will be done that day. If work order time estimates are unreliable then the scheduling will always be wrong and no one will trust or believe what is on the schedule.

A Maintenance Planner cannot estimate jobs with  $\pm 30$  minutes completion accuracy unless they know what each task in the job entails. Planners who do not know the equipment being worked on, and/or the job that they are planning, must get advice from those people that can deliver  $\pm 30$  minutes job completion accuracy. That often means the crew supervisor and/or the maintainer doing the job will need to be asked by the Planner to assistance in planning the work.

# You Do Need Detailed Job Procedures

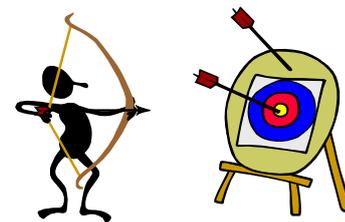
**“The more detailed the procedures and the more insistence on compliance with procedures an organisation becomes, the more precise and less error prone its maintenance will be.”** Jack Nicholas Jr., [www.reliabilityweb.com](http://www.reliabilityweb.com)

This is where the Maintenance Planner makes the greatest difference for their people.



Help them to do expert work done faultlessly with world-class Job Procedures full of world-class content.

*The Maintenance Planner also gets **procedures written by their people.** From now on get every job documented by the technician as they do it. Ask them to also note how they know each task they do is done right. Whether 12 tasks long or 75 tasks long... record it all into a procedure.*



It's an incredibly wonderful and satisfying feeling when you do great work. Great work happens when you do a job expertly, to best-of-class standards. A Maintenance Planner can help their maintenance crew be world-class by developing world class job procedures.

You need to understand that Job Procedures are very special documents that play a most important role in the eventual success of your organization. Job Procedures let you write the script that everyone follows. If you want world-class performance in your operation, then write your Job Procedures with world-class content to world-class quality. It is as simple as that. Once you have world-class procedures, train your people to them so they can deliver world-class performance. If you have a team of world-class performers doing world-class workmanship, you will soon have a world-class performing business.

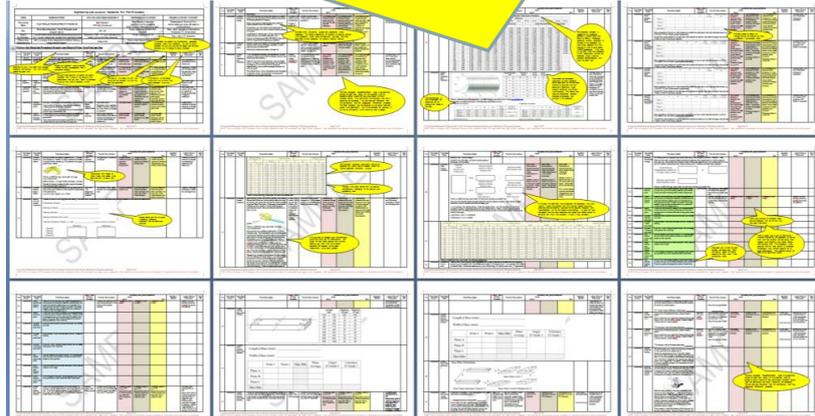
We will talk more later about how to produce world-class job procedures.

# A Job Plan is Not a Job Procedure

1. Prepare for Job in Dirt-Free Work Area
2. Safe Isolation and Handover
3. Check Parts and Materials are Correct
4. Access Plummer Block and Bearings
5. Check Shaft Condition and Tolerance
6. Measure Bearing Internal Clearance
7. Measure Plummer Base Plate Accuracy
8. Locate Bearings on Shaft
9. Mount Bearings on Shaft
10. Position Plummer Blocks and Place Pulley
11. Complete Plummer Block and Seals Assem
12. Align Plummer Blocks
13. Lubricate Bearing and Seals
14. Locate Plummer Blocks and Bolt Down
15. Commission and Test
16. Clean-up and Hand Back

**THE 16-  
MILESTONE  
JOB PLAN  
TO INSTALL  
CONVEYOR  
PULLEY  
BLOCK**

**THE 75-TASK  
ACCURACY  
CONTROLLED  
ENTERPRISE  
3T (Target-  
Tolerance-Test)  
PROCEDURE  
FOR THE JOB**



35

It is very **unlikely** that a person will get the job right if they are not given a detailed procedure with the **right information and engineering measurements** they need at every point throughout the job.

The slide shows you the **75-task job procedure that is needed** for the 16-step job plan to change the taper sleeve mounted spherical roller bearing in Plummer block. Without the job procedure the people doing the work must count on their memory of how to do each job plan step. It is impossible to do a 75 task job from memory and get it right. We solve that problem with ACE 3T procedures.

## **Example of an ACE 3T Procedure (Conveyor Pulley)**

**with reliability standards to install taper spherical roller bearings on adaptor sleeves in Plummer blocks with taconite seals for 30mm-250mm diameter conveyor shafts**

### **Abstract:**

*Example ACE 3T (Target-Tolerance-Test) Procedure with Reliability Standards:* Machine performance is totally dependent on human beings. To address the problem of human error causing equipment failure, an Accuracy Controlled Enterprise sets best practice quality standards and uses 3T Target-Tolerance-Test work task quality control that assures high quality workmanship for high reliability results. Their work procedures are standardised so everyone follows the same methods to produce the same results, their training teaches people how to do craftsmanship work that creates outstandingly reliable plant and machinery. They create the reliability they want and as a result achieve operational excellence.

Keywords: precision job procedures, maintenance work quality assurance,

High equipment reliability requires parts made to precise sizes and assembled to precision standards. Our machines and equipment are dumb, lifeless objects that cannot tell they are suffering and in trouble. They cannot adjust their behaviour when stress and strain gets too much. They just brake and die. It is up to us to make machines work properly by ensuring they are made well and kept healthy. If we want high equipment reliability we need to use the skills, methods and processes that produce high equipment reliability.

Maintenance work processes that deliver better than 3-sigma quality accuracy (7 errors per hundred opportunities for error) are uncommon in industry. Most maintenance and repair work processes range from 2-sigma to 2-1/2-sigma, or 30 to 10 errors respectively per 100 opportunities<sup>1</sup>. You can truly say that due to human error maintenance destroys the equipment that it is meant to maintain reliably. To address that problem an Accuracy Controlled Enterprise creates high quality work procedures full of double-checks and measurable task quality standards that must be met. An example ACE 3T Procedure with work reliability quality standards for mounting spherical roller bearings on shaft adaptor sleeves in Plummer blocks follows.

With an ACE 3T procedure high maintenance work quality is assured. It also brings many other wonderful benefits to organisations that chose to become great at operational excellence. It sets standards that everyone must adhere to, from equipment vendor to subcontractor to employee to professional engineer. It allows workmanship skills to be trained for targeted reliability outcomes. It drives continuous reliability improvement as people reach higher and higher workmanship quality standards and become an Accuracy Controlled Expert. ACE 3T procedures are written at three levels of work quality performance. The lowest work quality level is the best of current site practices; it is 'bronze medal' level performance. The third level is set at world class reliability standards and tells everyone where they need to be if they want to deliver 'gold medal' results reliability (To be that good takes training in precision maintenance skills, use of quality control proof-tests and a mindset that values high quality workmanship.). In-between is the intermediate level, which is a hard stretch target above the best existing level of work quality; it is 'silver medal' standard.

Writing an ACE 3T maintenance procedure takes a lot of research into the fine technical details of what delivers ultra-high reliability, you need to appreciate and understand exacting engineering standards and be able to decide which apply in a situation, it needs a good grasp of the reliability of a design and of materials of construction issues. It is the work of technically competent and engineering knowledgeable persons working together with trade savvy people to create a document that helps technicians to do expert, masterly work first-time, every-time.

Mike Sondalini

[www.lifetime-reliability.com](http://www.lifetime-reliability.com)

<sup>1</sup> Smith, Dr, David J., Reliability, Maintainability and Risk, Seventh Edition, Appendix 6, Elsevier, 2005

## Example Accuracy Controlled Enterprise 3T (Target-Tolerance-Test) Procedure to install taper spherical roller bearings on adaptor sleeves in Plummer blocks with taconite seals for 30-250mm diameter conveyor shafts

It is best to have a procedure for each shaft size because one procedure for multiple sizes ensures that human error will happen at some point. I have covered multiple sizes for the sake of giving you an example of the ACE 3T method. In reality I would use this as a master document and then create each shaft procedure from it.

### Installation Procedure M0234

Work Order Number \_\_\_\_\_

**Description:** Mounting spherical roller bearings of C2, CN, or C3 internal clearance on adaptor sleeve in a Plummer block with taconite seals for  $\phi 30\text{-}\phi 250\text{mm}$  (inclusive) pulley shafts

*Your Responsibility on this Job:* This procedure explains how to properly install a spherical roller bearing with a sleeve adaptor on a shaft. It is vital for the success of this operation that you do quality work that produces long, reliable bearing life measured in decades. You are responsible for the work you do and to use the master craftsman skills such great performance needs.

This procedure is provided for you to follow and to record your actions and findings as you do the job. The completed procedure becomes a record of the job and proof of workmanship quality. It is our current best-practice and includes careful engineering detail and peoples' learning and experience over many years. It is the best way yet found to do the job right-first-time to top-class quality. Follow the tasks described in this document and ask if you are not certain how to get the needed results. We want you do expert work and will help you to do so. If you have a problem that you cannot solve correctly please see your supervisor immediately and do not progress with the job until the issue is properly fixed.

If after you master this procedure you believe that you know of improvements, please bring them forward for discussion. You can test your ideas and compare them to the procedure. If a suggestion proves to be better, it will become the new way to do this job throughout the company.

This information is used for planning and to check what is actually used on the job.

### **Necessary Parts, Equipment and Tools:**

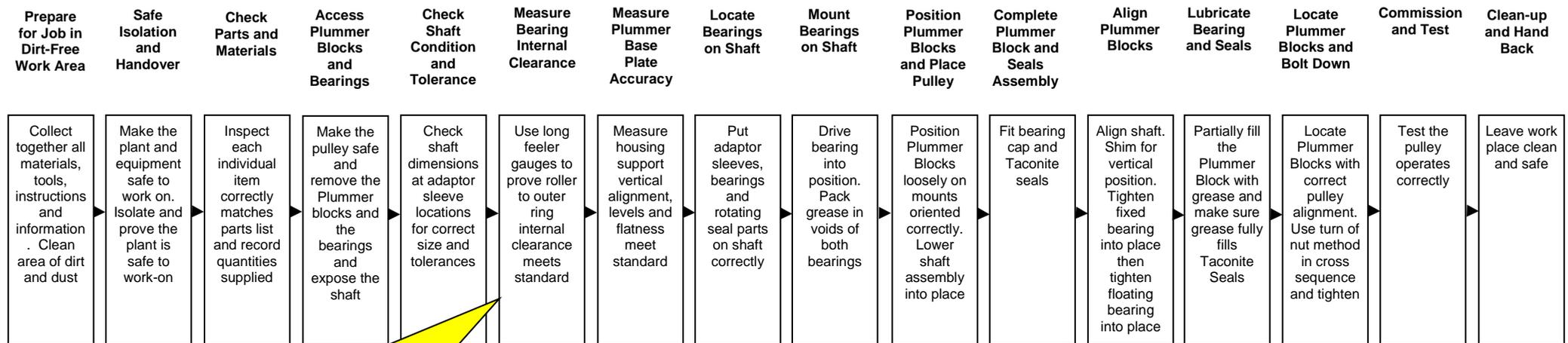
No	Identification Number	Item Description	No for Job	Number Supplied
1	Part ID number	Bearing ,spherical roller, ??mm bore, ??mm wide, 1:12 taper	2	
2	Part ID number	Adaptor sleeve, ??mm bore, 119mm wide, c/w locking tab washer	2	
3	Part ID number	Plummer block, closed, capped end, ??mm shaft, c/w two Taconite seals	1	
4	Part ID number	Plummer block, open, ??mm shaft, c/w one Taconite seals	1	
5	Part ID number	Studs, lengths to suit Plummer block and support base thickness	8	
6	Part ID number	Spacer ring, gap type, ??mm bore	2	
7	Part ID number	M??mm nuts and M?? washers	16	
8	Ring spanners	NOTE: Do not use adjustable shifters and pipe wrenches as they damage corners of bolt heads and nuts making their removal dangerous and unsafe	As required	
9	Part ID number	Shim Set, 316SS, each of 3mm, 2mm, 1mm, 0.6mm thick shims	2	
10	Micrometer/Vernier	??mm to ??mm		
11	Feeler gauges	Long series feelers, 316 stainless steel, 0.02mm thinnest	1	
12	Grease / Oil	?? grade	1kg tube	
13	Mounting Paste	??	1 tube	
14	Bearing remover	Hydraulic oil pressure unit	As required	
15	Hydraulic nut	To suit bearings size (for 80mm and over), Hydraulic oil pressure unit	As required	
16	C-spanner	To suit bearing nut size	As required	
17	Marker pen	Permanent Marker, 0.2 mm, felt tip, black	1	
18	Marker pen	Permanent Marker, 0.2 mm, felt tip, white		
19	Precision edge ruler	Ruler, precision straight edge, 1 meter long	1	
20	Precision level	Level, precision, bubble, 1 meter long	1	
21	Tape measure	Tap measure, 5m long, 19mm wide tape, metric	1	
22	Bearing restrainer	Slotted bearing restrainer c/w bolt for shaft end to stop bearing flying off on hydraulic oil removal	As required	

**NOTE:** This is an example ACE 3T procedure. **Do not use this procedure without the exact details that apply to your equipment.** Each organisation must research, develop and approve all procedures used on their plant and equipment.

**Job Process Summary**

A summary of the work process or job plan for doing the job is shown below. Be familiar with the workflow when preparing to do the job. The fully detailed procedure follows.

## Job Plan of the Process for Installing Spherical Roller Bearings with Adaptor Sleeve in Plummer Blocks with Taconite Seals on a Conveyor Pulley Shaft



The paper size used to print the procedure can be up to A3 size. It should be easy to read text no smaller than 12 point font with space to record measurements and readings clearly

This flow chart is the JOB PLAN. It does several things:

- It is a 'picture' of the job that can be discussed with people
- It makes the job into a process that delivers a measurable output
- You can now build performance KPIs into the process and measure effectiveness
- It allows you to do Lean value stream mapping for efficiency improvements

**NOTE:** This is an example ACE 3T procedure. **Do not use this procedure without the exact details that apply to your equipment.** Each organisation must research, develop and approve all procedures used on their plant and equipment.



**Engineering and Accuracy Standards For This Procedure**

ITEM	DESCRIPTION	STANDARD REQUIREMENT	METHOD and TARGET	TOLERANCE ON TARGET
<b>Mounting Bolts</b>	High Strength Structural Class 8.8 bolt and nut	<b>Bolt Tension</b> 220 kN (minimum)	<b>Bolt Tension Accuracy</b> Use Turn-of-Nut method: Half (1/2) turn from fully snug tight	<b>Tolerance on Turn-of-Nut</b> One twelfth turn over (30°) and nil under half turn
<b>Fits</b>	Hole (Bore Diameter) / Shaft (Diameter under adaptor sleeve)	H8 / h9	Finely machined to ISO 286 tolerance	Stay within respective International Tolerance (IT) Grade limits
<b>Shaft Cylindricity</b>	A three-dimensional geometric tolerance that controls how much a feature can deviate from a perfect cylinder	Defined in ISO 1101 and identical to the mating part cylindricity tolerance	Finely machined to IT5	Stay within IT7 tolerance
<b>Measuring Temperature</b>	Item's average body temperature at time of taking a measurement reading	5C to 35C	Measure item temperature if ambient temperature is outside standard range	Within standard requirements, else cool the item's body temperature to within range

**NOTE:** This is an example ACE 3T procedure. Do not use this procedure without the exact details that apply to your equipment. Each organisation must research, develop and approve all procedures used on their plant and equipment

In this table you specify the internationally accepted standards used in the procedure; you set the quality standard for your site, you set the ACE 3T target and the outer tolerance you will accept for each standard.

**Follow this Detailed Procedure Exactly and Record What You Find and See**

No	Task Step Owner	Task Step Name	Task Description	Matl, Tools & Their Condition	Test for Correctness	Reliability and Quality Standards			Reading / Result	Action if Out of Tolerance	Sign off
						Good	Better	Best			
1.	Technician	4-5 words Prepare for the job	Include diagrams and pictures Prepare for the job together all parts, materials, job work order, equipment danger tags, handover permit, instructions, PPE	Necessary Equip	Inc diagrams and pictures All parts, equipment and tools are on hand before the job	Request and collect issued items from store	Planner arranged all items ready for issue from Store	Planner has items at job ready for use		Only start once all requirements are at the job site	
			Describe the task in full detail and include diagrams and pictures. You want to help people do great work.		Specify the proof-test used to decide whether the task is acceptable and is completed correctly	All items are on-hand and visually inspected	All items are on-hand and visually inspected	All items on-hand & all are pre-certified to specification. A random inspection		Immediately inform the Job Supervisor if the parts are wrong or they are not to specification	
3.	Plant Operator	Make workplace safe	Equipment		You use these columns to specify the quality standards that will deliver the reliability and performance that you want. 'Best' is world-best, which you may have to research to find.					Only start when there is a safe handover	
4.	Technician and Plant Operator	Safe isolation and handover	Contact Operations personnel responsible and place personal danger tags at isolation points and only accept plant handover after proving isolations have de-energised equipment and removed hazards	Danger Tags	Isolation procedure is correctly done and isolations proven safe by testing	Operator and Technician walk process & identify, prove & tag isolation points	Operator previously isolated plant & tagged isolations with out-of-service tag & proves to Technician that the isolation are effective	Operator provides isolation point drawing & walks process with Technician to show prior tagged isolations & prove plant safe for work		Only start when equip is proven safe to work-on & handover procedure is properly completed	
5.	Technician	Position equipment safely	Do Take 5 hazard analysis and address all risks over Low Move and/or lift the pulley into a safe and comfortable working position and chock it into place If possible ensure a line-of-sight between Plummer blocks to allow easy measurement later.	20T Crane, timber chocks, timber blocks	Task done safely. Equipment to be worked-on is firmly secured, unable to fall even if heavily knocked by accident	Task done safely	Task done safely and restraints properly located	Task done safely, restraints properly located and tested to prove safe		Report safety concerns or removal problems or damage to Job Supervisor	
6.	Technician	Match mark and	Before removing any items and stripping the assembly use a white marker to match-mark all parts for identical	Tape	Hand sketch showing measurements from datum or	Measure from datum, record	Measure from datum, record	Measure from datum, record			

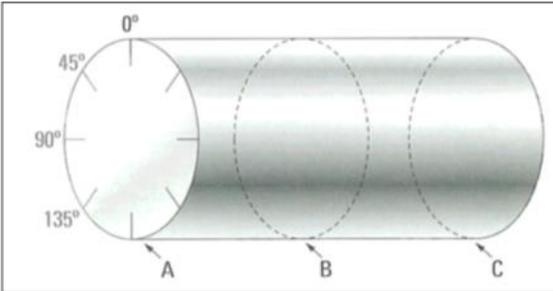


No	Task Step Owner	Task Step Name	Task Description	Matl, Tools & Their Condition	Test for Correctness	Reliability and Quality Standards			Reading / Result	Action if Out of Tolerance	Sign off
						Good	Better	Best			
		measure assembly	reassembly. Take measurements and record the position of all bearing centres from the ends of the shaft as a datum for reassembly.	measure	general assembly drawing with site measurements marked on it	distances	distances and double check	distances and get someone else to double check			
7.	Technician	Remove Plummer blocks	For 80mm bearings and above use hydraulic oil bearing remover to pop the bearing off the adaptor sleeves once the bearing restrainer is in place. Follow the separate instructions for doing hydraulic bearing removal safely and correctly. For bearings less than 80mm use the correct size C-spanner to remove the lock nut once the bearing restrainer is in place. Match-mark all mating parts with the white or black marker for easy and correct reassembly later. Keep all old bearings and DO NOT CLEAN them until after full inspection and reporting on condition	Hydraulic nut remover and C-spanners. Marker – white and	Remove locknut safely without harm to people or equipment	Nuts removed and Plummer blocks removed safely and retained parts cleaned thoroughly	Nuts removed and Plummer blocks removed safely and old parts kept for later inspection and retained parts cleaned thoroughly	Nuts removed and Plummer blocks removed safely. Old parts immediately inspected for evidence of problems and report completed. Completely clean		Report safety concerns or removal problems or damage to Job Supervisor	
8.	Technician	Recover usable parts	Layout all parts to be reused in a dirt-free area in orderly fashion after cleaning thoroughly and safely with de-greasing agent and drying-off. Check part numbers are correct with parts list		All reused parts cleaned spotless, inspected for quality to remain in service and part number identified as correct with parts list	Parts are clean and correct	Parts are clean and correct and tagged with part number	Parts are clean, correct, tagged with part number and double checked for condition			
9.	Technician	Check Shaft Condition and Tolerance	With a micrometer measure the dimensions of the shaft location in three planes where the adaptor sleeves sit and check them for suitability. From the end of the shaft measure to where the adapter sleeve will finally sit and mark the shaft with a black felt tip marker at 0°, 45°, 90° and 135° in the planes corresponding to the ends of the adapter sleeve and its mid-way point. The diagram below shows the positions under the adaptor to measure, along with a table showing the required tolerances that the shaft must meet.	Suitably sized and vernier callipers or micrometer	The section of shaft under the adaptor sleeves simultaneously meets the minimum requirements for shaft tolerance and for taper, roundness and cylindricity grade	Use vernier callipers or micrometer to measure shaft tolerance, taper, roundness and cylindricity are all within tolerance limits	Use vernier callipers or micrometer to measure shaft tolerance, taper, roundness and cylindricity are all within tolerance limits and repeat measurements to confirm results	Use vernier callipers or micrometer to measure shaft tolerance, taper, roundness and cylindricity are all within tolerance limits and get another person to check and confirm the results		Replace shaft with new if maximum limits exceed allowed requirement for shaft tolerance, taper, roundness and cylindricity	

Do attach other instructions, guides and procedures where necessary. To include a description of hydraulic oil bearing removal in this procedure would make the document too large. But there does need to be a procedure for hydraulic bearing removal.

The three standards, Good-Better-Best, need to be identified and set for each task, along with the proof-test and the corrective action should the test prove below minimum standard results. Your technicians and engineers can help in compiling the standards. You can also get information from the manufacturer and from recognised international standards. The 'Best' standard must be approved by the senior technical expert in the organisation, as it is the standard the company is striving for and against which everything else is judged.



No	Task Step Owner	Task Step Name	Task Description	Matl, Tools & Their Condition	Test for Correctness	Reliability and Quality Standards								Reading / Result	Action if Out of Tolerance	Sign off																																																																																																																																																																																																																																																																																																																																																																																																																																													
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10.			<table border="1"> <thead> <tr> <th colspan="2">Basic Sizes (mm)</th> <th colspan="11">International Tolerance Grades</th> </tr> <tr> <th rowspan="2">Over</th> <th rowspan="2">Including</th> <th colspan="3">Measuring Tools</th> <th colspan="8">Materials</th> <th rowspan="2">IT 15</th> <th rowspan="2">IT 16</th> <th rowspan="2">IT 17</th> </tr> <tr> <th>IT 05</th> <th>IT 06</th> <th>IT 07</th> <th>IT 08</th> <th>IT 09</th> <th>IT 10</th> <th>IT 11</th> <th>IT 12</th> <th>IT 13</th> <th>IT 14</th> </tr> </thead> <tbody> <tr> <td colspan="13">Fits for parts in precision and general engineering</td> <td colspan="3">Large Manufacturing Fabrication</td> </tr> <tr> <td>1</td> <td>3</td> <td>0.004</td> <td>0.006</td> <td>0.010</td> <td>0.014</td> <td>0.025</td> <td>0.040</td> <td>0.060</td> <td>0.100</td> <td>0.140</td> <td>0.250</td> <td>0.400</td> <td>0.630</td> <td>1.000</td> <td>1.600</td> <td>2.500</td> </tr> <tr> <td>3</td> <td>6</td> <td>0.005</td> <td>0.008</td> <td>0.012</td> 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<td>0.011</td> <td>0.016</td> <td>0.025</td> <td>0.039</td> <td>0.062</td> <td>0.100</td> <td>0.160</td> <td>0.250</td> <td>0.390</td> <td>0.620</td> <td>1.000</td> <td>1.600</td> <td>2.500</td> <td>4.000</td> <td>6.300</td> </tr> <tr> <td>50</td> <td>80</td> <td>0.013</td> <td>0.019</td> <td>0.030</td> <td>0.046</td> <td>0.074</td> <td>0.120</td> <td>0.190</td> <td>0.300</td> <td>0.460</td> <td>0.740</td> <td>1.200</td> <td>1.900</td> <td>3.000</td> <td>4.600</td> <td>7.400</td> </tr> <tr> <td>80</td> <td>120</td> <td>0.015</td> <td>0.022</td> <td>0.035</td> <td>0.054</td> <td>0.087</td> <td>0.140</td> <td>0.220</td> <td>0.350</td> <td>0.540</td> <td>0.870</td> <td>1.400</td> <td>2.200</td> <td>3.500</td> <td>5.400</td> <td>8.700</td> </tr> <tr> <td>120</td> <td>180</td> <td>0.018</td> <td>0.025</td> <td>0.040</td> <td>0.063</td> <td>0.100</td> <td>0.160</td> <td>0.250</td> <td>0.400</td> <td>0.630</td> <td>1.000</td> <td>1.600</td> <td>2.500</td> <td>4.000</td> <td>6.300</td> <td>10.000</td> </tr> <tr> <td>180</td> <td>250</td> <td>0.020</td> <td>0.029</td> <td>0.046</td> <td>0.072</td> <td>0.115</td> <td>0.185</td> <td>0.290</td> <td>0.460</td> <td>0.720</td> <td>1.150</td> <td>1.850</td> <td>2.900</td> <td>4.600</td> <td>7.200</td> <td>11.500</td> </tr> <tr> <td>250</td> <td>315</td> <td>0.023</td> <td>0.032</td> <td>0.052</td> <td>0.081</td> <td>0.130</td> <td>0.210</td> <td>0.320</td> <td>0.520</td> <td>0.810</td> <td>1.300</td> <td>2.100</td> <td>3.200</td> <td>5.200</td> <td>8.100</td> <td>13.000</td> </tr> <tr> <td>315</td> <td>400</td> <td>0.025</td> <td>0.036</td> <td>0.057</td> <td>0.089</td> <td>0.140</td> <td>0.230</td> <td>0.360</td> <td>0.570</td> <td>0.890</td> <td>1.400</td> <td>2.300</td> <td>3.600</td> <td>5.700</td> <td>8.900</td> <td>14.000</td> </tr> <tr> <td>400</td> <td>500</td> <td>0.027</td> <td>0.040</td> <td>0.063</td> <td>0.097</td> <td>0.155</td> <td>0.250</td> <td>0.400</td> <td>0.630</td> <td>0.970</td> <td>1.550</td> <td>2.500</td> <td>4.000</td> <td>6.300</td> <td>9.700</td> <td>15.500</td> </tr> <tr> <td>500</td> <td>630</td> <td>0.032</td> <td>0.044</td> <td>0.070</td> <td>0.110</td> <td>0.175</td> <td>0.280</td> <td>0.440</td> <td>0.700</td> <td>1.100</td> <td>1.750</td> <td>2.800</td> <td>4.400</td> <td>7.000</td> <td>11.000</td> <td>17.500</td> </tr> <tr> <td>630</td> <td>800</td> <td>0.036</td> <td>0.050</td> <td>0.080</td> <td>0.125</td> <td>0.200</td> <td>0.320</td> <td>0.500</td> <td>0.800</td> <td>1.250</td> <td>2.000</td> <td>3.200</td> <td>5.000</td> <td>8.000</td> <td>12.500</td> <td>20.000</td> </tr> <tr> <td>800</td> <td>1000</td> <td>0.040</td> <td>0.056</td> <td>0.090</td> <td>0.140</td> <td>0.230</td> <td>0.360</td> <td>0.560</td> <td>0.900</td> <td>1.400</td> <td>2.300</td> <td>3.600</td> <td>5.600</td> <td>9.000</td> <td>14.000</td> <td>23.000</td> </tr> <tr> <td>1000</td> <td>1250</td> <td>0.047</td> <td>0.066</td> <td>0.105</td> <td>0.165</td> <td>0.260</td> <td>0.420</td> <td>0.660</td> <td>1.050</td> <td>1.650</td> <td>2.600</td> <td>4.200</td> <td>6.600</td> <td>10.500</td> <td>16.500</td> <td>26.000</td> </tr> <tr> <td>1250</td> <td>1800</td> <td>0.055</td> <td>0.078</td> <td>0.125</td> <td>0.195</td> <td>0.310</td> <td>0.500</td> <td>0.780</td> <td>1.250</td> <td>1.950</td> <td>3.100</td> <td>5.000</td> <td>7.800</td> <td>12.500</td> <td>19.500</td> <td>31.000</td> </tr> <tr> <td>1800</td> <td>2000</td> <td>0.065</td> <td>0.092</td> <td>0.150</td> <td>0.230</td> <td>0.370</td> <td>0.600</td> <td>0.920</td> <td>1.500</td> <td>2.300</td> <td>3.700</td> <td>6.000</td> <td>9.200</td> <td>15.000</td> <td>23.000</td> <td>37.000</td> </tr> <tr> <td>2000</td> <td>2500</td> <td>0.078</td> <td>0.110</td> <td>0.175</td> <td>0.280</td> <td>0.440</td> <td>0.700</td> <td>1.100</td> <td>1.750</td> <td>2.800</td> <td>4.400</td> <td>7.000</td> <td>11.000</td> <td>17.500</td> <td>28.000</td> <td>44.000</td> </tr> <tr> <td>2500</td> <td>3160</td> <td>0.093</td> <td>0.135</td> <td>0.210</td> <td>0.330</td> <td>0.540</td> <td>0.880</td> <td>1.350</td> <td>2.100</td> <td>3.300</td> <td>5.400</td> <td>8.800</td> <td>13.500</td> <td>21.000</td> <td>33.000</td> <td>54.000</td> </tr> </tbody> </table>													Basic Sizes (mm)		International Tolerance Grades											Over	Including	Measuring Tools			Materials								IT 15	IT 16	IT 17	IT 05	IT 06	IT 07	IT 08	IT 09	IT 10	IT 11	IT 12	IT 13	IT 14	Fits for parts in precision and general engineering													Large Manufacturing Fabrication			1	3	0.004	0.006	0.010	0.014	0.025	0.040	0.060	0.100	0.140	0.250	0.400	0.630	1.000	1.600	2.500	3	6	0.005	0.008	0.012	0.018	0.030	0.048	0.075	0.120	0.180	0.300	0.480	0.750	1.100	1.700	2.700	6	10	0.006	0.009	0.015	0.022	0.036	0.058	0.090	0.150	0.220	0.360	0.580	0.900	1.400	2.100	3.200	10	18	0.008	0.011	0.018	0.027	0.043	0.070	0.110	0.180	0.270	0.430	0.700	1.100	1.700	2.700	4.000	18	30	0.009	0.013	0.021	0.033	0.052	0.084	0.130	0.210	0.330	0.520	0.840	1.300	2.100	3.300	5.000	30	50	0.011	0.016	0.025	0.039	0.062	0.100	0.160	0.250	0.390	0.620	1.000	1.600	2.500	4.000	6.300	50	80	0.013	0.019	0.030	0.046	0.074	0.120	0.190	0.300	0.460	0.740	1.200	1.900	3.000	4.600	7.400	80	120	0.015	0.022	0.035	0.054	0.087	0.140	0.220	0.350	0.540	0.870	1.400	2.200	3.500	5.400	8.700	120	180	0.018	0.025	0.040	0.063	0.100	0.160	0.250	0.400	0.630	1.000	1.600	2.500	4.000	6.300	10.000	180	250	0.020	0.029	0.046	0.072	0.115	0.185	0.290	0.460	0.720	1.150	1.850	2.900	4.600	7.200	11.500	250	315	0.023	0.032	0.052	0.081	0.130	0.210	0.320	0.520	0.810	1.300	2.100	3.200	5.200	8.100	13.000	315	400	0.025	0.036	0.057	0.089	0.140	0.230	0.360	0.570	0.890	1.400	2.300	3.600	5.700	8.900	14.000	400	500	0.027	0.040	0.063	0.097	0.155	0.250	0.400	0.630	0.970	1.550	2.500	4.000	6.300	9.700	15.500	500	630	0.032	0.044	0.070	0.110	0.175	0.280	0.440	0.700	1.100	1.750	2.800	4.400	7.000	11.000	17.500	630	800	0.036	0.050	0.080	0.125	0.200	0.320	0.500	0.800	1.250	2.000	3.200	5.000	8.000	12.500	20.000	800	1000	0.040	0.056	0.090	0.140	0.230	0.360	0.560	0.900	1.400	2.300	3.600	5.600	9.000	14.000	23.000	1000	1250	0.047	0.066	0.105	0.165	0.260	0.420	0.660	1.050	1.650	2.600	4.200	6.600	10.500	16.500	26.000	1250	1800	0.055	0.078	0.125	0.195	0.310	0.500	0.780	1.250	1.950	3.100	5.000	7.800	12.500	19.500	31.000	1800	2000	0.065	0.092	0.150	0.230	0.370	0.600	0.920	1.500	2.300	3.700	6.000	9.200	15.000	23.000	37.000	2000	2500	0.078	0.110	0.175	0.280	0.440	0.700	1.100	1.750	2.800	4.400	7.000	11.000	17.500	28.000	44.000	2500	3160	0.093	0.135	0.210	0.330	0.540	0.880	1.350	2.100	3.300	5.400	8.800	13.500	21.000	33.000	54.000																		
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			30	50	0.011	0.016	0.025	0.039	0.062	0.100	0.160	0.250	0.390	0.620	1.000	1.600	2.500	4.000	6.300																																																																																																																																																																																																																																																																																																																																																																																																																																										
			50	80	0.013	0.019	0.030	0.046	0.074	0.120	0.190	0.300	0.460	0.740	1.200	1.900	3.000	4.600	7.400																																																																																																																																																																																																																																																																																																																																																																																																																																										
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			180	250	0.020	0.029	0.046	0.072	0.115	0.185	0.290	0.460	0.720	1.150	1.850	2.900	4.600	7.200	11.500																																																																																																																																																																																																																																																																																																																																																																																																																																										
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			1000	1250	0.047	0.066	0.105	0.165	0.260	0.420	0.660	1.050	1.650	2.600	4.200	6.600	10.500	16.500	26.000																																																																																																																																																																																																																																																																																																																																																																																																																																										
			1250	1800	0.055	0.078	0.125	0.195	0.310	0.500	0.780	1.250	1.950	3.100	5.000	7.800	12.500	19.500	31.000																																																																																																																																																																																																																																																																																																																																																																																																																																										
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2000	2500	0.078	0.110	0.175	0.280	0.440	0.700	1.100	1.750	2.800	4.400	7.000	11.000	17.500	28.000	44.000																																																																																																																																																																																																																																																																																																																																																																																																																																													
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This reference standard is needed for this procedure because in covers sizes from 30mm to 250mm. Reference tables are normally appended to the back of the procedure but shown here because this is an example of what to do to create ACE 3T procedures. If this was an individual shaft size procedure (which I recommend you do) the tolerance values would be selected, double-checked and shown for each task.

Such tables are developed specifically for each procedure so the technician on the job does not have to stop and work the details out themselves under stressful conditions and difficult work situations. The details they need are researched, double-checked to be correct and provided in the procedure.

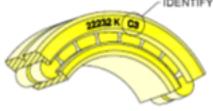
Provide examples of how to complete the tables and do the analysis that needs to be made.



No	Task Step Owner	Task Step Name	Task Description				Matl, Tools & Their Condition	Test for Correctness		Reliability and Quality Standards			Reading / Result	Action if Out of Tolerance	Sign off
										Good	Better	Best			
12.	Technician	Evaluate Fixed Bearing Shaft Tolerance		0°	45°	90°	135°	Plane Average	Required Tolerance h9	Use vernier calliper to measure shaft tolerance within h9 and double-check it again. Measure to second decimal place accuracy.	Use micrometer to measure the shaft tolerance is within h9 and double-checks it again. Measure to second decimal place accuracy.	Use micrometer to measure shaft tolerance is within h9 and gets another person to measure and double-check values match. Measure to second decimal place accuracy.		Replace shaft with new if minimum tolerance is exceeded	
			Plane A												
			Plane B												
			Plane C												
		Max-Min													
Enter appropriate high and low shaft tolerance value from the table above in the right hand side column. e.g. 0.000 to -0.100 for 150mm nominal bore bearing Record final measurements in the table above then subtract the smallest value from the largest value and note if 'Pass' or 'Fail' in the Result Column															
13.	Technician	Evaluate Fixed Bearing Cylindricity Tolerance		0°	45°	90°	135°	Plane Average	Target IT Grade 5	Tolerance IT Grade 7	Use vernier calliper to measure and record measurements then double-check them again that values match. Measure to second decimal place accuracy. Tolerance Grade is up to IT7	Use micrometer to measure and record measurements then double-check it again that values match. Measure to second decimal place accuracy. Tolerance Grade is up to IT6	Use micrometer to measure and record measurements then get another person to measure and double-check values match. Measure to second decimal place accuracy. Tolerance Grade is within IT5		Replace shaft with new made to IT5 tolerance if IT7 Grade is exceeded
			Plane A												
			Plane B												
			Plane C												
		Max-Min													
Enter appropriate maximum IT value from the table above in the two right hand side columns. e.g. IT5 of 0.018 and IT7 of 0.040 for 150mm nominal bore bearing Record final measurements in the table above then subtract the smallest value from the largest value and note if 'Pass' or 'Fail' in the Result Column															
14.	Technician	Evaluate Floating Bearing Shaft Tolerance		0°	45°	90°	135°	Plane Average	Required Tolerance h9	Use vernier calliper to measure shaft tolerance within h9 and double-check it again. Measure to second decimal place accuracy.	Use micrometer to measure the shaft tolerance is within h9 and double-checks it again. Measure to second decimal place accuracy.	Use micrometer to measure shaft tolerance is within h9 and gets another person to measure and double-check values match. Measure to second decimal place accuracy.		Replace shaft with new if minimum tolerance is exceeded	
			Plane A												
			Plane B												
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15.	Technician	Evaluate Floating Bearing Cylindricity Tolerance		0°	45°	90°	135°	Plane Average	Target IT Grade 5	Tolerance IT Grade 7	Use vernier calliper to measure and record measurements then double-check them again that values match. Measure to second decimal place accuracy. Tolerance Grade is up to IT7	Use micrometer to measure and record measurements then double-check it again that values match. Measure to second decimal place accuracy. Tolerance Grade is up to IT6	Use micrometer to measure and record measurements then get another person to measure and double-check values match. Measure to second decimal place accuracy. Tolerance Grade is within IT5		Replace shaft with new made to IT5 tolerance if IT7 Grade is exceeded
			Plane A												
			Plane B												
			Plane C												
		Max-Min													
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Provide a place to record the findings and do the analysis so there is evidence it was correctly done.

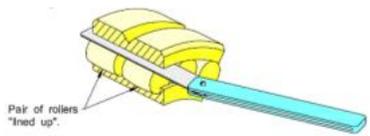


No	Task Step Owner	Task Step Name	Task Description	Matl, Tools & Their Condition	Test for Correctness	Reliability and Quality Standards			Reading / Result	Action if Out of Tolerance	Sign off						
						Good	Better	Best									
16.	Technician	Confirm bearing is correct	See part number for internal clearance suffix. If no suffix the clearance is 'normal'. If suffix is present the clearance is special for the situation e.g. C3 clearance is one group greater than 'normal'  Thanks to CBC Bearings, Australia for the image <a href="http://www.conbear.com">www.conbear.com</a> Suffix K means 1:12 taper; Suffix K30 means 1:30 taper. Record the bearing number including taper and clearance range designations in table below.	New spherical roller bearing	Part provided is identical to listed part	Record bearing number including taper and clearance designations	Record bearing number including taper and clearance designations	Record bearing number including taper and clearance designations and double check correct		If bearing is not the same as on the parts list immediately inform the Job Supervisor							
17.	Technician	Confirm bearing bore is correct	Calculate the bearing bore size by multiplying the last two digits of the part number by 5 and record the nominal bore in the table below. e.g. 23134 has a bore $34 \times 5 = 170\text{mm}$	Steel ruler with graduation marks clearly readable	The bearing's small bore matches the calculated bore size	Calculate bore and record value.	Calculate bore and measure bearing small end bore with steel ruler within 1mm accuracy	Calculate bore and measure bearing small end bore with steel ruler within 1mm accuracy and double check size		If bore is wrong size immediately inform the Job Supervisor							
18.	Technician	Identify allowed internal clearance	Record the details of the equipment and bearing in the table below and record the minimum and maximum permitted clearance values from the clearance table Equipment Number: _____ Bearing Location: _____ Bearing Number: _____ Bearing Nominal Bore (mm): _____ Internal Clearance Range i.e. C#?: _____ (Located anywhere on bearing)  <table style="width: 100%; border: none;"> <tr> <td style="width: 50%; text-align: center;">Minimum</td> <td style="width: 50%; text-align: center;">Maximum</td> </tr> <tr> <td style="text-align: center;">Allowed Bearing Internal Clearance:</td> <td style="text-align: center;">Allowed Bearing Internal Clearance:</td> </tr> <tr> <td style="text-align: center;"><input style="width: 100px; height: 40px;" type="text"/></td> <td style="text-align: center;"><input style="width: 100px; height: 40px;" type="text"/></td> </tr> </table>	Minimum	Maximum	Allowed Bearing Internal Clearance:	Allowed Bearing Internal Clearance:	<input style="width: 100px; height: 40px;" type="text"/>	<input style="width: 100px; height: 40px;" type="text"/>								
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Use pictures and images to make it clear what needs to be done and how it is done right.

Include tables and lists to guide in recording necessary information that the technician must use.



No	Task Step Owner	Task Step Name	Task Description	Matl, Tools & Their Condition	Test for Correctness	Reliability and Quality Standards			Reading / Result	Action if Out of Tolerance	Sign off																																																																																																																																																																	
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19.	Technician	Measure internal clearance	<p>Stand bearing vertical on a clean, dust-free, solid surface. Ensure both rollers are lined-up side-by-side at the top of the bearing and pinch them between the thumb and pointer finger and firmly hold them. Measure top internal radial clearance of new bearing with long feeler gauges by pushing them axially between rollers and outer ring, as shown in the</p>  <p>picture.</p> <p><i>Thanks to CBC Bearings, Australia for the image <a href="http://www.conbear.com">www.conbear.com</a></i></p> <p>Select feelers of a combined thickness that will fit the clearance gap. For large bearings use two feelers together and for small bearings use three together so they slip over each other as they are fed between rollers and raceway. For example, on a 23134 K C3 bearing the internal clearance shown in the clearance table below for a C3 clearance allows 0.200mm to 0.260mm gap in an unmounted bearing and you would select long feelers that as a pair, would fit that range, say start with a 0.1 and a 0.15 (or a 0.25) and test if it fits between rollers and outer race, if not then use the 0.1 with a 0.12 and so on. <b>Wear gloves when forcing feelers between rollers and race.</b></p> <p>Progressively increase the thickness of the feeler gauges until the rubbing resistance makes it very difficult to push the feelers in and out of the clearance gap. Feed the feelers into the gap 4-5mm at a time with your fingers. The feelers have to totally fill the clearance and it requires firm pushing of the feelers to get them through to the other side of the bearing. Under no circumstances rotate the</p>	Clean 'long-series' feeler gauges free of rust with every feeler in complete shape and every thickness identification clearly readable	Measured initial internal clearance is within tolerance shown on standards table for bearing clearance group	Measure top clearance between rollers and outer ring with feeler gauges accurately and record measurement	Measure top clearance between rollers and outer ring with feeler gauges accurately and repeat measurement	Measure top clearance between rollers and outer ring with feeler gauges accurately. Get another person to measure and double-check values match, and record measurement.		If the clearance is out of the range immediately inform the Job Supervisor																																																																																																																																																																		

This is another reference table better kept as an appendix, but shown here to indicate where the internal clearance information is found.

The data in the table comes from the bearing manufacturer's catalogue for the bearing type and bearing size.

I'm trying here to indicate when the technician knows they have got the measurement right. To get 'the feel' takes practice and involves teaching your brain what is the correct sensation that equates to the proper measurement using feeler gauges.



No	Task Step Owner	Task Step Name	Task Description	Matl, Tools & Their Condition	Test for Correctness	Reliability and Quality Standards			Reading / Result	Action if Out of Tolerance	Sign off																																																																																																																																																																																																																																																																																																																																																																																
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			bearing to 'roll' feelers through. Record in the table below the 'hard' internal clearance measured with the feelers																																																																																																																																																																																																																																																																																																																																																																																								
20.	Technician	Calculate fitted internal clearance	<p><b>Measured Internal Clearance with Feelers (mm)</b></p> <div style="display: flex; align-items: center; justify-content: center;"> <div style="border: 1px solid black; width: 60px; height: 100px; margin-right: 10px;"></div> <span style="margin: 0 10px;">minus</span> <div style="border: 1px solid black; width: 80px; height: 30px; margin-right: 10px;"></div> <span style="margin: 0 10px;">=</span> <div style="border: 1px solid black; width: 60px; height: 30px; margin-right: 10px;"></div> </div> <p style="text-align: center; margin: 5px 0;"><b>Minimum required reduction of internal clearance (mm)</b></p> <div style="display: flex; align-items: center; justify-content: center;"> <div style="border: 1px solid black; width: 60px; height: 100px; margin-right: 10px;"></div> <span style="margin: 0 10px;">minus</span> <div style="border: 1px solid black; width: 80px; height: 30px; margin-right: 10px;"></div> <span style="margin: 0 10px;">=</span> <div style="border: 1px solid black; width: 60px; height: 30px; margin-right: 10px;"></div> </div> <p style="text-align: center; margin: 5px 0;"><b>Maximum possible fitted clearance (mm)</b></p> <p style="text-align: center; margin: 5px 0;">Check: Subtract values above</p>			<p>Show hand calculation of required reduction range and double check mathematics is correct</p> <p>Subtract values in boxes and note it in the space under the boxes. Check both results are identical</p>	<p>Show hand calculation of required reduction range and double check mathematics with a digital calculator</p> <p>Subtract values in boxes and note it in the space under the boxes. Check both results are identical</p>	<p>Show hand calculation of required reduction range, double check with digital calculator</p> <p>Subtract values in boxes and note it in the space under the boxes. Check both results are identical</p> <p>Get a second person to do the calculation independently and confirm values are same</p>																																																																																																																																																																																																																																																																																																																																																																																			
			<p><i>Thanks to CBC Bearings, Australia for the calculation method <a href="http://www.conbear.com">www.conbear.com</a></i></p> <p>Calculate the required internal clearance reduction when the bearing is correctly fitted. Use the required reduction values in the table below for the bearing size.</p> <p>As an example, for a bearing of bore 170mm read across the row 'over 160 including 180' and for C3 clearance see that it must be reduced by between 0.080mm and 0.110mm. In other words the residual clearance left in the bearing between roller and outer raceway after it is fitted and tightened on the adapter sleeve is between:</p> <p>0.260 minus 0.080 = 0.180mm and                  0.260 minus 0.110 = 0.150mm</p>	<div style="border: 2px solid yellow; border-radius: 50%; padding: 10px; width: fit-content; margin: 10px auto;">                     In this case the technician has to calculate the tolerances they must work to. I would not normally do it this way but instead have one shaft size and one bearing type and list the required reduction and fitted clearance just for that specific circumstance. As soon as I see that people have to make decisions and select from tables as part of doing the job, I know that someone will get it wrong someday.                 </div>																																																																																																																																																																																																																																																																																																																																																																																							
21.			<table border="1" style="width: 100%; border-collapse: collapse; text-align: center;"> <thead> <tr> <th colspan="2" rowspan="2">Nominal bearing bore diameter (d) A</th> <th colspan="6">Initial Clearance B</th> <th colspan="2" rowspan="2">Required reduction in radial clearance C</th> <th colspan="4">Axial Displacement Taper 1:12 D</th> <th colspan="4">Axial Displacement Taper 1:30 D</th> <th colspan="3" rowspan="2">Minimum permissible residual clearance E</th> </tr> <tr> <th colspan="2">Normal</th> <th colspan="2">C3</th> <th colspan="2">C4</th> <th colspan="2">Shaft</th> <th colspan="2">Sleeve</th> <th colspan="2">Shaft</th> <th colspan="2">Sleeve</th> </tr> <tr> <th>over</th> <th>including</th> <th>min</th> <th>max</th> <th>Normal</th> <th>C3</th> <th>C4</th> </tr> </thead> <tbody> 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<tr><td>65</td><td>80</td><td>0.070</td><td>0.095</td><td>0.095</td><td>0.120</td><td>0.120</td><td>0.150</td><td>0.040</td><td>0.050</td><td>0.600</td><td>0.750</td><td>0.700</td><td>0.850</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>0.025</td><td>0.040</td><td>0.070</td></tr> <tr><td>80</td><td>100</td><td>0.080</td><td>0.110</td><td>0.110</td><td>0.140</td><td>0.140</td><td>0.180</td><td>0.045</td><td>0.060</td><td>0.700</td><td>0.900</td><td>0.750</td><td>1.000</td><td>1.700</td><td>2.200</td><td>1.800</td><td>2.400</td><td>0.035</td><td>0.050</td><td>0.080</td><td></td><td></td></tr> <tr><td>100</td><td>120</td><td>0.100</td><td>0.135</td><td>0.135</td><td>0.170</td><td>0.170</td><td>0.220</td><td>0.050</td><td>0.070</td><td>0.700</td><td>1.100</td><td>0.800</td><td>1.200</td><td>1.900</td><td>2.700</td><td>2.000</td><td>2.800</td><td>0.050</td><td>0.065</td><td>0.100</td><td></td><td></td></tr> 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22.	Technician	Determine sleeve axial drive-up displacement range	<p>From the table above read the axial displacement for a bearing mounted on a tapered sleeve to be properly seated to get the required final fitted clearance and record it in the boxes below. As an example, for a bearing of nominal bore 170mm read across the row 'over 160 including 180' and for sleeve with 1:12 taper see that the bearing must be displaced up the sleeve from snug fit on the taper by between 1.4mm and 1.9mm.</p> <p>From the table above read and record the minimum permitted fitted clearance below which it cannot be allowed to go. For example, for a bearing of bore 170mm read across the row 'over 160 including 180' and for a C3 internal clearance see that it must not be less than 0.1mm final minimum fitted clearance.</p> <p style="text-align: center;">Axial Drive-up Displacement Range for 1:12 taper Sleeve (mm)</p> <div style="display: flex; justify-content: space-around; align-items: center;"> <div style="border: 1px solid black; width: 80px; height: 30px;"></div> <span>to</span> <div style="border: 1px solid black; width: 80px; height: 30px;"></div> </div> <p style="text-align: center;">Minimum permissible fitted clearance (mm)</p> <div style="border: 1px solid black; width: 80px; height: 30px; margin: 0 auto;"></div> <p><i>Thanks to CBC Bearings, Australia for the calculation method <a href="http://www.conbear.com">www.conbear.com</a></i></p>								
23.	Technician	Get fixed bearing parts	Review the fixed bearing assembly drawing and identify all parts that go into the bearing assembly and Plummer Block and gather them together in order of installation.	Bearing parts	Parts protected from damage and ordered for ease of installation on a clean layout area						
24.	Technician	Mark position of adaptor sleeve	From the installation drawing, or from measurements of the distance on the original assembly, determine how far along the shaft the adaptor sleeve will be located in its final position and draw a mark on the shaft with a black marker where the rear and front ends sit as guidance of where to slide the adaptor sleeve.		Bearing final position after axial displacement brings it in the middle of the bearing housing	Centred to within ±2mm	Centred to within ±1.5mm	Centred to within ±1mm		Identify why the bearing cannot be centred and rectify the problem.	
25.	Technician	Smear mounting paste	Clean the shaft and thinly smear a level teaspoon amount of mounting paste around the shaft from the rear of the adaptor sleeve to the end of the shaft to help parts slide up the shaft								
26.	Technician	Slip rear labyrinth onto shaft	Slide the inner labyrinth seal down the shaft with its o-ring outward t								
27.	Technician	Slip rear V-seal onto shaft	Slide the rear V-seal down the shaft with the V toward the bearing								
28.	Technician	Slip rear wear plate onto shaft	Slide the V-seal wear plate onto the shaft with the running side against the V-seal seat								
29.	Technician	Slip adapter sleeve onto shaft	Slip the adapter sleeve onto the shaft with the taper toward the end of the shaft and move the sleeve to about 5mm before its final position.								
30.	Technician	Snug bearing onto adaptor sleeve	Slide the bearing over the shaft and push it firmly onto the adapter sleeve taper								
31.	Technician	Move adaptor sleeve into place	With a copper wedge dolly tap the adapter sleeve into its final position between the rear and front black marks								

I didn't get a chance to complete these columns because I ran out of time. But they need to be done.

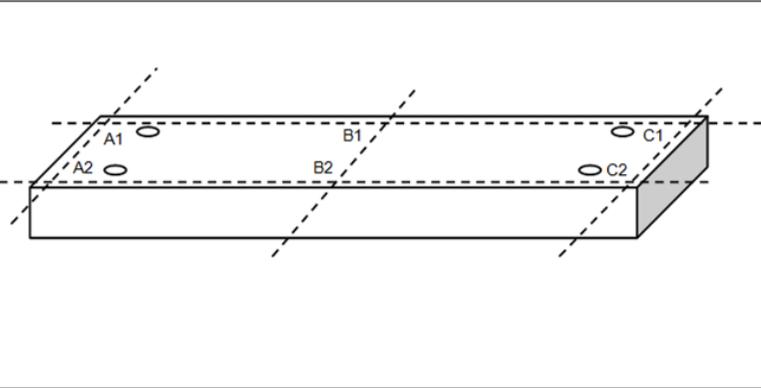
Keep each part to itself as proof the task was done right. Don't start saying 'repeat the above steps for this item', even if they are identical steps.

Here is a great spot to get the technicians involved in compiling the procedure by asking them what they currently do and letting them suggest ways of getting even better results, then including them in the procedure where possible. But the 'best' column is a standard the company must set and approve as its target performance. That decision cannot be done by the technicians alone.



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32.	Technician	Get floating bearing parts	Review the fixed bearing assembly drawing and identify all parts that go into the bearing assembly and Plummer Block and gather them together in order of installation.								
33.	Technician	Mark position of adaptor sleeve	From the installation drawing, or from measurements of the distance on the original assembly, determine how far along the shaft the adaptor sleeve will be located in its final position and draw a mark on the shaft with a black marker where the rear and front ends sit as guidance of where to slide the adaptor sleeve.		Bearing final position after axial displacement is in the middle of the bearing housing	Centred to within $\pm 2\text{mm}$	Centred to within $\pm 1.5\text{mm}$	Centred to within $\pm 1\text{mm}$		Identify why the bearing cannot be centred and rectify the problem.	
34.	Technician	Smear mounting paste	Clean the shaft and thinly smear a level teaspoon amount of mounting paste around the shaft from where the rear of the adaptor sleeve will be to the end of the shaft to help parts slide up the shaft without damage and to prevent fretting corrosion when in service.								
35.	Technician	Slip rear labyrinth onto shaft	Slide the inner labyrinth seal down the shaft with its o-ring outward								
36.	Technician	Slip rear V-seal onto shaft	Slide the rear V-seal down the shaft with the V toward the bearing								
37.	Technician	Slip rear wear plate onto shaft	Slide the V-seal wear plate onto the shaft with the running side against the V-seal seat								
38.	Technician	Slip adapter sleeve onto shaft	Slip the adapter sleeve onto the shaft with the taper toward the end of the shaft and move the sleeve to about 5mm before its final position.								
39.	Technician	Snug bearing onto adaptor sleeve	Slide the bearing over the shaft and push it firmly onto the adapter sleeve taper								
40.	Technician	Move adaptor sleeve into place	With a copper wedge dolly tap the adapter sleeve into its final position between the rear and front black marks								
41.	Technician	Check fixed bearing base plate flatness	Check the base plate flatness for the fixed bearing by placing a straight edge across the entire base from end to end. With feeler gauges measure the gap at each hold-down bolt area and the middle of the Plummer Block and record them in the table	Straight edge, short feeler gauges	Thickest feeler gauge that fits between the straight edge and base plate at any point is less than IT7 maximum	Tolerance Grade is up to IT7. Ensure base plate is stiff and cannot flex more than IT7/10 under full load	Tolerance Grade is up to IT6. Ensure base plate is stiff and cannot flex more than IT6/10 under full load	Tolerance Grade is up to IT5. Ensure base plate is stiff and cannot flex more than IT5/10 under full load		Get base plate machined flat to IT5. Ensure base plate is stiff and cannot flex more than IT5/10 under full load. Stiffen-up base	



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42.	Technician	Check bearing base plate flatness				<table border="1"> <thead> <tr> <th colspan="2">Length mm</th> <th>Flatness IT5 µm</th> <th>Flatness IT7 µm</th> </tr> <tr> <th>over</th> <th>incl</th> <th>max</th> <th>max</th> </tr> </thead> <tbody> <tr><td>80</td><td>120</td><td>15</td><td>35</td></tr> <tr><td>120</td><td>180</td><td>18</td><td>40</td></tr> <tr><td>180</td><td>250</td><td>20</td><td>46</td></tr> <tr><td>250</td><td>315</td><td>23</td><td>62</td></tr> <tr><td>315</td><td>400</td><td>25</td><td>57</td></tr> <tr><td>400</td><td>500</td><td>27</td><td>63</td></tr> <tr><td>500</td><td>630</td><td>30</td><td>70</td></tr> <tr><td>630</td><td>800</td><td>35</td><td>80</td></tr> <tr><td>800</td><td>1000</td><td>40</td><td>90</td></tr> </tbody> </table>	Length mm		Flatness IT5 µm	Flatness IT7 µm	over	incl	max	max	80	120	15	35	120	180	18	40	180	250	20	46	250	315	23	62	315	400	25	57	400	500	27	63	500	630	30	70	630	800	35	80	800	1000	40	90				
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44.	Technician	Check floating bearing base plate flatness	Check the base plate flatness for the floating bearing with a straight edge and feeler gauges at the 3 locations shown in the sketch – under each hold-down bolt area and the middle of the Plummer Block – and record them in the table	Straight edge, short feeler gauges	Thickest feeler gauge that fits between the straight edge and base plate at any point is less than IT7 maximum	Tolerance Grade is up to IT7. Ensure base plate is stiff and cannot	Tolerance Grade is up to IT6. Ensure base plate is stiff and cannot flex	Tolerance Grade is up to IT5. Ensure base plate is stiff and cannot flex		Get base plate machined flat to IT5. Ensure base plate is																																												



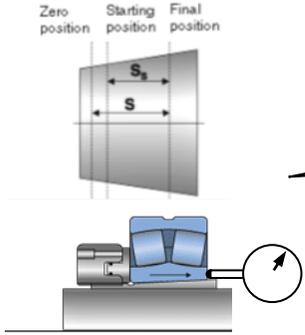
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46.	Technician	Check Base Plate Orientation	<p><b>Base Plate Orientation</b></p> <p>Base Plates Level 'T'</p> <p>Base Plates Separation Distance 'A'</p> <p>Base Plates Vertical Misalignment 'B'</p>																																									
47.	Technician	Check base plate vertical alignment	Measures the distance 'A' between centres of the Plummer block bases and record it below.	String line and precision bubble level or Surveyor's	See the Tolerance Grade Table for maximum allowable vertical height difference for IT15 tolerance	Maximum allowed IT15 distance	One-half of the maximum allowed IT15 distance	One-quarter of the maximum allowed IT15 distance	Actual gap B measured (mm)	Shim-up the lowest Plummer block to within one-quarter of the maximum																																		



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			'A' Ctr-toCtr distance of bases (mm): _____ Use a string line and a precision level to measure the vertical alignment between bases. Place the precision level on top the highest base and centre the bubble. Pull the string line tight and bring the string line up to the underside of the level until the string is also level. Measure the gap from the underside of the string line to the lowest base. (If there is no line-of-sight then transfer the datum to suitable points.)  'B' Vertical height difference of bases (mm): _____	laser	over the distance between bases and record the Maximum allowed measurement gap B (mm)  Max allowed gap B (mm) _____				_____	allowed vertical misalignment distance	
48.	Technician	Fixed bearing base plate level	Measure the Plummer block base width and record it below. Place a precision level across fixed bearing base plate and bring it level with the bubble centred. Measure distance T with the end of a vernier calliper.  'T' Measured width of Plummer base (mm): _____	Precision level and vernier callipers	Use Tolerance Grade value for IT12 as the maximum allowable level difference over the base width. Max allowed gap T (mm): _____	Maximum allowed IT12 distance	One-half of the maximum allowed distance	One-quarter of the maximum allowed distance	Actual gap T measured (mm)  _____	Shim-up the lowest Plummer block to within one-quarter of the maximum allowed vertical out of level distance	
49.	Technician	Floating bearing base plate level	Measure the Plummer block base width and record it below. Place a precision level across fixed bearing base plate and bring it level with the bubble centred. Measure distance T with the end of a vernier calliper.  'T' Measure width of Plummer base (mm): _____	Precision level and vernier callipers	Use the Tolerance Grade Table value for IT12 as the maximum allowable level difference over the base width. Max allowed gap T (mm): _____	Maximum allowed IT12 distance	One-half of the maximum allowed distance	One-quarter of the maximum allowed distance	Actual gap T measured (mm)  _____	Shim-up the lowest Plummer block to within one-quarter of the maximum allowed vertical out of level distance	
50.	Technician	Prepare fixed end bearing	The fixed bearing now needs to be driven up the taper into its final position on the adaptor sleeve. Check the adaptor sleeve is still in the right position between the front and back lines marked on the shaft and that it will sit in the middle of the Plummer block bearing seat when finally positioned. Tap adapter sleeve back into place with a copper dolly if necessary. Check the bearing is snugly seated on the taper with no clearance between sleeve and bearing.								
51.	Technician	Lock-up fixed end bearing on adaptor sleeve	The final position is the distance up the taper that produces the final residual internal clearance for the bearing. Once in location the internal clearance is checked to be above the minimum and within the residual clearance tolerance. If necessary the bearing is refitted on the adaptor sleeve.   From the zero position on the sleeve the bearing is first moved into the start position. At this point the sleeve is tight on the shaft. From the start position the bearing is moved further up the taper by the required axial								

The three standards, Good-Better-Best, need to be identified and set for each task, along with the proof-test and the corrective action should the test prove below standard results. Again the technicians can help in compiling the standards. You can also get information from the manufacturer and from recognised international standards.

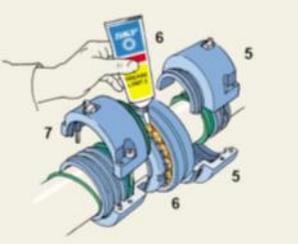
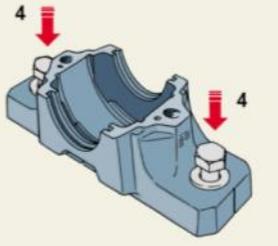


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			<p>displacement to its final position, at which point the internal clearance is reduced to its final residual clearance. On bearings less than 80mm bore use C-spanners. Bearings 80 mm and over use a hydraulic nut with oil pressure to drive a piston.</p> <p>Once correctly located the bearing is fixed in place with the tab washer and nut. The nut is driven tight with a C-spanner and hammer and a tab is bent into the slot in the nut to fix the assembly in-place. <b>Do not attempt to tighten the locknut with hammer and drift.</b> The locknut will be damaged and chips can enter the bearing.</p>  <p>A dial gauge is installed against the inner ring at the nonut side of the bearing to measure the axial displacement. If there is not space for a dial gauge clamp a clean stainless steel flat bar across the inner and outer rings and transfer the datum to a convenient location. Once in position the tab washer and nut hard against the inner rung.</p> <p>Follow the separate instructions for doing hydraulic nut mounting.</p>								
52.		Grease the fixed bearing	Completely fill the fixed bearing with grease. The remainder of the recommended grease quantity is later put in the housing base at the sides								
53.	Technician	Prepare floating end bearing	Check the adaptor sleeve is still in the right position between the front and back lines marked on the shaft and that it will sit in the middle of the Plummer block bearing seat when finally positioned. Tap adapter sleeve back into place with a copper dolly if necessary. Check the bearing is snugly seated on the taper with no clearance between sleeve and bearing.								
54.	Technician	Lock-up floating end bearing on adaptor sleeve	<p>From the zero position on the sleeve the bearing is first moved into the start position. At this point the sleeve is tight on the shaft. From the start position the bearing is moved further up the taper by the required axial displacement to its final position, at which point the internal clearance is reduced to its final residual clearance.</p> <p>Repeat the procedure used for the fixed end bearing.</p>								
55.		Grease the floating	Completely fill the bearing with floating grease. The remainder of the recommended grease quantity is later put								

This image is used to clearly explain what must be done. The information it conveys could never be explained successful with words alone.

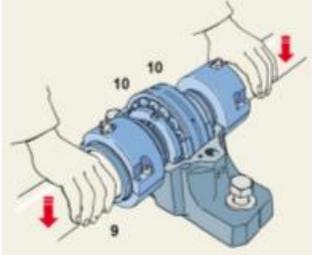
All these tasks must have reliability standards set for them, along with the proof-test and the corrective action.



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		bearing	in the housing base at the sides								
56.	Technician	Mount fixed bearing Taconite seals	<p>On the no-nut side of the Plummer block place the bottom Taconite split ring over the V-ring and labyrinth then fit the top half ring and screw them together. The two halves of this split ring are not interchangeable. Check to see that they carry the same identification.</p>  <p><i>Thanks to SKF Bearings for the image www.skf.com</i></p> <p>Repeat the above for the nut side of the Plummer block.</p>								
57.	Technician	Mount floating bearing Taconite seals	<p>On the no-nut side of the Plummer block place the bottom Taconite split ring over the V-ring and labyrinth then fit the top half ring and screw them together. The two halves of this split ring are not interchangeable. Check to see that they carry the same identification.</p> <p>Repeat the above for the nut side of the Plummer block.</p> <p>If the housing is to be used at a shaft end, the second seal is omitted and an end cover inserted in the housing base instead.</p>								
58.	Technician	Mount fixed bearing Plummer block	<p>Temporarily position the floating bearing Plummer block on its base frame and fit hold-down bolts loosely.</p> <p>Locate the housing so the grease nipple on one side of the housing cap is at the no-nut side, opposite to the sleeve nut. It is necessary to consider the whole Plummer block as the base and cap will only fit together as supplied.</p>  <p><i>Thanks to SKF Bearings for the image www.skf.com</i></p> <p>With the Plummer block in position on the base check for 'softfoot' gaps under the base with feeler gauges. The allowed flatness tolerance is IT7 for the distance between bolt centres. If the 'softfoot' gap is above tolerance replace the Plummer block.</p>								

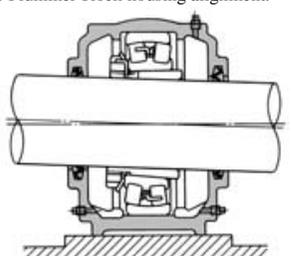
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59.	Technician	Mount floating bearing Plummer block	<p>Install the floating bearing Plummer block on its base and fit hold-down bolts loosely.</p> <p>Locate the housing so the grease nipple on one side of the housing cap is at the side opposite to the sleeve nut. It is necessary to consider the whole Plummer block as the base and cap will only fit together as supplied.</p> <p>With the Plummer block in position on the base check for 'softfoot' gaps under the base with feeler gauges. The allowed flatness tolerance is IT7 for the distance between bolt centres. If the 'softfoot' gap is above tolerance replace the Plummer block.</p>								
60.	Technician	Position fixed bearing in Plummer block	<p>Fit the locating bearing into the lower Plummer block housing, together with the seals.</p>  <p><i>Thanks to SKF Bearings for the image www.skf.com</i></p> <p>Fit the split locating rings both sides of the drive-end bearing to fix it in the Plummer Block so it cannot move axially</p>	Locating rings with gap	Drive end bearing is axially fixed firmly within the housing	Maximum total indicator run-out at drive end of shaft of 0.018mm	Maximum total indicator run-out at drive end of shaft of 0.010mm	Maximum total indicator run-out at drive end of shaft of 0.005mm			
61.	Technician	Position floating bearing in Plummer block	Fit the locating bearing into the lower Plummer block housing, together with the seals and adjust the position to centre the bearing in the bearing seating. If the Plummer block is to be used in a high temperature environment, carefully position the bearing considering the direction for thermal expansion of the shaft.								
62.	Technician	Grease the fixed bearing housing cavity	The recommended volume of grease to put into the Plummer blocks cavity each side of the bearing is 1/2 the empty cavity space. The volume of grease should be carefully selected as it can lead to overheating of the bearing, outward leakage from the seal, or ingress of dust.								
63.		Grease fixed bearing Taconite seals	Rotate the shaft and supply grease into the Taconite seal via the nipple until it exudes from the labyrinth rings. Use the same grease as that used for the bearings.								
64.		Grease the floating bearing housing cavity	The recommended volume of grease to put into the Plummer blocks cavity each side of the bearing is 1/2 the empty cavity space. The volume of grease should be carefully selected as it can lead to overheating of the bearing, outward leakage from the seal, or ingress of dust.								
65.		Grease floating bearing Taconite seals	Rotate the shaft and supply grease into the Taconite seal via the nipple until it exudes from the labyrinth rings. Use the same grease as that used for the bearings.								

All these tasks must have reliability standards set for them, along with the proof-test and the corrective action.



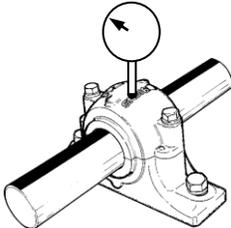
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66.	Technician	Align floating bearing	<p>Once the bearing is correctly located, check the squareness of the Plummer block relative to the shaft (make sure the face of bearing inner ring is parallel with that of the outer ring and the shaft is central in the seals). Carefully align the housing base so that the circumferential gap around the seal is uniform right around. If the housing must be lifted, install shims under the Plummer blocks that are 100% the full size of the Plummer block base. Remember a large mounting error can cause the seal to fail or the shaft to flex the bearing bore and rollers. If such a problem occurs, correct the Plummer block housing alignment.</p>  <p>Thanks to NTN Bearings for the image <a href="http://www.ntn.co.jp">www.ntn.co.jp</a></p>								
67.	Technician	Align fixed bearing									
68.	Technician	Install fixed bearing cap	The housing cap should be placed over the base and the cap bolts (to join cap and base) tightened to the torque Specified. The cap and base are not interchangeable with those of other housings. Checked to see that they bear the same identification.								
69.	Technician	Install floating bearing cap	The housing cap should be placed over the base and the cap bolts (to join cap and base) tightened to the torque Specified. The cap and base are not interchangeable with those of other housings. Checked to see that they bear the same identification.								
70.	Technician	Tighten hold-down bolts	<p>Only when both bearing alignments are complete do you fully tighten the hold-down bolts.</p> <p>Pull-up bolts snug tight in cross tightening sequence. Sung means in firm contact under about 20% of final bolt torque. It is obtained by the full effort of a well-built man pulling on a ring spanner until it can no longer be moved by hand. It can also be achieved by use of an impact wrench. When the spinning nut turns to blows, count three blows, and the bolt will be snug tight<sup>2</sup>.</p>								
71.	Technician	Match mark fasteners	Match-mark nut position with a pencil when all nuts on both flanges are snug.	Pencil	Scribed marks in correct position and easily observable	Match-mark the nut and base	Clearly match mark the nut and base within 1 minute	Clearly match-mark the nut and base within 45 seconds			

All these tasks must have reliability standards set for them, along with the proof-test and the corrective action.

This bolting method does not need a tension wrench. A tension wrench has at best a ±15% accuracy, and as bad as ±25% accuracy. Best of all is to use shank length extension tensioning with an accuracy of ±5%.

<sup>2</sup> Sheppard, Alan T., 'High Strength Bolting', The DuRoss Group, Inc.



No	Task Step Owner	Task Step Name	Task Description	Matl, Tools & Their Condition	Test for Correctness	Reliability and Quality Standards			Reading / Result	Action if Out of Tolerance	Sign off
						Good	Better	Best			
72.	Technician	Tighten fasteners	Turn each nut an extra 1/3 of a turn to final position in cross tightening sequence. Re-tension continuously until all nuts are equally tight. No rotation of stud is permitted while tightening the nut.			Tighten nuts 1/4 of a turn in cross sequence and finally tighten nuts to 1/3 of a turn in cross sequence.	Tighten nuts 1/4 of a turn in cross sequence and finally tighten nuts to 1/3 of a turn in cross sequence in 5 minutes.	Tighten nuts 1/4 of a turn in cross sequence and finally tighten nuts to 1/3 of a turn in cross sequence in 4 minutes.		If a stud rotates it indicates that the nuts were not snug. Immediately stop and undo all studs and repeat nut snug tensioning procedure	
73.	Technician	Commission and test equipment operation	<p>Once the bearing arrangement has been assembled, check the assembly has been done correctly by following the procedure below.</p> <p>(1) First, turn the bearing by hand to check that the bearing and seal are free from any irregularities.</p> <p>a. Non-smooth touch: Trapped dust or scratch                      b. Irregular torque: Abnormal interference                      c. Excessively large running torque: Too small bearing clearance, poor flatness of mounting seat</p> <p>(2) Next, run the bearing by power. Begin with no load, and at lower speed check.</p> <p>a. Abnormal noise: Dust, dent mark, or poor lubrication                      b. Vibration: Greater misalignment, or excessively large residual clearance</p> <p>(3) Run the bearing under normal operating conditions to check for temperature rise on the bearing. The possible causes to abnormal temperature rise with bearings are as follows:</p> <p>a. Allowable speed has been exceeded.                      b. Overloading                      c. Too small residual clearance                      d. Negative clearance owing to excessive expansion or compression with the shaft                      e. Warped Plummer block owing to poor flatness with the mounting base                      f. Poor lubrication (excessive or insufficient lubricant, inappropriate lubrication method of lubricant)                      g. Too great tightening allowance for the contact seal, or interference with rotating components such as those around the labyrinth seal If any irregularity is found as a result of running inspection, determine and remove the cause. Then redo the running inspection to make sure the bearing runs normally.</p>							<p>These activities often are found in the manufacturer's literature and in machinery handbook and engineering standards.</p> <p>After such an amount of intrusive maintenance is done on equipment it is necessary to write a commissioning plan with the tests to be performed and places to record the evidence that the equipment is performing correctly.</p>	
74.		Measure base plate start-up load flexing	 <p>Thanks to NTN Bearings for the image <a href="http://www.ntn.co.jp">www.ntn.co.jp</a></p> <p>Mount a free-standing digital dial gauge (i.e. mounted so it is separate to the base plate) with the dial gauge tip touching the top of the Plummer block. When the equipment starts-up note and record the tip movement.</p>					Ensure base plate and support is stiff and cannot flex more than IT5/10 under full load		Stiffen-up base and support frame by strong cross bracing. Ensure welding does not distort the base	<p>This proof-test can only be done when the equipment is operating. It is vital that it is done to check that deformation under load is not able to destroy the bearings.</p>



No	Task Step Owner	Task Step Name	Task Description	Matl, Tools & Their Condition	Test for Correctness	Reliability and Quality Standards			Reading / Result	Action if Out of Tolerance	Sign off
						<i>Good</i>	<i>Better</i>	<i>Best</i>			
			When the equipment is in operation under full load note and record the tip movement.								
75.	Technician	Clean and hand back	Safely clean-up, hand-back, complete job record and sign-off and record Work Order history		All equipment, tools and waste removed - area left spotlessly clean	Recommission procedure is written, reviewed and correctly done and plant proven safe for continued use	Recommission procedure is written, reviewed and correctly done and plant proven safe for continued use	Recommission procedure is written, reviewed and correctly done and plant proven safe for continued use			

**NOTE:** This is an example ACE 3T procedure. **Do not use this procedure without the exact details that apply to your equipment.**  
 Each organisation must research, develop and approve all procedures used on their plant and equipment.

## **Bibliography**

1. SKF SNL Plummer block housings publication
2. NTN Plummer blocks publication 2500/E
3. CBC Bearing drawings CBC-DC-01B, CBC-DC-02B, CBC-DC-03B, CBC-DC-04B, CBC-DC-11A
4. ISO 286 International Tolerance Grade Table

**NOTE:** This is an example ACE 3T procedure. **Do not use this procedure without the exact details that apply to your equipment.** Each organisation must research, develop and approve all procedures used on their plant and equipment.

## ***Creating Procedures and Check Sheets with Quality to Improve Reliability***

### **Abstract**

*Creating Procedures and Check Sheets with the Quality that Improves Reliability.* Ultimately reliability is in the hands of the people that use, build and rebuild equipment. High equipment reliability requires precision workmanship and steady, considerate operation (known as Degradation Management). Both equipment operator and equipment maintainer need to be precise, they need to know exactly what to do to always produce great reliability. Most procedures and check sheets are so poorly written that they cause equipment to be failed. Standard operating procedures can create reliability if they ensure that users meet minimum quality standards. World-class standard operating procedures set not only a minimum level of quality, they also set a highest level of quality that when achieved will deliver amazing equipment reliability.

Keywords: precision maintenance, work quality standards, work quality assurance, degradation management

For a long time now I have wondered why so many companies around the world suffer poor operational equipment performance. I think back to when I was an apprentice fitter and machinist 35 years ago and the same problems that hounded us back then with our equipment condition still hound us today. I remember as an apprentice the old tradesmen telling their ‘war stories’ about the failures and errors which happened to them twenty and thirty years earlier. For at least 70 years that I know of operational and maintenance errors and failures have wrecked our machines and businesses. I suspect that it has always been that way. I’m now of the mind that we have serious systematic problems with the design of our business processes and with our manager’s, trades peoples’ and engineers’ education processes. I fear that we have created processes and systems that teach people to destroy machines and fail our businesses because we do not teach them how to produce outstanding quality work without errors, mistakes and failures.

Reliability is an outcome you design and then create. You get reliability after meeting the quality requirements that produce the intended reliability. You specify the quality of manufacture, assembly, installation, operation and maintenance needed for a level of reliability. Quality is an exact number and it is measured in indisputable engineering values. It is not a happy state of mind and a nice feeling from seeing something go well. That may have happened totally by luck. There is no ‘lucky’ factor in creating quality and reliability. You make reliability happen intentionally – you design the business processes and practices across the life-cycle to produce it on purpose. Unless your standard operating procedures (SOPs) and check sheets contain measurable quality values that are met when the work is performed, they will destroy your machines and equipment because they work by luck instead of providing the sure way to produce high reliability.

In this article are several common styles of standard operating procedures, record sheets and check sheets used in industry. We will investigate them and highlight how they can be improved to prevent the operating and maintenance disasters that they will undoubtedly cause if they are used. To address the problems and limitations caused by the example SOP, a new style of SOP based on the Accuracy Controlled Enterprise 3T (Target-Tolerance-Test) procedure format is discussed. If you want high equipment reliability you need to make sure your managers, engineers, operators and maintainers know what to do to deliver it. You do that by installing and using only those business processes and practices that intentionally produce the reliability you need.

**Service Report Sheets**

		DATE	2 Nov 05	
		JOB NUMBER	3110527	
		MACHINE MODEL		
		MACHINE SERIAL No.		
<b>FIELD SERVICE REPORT</b>				
CONDITION MONITORING CHECK USING <i>SENTINEL</i>				
<b>AIREND</b>		<b>GEARBOX</b>	<b>DRIVE MOTOR</b>	<b>LUBRICANT</b>
MDE	49/53	MNDE	49/54	DE
FDE	48/52	FNDE	47/50	NDE
		INPUT	N/A	SUPPLIER
				GRADE
<b>LUBRICANT</b>				
CHANGED?		<input checked="" type="checkbox"/> YES <input type="checkbox"/> NO		SAMPLE
		<input type="checkbox"/> YES <input checked="" type="checkbox"/> NO		
MOTOR BEARINGS LUBRICATED?		<input type="checkbox"/> YES <input checked="" type="checkbox"/> NO		
MOTOR F.L.C./VOLTAGE AT DESIGN PRESSURE				
GENERAL CONDITION		<input checked="" type="checkbox"/> GOOD <input type="checkbox"/> FAIR <input type="checkbox"/> POOR		
<b>TEMPERATURE CHECKS</b>				
THERMAL VALVE OPENING		YES		
AMBIENT		22°	DISCHARGE	78°
COOLER IN		5/8	COOLER OUT	27
L1		/	L2	/
L3		/		
<b>REFRIGERATED AIR DRYER</b>				
GENERAL CONDITION		<input type="checkbox"/> GOOD <input checked="" type="checkbox"/> FAIR <input type="checkbox"/> POOR		
DRYER DEW POINT		3°C		
CONDENSOR CLEANED/SERVICEABLE				
<b>AIR RECEIVER</b>				
GENERAL CONDITION		<input checked="" type="checkbox"/> GOOD <input type="checkbox"/> FAIR <input type="checkbox"/> POOR		
TEST REQUIRED DATE				
SAFETY VALVE TEST DATE				
LEAD PRESSURE SWITCH SET POINTS		IN 6.5 OUT 7.8		
LAG PRESSURE SWITCH SET POINTS		IN OUT		
<b>REPLACED (O)</b>				
<input checked="" type="checkbox"/> INTAKE AIR FILTER				
<input type="checkbox"/> INLET AIR FILTER				
<input type="checkbox"/> MAIN OIL FILTER				
<input checked="" type="checkbox"/> BEARING OIL FILTER				
<input type="checkbox"/> SEPARATOR ELEMENT				
<input type="checkbox"/> PURGE LINE FILTER				
<input type="checkbox"/> LUBRICANT				
<input checked="" type="checkbox"/> BELT CONDITION / TENSION				
<input checked="" type="checkbox"/> BELT / DRIVE WEAR				
<input checked="" type="checkbox"/> BELT / DRIVE ALIGNMNT				
<b>CHECKED AND SERVICEABLE (✓)</b>				
<input checked="" type="checkbox"/> CONTROL REGULATOR				
<input checked="" type="checkbox"/> INTAKE CONTROLLER				
<input checked="" type="checkbox"/> PRESSURE SWITCH				
<input checked="" type="checkbox"/> BLOWDOWN VALVE				
<input checked="" type="checkbox"/> MINIMUM PRESSURE VALVE				
<input checked="" type="checkbox"/> OIL STOP VALVE				
<input checked="" type="checkbox"/> DISCHARGE CHECK VALVE				
<input checked="" type="checkbox"/> THERMOSTATIC VALVE				
<input checked="" type="checkbox"/> SAFETY VALVE				
<input checked="" type="checkbox"/> TUBING SECURITY / CONDITION				
<b>REQUIRES FURTHER ATTENTION (X)</b>				
<input checked="" type="checkbox"/> ELECTRICAL CONNECTIONS				
<input checked="" type="checkbox"/> GAUGES				
<input checked="" type="checkbox"/> PANEL LIGHTS / INDICATORS				
<input checked="" type="checkbox"/> AFTER COOLER				
<input checked="" type="checkbox"/> OIL COOLER				
<input checked="" type="checkbox"/> RECIPROCATING VALVES				
<input checked="" type="checkbox"/> DRAIN AIR RECEIVER				
<input checked="" type="checkbox"/> AUTO DRAINS				
<input checked="" type="checkbox"/> MACHINE CLEANING (INT)				
<input checked="" type="checkbox"/> MACHINE CLEANING (EXT)				
1. <i>Conducted Routine major service</i>				
2. <i>Replaced items checked above</i>				
3. <i>Checked items ticked above</i>				
4. <i>Have unit for operational checks</i>				
5. <i>Conducted Vibration Analysis on air end + motor</i>				
6. <i>Air End will require new pulley and belts, hope back next service</i>				
WORKPLACE INSPECTION REQUIRED		<input type="checkbox"/> YES <input checked="" type="checkbox"/> NO		
WORKPLACE INSPECTION COMPLETED AND ATTACHED		<input type="checkbox"/> YES <input type="checkbox"/> NO		
CUSTOMER SUPPORT TECHNICIAN		CUSTOMER <i>X</i> REVIEW		

Figure 1 - Copy of a Service Report Sheet from Air Compressor Maintenance Subcontractor

The style of service report in Figure 1 is common. A tick-the-box plus freehand comments method of feedback is quick and simple for the technician. Unfortunately the report contains little of value regarding the condition of the equipment and its likely future reliability. All I can discern from the report is the technician looked at the equipment, did some overall vibration measurement, checked the machine was in a 'good-enough' condition to continue running, and left site after seeing someone to sign his time sheet. If the equipment owner kept using service reports like that of Figure 1 to monitor the machine, their air compressor will fail catastrophically before they will ever know there is something seriously wrong with it. There is no information in the report to prove the air compressor and dryer are able to continually produce quality compressed air and will deliver long-term, highly reliable operation. The better approach is to re-draft the report with clear, unambiguous descriptions and/or photographs of upper and lower acceptance limits for each item inspected. The vibration values recorded have no meaning to anyone except people that know the Sentinel Vibration Monitor System. The vibration analysis results need to be presented on a trending control chart. The vibration readings seem to show total vibration,

which are of no use for diagnosing bearing condition and budding reliability problems in rotating equipment.

**Inspection Acceptance Forms**

**New/Rebuilt Motor Vibration Test Form (0- 20 HP)**

Scope  
 This form is to be used to record the shop test data taken on motors running solo in the shop.

Set up

- Motor to have a 1/2 key installed.
- Motor to be placed on rubber mat at least 1/4" thick.
- Where possible motor to be tested at full service speed.
- Maximum line amplitude is the amplitude value of the highest discrete frequency component within the stated frequency range in any direction (HVA).
- Scope of this criteria is 2, 4, & 6 pole motors.

Equipment ID: \_\_\_\_\_

Acceptance Criteria 0-20 HP Motors		Vibration Test Data New/Rebuilt Motors				
Frequency Range	Max Line Amplitude ips pk	MOV	MIV	MOH	MIH	MIA
Sub-harmonic (< 1x RPM)	0.02					
1 x RPM	0.03					
Lower Multiples (1x RPM – 10x RPM)	0.02					
Higher Frequencies (10x – 50x RPM)	0.01					
Overall Acceleration g pk (0- 20kHz)	0.5					

Measurement locations

Figure 2 - Copy of Vibration Records of Electric Motor Baseline Vibration

Figure 2 is a baseline check sheet for a new electric motor. At first glance it seems to look the part. It has good images with clear indication of where to position the vibration detector. The vibration values are selected to detect a range of problems. My big concern is that the acceptance limits are the ‘good enough’ type. This really means that the performance is not yet ‘bad enough’ to correct. Would it not be fantastic to have another column showing world-class vibration results? Then everyone knows what superb vibration performance is and can look for ways to produce it. The one-sided acceptance limit used in Figure 2 is a trap. You only know what ‘bad’ looks like. People using the form of Figure 2 will tend to accept motors that are just outside the limit because of the unwanted hassle and cost of getting them re-worked. The one-sided acceptance lets them think that they are saving the company money and time if the result is ‘close enough’, but in fact what they really do is bring future failures into the business. Once you create a two-sided acceptance limit that includes world-class performance, nobody can kid themselves, or anyone else, as to how the equipment is really performing. **A one-sided acceptance limit shows people how bad they can be. But a two sided acceptance limit shows them how good they need to be to reach world-class.**

Unfortunately the form in Figure 2 is designed and promoted by a world-leading maintenance consultancy. They give all their clients these forms. They teach people around the world to write forms just like Figure 2. It is a tragedy for industry. To me this explains a lot of the reason so many companies

around the world have operational equipment problems. They are systematically wrecking their equipment through ignorance and wrong advice.

**Equipment Condition Inspection Forms**

<u>Equipment Number</u>		<u>Work Order Number</u>		<u>Date</u>	
<u>Pump description</u>			<u>Running Hrs</u>		
<u>Machine History Checked ?</u>			<u>Clearance #</u>	<u>Isolation Points</u>	
				<u>Valves</u>	<u>Breakers</u>
<u>Pump Manufacturer</u>			<u>Pump Size</u>		
<u>Reason that Work Order was Written for Pump</u>					
<b>Inspection Section</b>					
<b>Pump Foundation &amp; Piping</b>					
<u>Item</u>	<u>Condition</u>		<u>Comments</u>		
Grout/Foundation	Good	Bad	Not Checked		
Anchor Bolts	Good	Bad	Not Checked		
Base Condition	Good	Bad	Not Checked		
Pusher Bolts	Yes	No	Not Checked		
Suction Piping Strained	Yes	No	Not Checked		
Discharge Piping Strained	Yes	No	Not Checked		
<b>Pump Coupling</b>					
Coupling Spacer	Good	Bad	Not Checked		
Coupling Flanges	Good	Bad	Not Checked		
Coupling Hubs	Good	Bad	Not Checked		
Key Length	Good	Bad	Not Checked		
Lubricant Condition	Good	Bad	Not Checked		
<b>Pump Bowl</b>					
Impeller Rub	Yes	No	Not Checked		
Corroded/Eroded	Yes	No	Not Checked		
Gasket Leak	Yes	No	Not Checked		
Plugged in Suction/Discharge	Yes	No	Not Checked		
Wear Ring Condition	Good	Bad	Not Checked		
<b>Pump Impeller</b>					
Impeller Rub	Yes	No	Not Checked		
Corroded/Eroded	Yes	No	Not Checked		
Impeller Gasket Condition	Good	Bad	Not Checked		
Cavitation Wear	Yes	No	Not Checked		
Impeller Tips Bent/Worn	Yes	No	Not Checked		
<b>Rear Cover</b>					
Backplate Corroded/Eroded	Yes	No	Not Checked		
Stuffing Box Corroded	Yes	No	Not Checked		
Gland Gasket Leaking	Yes	No	Not Checked		
<b>Mechanical Seal</b>					
Seal Leaking	Yes	No	Not Checked		
O-rings	Good	Bad	Not Checked		
Rotating Face	Good	Bad	Not Checked		
Stationary Face	Good	Bad	Not Checked		
Seal Flush Operational	Yes	No	Not Checked		
<b>Shaft</b>					
Sleeve	Yes	No	Not Checked		
Fretted	Yes	No	Not Checked		
Grooved	Yes	No	Not Checked		
Corroded/Pitted	Yes	No	Not Checked		
Threads Worn	Yes	No	Not Checked		
Bent/Broken	Yes	No	Not Checked		
<b>Cartridge</b>					
Front Bearings	Good	Bad	Bearing Manuf. & #		
Rear Bearings	Good	Bad	Bearing Manuf. & #		
Oil Seals/Isolators	Good	Bad			
Oil Level	Good	Low			
Oil Contaminated	Yes	No			

Figure 3 - Copy of Pump Inspection and Condition Reporting Form

You see the format and content style of Figure 3 everywhere in industry. I believe it causes far more equipment failures than it prevents. My guess is that it is written by a technician with years of experience inspecting and repairing centrifugal pumps, or by a professional engineer with long years of pumping system experience. No one else could possibly hope to understand it, much less use it effectively. Like the air compressor service report of Figure 1, this form will let the pump fail catastrophically before you will ever know there is something seriously wrong with it. The reason is no one knows what 'good', 'bad', 'yes' or 'no' looks like. Such measures are entirely subjective. You must have measurable parameters to decide if a thing is, or is not, good or bad. Parameters don't move. They cannot be adjusted depending on circumstances. An inspection form needs to tell you what world-class results are for every inspections, along with what is the worst performance accepted before doing something about it. For each inspection you must know how to conduct the inspection to ensure test correct results and prevent bad results. Furthermore, the form must tell me exactly what to do when the performance is 'bad'.

Imagine handing the work order to a maintenance tradesperson and telling them to do the inspections. Take the first inspection 'Grout/Foundation'. What could a maintenance tradesman possibly know about world-class pump base grouting and foundations? Only an experienced pump foundation and base plate design and installation engineer would know what they had to look for to decide if the pump base grout and foundation were in good or bad condition. You might be lucky and the tradesperson is highly knowledgeable in pump bases and grouting. If that happened it would be the luckiest day of your life. The same applies for every other inspection. How can you competently decide during the inspection what is 'good' and what is 'bad' when there is nothing by which you can gauge such decisions?

This form, like that of Figure 2, was designed and promoted by a world-leading equipment maintenance consultancy. They give all their clients these forms and they are teach people to write inspection forms just like Figure 3. These forms are developed with all the best of intentions but they are nowhere adequate for creating high reliability. People will use them and think they are providing a good maintenance service to their company and its machinery. But they are terribly wrong. Inspection forms without upper and lower acceptance criteria, and a repeatable proof-test to confirm the quality level, cannot deliver reliable machines.

**Visual Management Based Instructions**

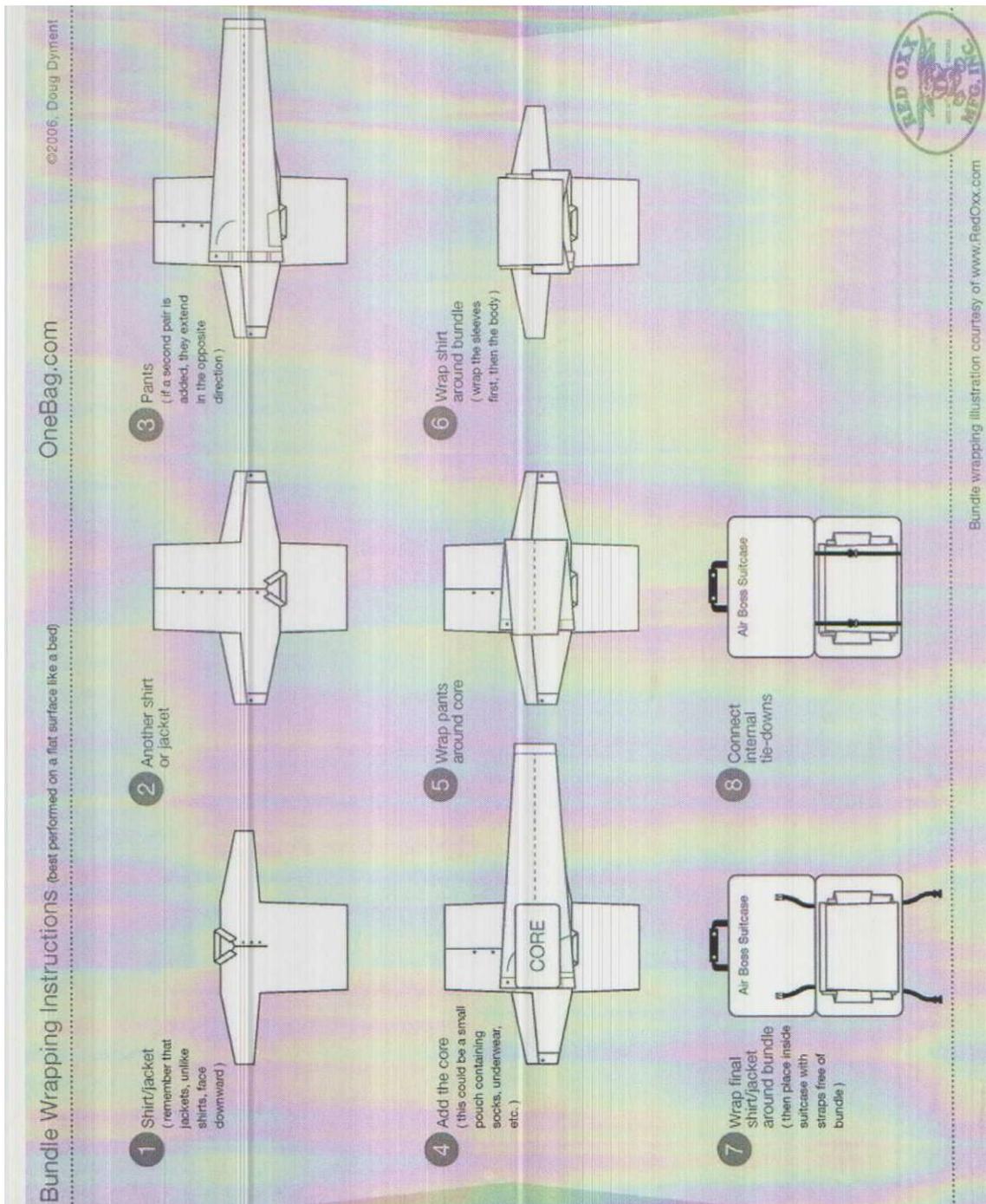


Figure 4 - Copy of Visual Instructions for Folding Clothes

Figure 4 is a great attempt to keep things simple while getting the message across. Humans get 75% of their information through their eyes. Imagine trying to explain in words what these eight pictures say on one page. You could have five or more pages of description and still do the folding wrong. I bet a supervisor in charge of a group using a descriptive folding procedure would be worked-off their feet explaining and showing people the right way to do the folding. A supervisor of a group using the visual procedure would take a day to train their people and then everyone would get it right. There is a trap in the visual method of ‘writing’ procedures. You still have to make sure people meet the minimum standard while encouraging them to be world-class. There are no standards noted in Figure 4. I would like to see both a top class result and a not acceptable result shown during the training program for those people who fold clothes.

Go out of your way to provide people with detailed visual procedures and checklists and not detailed descriptive procedures and checklists. The next example shows you why it's worth it.

**Descriptive Based Acceptance Criteria**

<b>Visual Inspection Acceptance Criteria</b>													
<u>Discontinuity Category and Inspection Criteria:</u>	Statically Loaded Nontubular Connections	Cyclically Loaded Nontubular Connections	Tubular Connections (All Loads)										
<b>(1) Crack Prohibition:</b> Any crack shall be unacceptable, regardless of size or location.	X	X	X										
<b>(2) Weld /Base-Metal Fusion:</b> Thorough fusion shall exist between adjacent layers of weld metal and between weld metal and base metal.	X	X	X										
<b>(3) Crater Cross Section:</b> All craters shall be filled to provide the specified weld size, except for the ends of intermittent fillet welds outside of their effective length.	X	X	X										
<b>(4) Weld Profiles:</b> Weld profiles shall be in conformance with 5.24.	X	X	X										
<b>(5) Time of Inspection:</b> Visual inspection of welds in all steels may begin immediately after the completed welds have cooled to ambient temperature. Acceptance criteria for ASTM A 514, A 517 and A 709 Grade 100 and 100 W steels shall be based on visual inspection performed not less than 48 hours after completion of the weld.	X	X	X										
<b>(6) Undersized Welds:</b> The size of a fillet weld in any continuous weld may be less than the specified nominal size (L) without correction by the following amounts (U): <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="text-align: center;"><math>L,</math></td> <td style="text-align: center;"><math>U,</math></td> </tr> <tr> <td style="text-align: center;">specified nominal weld size, in. [mm]</td> <td style="text-align: center;">allowable decrease from L, in. [mm]</td> </tr> <tr> <td style="text-align: center;"><math>\leq 3/16</math> [5]</td> <td style="text-align: center;"><math>\leq 1/16</math> [2]</td> </tr> <tr> <td style="text-align: center;"><math>1/4</math> [6]</td> <td style="text-align: center;"><math>\leq 3/32</math> [2.5]</td> </tr> <tr> <td style="text-align: center;"><math>\geq 5/16</math> [8]</td> <td style="text-align: center;"><math>\leq 1/8</math> [3]</td> </tr> </table> In all cases, the undersize portion of the weld shall not exceed 10% of the weld length. On web-to-flange welds on girders, underrun shall be prohibited at the ends for a length equal to twice the width of the flange.	$L,$	$U,$	specified nominal weld size, in. [mm]	allowable decrease from L, in. [mm]	$\leq 3/16$ [5]	$\leq 1/16$ [2]	$1/4$ [6]	$\leq 3/32$ [2.5]	$\geq 5/16$ [8]	$\leq 1/8$ [3]	X	X	X
$L,$	$U,$												
specified nominal weld size, in. [mm]	allowable decrease from L, in. [mm]												
$\leq 3/16$ [5]	$\leq 1/16$ [2]												
$1/4$ [6]	$\leq 3/32$ [2.5]												
$\geq 5/16$ [8]	$\leq 1/8$ [3]												
<b>(7) Undercut:</b> (a) For material less than 1 in. [25mm] thick, undercut shall not exceed 1/32 in. [1mm], with the following exception: undercut shall not exceed 1/16 in. [2mm] for any accumulated length up to 2 in. [50mm] in any 12 in. [300mm]. For material equal to or greater than 1 in. thick, undercut shall not exceed 1/16 in. [2mm] for any length of weld. (b) In primary members, undercut shall be no more than 0.01 in. [0.25] deep when the weld is transverse to tensile stress under any design loading condition. Undercut shall be no more than 1/32 in. [1mm] deep for all other cases.	X												
<b>(8) Porosity:</b> (a) CJP groove welds in butt joints transverse to the direction of computed tensile stress shall have no visible piping porosity. For all other groove welds and for fillet welds, the sum of the visible piping porosity 1/32 in. [1mm] or greater in diameter shall not exceed 3/8 in. [10mm] in any linear inch of weld and shall not exceed 3/4 in. [20mm] in any 12 in. [300mm] length of weld. (b) The frequency of piping porosity in fillet welds shall not exceed one in each 4 in. [100mm] of weld length and the maximum diameter shall not exceed 3/32 in. [2.5mm]. Exception: for fillet welds connecting stiffeners to web, the sum of the diameters of piping porosity shall not exceed 3/8 in. [10mm] in any linear inch of weld and shall not exceed 3/4 in. [20mm] in any 12 in. [300mm] length of weld. (c) CJP groove welds in butt joints transverse to the direction of computed tensile stress shall have no piping porosity. For all other groove welds, the frequency of piping porosity shall not exceed one in 4 in. [100mm] of length and the maximum diameter shall not exceed 3/32 in. [2.5mm]	X												
		X	X										

*General Note: An "X" indicates applicability for the connection type. A shaded area indicates non-applicability.*

Figure 5 - Copy of Welding Acceptance Inspection Criteria

The acceptance criteria in Figure 5 are correct in detail and content. You just need to be a welding expert to understand them. You could say that only welding experts should be doing structural welding acceptance anyway. You would be right. But the written criteria in Figure 5 are a lot of hard work to fathom. If you were in a hurry you'd almost certainly misunderstand what was contained in the words. It would be far better if these written criteria were turned into pictures and drawings of exactly what 'pass' and 'fail' looked like. That's a lot of extra work people would say. I know. But how else do you stop welders making errors and rework – hope they don't happen? The images of pass-fail criteria are not for

the Inspector. The images are for the people doing the welding so that they can do a great weld every time. It is not the Inspector that needs educating on weld quality; it is the welders who make the weld that need to know what is, and is not, acceptable. By using images instead of text there is a much greater likelihood that there will be no welding errors for the third-party inspection to find.

**Inspection and Test Plans**

<b>INSPECTION AND TEST PLAN</b>									
Drawing No.: 129D		Rev: 129D		Customer:		WO No.:		ISO 9001:2000	
No.	DESCRIPTION Operation/ Inspection & Test	Applicable Specification	Inspection Points	Reference Documentation	Verification By:		Records	QA STANDARD	
					Date	Sub-contractor			
1.	Profile Material ▪ Profile Operator to record Plate details as plate is cut.	434D 373D	In Process	5.2			M001 Cutting Details		
2.	Plate Preparation ▪ Items to be pressed ▪ Preparation of items	785D							
3.	Fit and tack fabrication – verify before final welding	785D	In Process	5.1			I005 Dimensional Check		
4.	Weld Fabrication – Dimensional check on centre to centre front/back bores.	785D	In Process				I004 Dimensional Check		
5.	100% Visual Inspection	785D	On completion of welding	5.12					
6.	Surface Treatment	Class 2.5 Blast, Prime Coat.	On completion of stamping				Paint Certification		
7.	Machine and facing of bores	129D	In Process				Machine Inspection Record		
8.	Weld of supports to Assembly	785D	In Process				Weld Dimensional		
9.	Fit Bushes	129D	On completion				030 Final		

LEGEND: H= HOLD W=WITNESS S= INSPECTION

Revision 2      Date:

Page 1 of 2

Figure 6 - Copy of Page 1 of Welded Structure Quality Inspection and Test Plan (ITP)

**INSPECTION AND TEST PLAN**

Drawing No.: 129D      Rev:      Customer:      WO No.:

DESCRIPTION No.	Operation/ Inspection & Test	Applicable Specification	Inspection Points	Reference Documentation	QA STANDARD		Records
					Verification By:	Date	
10.	ID Stamped		of machining				Inspection for Fitting Bushes
11.	Final Inspection	Process 85D	On completion	5.12			I008 Inspection Report
12.	Documentation completed	QA Documentation completed	Prior to closing Work Order				Work Order File
13.	Dispatch as part of Gantry Assy	As per Purchase Order	On completion				

LEGEND: H= HOLD W=WITNESS S= INSPECTION      Revision 2      Date:

Page 2 of 2

Figure 7 - Copy of Page 2 of Welded Structure Quality Inspection and Test Plan (ITP)

An Inspection and Test Plan lists the quality requirements and the compliance tests that must be met for acceptance. It is the plan for collecting the evidence that all the work needed to make a thing has been done right. ITPs have been used for a long time. They are part of any quality managed organisation. Though they have been used for a long time for quality management they are not successful in preventing failures. The drawback with ITPs is that they are a feedback device. You are only required to inspect after the task is completed. You do the entire job first and then you check if you did it right. That seems crazy to me. Imagine working a whole week on a job and you only find out on Friday that you made a mistake on Monday. Feedback management and reporting is only useful for learning about mistakes, not for preventing them. To prevent errors and mistakes you need feed-forward measurement and reporting.

## Accuracy Controlled SOPs

A feed-forward driven SOP would tell you immediately that you have done the task right or you have made a mistake. It makes you aware of an error and lets you correct it to the required standard before doing the next task of the job. To develop a feed-forward SOP you need a world-class standard to hit and an idea of how close to the standard you need to be to still meet minimum quality. The upper and lower quality standards form ‘boundaries of excellence’. A proof-test confirms that the work produced acceptable quality. If the test shows the work is not within the quality boundary you fix it immediately and do not leave a defect. In this way all work is perfect because it always meets the necessary quality standard at every step and in every task. When you write SOPs with each task given a Target, Tolerance and Test you create an accuracy controlled 3T procedure.

Figure 8 shows the upper and the lower quality limit for rotating equipment shaft alignment. It comes from John Piotrowski’s ‘Shaft Alignment Handbook’. It is the ideal input into an accuracy controlled procedure because in one graph it provides the world-class quality target to strive for and the least acceptable result allowed. In the one chart you are given the ‘Target’ and the ‘Tolerance’ for high quality shaft alignment. The ‘Test’ is to measure the alignment with laser equipment (or reverse dial indicator) to prove the shaft alignment indeed meets the required standard. Including this two-sided acceptance standard into a shaft alignment procedure shows people the quality of alignment that brings with it high equipment reliability.

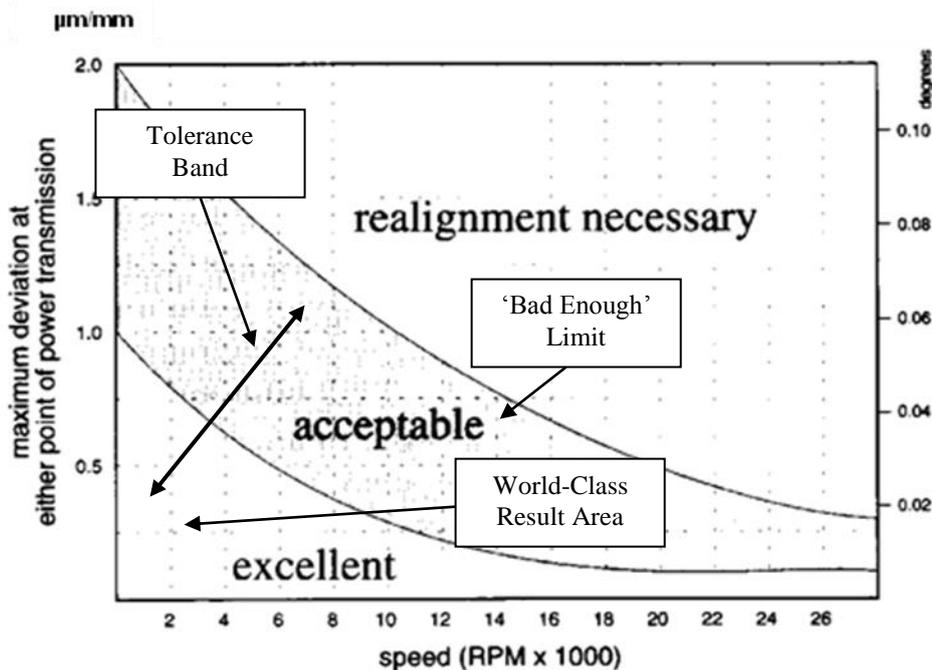


Figure 8 - Copy of Recommended Maximum Misalignment of Flexibly Connected Rotating Machinery – Shaft Alignment Handbook by John Piotrowski, CRC Press

Piotrowski’s chart makes clear what acceptable quality for rotating shaft alignment is. Once the specific values for the power transmission point deviation and angular misalignment at a given RPM are transferred into your procedure, they lock shaft alignment quality into place throughout the operation. No other standard is acceptable. Such ACE 3T procedure content says to everyone that this company wants only top-class results and anything less needs to be improved.

## What is Wrong with this Job Plan?

### JOB PLAN TO INSTALL NEW BEARINGS IN CONVEYOR PULLEY PLUMMER BLOCKS

1. Prepare for Job in Dirt-Free Work Area
2. Safe Isolation and Handover
3. Check Parts and Materials are Correct
4. Access Plummer Blocks and Bearings
5. Check Shaft Condition and Tolerance
6. Measure Bearing Internal Clearance
7. Measure Plummer Base Plate Accuracy
8. Locate Bearings on Shaft
9. Mount Bearings on Shaft
10. Position Plummer Blocks and Place Pulley
11. Complete Plummer Block and Seals Assembly
12. Align Plummer Blocks
13. Lubricate Bearing and Seals
14. Align Plummer Blocks and Bolt Down
15. Commission and Test
16. Clean-up and Hand Back



**ANSWER:** *no organisation, no times, no quality standards = no control of the job*

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This is the sort of job plan that you get on a very poorly planned maintenance work order. It is just a register of milestones to be achieved. The 16 tasks would be listed on one page and the page given to the maintenance technician to do. Good luck to the technician because luck is all that the person has to work with.

The problem with this job plan is that you have no idea if the work has actually been planned, nor can work performance be measured. You do not know how long it should take to do each task and cannot know the time the whole job should take. You do not know what quality of work is required to be done in the job. You do not know how detailed the preparation was looked into and performed by the Planner. This job has no chance whatever of going well except if good fortune smiles on it.

The planning system should have provided everything that this job needs for high quality work to be done right-first-time. With only a list of tasks to work from the technician will have to do his own preparation and planning on-the-run as the job develops.

If this job was to be done in place it can take a technician and his helper up to two days to do, but it could have been done in four hours if it was fully planned and prepared using a replacement head pulley with shaft and bearings already mounted ready to simply swap over to replace the old pulley.

## Develop a Job Plan with Quality Specifications that Indicate Achievement of Milestone Steps

### JOB PLAN TO INSTALL NEW BEARINGS IN CONVEYOR PULLEY PLUMMER BLOCKS

1. Work Area **prepared to site dirt-free work standard**
2. Safe Isolation and Handover **delivered from Operator**
3. Check Parts and Materials are **correct to BOM**
4. Plummer Blocks and Bearings **accessed for safe installation**
5. Shaft Condition and Tolerance **checked against OEM values**
6. Bearing Internal Clearance **measured against OEM values**
7. Plummer Base Plate **measured against OEM values**
8. Bearings on Shaft **located to OEM values**
9. Bearings on Shaft **mounted to OEM standards**
10. Plummer Blocks and Pulley **positioned to OEM standards**
11. Complete Plummer Block and Seals **assembled and positioned to OEM standards**
12. Plummer Blocks **aligned to OEM standards**
13. Bearing and Seals **lubricated to OEM standards**
14. Plummer Blocks **aligned and bolted to OEM standards**
15. Commission and Test that **operating specification is met**
16. Clean-up and Hand Back **to site workplace cleanliness standards**



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Because of the effort needed to properly develop and write job plans with full procedures most companies look for simpler ways to specify work to be done on a job. In companies that have had planning processes for some years many documents have been written. Though not written with the full details needed, it is difficult for managers to justify using their planners to write new documents. This thinking is wrong because nothing will be improved, but it is prevalent across industry.

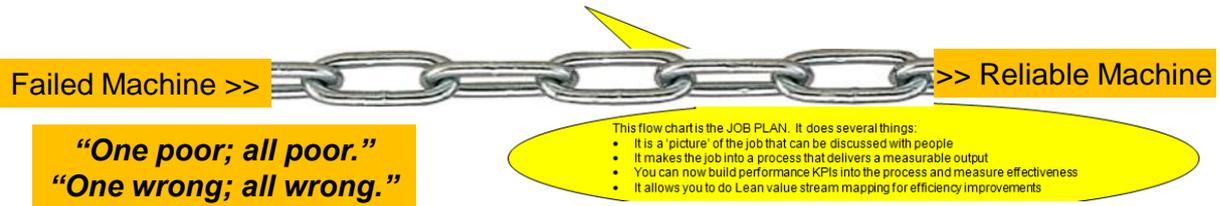
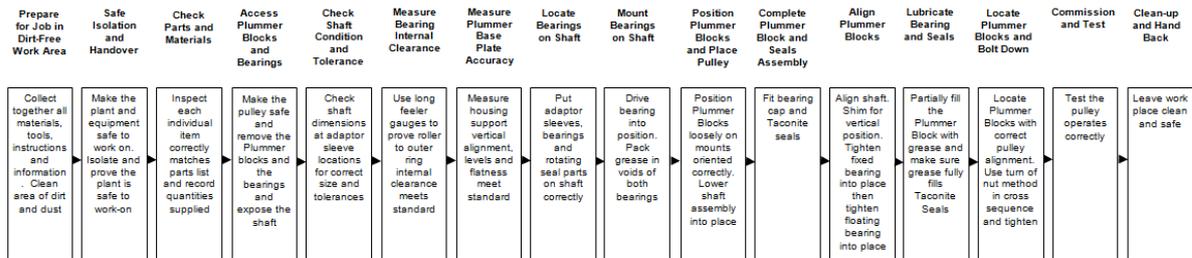
The slide shows an attempt to quickly introduce quality standards into work tasks. The old job plan is retained and work quality requirements are added into it. The minimum standards to meet are the site safety standards and the original equipment manufacturer (OEM) standards.

Once requirements for meeting standards are included into the work plan it becomes the technicians responsibility to go to the relevant documents and identify the values and requisites that meet the standards. The technician is given extra time to do the research. The values for each standard are recorded on the work order by the technician and the work order is handed back to the Maintenance Planner at job completion to record the specified values and so be able to include the values in all similar future work.

In this way the company makes use of their existing knowledgeable maintenance people to help the Planner develop a better planning system with work quality controls that aids all persons doing such work in the years ahead.

# Job Plan as a Process Flow Diagram makes Series Implications and Risks Clear

Job Plan of the Process for Installing Spherical Roller Bearings with Adaptor Sleeve in Plummer Blocks with Taconite Seals on a Conveyor Pulley Shaft



The Job Plan is presented as a flow diagram for a specific reason. Once you see that the job is made of activities done in series it makes clear that each activity is a link in the chain of successful job completion. Any activity done poorly will produce a poor job and an activity done wrongly will fail the whole job.

It is vital for a Maintenance Planner to see each job as a flow of work where every task is important to its proper completion. A Planner needs to understand that because a job is a series of linked activities everyone must be done correctly to produce a reliable and healthy machine.

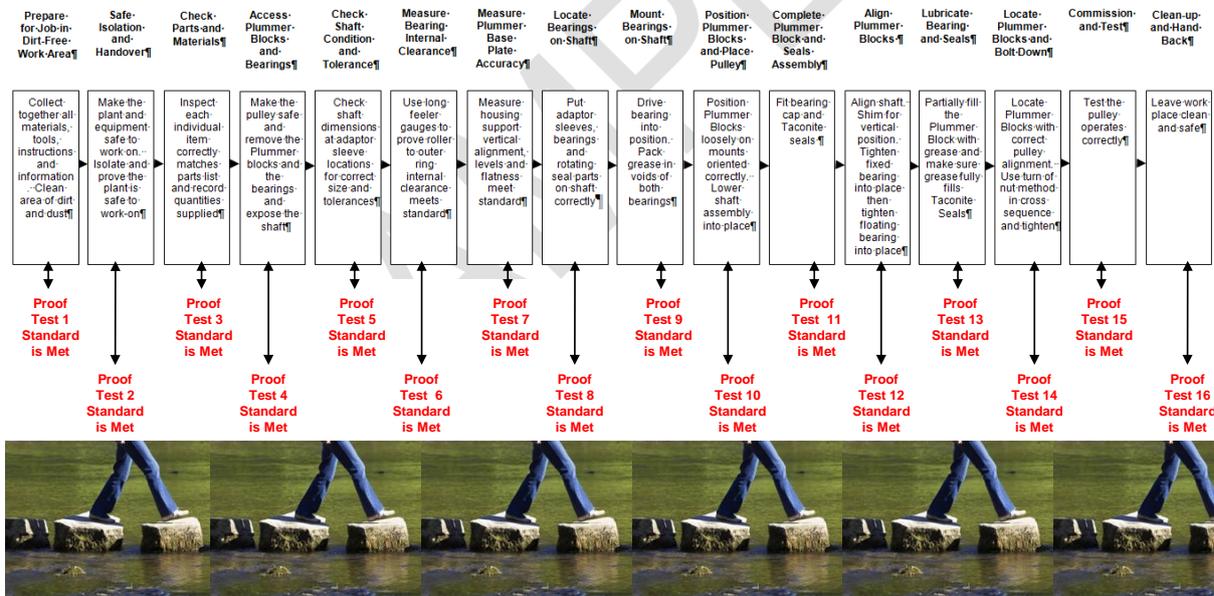
The realization that every activity is important justifies the effort needed to plan a job well. With full information provided to the technician on each activity the job has a far higher chance that the work will be done well.

Once there is a flow chart of the job plan we can use it to do several other things:

- It is a ‘picture’ of the job that can be discussed with people
- It makes the job into a process that delivers a measurable output
- You can now build performance KPIs into the process and measure effectiveness
- It allows you to do Lean value stream mapping for efficiency improvements

# As a Minimum... Set Standards in an Inspection and Test Plan (ITP) for the Job

## Overview of the Process for Installing Spherical Roller Bearings with Adaptor Sleeve in Plummer Blocks with Taconite Seals on a Conveyor Pulley Shaft



39

An Inspection and Test Plan (ITP) lists the quality requirements and the compliance tests that must be met for acceptance. It is the plan for collecting the necessary evidence that all the work needed to make or do a thing has been done right.

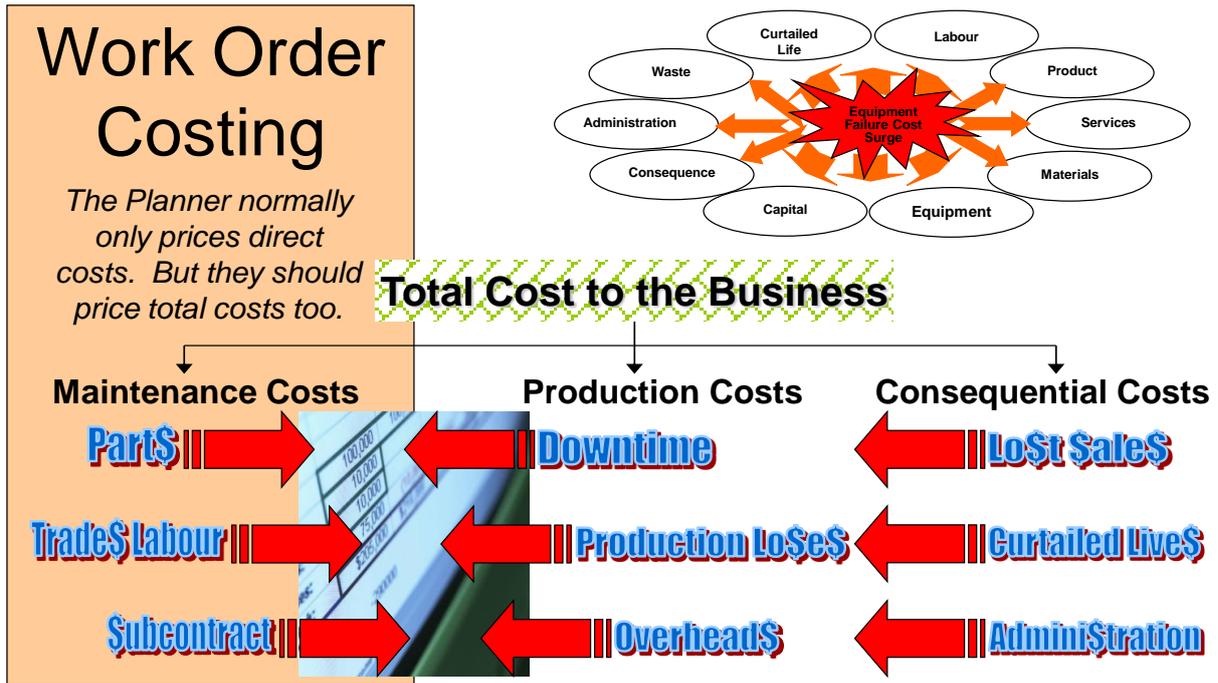
ITPs have been used for a long time. They are part of any quality managed organisation. Though they have been used for a long time for quality management they are not successful in preventing failures. The drawback with ITPs is that they are a feedback device. You are only required to inspect after the task is completed. You do the entire job first and then you check if you did it right.

That seems crazy to me. Imagine working a whole week on a job and you only find out on Friday that you made a mistake on Monday. Feedback management and reporting is only useful for learning about mistakes, not for preventing them. To prevent errors and mistakes you need feed-forward measurement and reporting.

Nonetheless, ITPs can be made to be useful if the inspections and tests are done at each milestone in a job. Since a job plan lists all the work milestones an ITP is created to test each one has passed the necessary quality.

The ITP for a job is separate to the job plan and is included in the work pack as an individual item. The technician completes each milestone proof test before doing the next phase of work to confirm what they have so far is correct. The ITP becomes the historical record that each step in the work was done right. It acts like stepping stones for the technician as they progress through the job. The ITP provides a safe and secure way to get through the job correctly.





See the Downtime Cost Spreadsheets for a list of over 65 costs of failure.

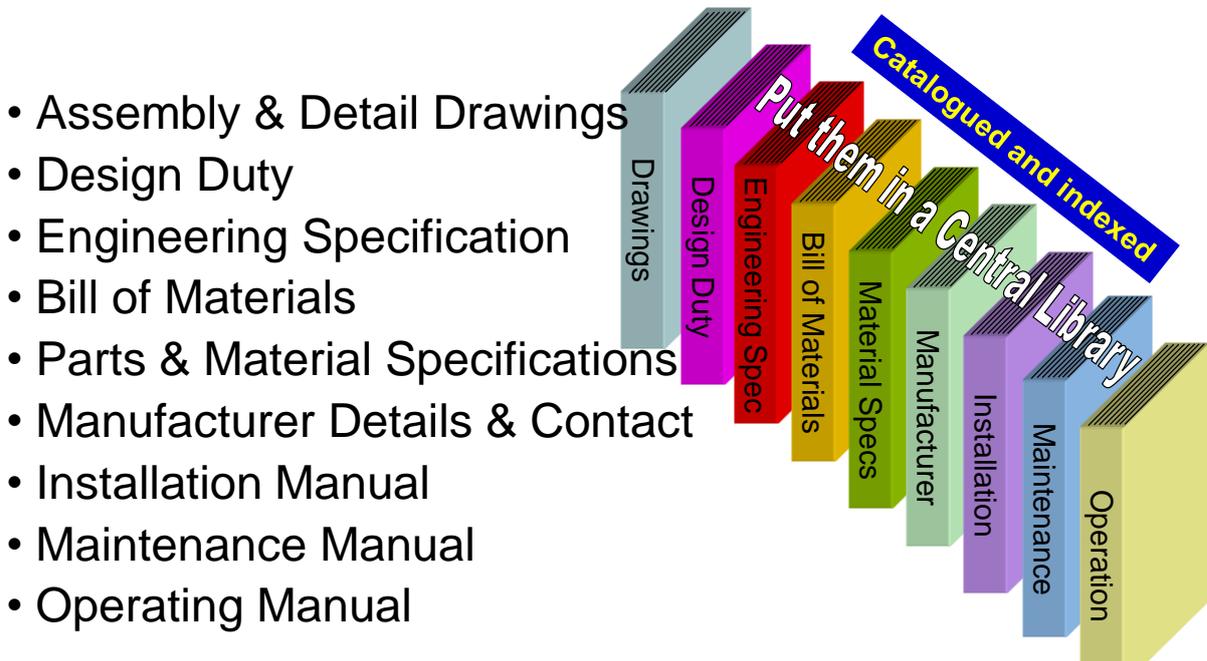
It is necessary to know the full cost of doing a job, and it should also be necessary to know the whole total cost of the job to the company; the two are not the same. Doing maintenance prevents the plant from working and making money for the business. That lost opportunity and its associated stoppage requirements are costs carried by the company because of the job. Knowing the direct maintenance costs of a work order is important, but knowing the total moneys lost by a business due to the maintenance job is just as important.

The direct cost of doing the work involves the cost of parts, men, equipment and other resources to complete the work. This is what a Planner must price to within ±10% accuracy of the final actual cost.

The cost of the job to the company includes the lost production, the production costs, the cost of services and utilities, the overhead costs, the handover costs, etc

The economic sense of doing maintenance must be seen in its full analysis. If you only cost jobs and do not see the total business costs that the jobs cause a company, you will never challenge peoples' thinking nor the organisation's practices to do maintenance better.

## Plant and Equipment Information



**Catalogue Index Convention: Site-Plant-Equip No-Discipline-Doc Type-Doc No-Rev No**

The information listed in the slide on plant and equipment used in the operation needs to be sourced, assembled together and catalogued for easy identification and access. Ideally all information should be in electronic form and backed-up in a separate, safe location. Working with electronic documents is easier and faster than using hardcopy documents. Hardcopy records are suitable but will degrade with use and they take-up floor and shelf space. They will get lost and different people have different levels of respect for their care. If you have to work with hardcopy documents then put the master copies away in a safe place and only work with copies of the originals. When the copies become unusable make new copies from the originals.

Cataloguing your documents into a central library is important. Each and every document must be identifiable and discernable from every other document. That means each and every document in the library must be separately identified with its own unique number. The best option when it comes to identifying documents is to adopt the same numbering system used by the projects and engineering group when the facility was built. By using a common numbering system you connect together all the design, engineering and vendor information throughout the operation. It will make it easier to train people in how to use the library and it will keep things simple when you are in a hurry to find information.

## Process and Equipment Data Capture Vital for Maintenance Planning

“Check the ‘Data Capture for Maintenance’ article to see the range of plant and equipment information you need in a planning system *(if you want to get the job done right every time).*”



Your maintenance planning and management system needs a lot of documented information built into it so that you can order the right parts and fully instruct people in how a job must be done. This information is critical to reduce the time it takes to develop and build work packs and to purchase parts from suppliers. If you don't have this information readily at hand people will take short-cuts and order what parts they can, even if they are not fully to specification.

If people do not have detailed information on how equipment goes together they will do what they think is right – which most times ends up being something close, but not quite exact. Now you have another variation to deal with in future!

Good and full documentation on your plant and equipment is worth every effort to collect and make easily available to everyone – that way you always get the right information to the people that need it.

## 2. Data Capture for Maintenance

### Capturing Data for Maintenance - When, What & Who

*By Yong Loong Bsc Mech Eng; MBus, Maintenance Coordinator, Clough AMEC Pty Ltd*

#### “What no info?”

- What a #@&\* useless system!!!

#### Reasons:

- Adding cost to Project (who’s paying for it?)
- Factor in cost of data capture/update
- Lack of dialogue or communication between Projects and Operations Department
- Lack of expertise in Project Team to understand maintenance issues
- Lack of organisational maturity and culture in the use of CMMS
- And . . . .

#### When to start capturing data ?

Project Phases: ASSESS SELECT DEVELOP EXECUTE

- From DEVELOP phase of project, if not earlier

#### Where are the sources of data ?

- Instrument/Electrical & Mechanical Index
- Datasheets, Drawings (P&ID, GA, Instrument Loop)
- Spare Parts List
- Installation & Operation Manual
- Miscellaneous data - Serial Number (valves, pumps), Purchase Order No.
- MDR (Manufacturer Data Report) - Mostly quality assurance stuff, material certificates, ...

#### **Data Source: Instrument/Electrical & Mechanical Equipment Index**

What to Tag?

- Maintainable items
  - Work orders to be raised against it
  - Required by statutory bodies, industry/national standards
- Package Equip usually notorious for lack of information
  - break tag down further?
  - depending if Technical data need to be captured
- Items can be bought off the shelf
  - manual valves for isolation
- Tag numbering convention
- Tag hierarchical structure

#### **Data Source: Datasheet**

Datasheet typically specifies local process operating condition, and the equipment designed to meet those process conditions

- “Process” Technical Data
  - Typical local operating conditions & settings for a Pressure Safety Valve

*Data Sheet Example for Process Plant*

Cold Differential Set Pressure **	14,200.000 kPa
Normal Pressure	11,500.000 kPa(g)
Relief Basis	THERMAL RELIEF
Medium Type	MIXED GAS/CONDENSATE
Fluid State	LIQUID & GAS
Relief Temperature	77.400 deg C

\*\* Cold Differential Set Pressure value is used to calibrate PSV

**“Design” Technical Data**

- Typical “Design” specification such as material specs, physical sizes and performance data
- Following data would be typical for a valve of a particular Manufacturer and Model

Design Code	AS 1271
Spindle Material	SUS 403
Nozzle Material	DUPLX SS UNSS31803HF
Disc Material	DUPLX SS UNSS31803HF
Bonnet Material)	A352-LC3 (YOKE
Body Material	A352-LC3
Valve Outlet Flange Type	ANSI 150LB RF
Valve Inlet Flange Type	ANSI 900LB RF
Valve Outlet (inch)	6 in
Valve Inlet (inch)	3 in
Relief Valve Type	CONVENTIONAL
Year of Manufacture	1991
Spring Material	SUP10 AL-METALLIZED

**Manufacturer and Model Number**

- Determine how
  - “Design” Technical Data are organised, and shared
  - Bill of Material are created, and shared

**Data source: Drawings**

**DRAWINGS**

- Piping & Instrumentation Diagram (P&ID)
  - Schematically shows relationship between various equipment
  - Can then work out the hierarchy of Tags
- General Arrangement (GA) / Assembly
  - Shows physical layout and dimensions
  - Itemising components on a assembly drawing
- Instrument Loop Diagram (ISA-5.4-1991) <http://www.isa.org>
  - symbolically represents a single control loop identifying control components and interconnections.
  - Special situations may necessitate a combination of loops on one drawing.
  - A loop diagram may document electrical or pneumatic instruments or a combination of both.
- Electrical Single Line Diagram
  - Uses symbol to represent the interconnection of components
- Cable Schedule Diagram
  - shows information about cables including to/from devices and length

### **Documents (Datasheets, Drawings)**

#### Storage & Retrieval

- On-line; physical files
- Document Number (Project/Vendor Vs Company)
- Revision Control
- Document Control

### **Data source: Spare Parts List**

#### **SPARE PARTS LIST**

- To be provided as part of the contract to supply
- Typical data provided:
  - Supplier Part Number
  - Manufacturer Part Number (should be supported by Mfgr brochure/catalogue)
  - Description of Part
  - Item Number on a drawing
  - Drawing reference
  - Cost
  - Delivery Lead Time
  - Material Specification
  - Shelf life for perishable items such as 'o' rings, gaskets
  - Recommended Quantity for Commissioning & Normal Operation
- Review by Project Requisition Engineer
  - Verify parts belonging to equipment that has been purchased
- Review by Project Maintenance Engineer
  - Information provided is complete and in the correct format
  - Recommend stocking level
- Review by Operation Focal Point
  - Determine and authorise requirement for stocking if required

#### **CATALOGUING of SPARE PARTS**

- electronic recording of all pertinent information concerning the purchase of goods and services for the organisation
  - collection, storage and presentation of material information
- Source: <http://www.health.qld.gov.au>

- AUSLANG was created within the Australian Commonwealth Department of Productivity in late 1979  
[http://www.oniqua.com/content\\_solutions/cataloging.asp](http://www.oniqua.com/content_solutions/cataloging.asp)
- Assigns a Stock/Material Code, description, Mfgr Part No, stocking level, etc
- Ensure no duplication of parts
- Stock/Material codes normally end up listed in the Bill of Material

**BILL OF MATERIALS**

- A Bill of Materials is a “parts list” of components that may be required to repair or refurbish equipment
- BOM can be hierarchical in nature with the top level representing the sub-assembly or end-item

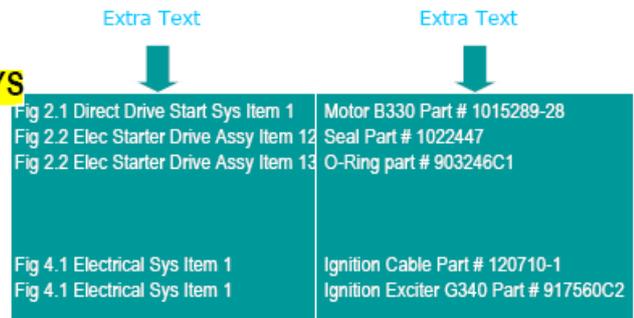
Typical example for a hierarchical structure with sub-assembly

# BILL OF MATERIALS

Typical for a hierarchical structure with sub-assembly

TURBINE123      TURBINE GAS – XXXXX POWER GENERTOR UNIT

<b>XXXX100</b>	<b>SPECIAL TOOLS</b>	
XXXXX123	TOOL, TROLLEY HOIST, SOLAR F,3T	1
XXXXX124	TOOL, ENG SNGL PNT LIFT,SOLAR	1
XXXXX125	TOOL, GANTRY EXT BEAM,SOLAR	1
XXXXX	.....	
<b>XXXX200</b>	<b>SOLAR - FIG 2 ELEC START SYS</b>	
XXXXX126	MOTOR,SOLAR 1015289-28,AC,STARTER	1
XXXXX127	SEAL,SOLAR MARS100,LIPSEAL,NTRL	1
XXXXX128	O RING,SOLAR T-4001,BS227,GBX	1
XXXXX	.....	
<b>XXXX300</b>	<b>SOLAR - FIG 4.1 ELEC SYS</b>	
XXXXX131	CABLE,SOLAR 120710-1,IGNITION	1
XXXXX132	EXCITER,IGN,10-32VDC INPUT,18KV SPARK	1
XXXXX	.....	



These info assist equipment maintainer to identify parts

**Data source:** IOM (Installation & Operating Maintenance Manual)  
 RCM / FMEA Workshop  
 Company own Maintenance Strategy documents  
 Industry Standards e.g. API, NASA, HSE  
 National / International Standards e.g. AS, BS, ANSI

**Maintenance Routine**

- Defines how often it’s to be done
- When to be done (e.g. a date)
- Shutdown required?  
     Should assign Shutdown code
- Should incorporate company’s own operating experience

**Data source:** IOM (Installation, Operating & Maintenance Manual)

**Maintenance Procedure**

- Defines or provides information about the job
  - Scope of work

- Checklist of tasks to be performed
- May include the “HOW’s”
- Special tools required
- Scaffolding or lifting tool required
- Spare Parts required
- Revision history of Maint Procedure can be useful
- May be used as Test/Calibration Certificate
- May include Limit settings for instrumentation/electrical
  
- Procedure Based Maintenance
  - “The more detailed the procedures and the more insistence on compliance with procedures an organisation becomes, the more precise and less error prone its maintenance will be”
  - Jack Nicholas Jr <http://www.reliabilityweb.com>
- Increasingly more important due to high turnover of staff & outsourcing work

### **Materials for Work Order**

Most good systems will do the following:

- Reserve materials for the job
- Material system starts ordering based on delivery lead time
- Nominate a particular warehouse to dispatch
- Nominate a Drop Point for parts

### **Demolished Equipment**

- Preventive Maintenance Routine
  - Delete Work order
    - Cancel requisition of Parts
  
- Bill of Materials
  - Delete BOM if it’s not used elsewhere
  - Obsolete Material
    - Delete Stock/Material No from system
      - Suspends further order of material
    - Dispose of any stock holding

# Planning System Documents & their Control



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The planning process also uses its own documents. The right resources and people need to be found to do each job. You will need lists of peoples' skill and subcontractor capabilities.

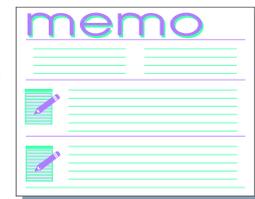
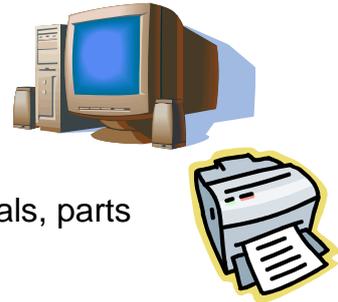
Access to similar past work orders will give you information on the problems encountered, trade skills required, special tools, times to do work, ancillary equipment such as cranes and overhead access equipment, and so on.

Can you apply Opportunity Maintenance and do several jobs during the one outage? Maybe there is an engineering improvement to be done on a piece of equipment and it can be included into the outage. You will need to monitor what jobs are on the backlog that can be included into the Opportunity. You will need to know the isolations required and how widely they affect the operation if you want to add work into the outage.

Equipment priority will dictate the urgency of each job, so you will need to move work around to suit fluctuating priorities.

## Equipment Records and their Control

- Operating Set Points
- Operating Specifications
- Calibration Settings
- Modifications / Changes e.g. materials, parts
- Inspection Records
- Condition Monitoring Records (inc Operator watch keeping records)
- Past Work Orders
- Photographs
- Root Cause Failure Analysis Reports
- Safety Requirements / Hazards
- Special Access Requirements
- Special Tooling



Equipment Records are documents that contain measurements and evidence of historic facts applying to a piece of plant. You will want to keep them as proof that work was done to the required standard, as reference for future work, and for identification of changes over time.

This necessitates setting up a system and procedures to collect, collate, catalogue and retrieve the records. Remember, that without written procedures to explain the system you don't have a usable system.

## Job Records and their Control

- Calibration Records
- Check & Inspection Sheets
- Job Feedback
- Forms
- As-Found, After-Adjustment Records
- Work Order 
- Watch-keeping Reports
- Inspection Routes Readings

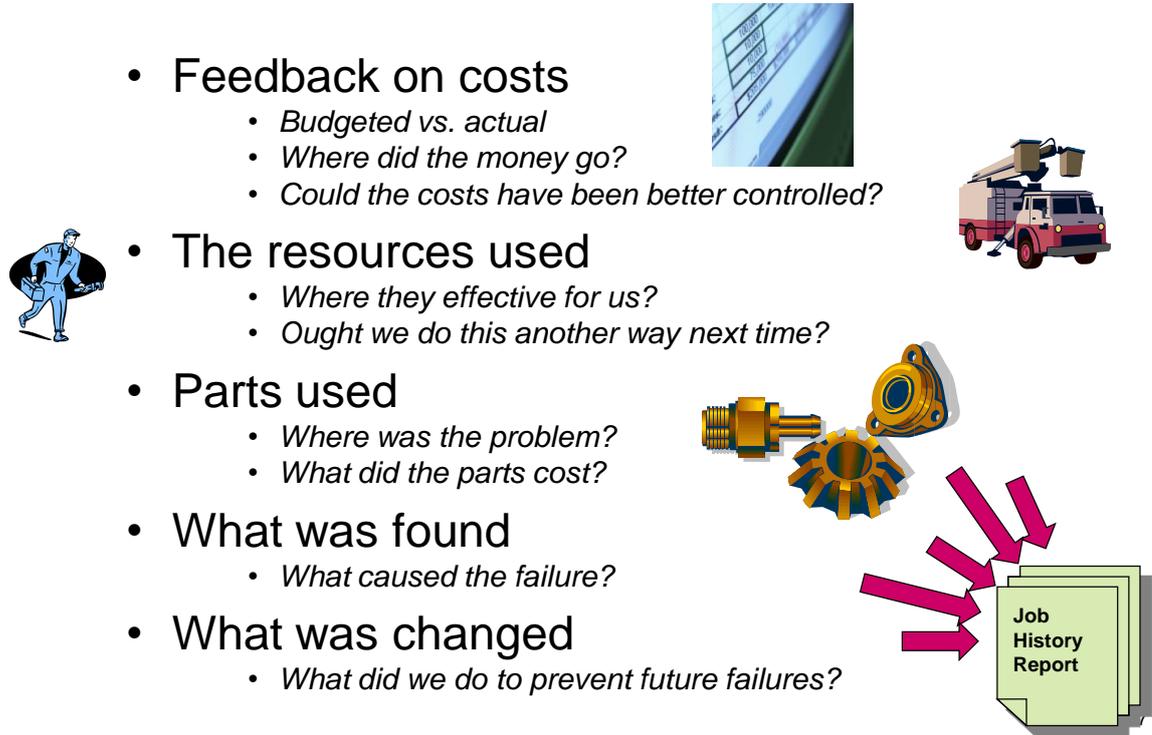


Job Records are the history of previous work done on an item of plant. In time the vast majority of maintenance work repeats. In the worst businesses they repeat many times.

Once a job has been done keep the records, as you can retrieve them and use the information they contain to speed-up the planning process. Use the information reported back to help you from jobs to understand what more to do to improve the odds that future work will be done better, e.g. updates to job procedures to further ensure your crew does good work, right-first-time.

# Information People Want from Job History

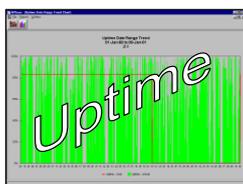
- Feedback on costs
  - *Budgeted vs. actual*
  - *Where did the money go?*
  - *Could the costs have been better controlled?*
- The resources used
  - *Where they effective for us?*
  - *Ought we do this another way next time?*
- Parts used
  - *Where was the problem?*
  - *What did the parts cost?*
- What was found
  - *What caused the failure?*
- What was changed
  - *What did we do to prevent future failures?*



A Planner will be asked to explain and justify how jobs were prepared and were conducted. Details need to be available from the CMMS and quickly converted into reports and KPI's.

# Equipment Performance Trending

- 'Bad Actors' Monitoring
- Mean Time Between Failure (MTBF)
- Mean Time to Repair (MTTR)
- Repeat Failures
- Uptime / Downtime
- Improvement/Change over a Time Period



Doing good maintenance, and the maintenance planning effort that goes into it, needs to be seen as being worthwhile and that it is producing worthy results. That is best done by displaying the trends that develop

because of the maintenance effort. The slide lists but a few of the types of information that can be presented. The sample graphs along the bottom of the slide are copies of graphs actually used in industry.

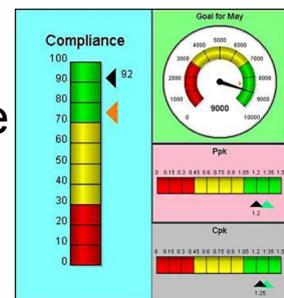
Another benefit of identifying equipment and maintenance performance visually is to pinpoint opportunities for focused improvement. The Pareto and Equipment Cost graphs are particularly valuable in showing the ‘bad actors’ that need to be addressed.

## Job Performance Trending

YOU WILL SEE THE EFFECTIVENESS OF YOUR PLANNING BY MEASURING...



- Jobs Complete Without Interruption
- Work Orders Complete per Technician
- Percentage WOs Right First Time
- Percent ‘Tool Time’ of Work Order Time



A ‘Dashboard’

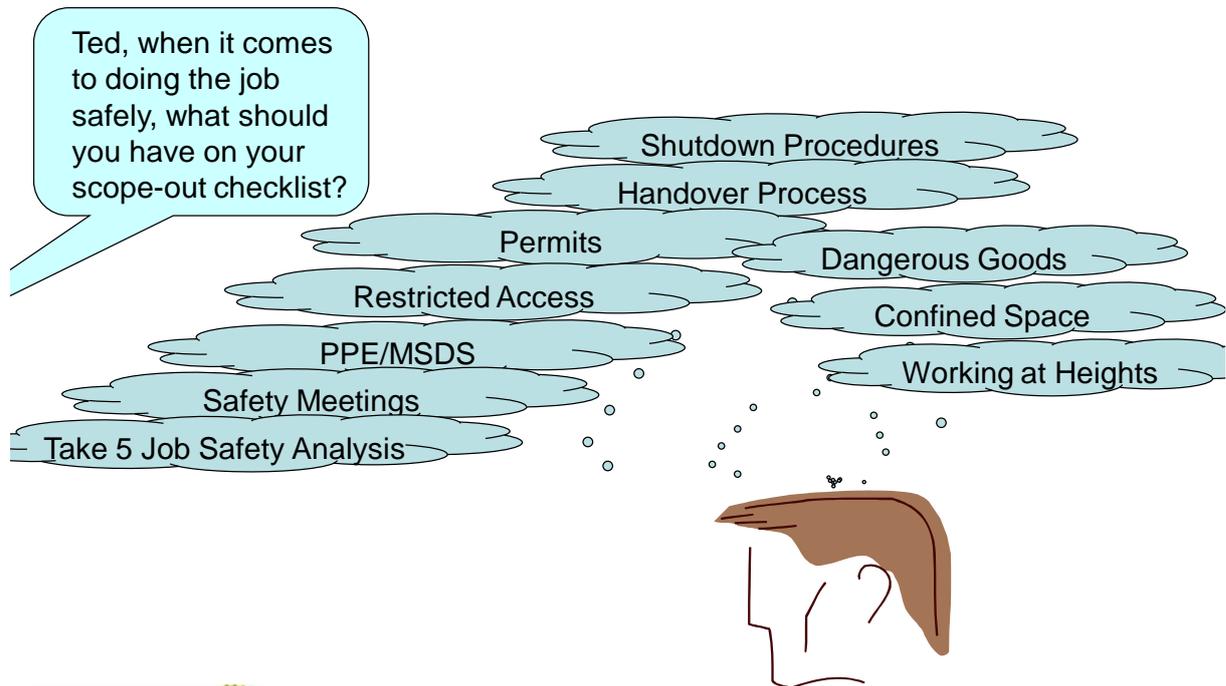
Job Performance Trending is all about measuring how the maintenance work is being done. It reflects the effectiveness of the planning process. As they say in maintenance, “piss poor planning means piss poor performance”.

If it is important to get maximum value from the Maintenance crew, then its performance needs to be measured and monitored to ensure that the right things are being done rightly. Trending work results is not meant to show-up poor performance, rather it is aimed at recognising when things are going well and when they are not. Everyone wants to see good outcomes and trending work performance means opportunities to improve can be found and acted on quickly.

The fairest and most open way to help people improve it to be honest with them.

The bullet points in the slide are possible KPIs to use as a way of monitoring the effectiveness of the work planning process. When planning is working well jobs will be started and completed without time loss, each person will get through more work, the work will be done to high quality, technicians will spend their time working on the plant and equipment and not waiting for access to plant, looking for parts, or getting hurt.

# Job, Work and Personnel Safety



Doing work safely must be paramount. The Maintenance Planner must weave safe work practices into the job through use of Job Procedures and stipulating safe work practices. This is where a database of each equipments' safety requirements and hazards is invaluable in saving his time and keeping the maintainers safe from harm.

The safety issues noted in the slide are all important and valid concerns for job risk management. A Planner needs to identify the safety requirements and risks in a job and add the risk management requirements into the work pack so what is needed is prepared and made available when the job starts.

For example, if 5 danger tags are needed for isolation then 6 tags are in the work pack. Another example—every job needs a JSA done by the people doing a job before starting it. The work pack should contain the necessary form. Otherwise the technician will go and get the JSA form to complete and that will take at least 20 minutes. That is 'tool time' loss. Because the JSA was not in the work pack the job blows out by 20 minutes before it even starts.

# Activity 6 – What are the Contents of a Maintenance Work Pack?

1. Develop a list of the item that could be in a maintenance work pack to do a maintenance job (all disciplines to be include)
2. Compare to the list in the workbook.



What do they need to know about the job? What do they need to know to protect their safety? What do they need to know about the equipment?

The activity is to compile a list of ALL the information someone doing a job needs to know about it. The exercise helps people realise that complete and correct information is necessary for a job to be done well, right-first-time.

### 3. Activity 6 – Work Pack Minimum Content

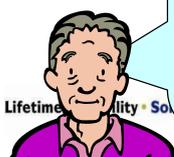
A Work Pack as a minimum requires the following content:

WORK PACK MINIMUM CONTENT		
ITEM No	DESCRIPTION	COMMENTS
1	WO/Job Plan	A work flow process diagram of job milestones in line-of-sight detail.
2	Skills and Competencies required	The expertise needed to do the job correctly
3	Job Procedure	Task by task fully detailed description with quality standards and corrective action.
4	All Drawings relevant to the job	Could be mechanical, electrical, civil, structural, process diagrams, etc.
5	Bill of Materials for the job	The parts used in the job including part number, part description and quantity required
6	Tools List for the job	The tools needed to do the job safely and correctly
7	Equipment List for the job	Include the equipment specification e.g. Franna Crane 20T, Mobile Air Compressor 150 CFM, etc.
8	Settings / Set Points	For calibration and adjustment.
9	Quality Standards	Pass / Fail criteria for each task. Includes providing parts

		tolerances and condition criteria to confirm a part can remain in-service or needs to be replaced.
10	Data Sheets of the equipment	Information on the design and service specifications.
11	Record Sheets	A place to make a record of an observation or measurement as proof. Often satisfied with an Inspection and Test Plan.
12	Calculation Sheets	A place to do the calculation laid-out in the sequence of the calculation with space for the figures and an example of a correct calculation.
13	All Permits and Tags	Safety, environmental, disposal, transport heritage, plant handover, etc approvals
14	Risk Assessment Forms	Site risk assessment and management documents.
15	All Technical Tables	Copies of manufacturer data tables or international engineering tables highlighted to show the information applying to the job.
16	Special Requirements	Instructions and particulars specific to the job that must be observed.
17	Commissioning Plan	Controlled testing to confirm proper operation.
18	Parts and Materials	All parts and materials are identified and gathered together in one location
19	Proof Test Recording Sheet	A check sheet to note the proof test results for each job plan activity that confirms work quality is achieved
20	Failure Mode and Equipment Health Report	A record of the Technicians observations and decisions and photographic evidence of failure modes

## Track Your Planning System Performance and the Benefits it Brings

- Plan Compliance {
  - Percent of Plan Followed During the Job
  - Work Orders With Complete Work Packs
- Plant Performance {
  - Improved Equipment Reliability
  - Improved Plant Availability
- Maintenance Performance {
  - Maintenance Backlog by Type
  - Preventive Maintenance Complete On-Time



You'll want to know how well your planning efforts are going. You can work that out in three ways. First, by seeing how closely the plan is followed. If it is done with 100% compliance and the final condition monitoring check is within standard, you can say the plan was perfect. Second, you can see what effect the work had on the plant's operation. Third, is by seeing if maintenance productivity improves. If all three trend positively, you are on-track.

The results of the planning effort can be seen in a number of ways, some of them are identified on the slide. Maintenance Planning should allow more work orders to be completed successfully with fewer people and with less waste of time and resources. If that is happening it should also be reflected in the performance of the plant and equipment by an increases in their reliability and availability.

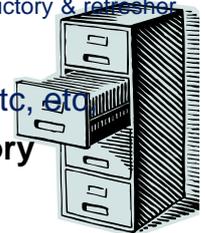
# Planning System Maintenance



The Maintenance Planner's life is a lot about document management and control, and that includes their work system management.

## **A planning system and its processes need maintenance too.**

- Identify the system maintenance in your planning process' procedures and make it clear **who** does it, **when** it is to be done and the **standard** to meet
- **It's an on-going requirement** – schedule time per day/week/month matched to importance
- Establish document numbering and cataloguing standard methods
- **Keep databases up-to-date**
- Train CMMS and planning system Users to use it properly – introductory & refresher
- **Keep planning process documents current**
- Keep job procedures current, keep engineering details current, etc, etc
- **Archiving of old records and maintenance work orders/history**
- Review suppliers, Stores performance, and condition of tools
- **Audit the planning system performance** – seek new opportunities to improve



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Documents need to be properly kept. Information must be current when people use it. Training people how to use the planning system, its processes and the CMMS properly is a necessity. Old paper records require long term storage. These are all activates vital to a well run and correctly operating planning system and cannot be evaded without the system performance degrading.

Some maintenance activities will need to be done by the Planner on their own system. Those up-keep tasks that do not need a Planner's know-how can be done by appropriate clerical staff or maintenance department personnel.

Wow, look at that time? Sorry to keep you here for so long Ted.

I could see that what you were saying was important. I didn't want to leave until you had covered it all.

Here's a question for you.

What, ...more questions!?

Now don't get stressed. I'm not keeping score.

Tomorrow tell me what you think is *the most important requirement to get top class performance from people?*

The session went over time ...

Today we need to be on time. I've got to go to the doctor's for my annual check-up. There is a lot I want to do when I retire, and I want to be sure that I'm up to it.

Would you call that condition monitoring or preventive maintenance, Joe?

Very good young fella. That's exactly what it's all about. I'd say a check-up was condition monitoring. Preventive maintenance would be if I have to change my diet. You could say that I have a 'passion of wellness'. The connotations between 'personal wellness' and 'plant and equipment wellness' are identical. Look after the health of your body and you can expect a long, fit future. Look after the health of your machinery and they will provide you a profitable future.

That question of yours yesterday had me awake all night. I know that when I do a job I'm only satisfied when it's been done right.

And you only know it's right if you can check it against a standard.

They meet again ...

## Specify the Workmanship Standards

- Create Standardised Work
- Selecting the Standards for a Job
- Identifying Necessary Skills for a Job
- Use Defect Preventing Job Procedures

People need to know what is expected from them. They need to know what excellent work is. How else can they ever get a sense of pride in doing a job well?



*“We must protect the plant and equipment from good intentioned people who don’t know what they are doing.”*

We know that unfortunately people cause most problems; human errors cause most failures by a long, long way. You can read the extracts below taken from white papers and books that indicate just how much people are at fault. It’s not really peoples’ fault that they make so many mistakes, we’re all human and humans make errors. The fault that errors are allowed to impact an operation is a business system issue.

We do not have enough protection within our business systems to save the business from the error made by the people they employ. We must protect the plant and equipment from good intentioned people who don’t know what they are doing. Your only means of protection is accurate documentation which sets the right standard of work performance and training your people to do it the way the procedure says. Finally you need to go out to the work faces and audit them to see for yourself what is really happening.

### **Extracts on the Causes of Equipment Failure**

**“Use Crow-AMSAA Reliability Growth Plots To Forecast Future System Failures”, H. Paul Barringer, P.E.**

Many managers and engineers believe most failures have a root cause in the equipment. Data from nuclear power plants (which maintain a culture of confessing failures and the roots of failures—this is in opposition to most industries where the culture is to hide the roots of failures) show the following roots for failures:

#### **Early in the life of nuclear power plants**

Design error	35% [people induced - not calculation errors]
Random component failures	18% [process/procedure problems]
Operator error	12% [people/procedure problems]
Maintenance error	12% [people/procedure problems]



Unknown	12%
Procedure error & (procedure) unknowns	10%
Fabrication error	1% [people/procedure problems]
<b>TOTAL</b>	<b>100%</b>

**Mature nuclear power plants**

People	38%
Procedures & Processes	34%
Equipment	28%
<b>TOTAL</b>	<b>100%</b>

ASME (2002) shows a similar root for failures. For 10 years, from 1992-2001, 127 people died from boiler and pressure vessel accidents and 720 people were injured. In the 23,338 accident reports, 83% were a direct result of human oversight or lack of knowledge. The same reasons were listed for 69% of the injuries and 60% of recorded deaths. Data shows that if you concentrate only on the equipment you miss the best opportunities for making improvements. Another point to seriously consider is little or no capital expenditures are required for improving people, procedures, and processes which can reduce failures. In case you believe that equipment is the biggest root of problems it will be instructive to download (<http://www.bpresponse.com>) the Final Report of BP’s Texas City Refinery explosion and tick off the reasons behind the explosion which took the lives of 15 people and maimed more than 200 addition people—you will see objective evidence for people, procedures, and processes as the major roots for failures. The #1 problem was not equipment!

**Design Paradigms: Case Histories of Error and Judgment in Engineering**, Petroski, Henry, Cambridge Press, New York, 1994, on pages 7 and 8 remarks about the role of humans in failures:

“... the major challenge to reliability theory was recognized when the theoretical probabilities of failure were compared with actual rates of failure [and the] actual rates exceed the theoretical values by a factor of 10 or 100 or even more. They identified the main reason for the discrepancy to be that the theory of reliability employed did not consider the effect of human error..... Human error in anticipating failure continues to be the single most important factor in keeping the reliability of engineering designs from achieving the theoretically high levels made possible by modern methods of analysis and materials..... nine out of ten recent failures [in dams] occurred not because of inadequacies in the state of the art, but because of oversights that could and should have been avoided..... the problems are essentially non-quantitative and the solutions are essentially non-numerical.”

## Identifying Necessary Skills to Deliver the Needed Results

The Required Skills are Defined By:

- Necessary Perfection and Accuracy
- The Standards to be Met
- The Consequence if Things go Wrong



Not all people are equal in their capability to do a task. Training and knowledge helps, but training and education do not actually guarantee the take-up and use of necessary skills. You can go to a training course and come back from it no more skilled than before you went.

What you want is competent people. Competence is defined as, 'The demonstrated ability to use knowledge, understanding, practical and thinking skills to perform effectively to the standards required in a job'. In other words, you want skilled people that can deliver the needed results.

As a Maintenance Planner, you will indicate what skilled resources are required to do a task. The crew Supervisor will select the actual person to do the task. This person must be able to do the task well. Whether in your own crew, or a sub-contractor, the person given a job must know how to do the job right the first time. If you use people who may not have the necessary competence, you are taking a big risk. Maintenance is not about taking risks, it is about reducing them so that fewer and fewer things go wrong.

If you need more skilled people on your crew, then either hire them in with the competency you need, or train your people and get them to do the job three times in a row without fault before putting them on the same job in your plant. When they can do the same job right three times in a row, they will have proved their competence and can be trusted

In the Workbook is a Table titled 'Human Error Rates'. You will see that it confirms that the 'human element', the human error rate, is real and unavoidable. We do not perform well when tasks require care, and we perform especially badly under complicated non-routine conditions. Add stress into that that mix and you get disaster.

How often do we see managers and supervisors put their staff into stressful situations and then complain that their people are not up to standard? The Table tells us that people simply do not perform well if things get difficult. Foolish and incompetent managers expect great results regardless of prevailing conditions and the real abilities of their staff. But wise and successful managers turn complicated

situations into easy and effortless routine through SOPs and training to ensure the best performance from their people.

If you want to turn the tasks you do, or those done by your people, into routine simple tasks that hardly ever go wrong, simply write clear and detailed SOPs incorporating the very best failure prevention practices available in the book “Employee Training and Development with Standard Operating Procedures” by Mike Sondalini. Then train your people to them and watch the error rate fall by 100 to 1000 times.

## If this was your family car... what do you expect of this man maintaining it?



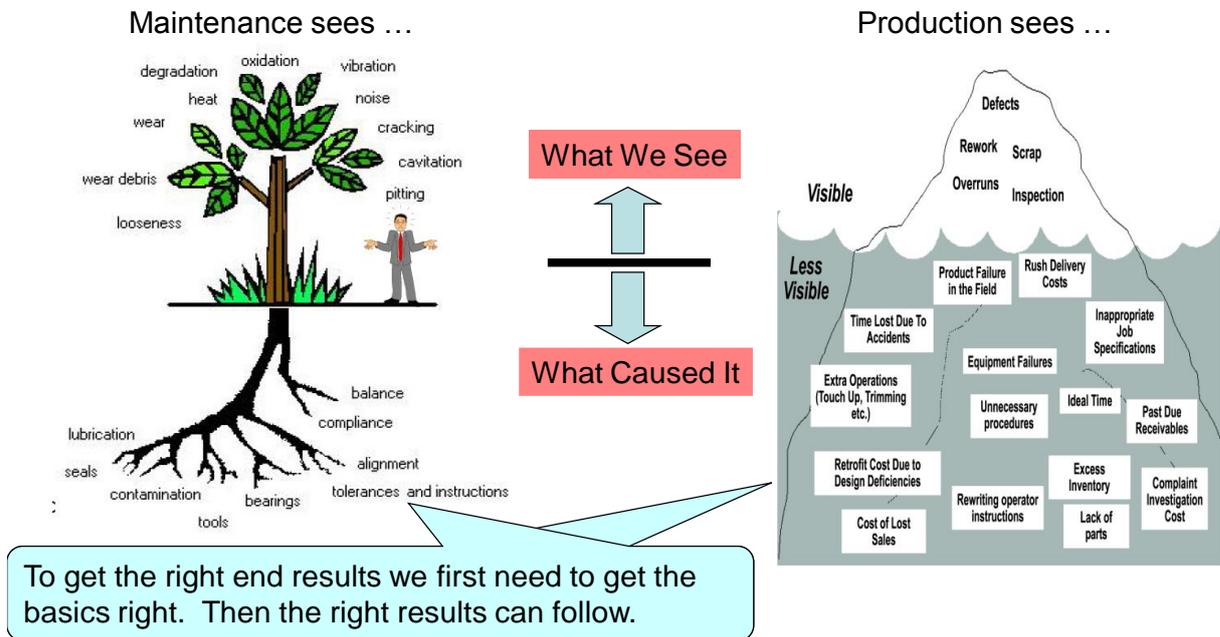
• His knowledge	• Workmanship quality
• Rate of work	• Provision of feedback
• His servicing skills	• His personality
• His cleanliness	• His level of interest
• His fault-finding capacity	• In a breakdown situation...

Have you set standards for the skills and attributes your people need to exhibit? Unless your people know what you are looking for from them, they will give anything that they think is ‘good enough’.

The same logic applies to the quality of work they deliver – how good must it be? What is the lowest acceptable standard that must be met, and how can it be measured to prove performance is to standard, or it is better?

These are fair questions ask and the answers are important . If people are the wrong fit for the job, then do everyone a favour and get them out of their current job and into work that they can be great at doing.

# How do we to Stop Problems Happening?

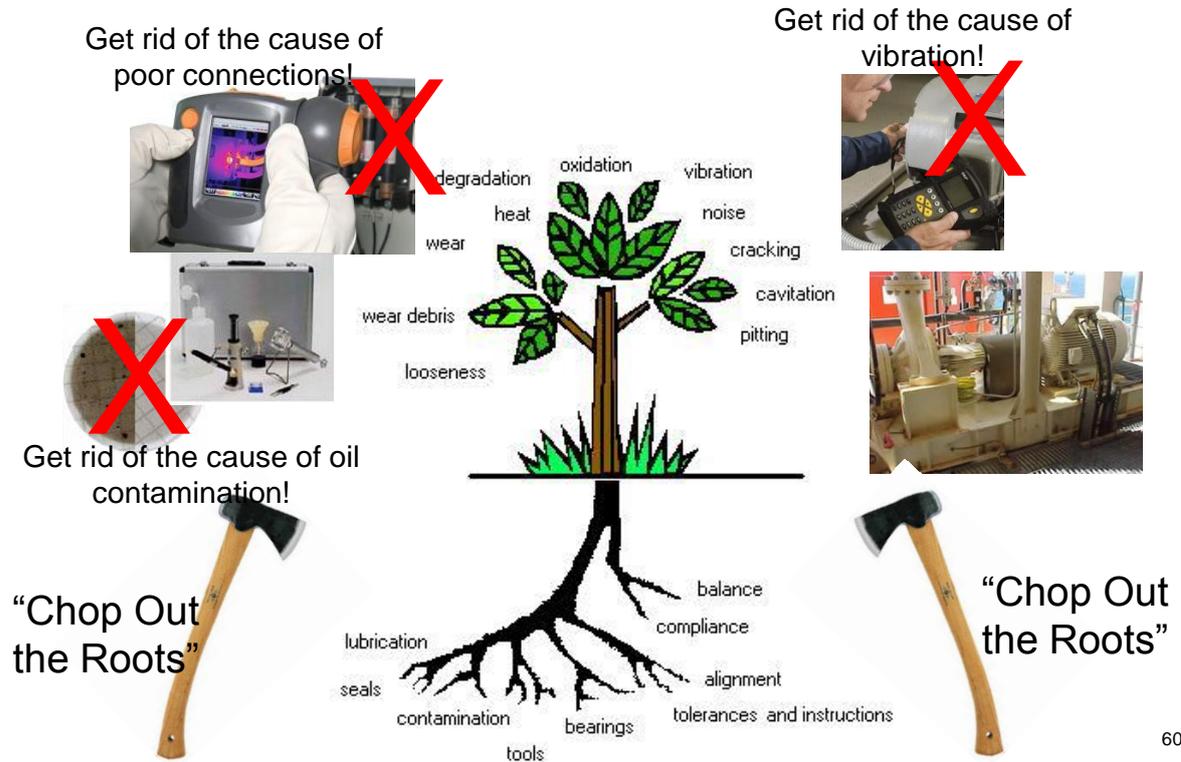


The problems our plant and equipment suffer are the symptoms of bad practices and/or failed processes. When we detect noisy, hot bearings in our machines the incident that started the failure happened long before from something was done wrong. When we find contamination in oils and lubricants they are warning signs of poor past lubrication practices that occurred and eventually caused failure. When trouble confronts us, whether in maintenance or operations, it is because a problem grew from something small into something big. By the time everyone can see the effects of the problem it wastes a lot of time, uses a lot of resources and it will be expensive to correct. But it did not have to be so.

The slide shows how the signs of trouble are the effects of previous bad practices or business process failures that were not prevented. Below the failures that we see lay the root causes of the problem. Had the root causes been prevented there would have been no failure to fix.

It is a great revelation to realize that all problems can be stopped by preventing their causes. If we build and use business processes that avert the beginnings of failure then we will stop evils from starting.

# “Chop Out The Roots of Failure”



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As wonderful as it is to have condition monitoring find a problem it still needs to be fixed. We condition monitor frequently enough to detect the onset of failure so we have time to address the failure before it happens. The condition monitoring can be as simple as regular ‘feel and listen’ observations of parts and equipment performance by the operator, through to complex continuous on-line monitoring with instrumentation using computer-controlled diagnostic and prognostic programs.

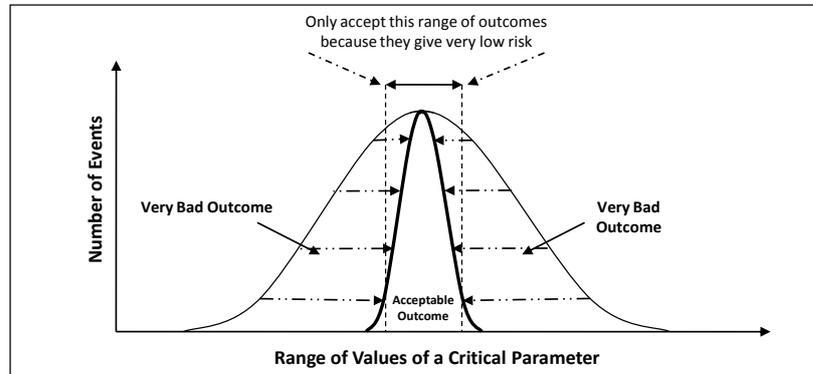
The problem with condition monitoring is that we have not actually stopped the cause of the failure. We simply detect an imminent failure before it happens and turn a breakdown into a planned maintenance job. As good as that is in reducing production costs and downtime, the failure causes remain and the failure will recur.

The aim is to not have problems that need to be fixed. This requires a proactive approach that stops the cause of problems. Though the thermography camera found the hot connection and it can be fixed before it fails, the question is why was the fastening done wrong in the first place. If the fastening was properly done there would be no hot connection to now have to fix. The root cause of the poor connection needs to be found and stopped from ever happening again, otherwise more hot connections will arise in future.

Vibration analysis will find a problem motor bearing and you can then fix it. But why is the motor bearing allowed to be installed or maintained so poorly that it begins to fail and needs to be replaced? The root causes of roller bearing failures are solvable and preventable. There is no need for bearings to fail early if the causes of failure are prevented.

Equipment repair is always possible, but prevention is easier and far less costly. The best strategy to apply if you do not want failures is to chop-out the root causes of failure.

# Remove the Variability in How a Job is Done by Using Error Proof Techniques



By setting quality controls into a job you ensure the actions that create reliability are done thereby greatly reducing the chance that a mistake will be made.

**In the end... reliability is a quality control issue because the standards you meet create the reliability you get**

When we create repeatable, standardised processes we have designed a way to always produce outcomes that are within the agreed parameters. To get high equipment reliability the risks to our equipment parts that lead to their failure need to be removed. The planning process is a major factor in delivering to our machines the right methods and practices that produce high reliability.

In order to produce the right results every time, the right actions must be done every time. This needs quality control on those actions. It is the quality control standards that you set and practices that you do which delivers the reliability that you get.

By using quality controls you ensure the actions that create reliability are done thereby greatly reducing the chance that a mistake will be made.

# Why Setting Standards is Vital: Lubricating Oil and Hydraulic Oil Cleanliness

## Relativity of ISO 4406 Codes



Source: Wayne Bissett, 'Management of Particulate Contamination in Lubrication Systems' Presentation, CM and Lubrication Forum 2008, Australia

Oil contamination by solid particulate matter is known to cause failure of bearings and hydraulic oil system parts. If the oil is kept clean and few particles are present the chance of failure falls dramatically.

Service lives can increase 5 and 6 times more than if the oil is not kept clean. This slide shows images of oil at various ISO 4406 cleanliness codes. The higher the numbers the more contaminated and dirty is the oil and the shorter the equipment service life. The first number of the three number ISO 4406 code represents the count of all particles larger than 4 micron (the number is not how many particles are present, but it equates to the number of solid particles in a 1ml of oil; about 20 drops of water in volume). The second number represents all particles greater than 6 micron and the third number indicates all particles larger than 15 micron.

At an ISO contamination count value of 18/16/13 the spool shown in the slide that slide inside the cylinder of the over-speed protection valve controlling the speed of a steam turbine jammed. The score marks on the bore were cause by the solid contaminant particles. The turbine suffered a forced shutdown that caused \$25M of damage and took two months to repair. All this cost and waste was because of hydraulic oil contamination at a value that is commonly accepted in industry. Had there been no wear particles the spool would not have jammed and the \$25M cost and two months of lost sales would have been pure operating profit. Allowing contaminated oil in your machines is a very expensive mistake that is easy to prevent.

# The Importance of Setting Standards

**Hydraulic System**

UNIT: K27-146  
 COMPARTMENT: Hydraulic System  
 UIN: 0028FDD

**DIAGNOSIS AND RECOMMENDATION**

Wear levels lower than 8 micron appear satisfactory. However, Oil cleanliness rating exceeds considered recommended limit. Lubricant manufacturers published specifications indicate viscosity high for specified oil type.

Action: Recommend checking oil filters/strainers for abnormal wear particles or debris. Resample at a reduced service interval to further monitor.

**SAMPLE STATUS**

SAMPLE NO	Caution	Caution	Caution	Caution	Normal
80380002	809/399	6192471	6088636	4943161	
DATE SAMPLED	31/12/09	29/12/08	31/01/08	01/02/07	06/07/04
DATE RECEIVED	08/01/10	06/01/09	06/02/08	06/02/07	14/07/04
DATE REPORTED	06/01/10	06/01/09	06/02/08	06/02/07	14/07/04

**ANALYTICAL DETAILS**

ISO Clean Code (Filter Patch) **23/22/19**

ISO Clean Filter Patch (4 µm) 22

ISO Clean Filter Patch (6 µm) 19

ISO Clean Filter Patch (14 µm) 19

Catalogue HY11-2500/UK  
**Technical Data**

Low-Noise Power Units  
**Series L-Pak**

Hydraulic fluid	Mineral oil HLP to DIN 51 524, part 2 (other hydraulic fluids on request)		
Ambient temperature [°C]	-10 ... +50		
Hydraulic fluid temperature [°C]	-10 ... +70		
Hydraulic fluid temperature (const. operation) [°C]	+20 ... +55		
Cooling capacity	Dimensioning according to overall system		
Operating pressure	Max. 350 bar		
Flow rate	Max. 400 l/min		
Pump type	Axial piston pump PV External gear pump PGP (for cooling circuit) (additional technical details on request)		
Noise	Depending on application and insulation, the following values can be reached:		
	System pressure [bar]	Noise emission [dB(A)]	
		at 1000 U/min	at 1500 U/min
	100	65	68
	160	68	71
	210	70	73
	350	72	76

Return filter β<sub>10</sub> = 75

Tolerable degree of contamination NAS 1638 class 7, ISO 11171 18/16/13

Installed load Max. 110 kW

Ave. ISO Code	Ave. Hrs between Breakdown	Relative Life Factor
24/21	200	0.19
23/20	250	0.24
22/19	325	0.31
21/18	430	0.41
20/17	600	0.57
19/16	800	0.76
<b>18/15</b>	<b>1050</b>	<b>1</b>
17/14	1400	1.33
16/13	1900	1.81
15/12	2600	2.48
14/11	3800	3.62
13/10	5000	4.76
12/9	6500	6.19
11/8	9000	8.57
10/7	20,000	19.05

The lubrication quality report on the left is for a hydraulic oil circuit pump like those in the picture. Note the ISO 4406 particle contamination code in the report is 23/22/19. The Manufacture's Manual limits contamination to 18/16/13. This pump and the equipment in the hydraulic circuit is in great danger and at high risk of failure.

You immediately know the pump is in trouble once a worst contamination standard is set. But you cannot know that unless you first know what standard is acceptable performance. This report is virtually useless until it also specifies the standard that the machine must meet. With the standard specified on the same page as the result you immediately know that there is a problem. When you see an ISO contamination count of 23/22/19, and it should never be higher than 18/16/13, you know that you need to act and you need to do it immediately, otherwise the chance of failure grows very higher as more contamination collects.

The table in the bottom right hand side corner shows the results of a 1990's British Hydromechanics Research Association (BHRA) - three year con-trolled 'field' study of 117 hydraulic machines (injection molding, machine tools, material handling, mobile equipment (earth moving, etc), marine hydraulics, and test stands) done with the sole purpose of correlating fluid cleanliness to breakdown frequency. They took 18/15 contamination as producing one lifetime of service. The more the hydraulic oil was contaminated the greater the lifetimes fell. When the oil was clean lifetimes extended. The clearer the oil the more reliable the machinery.

The message is clear—set high quality standards, measure actual performance against the standard and improve your practices until you get great results.

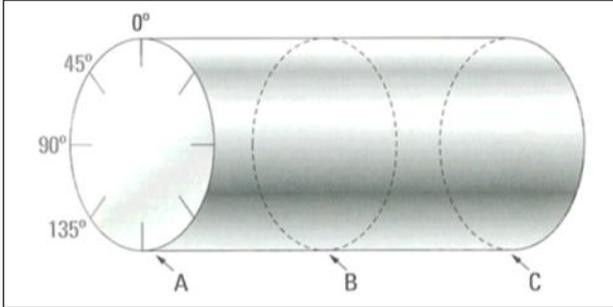
The worst cleanliness you should have in machinery is a ISO count first number no higher than 14. At this level of contamination you have between 80 to 160 particles larger than 4 micron in the same volume that at an 18/16/13 count carried 1300 to 2500 particles. As the contaminant level falls the risk of failure

lessens because opportunity for failure decreases since fewer and fewer particles are present to initiate a failure event.

**Case Study 1 – Shaft Quality Control for Bearing Reliability**

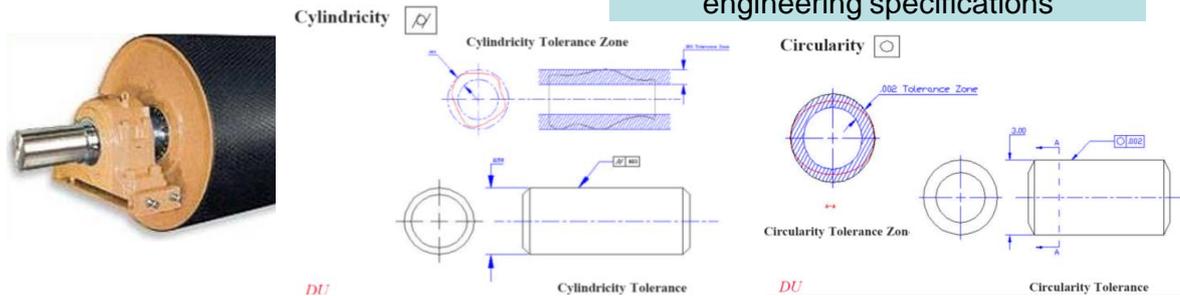
# Case Study 1 : Shaft Quality Control for Bearing Reliability

See 150mm diameter shaft example in workbook on how to check the quality of a shaft is suitable for a roller bearing



Shaft Diameter mm		Tolerance h9 μm		Form IT5 μm	Form IT7 μm
over	incl	high	low	max	max
18	30	0	-52	9	21
30	50	0	-62	11	25
50	80	0	-74	13	30
80	120	0	-87	15	35
120	180	0	-100	18	40
180	250	0	-115	20	46

From manufacturer or appropriate engineering specifications

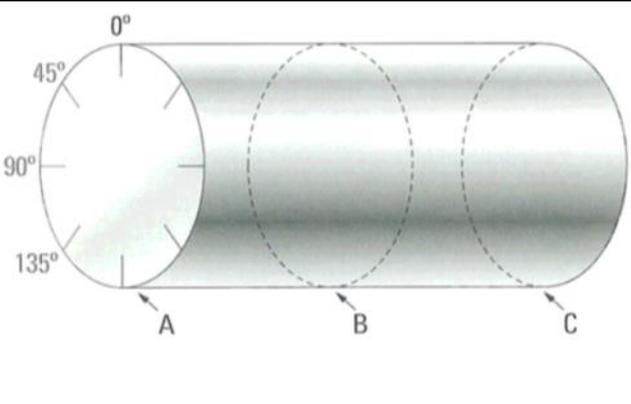


Hardly anyone ‘gets’ what quality is about. The issue of setting standards applies every time you require a specific level of quality. Control over variation and defect creation needs standards of quality to be met. Operations and businesses overcome failure and error with systems guaranteeing precision and accuracy. This is the Precision Principle – set clear and precise work quality requirements. Set standards for every step of a process and measure they are accurately met. A process continually achieving the precision requirements of every step automatically delivers its best quality and throughput.

This is another example of the importance and value of setting quality standards to gauge if a condition meets the minimum requirements. When roller bearings are mounted on shafts the inner ring needs to be fully supported over its entire contact surface. The section of shaft holding the inner ring **must meet both** the tolerance requirements **and** the form requirements.

The Plummer block housed a 150mm spherical roller bearing on a taper sleeve mounted on the shaft of the head pulley. The bearing always failed in a matter of two to three weeks. This had gone on for years. Eventually the bearing manufacturer was called in and they asked that the shaft diameters be measured at the points shown in the diagram.

With a micrometer the dimensions of a journal were checked and recorded and their suitability to remain in service was compared with the manufacturers standard. The measurements showed the shaft was not cylindrical nor round. This shaft must not be used because it cannot support the bearing properly. If a bearing were fitted to this shaft it would fail in a matter of weeks.



Shaft Diameter mm		Tolerance h9 µm		3T TARGET Form IT5 µm	3T TOLERANCE Form IT7 µm
over	incl	high	low	max	max
18	30	0	-52	9	21
30	50	0	-62	11	25
50	80	0	-74	13	30
80	120	0	-87	15	35
120	180	0	-100	18	40
180	250	0	-115	20	46
250	315	0	-130	23	62

**Tolerance Evaluation**

	0°	45°	90°	135°	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	

The shaft tolerance is within h9 requirements.

**Cylindricity Evaluation**

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

Shaft cylindricity is out of tolerance and the shaft at the location of the bearing is not cylindrical.

**Roundness Evaluation**

	0°	45°	90°	135°	Plane Max-Min	Required Form IT Grade 5	IT Grade 7
Plane A	149.98	149.99	149.98	149.99	<b>0.01</b>	<0.018	0.040
Plane B	149.97	149.94	149.98	149.95	<b>0.04</b>		
Plane C	149.98	149.98	149.95	149.99	<b>0.04</b>		

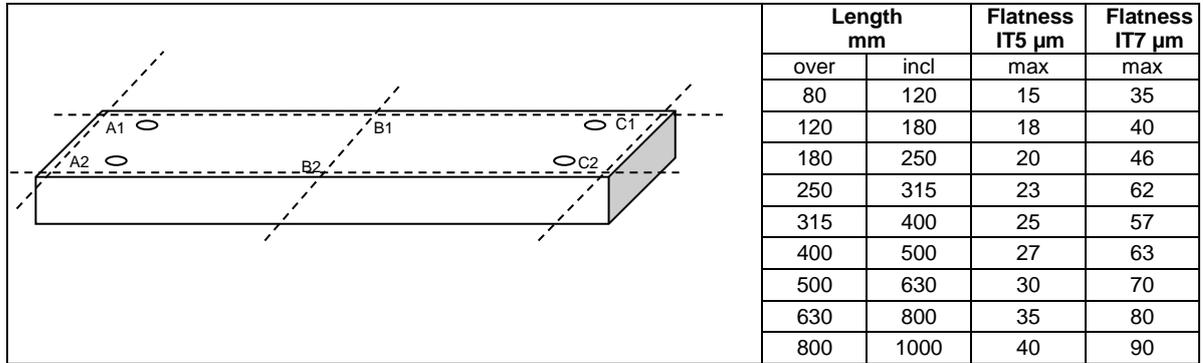
Shaft roundness is out of tolerance and the shaft at the location of the bearing is not round.

Why the shaft was not measured each time a bearing was installed I do not understand. That you must be sure a shaft properly supports the bearing to be mounted is standard engineering practice. Had the shaft been checked against the bearing manufactures minimum requirements the problem would have been found long ago. But no standards were given in the work orders against which the shaft sizes could be

checked, and so no checks were made by the installers. Not having a standard to control quality caused failure after failure.

### Base Plate Flatness

How flat should a base plate be so that it does not distort the item sitting on it? It is a vitally important answer to know if you want highly reliable machines.

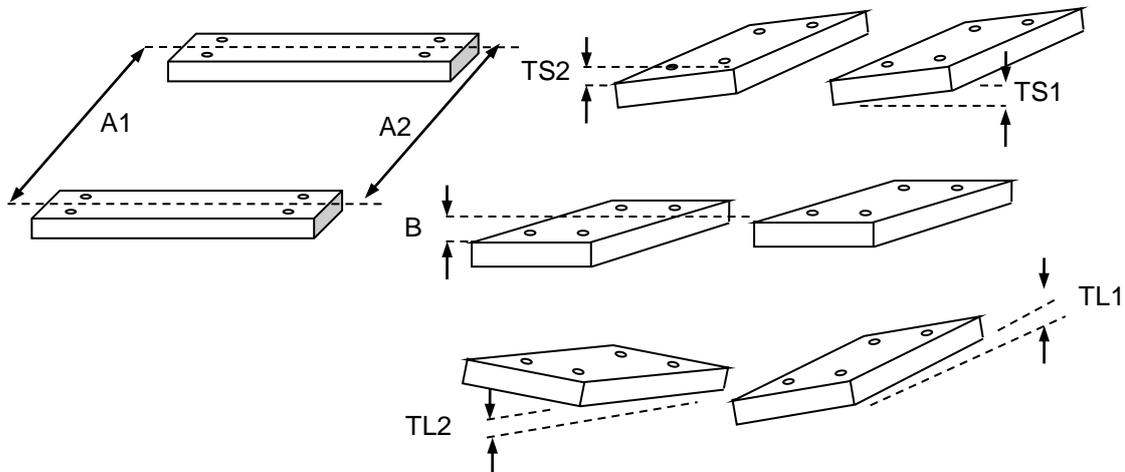


Length of base (mm): \_\_\_\_\_

Width of Base (mm): \_\_\_\_\_

	Point 1	Point 2	Max-Min	Plane Average	Target IT Grade 5	Tolerance IT Grade 7
Plane A						
Plane B						
Plane C						
Max-Min						

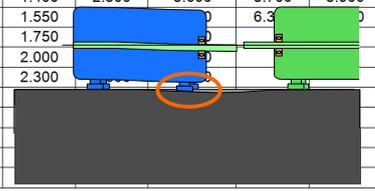
### Base Plate Orientation



# Challenge Yourself to IT5 Standard

International Tolerance Grades Table

Basic Sizes (mm)		International Tolerance Grades													
Over	Including	Measuring Tools			Materials										
		IT 05	IT 06	IT 07	IT 08	IT 09	IT 10	IT 11	IT 12	IT 13	IT 14	IT 15	IT 16	IT 17	IT 18
		Fits for parts in precision and general engineering							Large Manufacturing and Fabrication						
1	3	0.004	0.006	0.010	0.014	0.025	0.040	0.060	0.100	0.140	0.250	0.400	0.600	1.000	1.400
3	6	0.005	0.008	0.012	0.018	0.030	0.048	0.075	0.120	0.180	0.300	0.480	0.750	1.200	1.800
6	10	0.006	0.009	0.015	0.022	0.036	0.058	0.090	0.150	0.220	0.360	0.580	0.900	1.500	2.200
10	18	0.008	0.011	0.018	0.027	0.043	0.070	0.110	0.180	0.270	0.430	0.700	1.100	1.800	2.700
18	30	0.009	0.013	0.021	0.033	0.052	0.084	0.130	0.210	0.330	0.520	0.840	1.300	2.100	3.300
30	50	0.011	0.016	0.025	0.039	0.062	0.100	0.160	0.250	0.390	0.620	1.000	1.600	2.500	3.900
50	80	0.013	0.019	0.030	0.046	0.074	0.120	0.190	0.300	0.460	0.740	1.200	1.900	3.000	4.600
80	120	0.015	0.022	0.035	0.054	0.087	0.140	0.220	0.350	0.540	0.870	1.400	2.200	3.500	5.400
120	180	0.018	0.025	0.040	0.063	0.100	0.160	0.250	0.400	0.630	1.000	1.600	2.500	4.000	6.300
180	250	0.020	0.029	0.046	0.072	0.115	0.185	0.290	0.460	0.720	1.150	1.850	2.900	4.600	7.200
250	315	0.023	0.032	0.052	0.081	0.130	0.210	0.320	0.520	0.810	1.300	2.100	3.200	5.200	8.100
315	400	0.025	0.036	0.057	0.089	0.140	0.230	0.360	0.570	0.890	1.400	2.300	3.600	5.700	8.900
400	500	0.027	0.040	0.063	0.097	0.155	0.250	0.400	0.630	0.970	1.550	2.500	4.000	6.300	
500	630	0.032	0.044	0.070	0.110	0.175	0.280	0.440	0.700	1.100	1.750	2.800	4.400	6.300	
630	800	0.036	0.050	0.080	0.125	0.200	0.320	0.500	0.800	1.250	2.000	3.000	4.500	6.300	
800	1000	0.04	0.056	0.090	0.140	0.230	0.360	0.560	0.900	1.400	2.300	3.600	5.600	8.900	
1000	1250	0.047	0.066	0.105	0.165	0.260	0.420	0.660	1.050	1.650	2.600	4.200	6.600	10.500	
1250	1800	0.055	0.078	0.125	0.195	0.310	0.500	0.780	1.250	1.950	3.100	5.000	7.800	12.500	
1800	2000	0.065	0.092	0.150	0.230	0.370	0.600	0.920	1.500	2.300	3.700	6.000	9.200	15.000	
2000	2500	0.078	0.110	0.175	0.280	0.440	0.700	1.100	1.750	2.800	4.400	7.000	11.000	17.500	
2500	3160	0.093	0.135	0.210	0.330	0.540	0.880	1.350	2.100	3.300	5.400	8.800	13.500	21.000	



ANSI pump base flatness = 0.375mm/m... this standard causes soft-foot problems

API 610 flatness = 0.150mm/m... this standard has few soft-foot problems

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This slide triggers a story of how professional, university-taught project engineers create future breakdowns and maintenance mayhem in companies. It is a story of what happened to me, but the theme in the story applies to just about every professional engineer.

When I was employed as a professional engineer in my first organization I was told to use the company's engineering standards. Those documents required me buy centrifugal pumps to American National Standards Institute (ANSI) pump standards. I brought many such pumps during my days as a project engineer. Many years later I came across an article that compared the base plate flatness specifications of ANSI pumps with the quality requirements of the America Petroleum Industry (API) 610 pumps specified by the oil and gas industry<sup>3</sup>. The article noted that ANSI pump bases were permitted to be manufactured to a un-flatness tolerance of 0.375 mm per meter length (0.005in/ft) before requiring correction. Five thousandth of an inch over a foot length is a soft-foot problem. Whereas the API 610 pump limited it to 0.150mm/m (0.002in/ft). Two thousandth of an inch un-flatness in a foot length leads to far fewer soft-foot problems. The API 610 pump standard required soft-foot to be removed. If you wanted to set world class flatness standards then set them at IT5 values.

In my ignorance I brought breakdowns into the company by using the ANSI pump standard. The ANSI pump standard allowed manufacturers to make faulty equipment and sell them to industry as a perfectly acceptable pump. I did not know better. I just followed what I was told to do by my managers and the other engineers. Clearly these older and experienced engineers had done the same mistake all their careers as they later passed on to me. This is how engineers get caught out and bring failures into companies—they use standards that specify a poor quality result which they do not understand will lead to many breakdowns in future.

The table in the slide shows a portion of the International Tolerance Grade Table used to tolerance dimensions and set form limits on machined parts used to make machinery. Overlaid are the API 60 and

<sup>3</sup> [www.itindustrialproducts.com](http://www.itindustrialproducts.com), Baseplate Flatness, Tech Talk article

ANSI pump baseplate flatness limits for a meter length. The API 610 standard produces top quality pumps, whereas the ANSI standard allows manufacturers to make new pumps that fail from flatness distortion. The message is to get yourself equipment with high standards of precision and you will get reliability.

If you use company and international standards to buy equipment you had better be sure that you understand what quality you get and what that means to the future operation of the item.

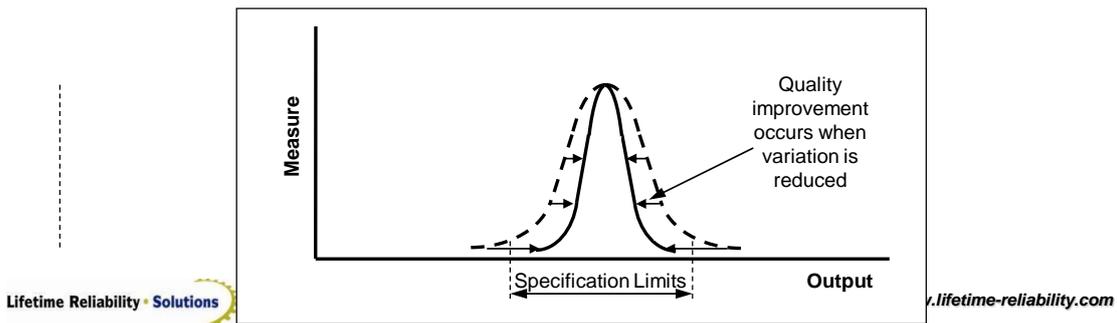
## Failure Preventing Job Procedures

*“In reality SOPs should be written to save organisations time, money, people and effort because, used properly, they will maximise productivity and deliver outstandingly reliable performance every time.”*

### Build Accuracy Control into SOPs

- Set a target for each task.
- Specify the acceptable tolerance.
- Do a test to prove accuracy.

**3Ts of Failure Prevention -**  
**. Target**  
**. Tolerance**  
**. Test**



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How many defects, errors and failures can your operation afford each day? Do your people have the time to go back and do a job twice or three times because it was done wrong the first time? Are people happy to regularly accept wasted production and lost time due to mistakes and poor quality? If not, then do your internal work procedures support doing the job right the first time?

The elimination of error is vital in business operation. Problems drastically reduce profits. Errors produce bad, unwanted outcomes. They are wasteful. They take resources and money away from where they were intended to be used. They use valuable time to correct what should have been done right in the first place. Worst of all is that they did not need to happen. Business systems need to prevent errors, and if not they must quickly detect and stop them from going further. The longer an error is undetected during production the more work is performed on the product, and the more money and time is wasted when it is finally scrapped.

The best failure prevention strategy is to proactively stop problems from entering the business. This requires that pre-emptive practices and methods are built into all business processes and systems as the normal way of doing work. Fortunately the business systems are in the written standard operating procedures and we can prevent errors by writing suitable preventive practices and measures in the operating procedures and teaching them to people.

### Controlling Accuracy – Removing Error

If it is important to be correct it will be necessary to introduce procedures to guide people to constantly attain the necessary standards of performance that deliver the desired results. Test laboratories, such as materials testing, pathology testing, etc, have long recognised that if they want consistent, reproducible,

correct results they need to work to proven and endorsed procedures. The test procedures provide clear guidance, set the required standard and stop variations in work performance. These standard operating procedures perform the role of helping employees efficiently (i.e. with the least use of resources) and effectively (i.e. in the least time required) deliver a specific result with certainty. The standard operating procedure, if followed faithfully, will produce the required outcome. But if there is no procedure to follow it is uncertain what the actual result will represent and the testing is invalid.

Standard operating procedures are much more valuable than normally understood by many managers. Not often appreciated is their ability to greatly improve the likelihood of top quality performance from employees. They are a quality control device which has the power to deliver **a specific level of excellence**. They should be used to step-by-step take people through both simple and complex tasks so that they are done correctly every time. For the best results include the 3Ts -target specification, tolerance and a test for proof - in the procedure to ensure people get feedback on how they are performing the tasks as they do them.

Having targets in your procedures to aim for will remove many current business problems. Target-based procedures recover great amounts of time and money. Adding targets, tolerances and tests in standard operating procedures will detect problems and prevent them from progressing further. They maximise productivity from current operating methods and turn-in a bigger profit.

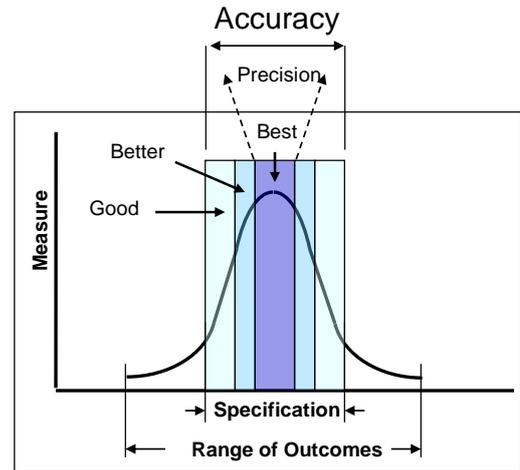
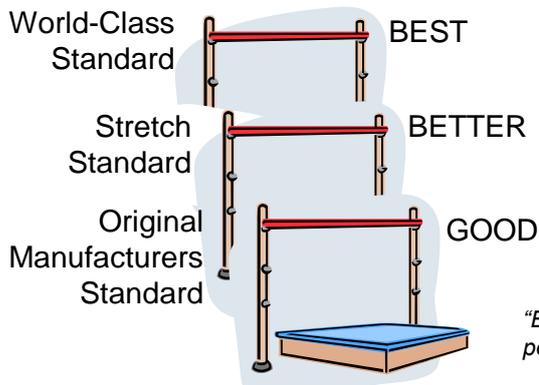
A classic example of what great value an accuracy-focused SOP can bring is in this story of a repair on a piece of production equipment. A shaft bearing of a fan regularly broke down. Instead of giving many years of reliable, failure-free service, the rear roller bearing on this fan never lasted more than about two months after a repair. Each time the bearing failed the production downtime caused by the breakdown was an expensive and great inconvenience. To take it out of the realm of a breakdown the bearing was replaced every six weeks as planned maintenance.

The bearing was also put on regular observation using bearing vibration condition monitoring. After several replacements enough vibration data was collected to diagnose the problem as a pinched outer bearing race. The bearing housing had been machined oval in shape when manufactured and it had squeezed the new bearing out-of-round, every time it was bolted up.

You could say that vibration analysis was applied wonderfully well, since it identified the cause of the recurring problem. But the real truth was the repair procedure failed badly. If there had been a task in the procedure to check and measure the bolted bearing housing roundness and compare the dimensions to allowable target measurements, it would have been instantly noticed at the first rebuild as having an oval-shaped hole. There was no need for the bearing to fail after the first time! A badly written standard operating procedure had let bad things happen! A failure prevention focused SOP, with target, tolerance and test for proof, (the 3Ts) would have found the problem on the first repair and it would have been fixed permanently.

# Use Two-Sided Error Proof Quality Control

- Put Mistake Proof Controls into SOPs with clear task standards
- Use the As-Designed Standards... then improve them
- Work to Internationally Recognised Standards
  - Set a **Target** for each task
  - Specify acceptable **Tolerance** range
  - Do a proof **Test** to prove accuracy



*"By stating the exact requirements to meet you are causing people to take all necessary actions to achieve them." 67*

I recommend that you start with using the design standards specified by the equipment designers. Ensure that all work tasks meet the equipment designers requirements.

Start by getting the equipment into the condition and environment the manufacturers expect. By starting in this way you can contact the equipment manufacturer for all the information you need. In the end it will not be good enough to become world-class, but it is a good place to start. Because equipment is a series arrangement of parts and components and the reliability of the series depends on the least reliable item, you must select the most demanding manufacturer's standard for the whole series. For example, a long coupled centrifugal pump set has a motor, coupling and pump. Depending on the coupling design it will still let the shafts turn even if they are misaligned by 2mm. But the motor manufacturer has used bearings that tolerate 0.01mm radial misalignment. So the radial alignment standard for the pump set will be the 0.01mm.

When you set standards you are applying the power of 'cause and effect', which is a Universal Law. By stating the exact requirements to meet you are causing people to take all necessary actions to achieve them. So setting a standard will, in time, cause it to be met, which has the effect of delivering the performance that the standard was meant to deliver. Setting Standards, and sticking with them till you reach them, produces the change you want to see happen.

## In Each Work Task Provide a Target to Hit



### Goal Posts and Targets

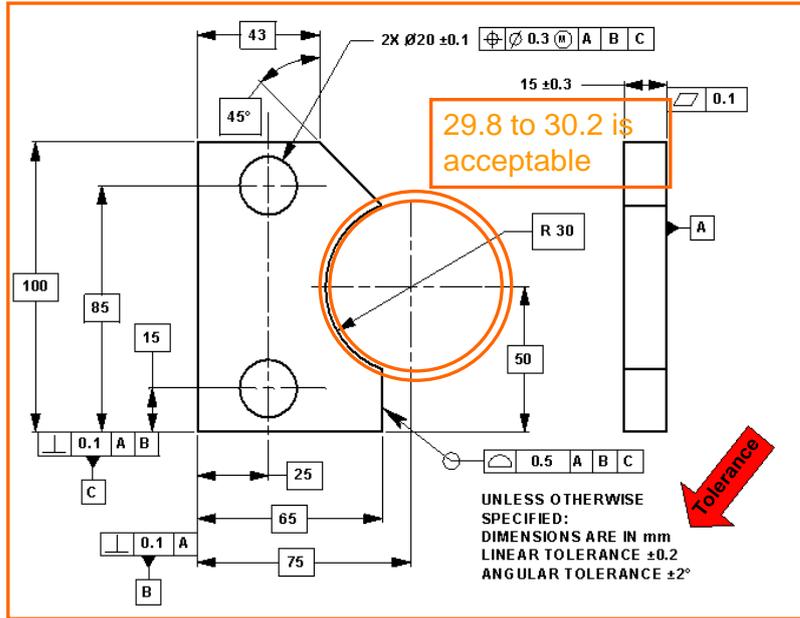
- Set a target of what is the best performance and people will aim for it!
  - Goal posts and targets set requirements for excellence.
  - SOPs need targets to meet as part of each task instruction.

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If you want to hit something it needs to become a target at which you aim. Doing a job well requires the same approach – a well done job is one that hits all its targets. In that case you would be wise to put targets into every task in a procedure for people to aim at and hit. What does a good result look like for the task? What standard must the task meet so you know it is right? Tell people what an excellent job is and then they will know what they must achieve to be considered top class.

The Amsterdam urinal ‘fly’ etched in ceramic caused 80% improved targeting by users. Once you introduce a target people will try and hit it; it’s human nature. By stating clear targets in SOP tasks, you have significantly improved the chances of hitting them.

## Provide a Tolerance Range of Performance



On an archery target you know exactly how well you have done! You should also know how well you have done your job.

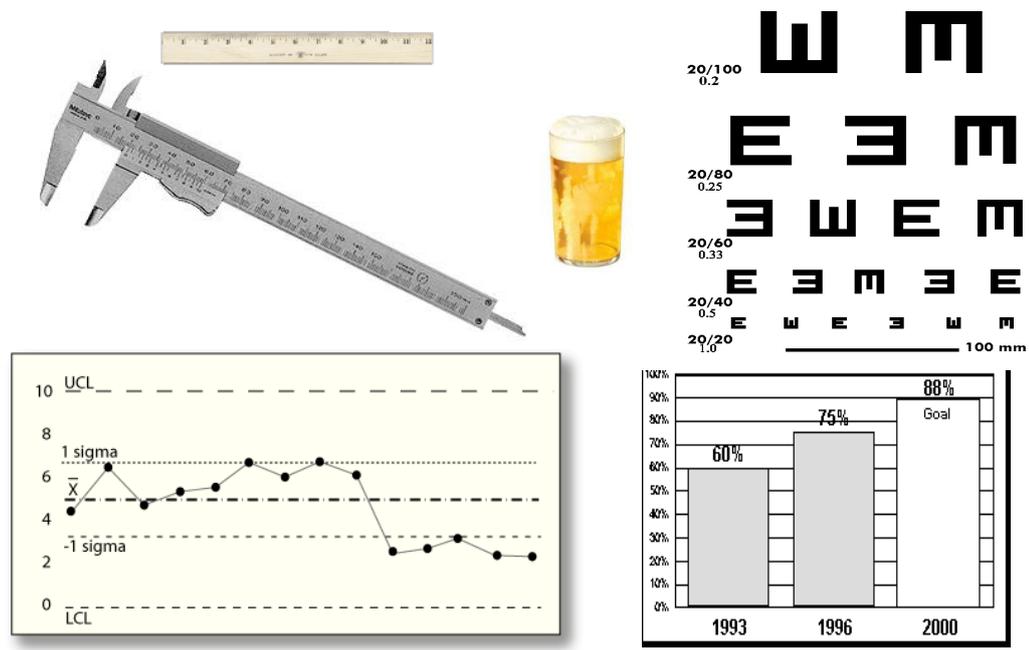
Considered accurate if within tolerance – Specify a range of acceptance.

[www.lifetime-reliability.com](http://www.lifetime-reliability.com)

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Notice that the bullseye in the archery target is not a pin prick in size. Though dead-centre is the perfect target, a hit anywhere inside the circle is a top result. When targets are provided in SOPs they must have a tolerance range within which the result is acceptable. The drawing of the part provides tolerances for its manufacture. Any size within the tolerance dimensions is fine. SOPs must be written with the same principle of using a tolerance about the target.

## Provide a Test For Proof of Accuracy



**Applying MEASUREMENT to TEST and PROVE accuracy produces self-correcting learning.**

Lifetime Reliability • Soli

[me-reliability.com](http://me-reliability.com)

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To confirm the target is hit within the allowed tolerance it is necessary to test its accuracy using a suitable measure. With an archery target you have a visual measure of the circle borders to prove accuracy. With a machined part you use certified measuring equipment to prove accuracy. With beer and wine you use a tasting panel of experienced tasters to test it quality. In a business you use charts and graphs to measure performance against target. Once you measure a thing you know where you are. If it is not yet on target you correct for the difference and try again. It only by measuring actual performance against a set target that you can be sure if a task is done right.

## Include Failure Prevention in SOPs with 3Ts

Task Step No.	Task Step Owner	Task Step Name	Tools & Condition	Full Description of Task	Test for Correctness	Tolerance Range			Record Actual Result	Action if Out of Tolerance	Sign-off After Completion
		(Max 3 - 4 words)		(Include all tables, diagrams and pictures here)		Good	Better	Best			
						Pass / Fail		World Class			

Typical Layout for 3T – Target, Tolerance, Test – Failure Prevention Procedure

When procedures are written with the 3Ts you can guide people right to the outcome they need to deliver. We build into 3T procedures the necessary actions that when performed will deliver the maintenance strategy. We give people a way to check that their work is exactly what it needs to be. They self-improve and gain the self-satisfaction of having done a great job.

The beauty of the 3T failure prevention method is its powerful influence for increasing the probability of good outcomes. It is a proactive control measure that drastically reduces defect creation and the future failures they cause. The 3T's provide statistical control over a task by setting clear performance requirements, installing control limits and specifying measures to track performance. Developing procedures that insure accuracy by imbedding targets, tolerance bands and tests in tasks is a highly secure way to meet specifications. They remove uncertainty of outcome. With sound targets and proof-testing used in your business processes, your organization moves from being uncontrolled, or at best quality-conscious if a quality management system is used, to being truly an accuracy-controlled enterprise, an ACE. Without any additional costs and demands on the organization, except to include the 3Ts into its standard operating procedures, and where needed, providing appropriate test devices, a business can be well-protected against all defects and failures.

With 3T defect elimination and failure prevention methods overlaid on standard operating practices the possibility of problems developing and getting deep into a business are greatly reduced. The business systems shrink in complexity because each person is now clearly responsible for product quality and conformity. Accuracy and quality are inherent in the system of work and become the only acceptable way to do a job.

The 3T method reduces the need for having supervisors and managers because each worker can see for themselves when a task is well-done. Employees receive positive feedback and satisfaction from the job itself when they see that their work is of top quality. Employees become their own quality control inspectors and learn to improve their performance until it is up-to-standard.

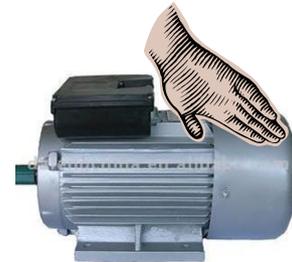
ACE procedures have in-built structure to prevent failure and the introduction of defects. Each task can be done correctly because each has a measurable target and tolerance to work to. When all tasks are done right the procedure is correct. Using the ACE 3T method in standard operation procedures makes them highly valuable work instructions that are far superior to the average standard operating procedures. As well as acting as guidelines for the work, they set clear performance criteria for every step in the job

process. They make it clear to the employee the degree of accuracy that must be achieved. Nothing less is suitable. It turns people into experts.

## Measure to Prove Equipment Start-up Condition is to Standards

The human senses are excellent for identifying and monitoring the relationships between things.

We can feel down to 0.2 mm/s vibration. Where 1 mm/s is excellent machine vibration levels and 8 mm/s is very rough



Stethoscope



Laser Thermometer



Touch Thermometer



Vibration Pen

(low speeds)

**Low cost condition monitoring tools**

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If equipment has been properly built it will work well from start-up. Once a machine is up to operating temperature test that it is behaving correctly. You do not need expensive analysis equipment to check if bearings are running hot or a gearbox is making an unusual sound.

Often a bearing vibration baseline reading is necessary to take when equipment is new to provide a benchmark against which to compare the equipment as it operates. The baseline vibration value should be low, below 1.5 mm/sec RMS (root mean square) velocity for the roller bearings in a well built machine properly installed. Higher values are suspicious, though the machine may run fine for a sufficiently long time.

## *Activity 7 – Adding 3T Error Proof Quality to a Job Plan (and to Job Procedures)*

### **Detailing the Quality Required for a Job**

Identify the quality work standards and the proof tests you would apply to confirm quality compliance for the job plan in the Workbook.

## Review and Discussion of Activity 7

The activity lets Attendees use their new knowledge gained following the Day's presentation to immediately help them improve the approach to their planning. In teams of two, Attendees set detailed quality standards for a job. They are to include the specifics they now believe should be added into their work process to control job quality.

This Activity is intended to achieve two purposes. The first is to allow course trainees to identify if their current planning process adequately meets the requirements for quality and stress parts' reduction recommended in this course.

The second purpose of the activity is to conduct a group discussion with the attendees upon its completion, and draw out the quality details people think should be included in the planning of maintenance work. The aim being to work with the group to recognise the need to have very detailed, clear and accurate tasks, and for them to recognise the need to set-up systems that will allow them to quickly gather together fully detailed , quality-controlled, and well-costed work packs for their maintenance people needs.

## 4. Activity 7 – Create a Job Plan with Time and Quality Controls

Below is a sample job plan to mount plummer blocks on the shaft of a conveyor pulley and install the assembled pulley into place.

You are required to alter the job plan to:

1. set milestones in the job plan to identify progress
2. specify the quality standards for each step in the table below.
3. set a proof test to confirm work quality is achieved

### **INSTALL CONVEYOR PULLEY PLUMMER BLOCK JOB PLAN**

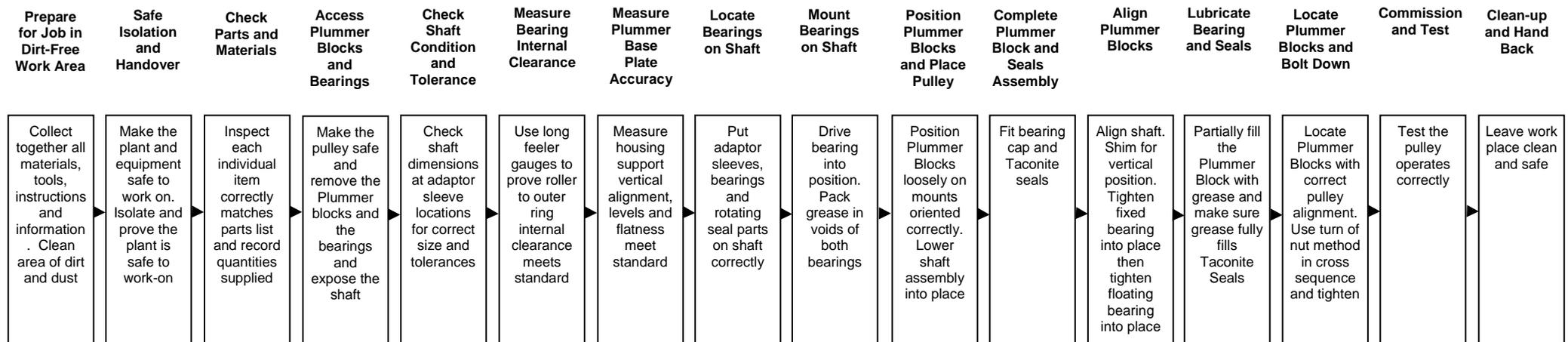
- 1. Prepare for Job in Dirt-Free Work Area**
- 2. Safe Isolation and Handover**
- 3. Check Parts and Materials are Correct**
- 4. Access Plummer Block and Bearings**
- 5. Check Shaft Condition and Tolerance**
- 6. Measure Bearing Internal Clearance**
- 7. Measure Plummer Base Plate Accuracy**
- 8. Locate Bearings on Shaft**
- 9. Mount Bearings on Shaft**
- 10. Position Plummer Blocks and Place Pulley**
- 11. Complete Plummer Block and Seals Assembly**
- 12. Align Plummer Blocks**
- 13. Lubricate Bearing and Seals**
- 14. Locate Plummer Blocks and Bolt Down**
- 15. Commission and Test**
- 16. Clean-up and Hand Back**



**Job Process Summary**

A summary of the work process for doing the job is shown below.

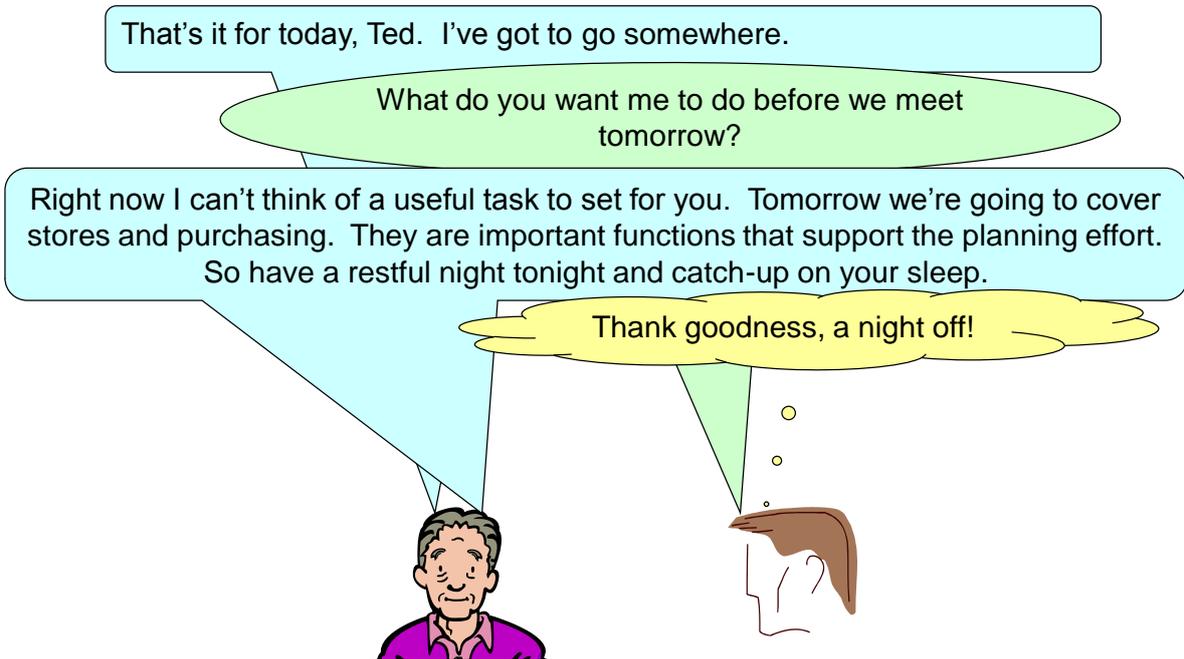
## Overview of the Process for Installing Spherical Roller Bearings with Adaptor Sleeve in Plummer Blocks with Taconite Seals on a Conveyor Pulley Shaft



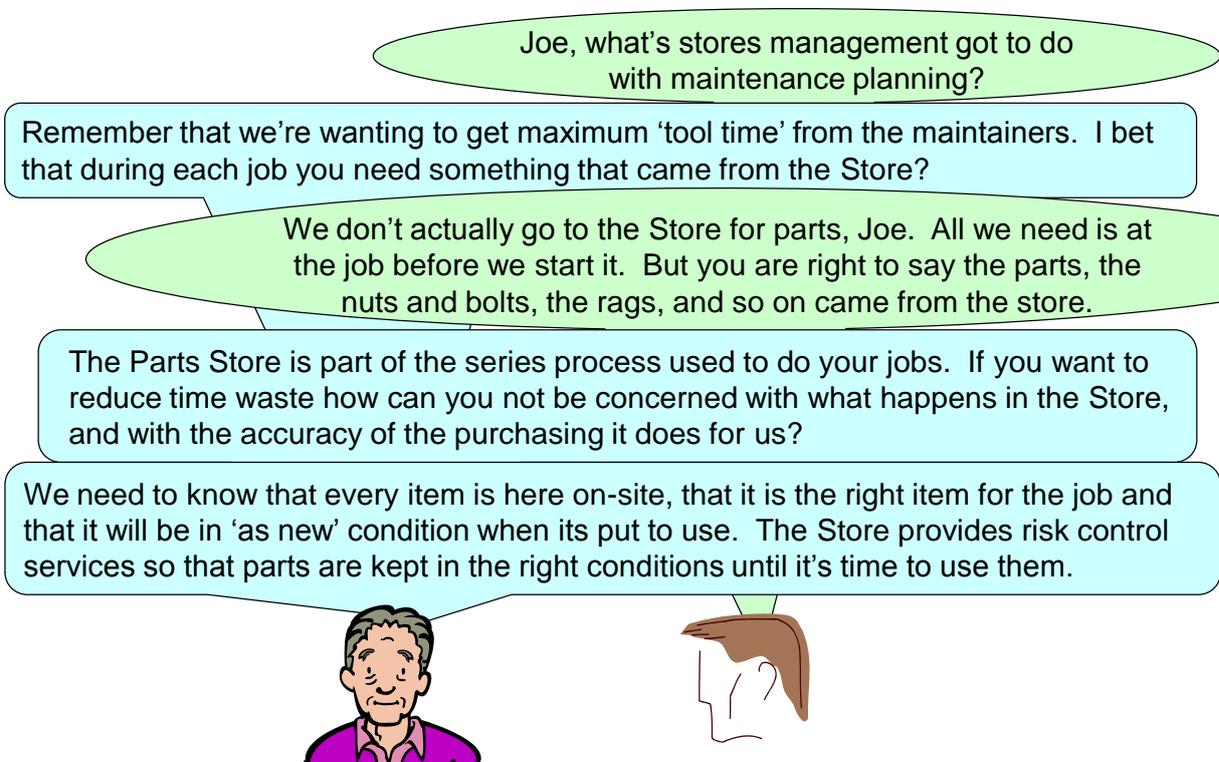
## Job Plan with Time and Quality Controls

No	Task	Include Milestone Tests at Suitable Activity Locations to Check Compliance to Standard	Full Task Description that includes Minimum Safety, Reliability and Quality Standards	Specify Proof Tests that Standards are Met	Actual Result
1.	Prepare for Job in Dirt-Free Work Area	Site-work cleanliness standard for roller bearing tasks to meet OEM specifications	Prepare work site for roller bearing work so that it meets the bearing OEM cleanliness requirements	Take photographs of site preparations before dismantling equipment	
2.	Safe Isolation and Handover	1) Operations isolate equipment and make safe to access 2) JSA conducted prior job start			
3.	Check Parts and Materials are Correct				
4.	Access Plummer Block and Bearings				
5.	Check Shaft Condition and Tolerance				
6.	Measure Bearing Internal Clearance				
7.	Measure Plummer Base Plate Accuracy				
8.	Locate Bearings on Shaft				

9.	Mount Bearings on Shaft				
10.	Position Plummer Blocks and Place Pulley				
11.	Complete Plummer Block and Seals Assembly				
12.	Align Plummer Blocks				
13.	Lubricate Bearing and Seals				
14.	Locate Plummer Blocks and Bolt Down				
15.	Commission and Test				
16.	Clean-up and Hand Back				



### The session finishes ...



### In the morning ...

# Inventory Purchasing and Management

- Purchasing Procedures
- Important Purchasing Information
- Useful Store Control Practices
- Good Storage Practices
- Working with and Developing Suppliers
- Equipment Refurbishment Decisions and Costs

A Maintenance Planner works closely with their Parts Store. A Planner will order and purchase parts into the Store and the Store will hold and manage the delivered parts. The Store will issue parts to be used on a maintenance or capital project job.

## Follow Corporate Purchasing Procedures

- Companies have legal obligations, such as taxation laws, accounting standards and liquidity requirements, that they need to meet
- Companies control their money by installing necessary accounting and purchasing practices that are to be followed
- Usually two or three quotes are required unless there is a contract with a preferred Supplier (using a single supplier causes less problems)
- Typically there is a hierarchy of expenditure authorisation
- Before purchasing ensure the cost estimate is  $\pm 10\%$  accurate. Identify all costs... no surprises...



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Parts, services and materials purchasing is a common activity that a Maintenance Planner does. Typically they follow buying rules put in place by the Accounts Department to ensure the company meets its legal, commercial and taxation requirements. Often the rules require multiple quotes, which is not ideal for streamlining the supply of maintenance parts, materials and services. But because the Maintenance Planner works in a regulated company environment they need to follow the set rules.

## Important Purchasing Information

- Supplier/Manufacturer
- Part Number
- Part Description
- Quantity
- Delivery Address
- *What else to include?*
  - Material Specification
  - Buyer Name and Contact Details
  - **+More...** E.g. Delivery date, site contact name, phone contact name, delivery instructions, handling instructions, terms and conditions; **PARTS PROTECTION AGAINST DAMAGE** e.g. vibration of bearings on shafts in transport



When purchasing maintenance parts and equipment it is critical to provide all the details necessary to get the right part, and make sure it is delivered to the right location, by the right date.

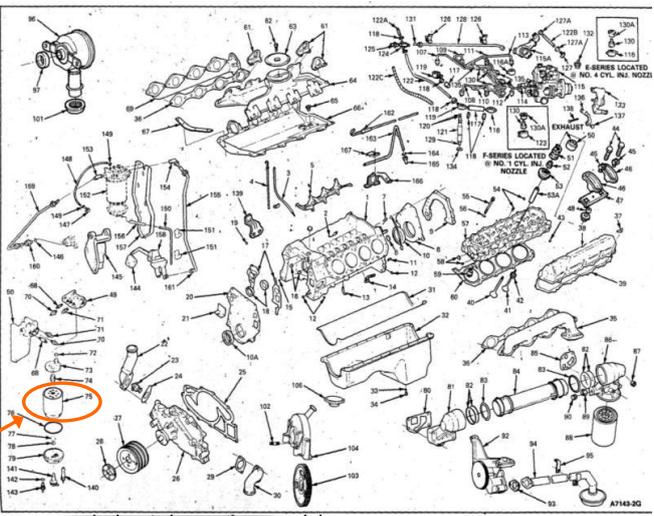
Just providing the Manufacturer Name, Part Number, Item Description and Quality is not really enough to be sure that the right goods will be sent and delivered to where you want them to go. If you know that your Store's catalogue is not accurate and some of the data is suspicious, then you should include additional confirmatory information to the Supplier in the purchase order free text field. If the Supplier is not sure exactly what you want they will most likely contact you to confirm the exact details. That is exactly what you want them to do.

If the delivery has to travel a long way and there is great opportunity for it to be damaged during transportation you will need to provide packaging and transport instructions for its safe delivery. A common problem when transporting heavy equipment is to leave the shafts sitting in their roller bearings. With all the impacts suffered by the machine during shipping and transport the bearing raceways get damaged by brinelling (dented by the weight of the shaft). The bearing will need to be replaced before the new machine can be used. This could have been prevented had the Supplier been instructed to remove the shafts from the machine and send the shafts in their own crate so that they could be reassembled safely at the destination site.

# Use the Correct Manufacturer's Parts List and Part Numbers

The most important thing you need is the part number for the model of equipment you have.

REF. NO.	BASIC PART NO.	DESCRIPTION	REF. NO.	BASIC PART NO.	DESCRIPTION	REF. NO.	BASIC PART NO.	DESCRIPTION
1	6009H	Cylinder Block Assy.	45	---	Front Valve Lever	80	---	Plug, 1/2"
2	6C329A	Guide, Tappet	46	---	Lever, Valve	80	---	Plug, 1/2"
3	6754	Tube Assembly, Oil Level Gauge (F-Series)	47	---	Retainer, Valve Lever Post	82	6600	Oil Pump
			48	---	Lock Valve Spring Retainer	83	6626	Gasket, C
4	6750	Oil Level Gauge (F-Series)	49	6514A	Retainer, Valve Spring (36)	84	6622	Pick-Up T
5	6C330A	Retainer, Tappet Guide	50	---	Shank, Oil (Exhaust)	85	6A561	Brazelet, C
6	6026A	Plug, Engine (1-1/2" O.D.)	51	6513B	Spring, Valve, with Damper (16)	86	6A565	CDR Valv
7	6L063A	Gasket, Rear Cover	52	6571A	Seat, Valve Stem-Intake (8)	87	6A892	Seal Ring
8	6L060A	Cover Assembly, Engine, Rear	53	6K333A	Rotator, Assembly Valve (16)	100	6758	Crankcase
9	6A369A	Adapter, Flywheel to Transmission	53A	---	Guide, Valve (Service)	101	6769	Grommet,
10	6701A	Rear Oil Seal, Crankshaft	54	---	Plug, 1/2 inch NPTF (4)	102	9F733	Mounting
10A	---	Front Oil Seal	55	6065A	Bot Cylinder Head (34)	103	9A546	Drive Gas
11	66041B	Dowel Pin, Fly Wheel Adapter	56	6L015A	Washer, Cylinder Head Bot (34)	104	9C516	Adapter H
12	67614S	Pipe Plug, 1/8 NPTF	57	6049A	Cylinder Head Assembly (2)	106	6766	Cap, Oil F
13	6C327A	Platen Cooling Jet	58	6029B	Plug, 1/4 Inch	107	6A559H	Pipe w/Nt
14	6A051A	Heater Assembly Block	59	6057A	Insert, Combustion Chamber (8)	108	6A555D	Pipe w/Nt
15	66041A	Dowel Pin, Front Cover Plate	60	6051B	Gasket, Cylinder Head (2)	109	6A555F	Pipe w/Nt
16	6060E	Cup Plug	81	---	Eye, Lifting (3)	110	6A555E	Pipe w/Nt
17	6020A	Gasket, Front Cover Plate	82	9C829A	Insert, Bolt Thread-Air Cleaner Stud	111	6A555D	Pipe w/Nt
18	6A251A	Bearing, Ntl, Crankshaft	83	9F460A	Screen, Intake Manifold	112	6A555C	Pipe w/Nt
19	6A529A	Ball, Oil Indicator Hole 1 1/2"	83	9F460A	Screen, Intake Manifold	112	6A555B	Pipe w/Nt
20	66070A	Plate, Front Cover	64	9424B	Manifold, Intake	114	6A555A	Pipe w/Nt
21	---	Indicator, Timing (Part of Front Cover)	65	9A450A	Drain Plug, Valley Pan	115	6A543	Injection F
			66	9439B	Gasket and Valley Pan	115A	---	Valve, Va (Auto. Tr)
22	6596D	Connection, Water Outlet	67	96470A	Strap, Valley Pan	116	---	Fuel Ret
23	6575	Thermostat	68	---	Fuel Priming Valve and Cap	116	---	Fuel Ret
24	6555A	Gasket, Water Outlet	69	9430A	Manifold, Exhaust, Right	116A	---	Elbow, Ex
25	6507A	Gasket, Water Pump	70	---	Continuous Vent with Check Valve	117	---	Hose
26	6501D	Water Pump	71	---	Vacuum Switch (Fuel Filter Element Replacement Indicator)	118	9B255	Clip
27	6506D	Pulley, Water Pump	72	---	Fuel Filter (Indicator)	118	9A364	Fuel Retu
28	6546A	Spacer, Fan	72	---	Fuel Heater O-Ring	120	6732-592	O-Ring,
29	6555A	Gasket, Water Inlet	73	---	Fuel Heater	121	9E327	Injection I
30	6592D	Connection, Water Inlet	74	---	Thermostat Inset	122	---	Fuel Retu
31	DA62-1952-A	RIV Sealant	75	---	Fuel Filter Element	122A	---	Hose
32	6675C	Oil Pan	76	---	---	---	---	Hose, Pump to Fuel Return Tube
33	6734A	Gasket, Oil Pan Drain	76	---	---	---	---	Inverted Flare Tube Nut
								Oil Level Gauge -- E-Series



Having the parts manuals and maintenance manuals is critically important to get the right part and number. Without them you have to make contact with the supplier, and between the two of you try and work-out what you need to buy. Usually the part number is marked on the part. But if it's illegible you are in trouble.

Most of the important purchasing information will be found in the manufacture's parts manual/list. The most important thing you need is the part number for the model of equipment you have. Once you have the right part number, you are almost certain to get the right part.

## Stores Need to Use the Best Practices Because they Can Destroy the Best Plans

- **Excellence:**

Stores system integrated to CMMS and accounting system; bar coding or radio frequency tags of all stores items; World-class Stores Management

- **Competence:**

Single source supplier partnerships established and effective; Area stores with visual controls; reliability of spares maintained

- **Understanding:**

Spares classified with separate maintenance strategies; Spares linked to BOMs/Equipment Drawings; Standardization policies exist; ABC parts management with 'A' parts protected

- **Awareness:**

Stores catalogue established; Inventory accuracy >95%; Goods receiving practices in-place

- **Innocence:**

- Ad-hoc stores; No costing or control of spares

The Store needs to be managed professionally. All parts need to be quickly and easily found and must be reliable when used. There are many stories where electric motors have failed bearing shortly after requested from the store and installed. The investigations found that the bearing had brinelled because it was never turned while it sat in the store for many months (sometimes years). When the motor was installed the bearings failed quickly because the races were damaged by the dimples of the brinelling.

You must maintain the health and condition of the parts in store if you want them to be reliable in-service. Electric motors stored horizontally must have their shafts turned a ¼ turn each week. Shafts must not be stored on blocks as they will bend under their own weight. A shaft needs to be fully supported its whole length. Long shafts must be stored vertically by hanging them from eyelets treaded into threaded holes at end of the shaft. Cast iron gearboxes to be stored for a long time should be flooded with clean oil to the very top so no air can get in to corrode the internals. The alternative is ensure the gearbox is leak proof and mount a desiccant drier at the breather to remove all moisture from the air. And while the gearbox is in storage the desiccant drier will need replacement once the element has absorbed too much moisture. Regular maintenance of the condition and health of parts in storage is a job that the Store must undertake when they keep for equipment for a long time.

## Useful Parts Store Control Practices

- Locked store
- Receipt for each issue
- Inspect physical condition of a delivery for damage
- Receipt for each delivery
- FIFO for aging, degrading, contamination risk items
- A-B-C prioritisation for inventory management
- Planned stock counts that audit entire holding
- Advise Purchaser when parts are in-store
- Ensure parts reliability/maintenance in Store
- Practice 5S in the Storage of parts -

**FIFO** *first-in, first-out*, oldest inventory items issued first  
**LIFO** *last-in, first-out*, most recent items issued first (used in inventory management to minimise tax)



The slide lists some basic principles to adopt to ensure that your parts can be found and used when needed. There are big risks in this store that would be removed if 5S workplace management practices were adopted:

- Provide labelling of stock,
- Provide labelling of bins and spaces
- No Items stored on the floor where they will be hit by the fork
- Be sure people use suitable access equipment and follow safe handling practices
- Ensure floor areas are marked to indicate their purpose

# Count the Good Storage Practices You See Here?

Every stocked item registered in a data base

Rotating equipment turned weekly

A place for everything and everything in its place (5S workplace)

Written 3T SOPs of storage practices



Every location clearly identified

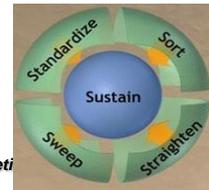
Every item clearly identified

Shafts stored upright, bearings stored flat

Stored safely and protected against damage and contamination

Identification that does not come off until taken off

Stored items needing maintenance are maintained



The slide lacks some basic principles to ensure your parts are kept in good condition until needed. The practices in a well-run store protect the parts, control and track their movement and minimise waste of time, manpower and resources.

# Good Order Receiving Practice

- Check purchasing description and quantity on docket matches delivery
- Is there a certificate required to prove compliance?
- Physically inspect the delivery for damage
- Sign and date the delivery docket legibly if delivery is accepted
- Unload items carefully and store in a safe place away from danger
- Confirm Purchase Order number and details match delivery docket details
- Identify items still outstanding from order
- Advise Purchaser that order has arrived

Canada Crafts  
 272 Great Lakes Road  
 CARMARTHEN NSW 2520  
 Phone: (08) 9635 2222

Delivery Docket

Date: 18 June 2008      #0011295

Country Décor  
 221 Norman Bay Road  
 NORMAN BAY NSW 2252

Item	Description	Quantity	Item Cost	Total Cost
LS2	Lamp Stand (hand turned)	5		
CT22	Beechworth Coffee Table	5		
CNT3	Beechworth Corner Table	5		
PT56	Pedestal Table & 6 chairs	1		
ST18	Cottage Style Stool (pine)	12		

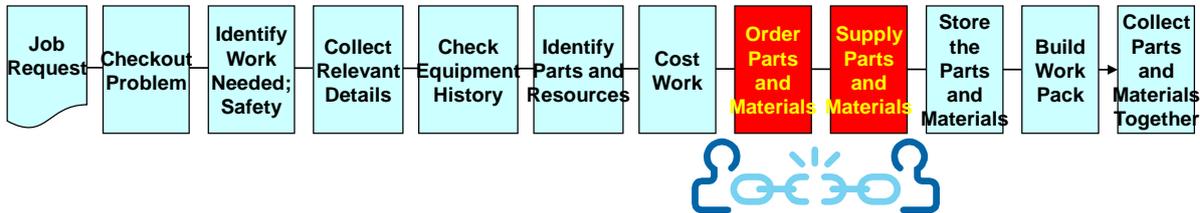
Goods received: \_\_\_\_\_

Date: \_\_\_\_\_

Thank you for your order

Items coming into a store must be receipted and checked against the order to confirm they are correct in quality and quantity. Only thorough physical examination with accompanying quality certification is truly adequate.

## Work with and Develop Your Suppliers to Reduce Risk, Variation and Complexity



- Build a long-term relationship; visit them regularly to see what they do
- Work with preferred suppliers, (allows you to standardize)
- Use Specifications and Contracts on Suppliers
- Have a supplier assessment process to rate them, and go with the result
- Keep a record of their performance to focus their improvement efforts
- Alliances and consigning work in reducing costs
- An ISO9001 quality management system doesn't mean a thing if people don't live it (check how many non-conformances are received and fix each month. If not at least one per person each month then they are not 'living quality')

Once plant and equipment are purchased you are locked-in for years of business with the equipment parts suppliers. By setting-up the few simple practices listed on the slide you will benefit from their expertise and knowledge. They will know your expectations and can work to meet it them consistently. They will develop systems to support your efforts if they feel there will be a long-term business commitment.

Your Suppliers are a link in the chain of taking your maintenance work from plan to completion. If they are poor suppliers you and your company will suffer. Because they are part of a series process, in which their mistakes and errors severely impact your company performance, you must introduce means to reduce the chance of error either from them or yourself. By working long term with the one supplier you both adapt your business processes over the time of the relationship to reduce the chance of mistakes.

Quality Management Systems, like ISO9001, are popular with equipment manufacturers. But their products will still have lots of problems if the system to guarantee quality is not actually followed by the people that make the equipment.

## Justifying Equipment Refurbishment Decisions and the Cost Drivers

- **What is the Economic Life of an Asset**

That life after which the asset is retired to minimise the Long Run Average Cost of Production, if necessary across several asset replacement cycles

Replace equipment when the cost to keep it in operation begins to force up the unit cost of production.

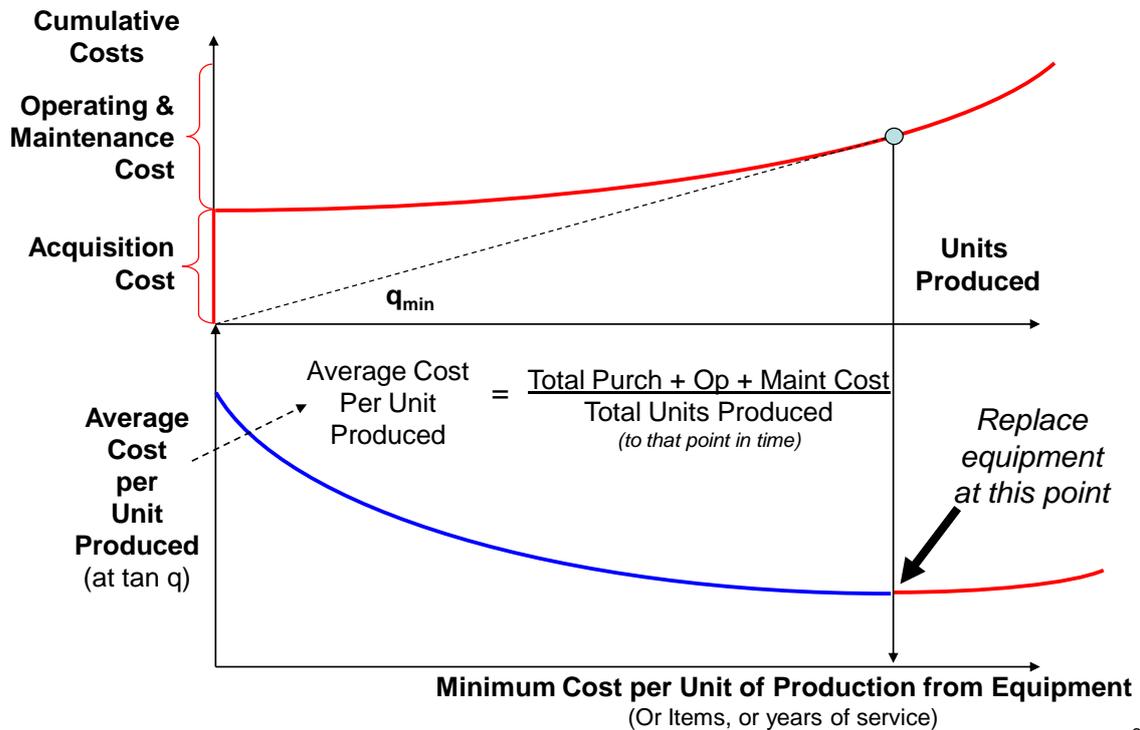
- **When to Repair or Replace?**

- Needs a Corporate Policy with 'rules' to follow
- Typically a Net Present Value (NPV) or Equivalent Annual Cost (EAC) financial model is used
- Include all DAFT Costs in the model for full and true impact on the business

$$\text{Unit Cost} = \frac{\text{Cost}}{\text{Capacity}}$$

When to replace plant and equipment can be a major financial decision. For expensive equipment that decision requires careful accounting analysis and your company's Accountants need to be involved when making it so that they can analyse the options available for the business. However, for lesser cost plant the replacement decision is often made by the Operations and Maintenance groups together, after reviewing the maintenance and operating cost of retaining it verses replacing it.

## Minimum Long-Run Average Cost of Production



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The Figure shows graphically when to replace plant and equipment based on the increasing cost to make product. Such graphs can be developed using historical data and trended to observe how the cost behaviour of plant and equipment impacts on the cost of production.

The cost of running equipment includes the cost of its maintenance. The end of an asset's economic life can be calculated based on how much it costs to continue using it. When the cost to use it is rising from its lowest historic value it is time to replace the asset, because to continue using it will cost increasingly more money.

That's enough on stores and inventory management, Ted. So that you get a good appreciation of parts store systems, we'll get you some time with the Store's guys later.

Do we meet again tomorrow Joe?

Sure do! We're going to introduce you to maintenance planning by learning about project management. The planning and work management principles are common. The only difference is a project is defined by its time span – it has a start and stop date. Whereas weekly maintenance is an on-going cycle.



This session finishes ...

Come in and sit down Ted.

Thanks Joe. You said we would review project management today.

Yes, it will be your introduction to the planning process. In fact project planning and maintenance planning uses the same planning tools and methods – bar charts, critical path analysis and tracking. That's especially so when we do shutdown planning.

Is shutdown planning like project management because they both have start and end dates?

Definitely, in shutdowns we have to hit those deadlines so the Production Plan can stay on-schedule. That means a lot of up-front preparation, double-checking and 'what-if' risk scenario analysis.



At next morning's meeting ...

## Project Management Principles and Practices

- Identify Work Priorities
- Define a Financial Budget
- Set Project Goals and Objectives
- Provide Drawings, Specifications & Standards to follow
- Plan and monitor with Bar (Gantt) Charts
- Prioritize with PERT Charts (Critical Path)
- Use Preventive Action Meetings to Prepare for All Contingencies
- Sensitivity Analysis (‘What-if’ risk analysis) 
- Manage to Checkpoints and with Checklists 
- Go see for yourself

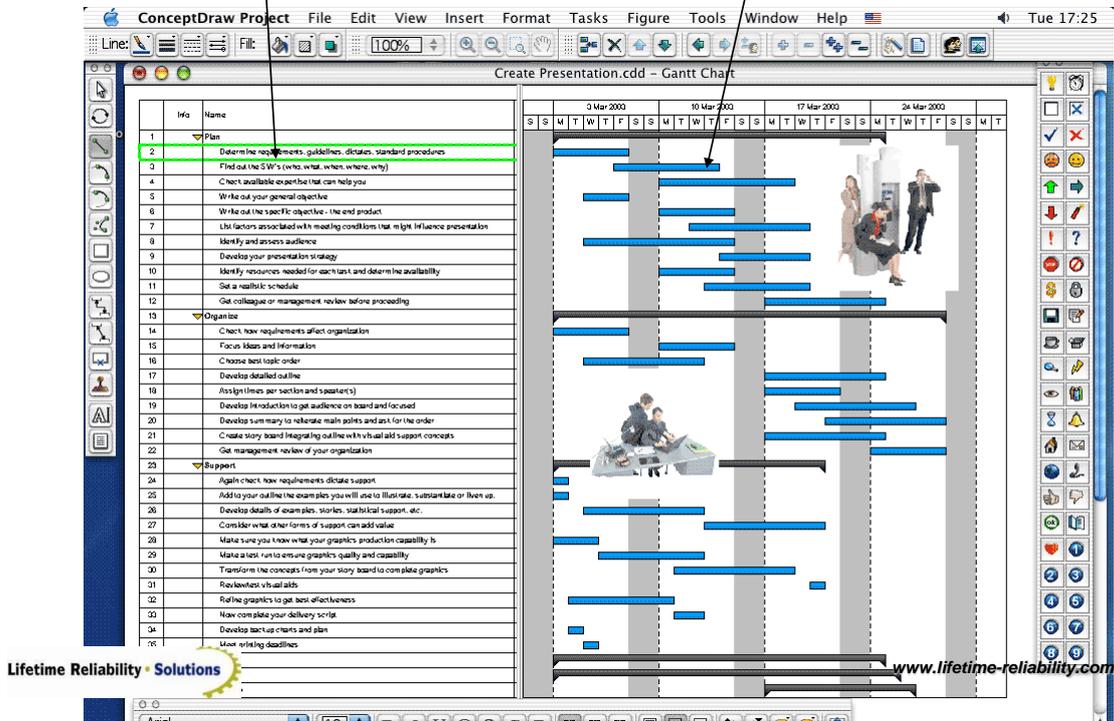


Maintenance Planners can benefit greatly by adopting basic project management practices for controlling the work load and the work priorities. The slide lists the basic project management principles to use which provide control in busy environments.

# Bar Charting Plans and Activities

Responsibilities

Date Driven



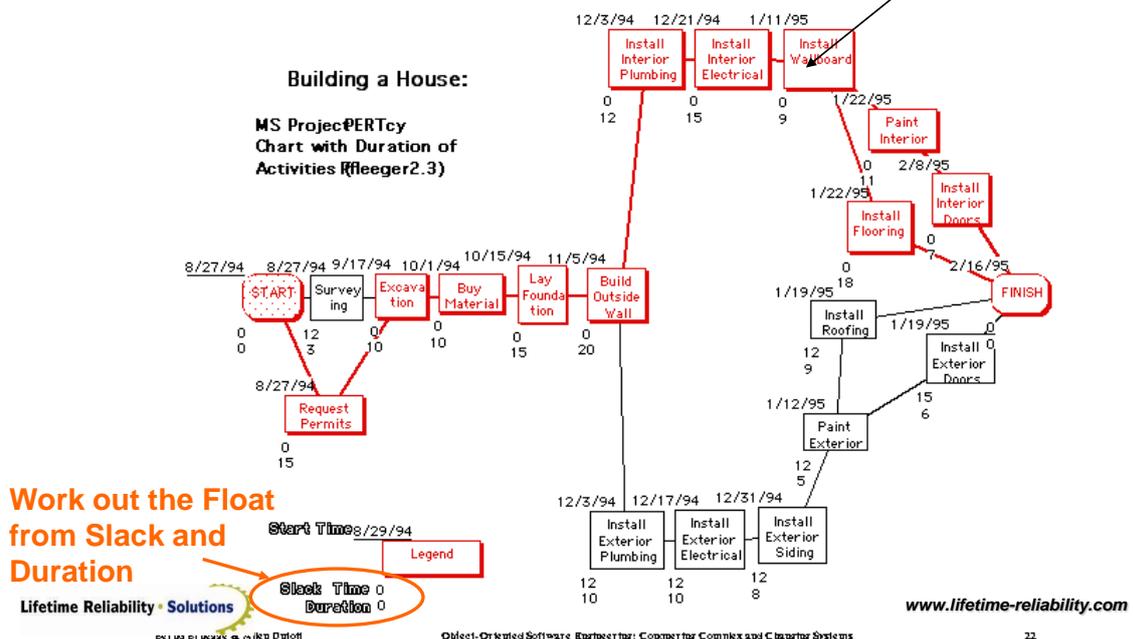
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The slide shows a Bar (Gantt) Chart used in managing a project. The Bar Chart identifies task responsibilities and the deadlines to meet.

# PERT Charting Plans and Activities

Activity Driven

## PERT Chart Example for "Building a House"

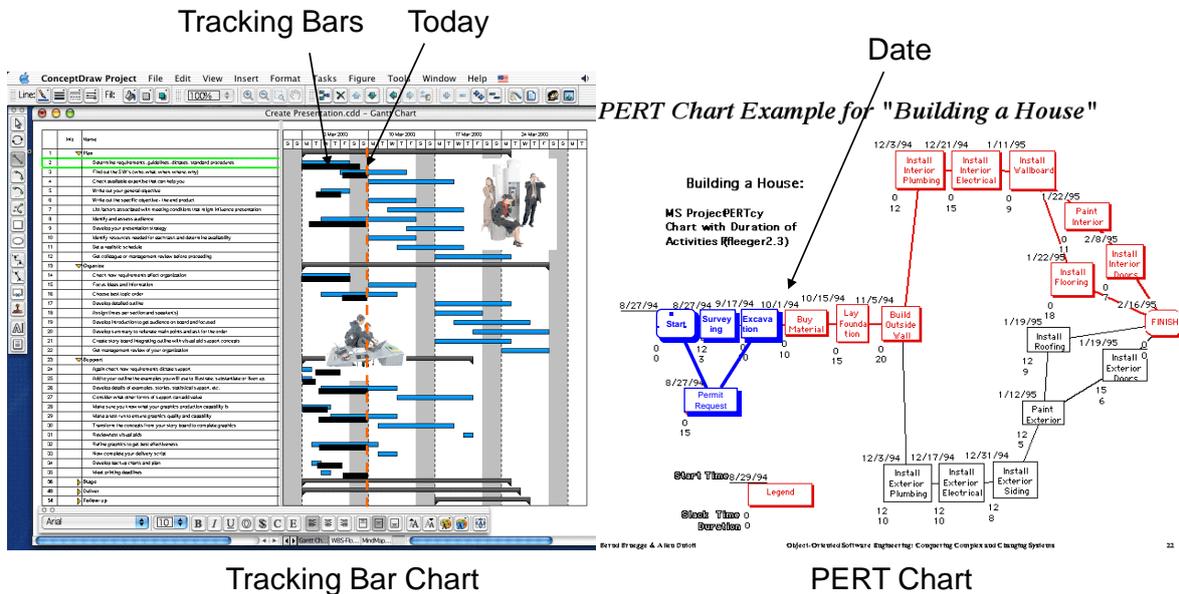


[www.lifetime-reliability.com](http://www.lifetime-reliability.com)

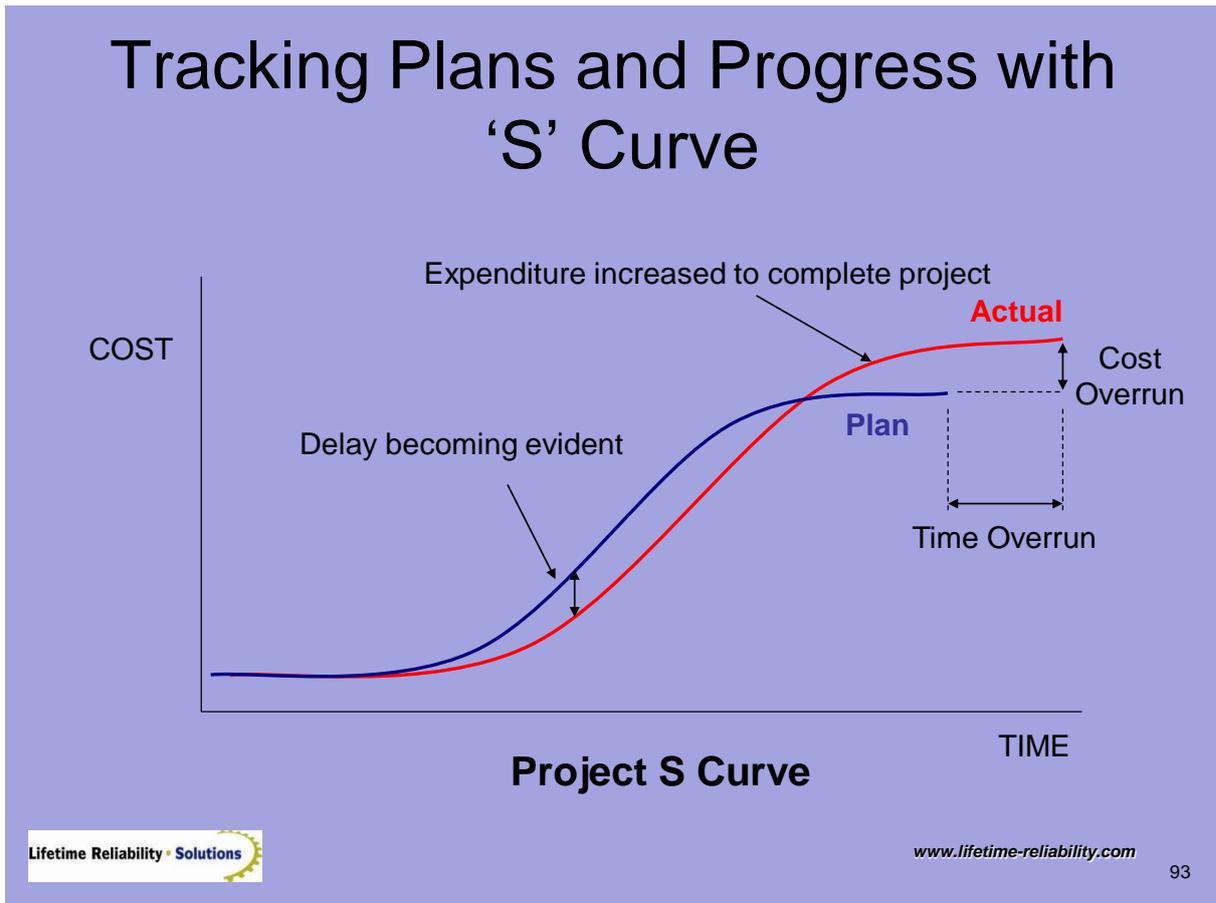
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A PERT Chart indicates importance and order of work to meet the project completion targets.

# Tracking Plans and Progress with Tracking Bar Chart and Critical Path



Once you have a Bar (Gantt) Chart and a PERT Chart they are used to track work progress. Each one gives a different picture of a situation. The Gantt Chart shows the total progress on all work fronts. The PERT Chart shows if crucial delays are happening that will cause project overruns.



The 'S' Curve on this slide shows the original plan for cost and time. As the project progressed the actual costs and time was recorded alongside the plan. By tracking progress in this form it becomes obvious when delays impact the project and when costs are rising faster than budgeted.

The S-Curve is often created using spreadsheet graphing tools if the project management software cannot provide an S-Curve diagram. The raw data is exported from the project management software into the spreadsheet and drawn up in the spreadsheet.

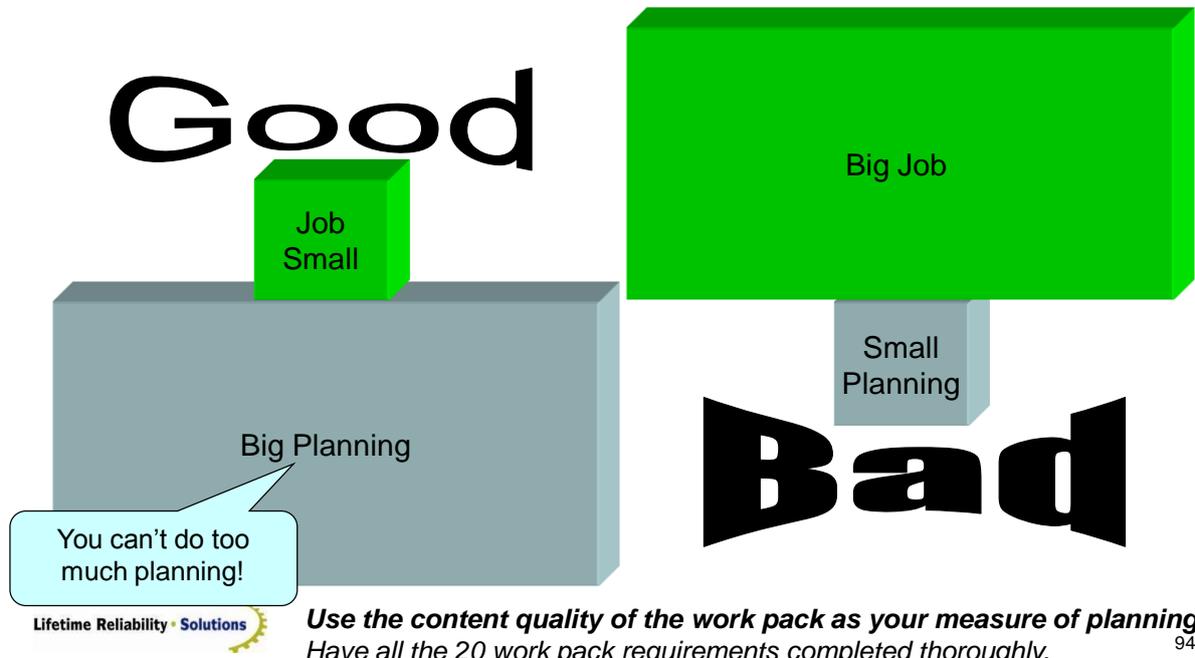
The S-Curve model simply makes use of the projected number of man-hours and costs to complete the project vs. the actual number of hours and costs incurred within the same time frame. The proposed time, man-hour and cost data are referred to as the 'baseline' data.

The S-Curve aims to represent the utilization of resources over the proposed time of the project. Simply stated, the curve illustrates the side by side comparisons of the actual time and expenditure components vs. the proposed time and costs allocations of specific resources. As a tracking tool, comparisons of different S-Curves against the standard S-Curve help in monitoring the growth or progress of the project. Data simultaneously plotted in graph form clearly shows how efficiently the team has performed so far, in accordance with the time or budget limitations

Go <http://www.brighthub.com/office/project-management/articles/51982.aspx#ixzz1YYGxnTZa> for more information

## How Much Maintenance Planning is Enough?

"In all things, success depends on **previous** preparation, and without such preparation there is sure to be failure." *Confucius (Analects)*



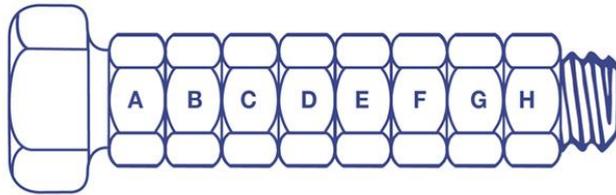
You need some way of knowing that a maintenance job has had enough planning to ensure the work will be done correctly and it will flow smoothly. The slide represents the understanding that the more planning and preparation done, the easier and simpler the job becomes. Where not enough planning is performed, the job becomes huge and cumbersome but, as Confucius reminds us with his 2500 year old advice, it does not need to be so if sufficient preparation is done beforehand.

One method to measure the extent of planning undertaken is to use the twenty item Work Pack content list previously shown as a gauge to decide if appropriate planning has been done. Each item on the list needs to be addressed as part of a job's preparations. If the item is not covered during planning then not enough planning was done.

Where an item on the Work Pack list does not apply to a job a suitable note to that effect is made, but the action of checking for every job whether or not a Work Pack item applies is not forgotten.

What the Work Pack list does not identify is the quality that each of the twenty items Work Pack must be done too to in order to produce effective planning. This issue is as vitally important as doing the planning. For example, if a job needs a job procedure that is highly detailed but the Planner only provides 25% of what is needed, then though the Work Pack item is apparently addressed, it is still a very poor planning outcome and the job will naturally go badly. Another example might be that detailed drawings are needed of machine assemblies but only general assembly drawings are provided. The Technician working on the machine will be required to guess the missing details, which puts the job at risk of unintended errors. Again the planning was poorly done even though the Work Pack item for Drawings can be ticked off as being completed.

## The Odds are Against Us Doing it Right!



Only one way to disassemble

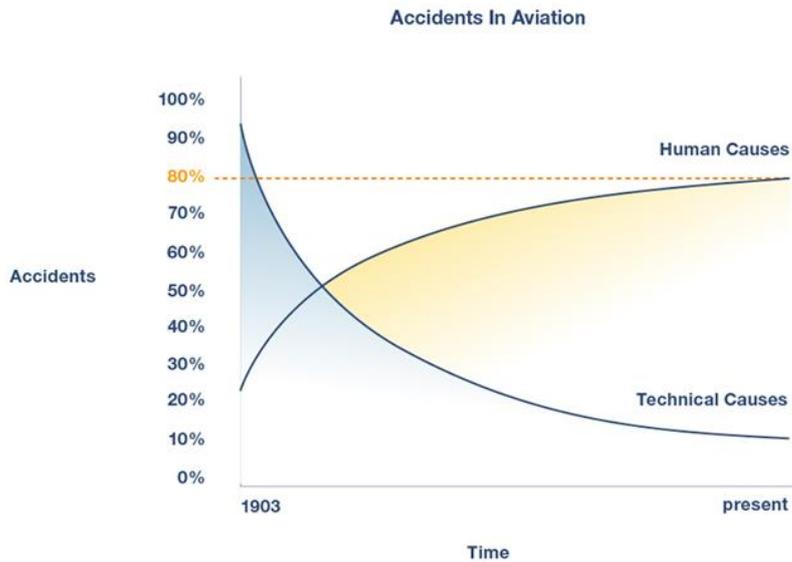
40,000+ ways to incorrectly reassemble!

Read the article ***"The Human Factor"*** in the workbook

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There are plenty of opportunities to make mistakes in maintenance. This example of one bolt with many nuts has over 40,000 combinations for reassembly (Factorial 8), of which only one is correct! It is an example of the complexity and chance of error in every maintenance situation.

# 80% of Failure Events are Caused by Human Factors and Human Error



**Nuclear Plants: 88 – 72%**  
 Barringer, H. Paul, 'Use Crow-AMSAA Reliability Growth Plots To Forecast Future System Failures'  
**Boiler Accidents: 82%**  
 (USA, ASME Report 2002)  
**Dams: 90%**  
 (Henry, P., 'Design Paradigms: Case Histories of Error and Judgment in Engineering')

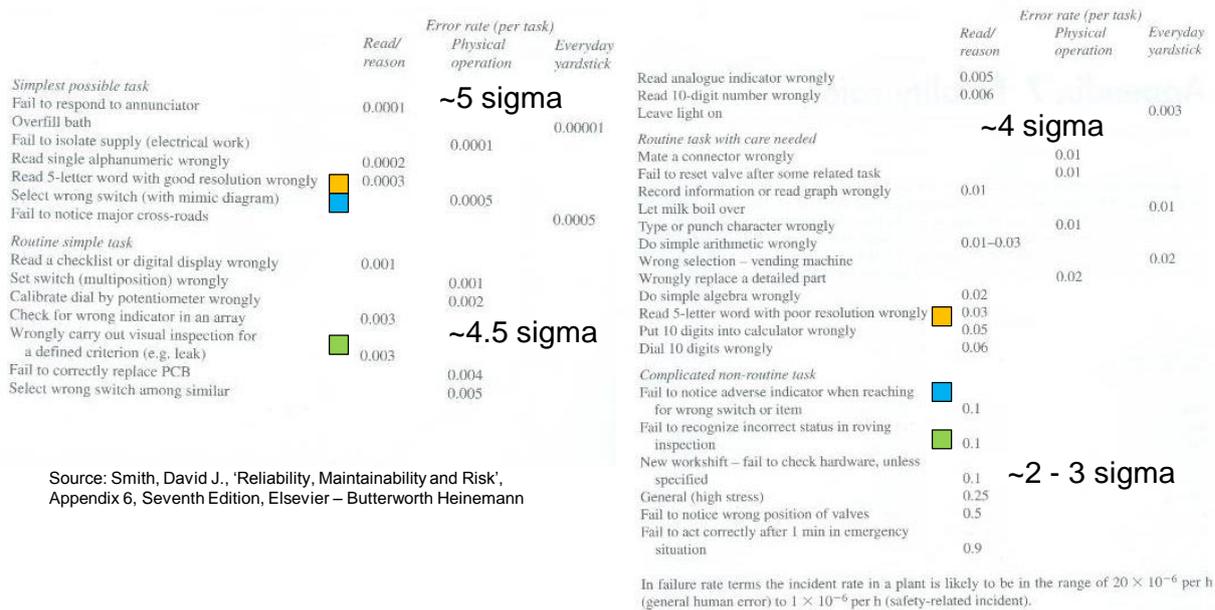
Source: Federal Aviation Authority, Human Error CD, 2008

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The slide confirms the evidence identified in 'The Human Factor' article. Most failures today are caused by poor business processes that rely on luck to work properly, and people across the life cycle who do not know what they are doing.

The slide tells us that our machines are fine. Our engineering is good, our materials of construction are good, our understanding of the science of failure is good. Our problems are not caused by our machines. Our problems are business system and human factor caused.

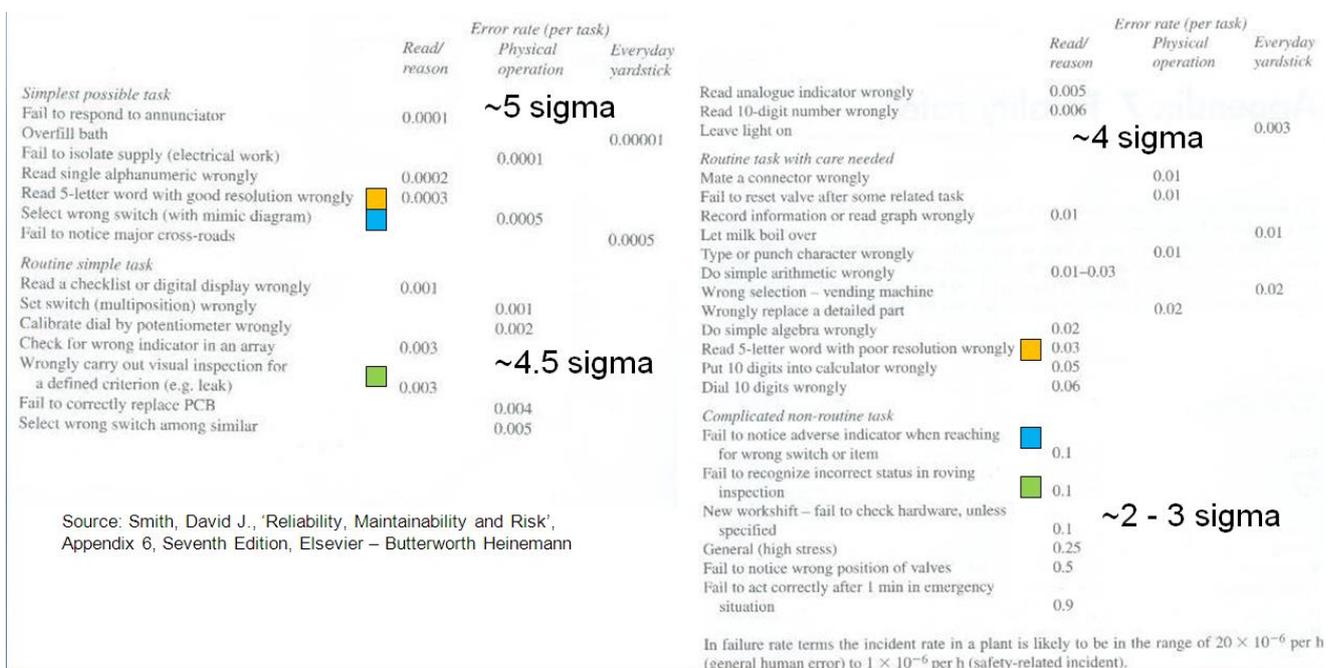
# The Story in Human Error Rate Tables



The Table confirms that 'human element' error is real and unavoidable. We do not perform well when tasks are structured in ways that require great care and we perform especially badly under complicated, non-routine conditions. Add stress into that that mix and you get disaster.

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An expanded version of the table that is easier to read is provided below.



There are many definitions of error, only a few of which are offered here. Generally, an error is "an unsafe act unintentionally committed". In other words, we don't err on purpose! An error can be a slip or a mistake.

- A slip is merely a good plan poorly executed. For example, you read a torque value from the job card and you transposed 26 to 62.
- A mistake is a 'bad plan'. For example, you select the wrong work card to conduct a specific job. Much of the information on the card may not apply to the work task.



- A violation is a very serious mistake. A violation occurs when you deviate from safe practices, procedures, standards, or regulations.

The Human Error table lists many examples of human errors and the typical rate at which they occur. An error rate of 0.001 means that there is one error for every 1000 opportunities to make an error. The figures are industry averages across many countries and situations. Due to many factors that impact human error the error rates in some companies will be less than those listed, while in others they will be more. Nonetheless the table provides indicative values that we can use to understand what can be done to reduce human error. Fortunately the table also contains the answers to human error. Notice how the error rate falls by an order of magnitude (ten times) as work goes from 'complicated, non routine, to 'routine task with care needed', to 'routine simple task', to 'simplest possible task'. If you want to reduce human error then make work simple and routine. You make work simple by planning for it fully and thoroughly. You make work routine by providing step-by-step activities to follow, i.e. a detailed job procedure with nothing left out of it on how to get the job done right.

Note that '*Read a 5-letter word with poor resolution wrongly*' can be changed from 3 errors per 100, to 3 errors per 10,000 (a 100 times fewer) by making it into '*Read 5-letter word with good resolution wrongly*'. All you have to do is make sure that your documents are clear and easy to read. It begs the question of what is the smallest font to use in your documents? Knowing that you will cause 100 times fewer errors with text that is easy for our mind to resolve, would it not make a lot of sense to never use small font ever again; to include colour and font changes so that we encourage our brains to easily resolve written text; to only ever write by hand in block letters and never use running writing; to ban hand-written and verbal instructions and only provide written instructions. I suggest that the smallest font you should ever use in any document is a 12 point font. I would even accept the argument that 14 point is the smallest font size to use—especially in technical and maintenance documents and for legally binding commercial documents. The human error table makes the right thing to do clearly obvious.

Another common example from industry is '*Fail to recognise incorrect status in roving inspection*' with an error rate of 1 in 10. In this case the person is intentionally monitoring for a problem and yet misses the obvious 1 times in 10. But for '*Read a checklist or digital display wrongly*' the error rate falls to 1 in 1,000. If you get your people to use checklists, instead of doing what they can remember to do, you will intentionally have designed your business to have 100 times fewer errors. That is a massively fantastic outcome that every business can gain for very little cost.

You can also see what happens when you add stress into a situation: for '*Complicated non-routine work*' the failure rate rises from 10 errors per 100 opportunities to 25 per 100 opportunities. The message is always the same when it comes to reducing human error—make things simple and make sure that there is enough time to do the job without undue haste. Once situations get stressful you guarantee huge increases in human failure rates.

The scariest advice of all is contained in the last error—'*Fail to act correctly after 1 minute in an emergency situation*'—9 errors in 10. Do not have emergencies; because by two minutes into an emergency situation every decision people make will be wrong!

# Likelihood of Human Error

Human Error is very difficult to manage as people can do unexpected things – That is, the failure types are unpredictable

## The likelihood of error increases when:

- the stress on the person is excessive (“stressed out”) or inadequate (boredom);
- the amount of information to process becomes greater or less than desirable;
- decisions are made in haste;
- unusual situations exist - people become entrapped by their habits (task capture);
- the mental picture of the system is poor or the system is ill-defined (poor training, ability/demand mismatch, poor feedback, or poor definition of roles and responsibilities);
- a task is considered unnecessary or it is thought that errors will be fixed by others.

Thanks to Howard Witt for this slide

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Use the list above to gauge whether your maintenance, operational and/or business processes are causing your people to make errors.

<sup>4</sup>What are the different kinds of error? The first type is active error, or the specific individual activity that is an obvious event. The second type is latent error, or the company issues that lead up to the event. In this example, the active error was falling from the ladder. The latent error was the broken ladder. Someone should have replaced the broken ladder, or the mechanic should have chosen not to use it. Which of the following are latent errors?

- A) Berndt misreads a torque value. It is 62 and he sees 26.
- B) Klaus cuts his hand when he slips from the wrench.
- C) Brian does not use a new locking device because the parts room was closed at the time he needed the hardware.
- D) Ted does not use the job card because he already knows the job from memory.
- E) All are latent errors.

The correct answer is C. When you see latent conditions that may lead to error you should report them.

---

<sup>4 4</sup> **Source:** ‘Maintenance Human Factors Presentation,’ Federal Aviation Administration

## Human Factors – the limitations of People



### Physical

- Size
- Gender
- Age
- Strength
- The five senses

### Psychological

- Experience
- Knowledge
- Training
- Attitude
- Emotional state

### Physiological

- Health
- Nutrition
- Lifestyle
- Alertness/fatigue
- Chemical dependency

### Psychosocial

- Interpersonal relations
- Ability to communicate
- Empathy
- Leadership

Source: 'Maintenance Human Factors Presentation,' Federal Aviation Administration

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<sup>5</sup>Aviation human factors started in the early 1900's when aircraft designers began to consider aircraft compatibility with we humans. At the same time, military researchers were already looking at medical factors concerning pilots. In World War II, many governments were mass-producing military aircraft. Engineers had to consider such factors as control design and instrument layout for compatibility with pilots. By the 1950's, the US Air Force was conducting experiments evaluating human personalities so as to better match people to their military job assignment. In 1988, the U.S. Government passed a law named the Aviation Safety Act, which demanded that the FAA conduct research on human factors in aviation, including factors related to aviation maintenance personnel. In that year, in Hawaii, a B737 experienced an in-flight break-up which, through investigation, was found to have had many human factors as the root cause of the incident. This incident generated much public concern about maintenance human factors. Throughout the 1990's, the FAA conducted extensive research on maintenance human factors. Much of that research evolved into regulatory guidelines for human factors training, like the material delivered in this class.

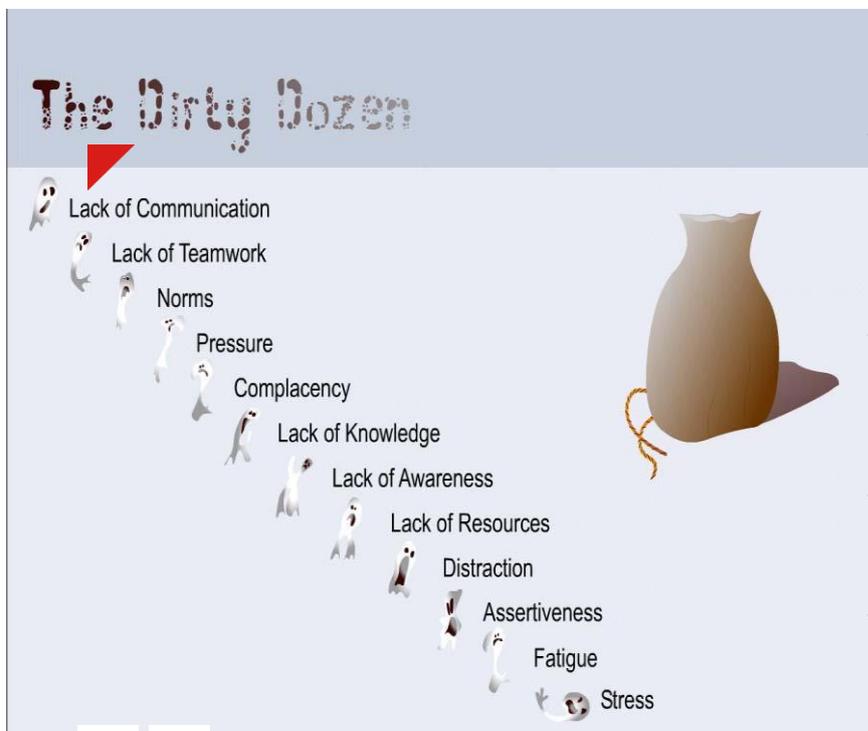
It is difficult to identify the exact historical beginnings of the various disciplines of human factors. With respect to anthropometrics - the size and strength of the human - you can refer to Leonardo da Vinci's (1452 to 1519) Anthropometric man. Another perspective is the research of Frank (1868 to 1924) and Lillian Gilbreth, (1878 to 1972), industrial engineers who studied medical operating procedures in the early 1900's. They created the verbal protocol whereby the receiver repeats any command given. The repetition helps to ensure clear communication. That protocol continues today in air traffic control communications. The psychologists Sigmund Freud (1856-1939) and Kurt Lewin (1890-1947) also conducted human factors work.

- Clinical psychology deals with your psychological composure. It can address topics like emotions, motivation, fears, and such things.

<sup>5</sup> Source: 'Maintenance Human Factors Presentation,' Federal Aviation Administration

- Anthropometrics is the study of factors such as size, strength, reach and other dimensions that can be quantified to match the machine to the human. An original Coca-Cola bottle, for example, was designed to fit the average human hand, thus making it easy to hold the bottle and drink a lot of the product.
- Experimental Psychology includes studying effects of stress on behavior and doing controlled studies of the effects of work policies and procedures.
- Computer scientists study the graphical user interface to be sure that humans can easily operate software. Therefore, computer science remains an excellent example of human factors.
- Cognitive science studies how humans think, how they solve problems and the ways in which they process information. This knowledge can be critical to design of equipment, software, and documentation.
- Safety engineering applies to worker safety, with respect to topics like safety equipment, labeling, rules, and such things.
- Medical science applies to topics such as vision, hearing, balance, and overall health issues.
- Organizational psychology looks at how people work within various size groups. Organizational psychologists have made excellent contributions to the field of Crew Resource Management, which is mandatory training for flight crews, and important to maintenance crews.
- Educational psychologists study how people learn. Excellent training programs are often the result of using applied educational psychology.
- Industrial engineering is the study of humans at work, using a systematic approach to understand how people work, and then to design the job and the equipment accordingly.

## The 12 Most Common Causes for Human Errors



- Eliminate these causes and you have conquered most human errors
- Talk about your experience in any of these
- What are the causes in your company?
- What are the corrective actions?



<sup>6</sup>We all make the same kind of errors and we are all human. "To err is human." In human factors training you will hear the words "Dirty Dozen" The dirty dozen is a listing of the 12 most common causes of human error in maintenance. The concept was developed by Mr. Gordon Dupont at Transport Canada. If we could eliminate or control these 12 causes of error we would eliminate a very high percentage of maintenance-related events.

**Lack of Communication;** Communication errors are the most common type of error. There are many opportunities to fail in communication. Stay aware of the communication challenge.

**Lack of Teamwork;** Maintenance requires teamwork. 'Lack of teamwork' is the failure of a group to work together to achieve a common goal.

**Norms;** Norms are the commonly accepted work practices within an organization. Norms are not usually written down - they are simply the methods by which the organization works. Here is an example of a good norm for shift turnover. (Klaus): "Hi Stefan, let me tell you what we did today and what are the next tasks. We also wrote this information on the job cards." (Stefan): "Thanks Klaus. I want to be sure I understand this so I can explain it to the team."

**Pressure;** There is often pressure in maintenance organizations, which can come from many sources. Often, you put the greatest pressure on yourself for high quality performance in minimal time. Your managers may apply pressure. Pressures to meet a deadline are the most common. And your co-workers may also apply pressure. They can create a sense of urgency that forces you to work at a pace faster than you are comfortable with. Conditions cause pressure. The closer it gets to departure, the more pressure builds up to get the task completed quickly. So, pressure is one of the dirty dozen. It is a possible contributing factor to an event.

**Complacency;** Complacency can contribute to a maintenance event when the mechanic is overconfident about a task. This is usually a result of performing the tasks repeatedly. Psychology experts say that many tasks become "automatic." Like driving to work, you sometimes can forget the trip. That is because you were on "automatic." You may have been inattentive. You have been "unsafe." Most likely you were complacent!

**Lack of Knowledge;** We don't know when we don't know. The lack of knowledge factor is usually compounded by a worker's failure to consult the manual, or failure to work as a team, or failure to communicate the lack of knowledge. Fatigue may also contribute to a lack of knowledge error. Don't use guesswork.

**Lack of Awareness;** Lack of awareness is an error that is often combined with other errors in the dirty dozen. Quite simply it can be called "failure to pay attention." All too often, an event investigation will result in quotes like the following: "I was not paying attention", "I did not see the obstacle", "I did not notice the wing tip was so close to the hangar door." Whatever the confounding excuse, usually the person acknowledges that there was a lack of awareness.

**Lack of Resources;** Resources can mean many things: tools, manuals, computers, people, time, and more. Lack of resources is likely to become a problem when it is combined with other errors in the dirty dozen. Speak-up, stop complacency and pressure to do a job correctly. Yet be realistic of the situation and find a legal and safe way. For example, if you need a part or a tool that is not available, then you must speak up. You must be assertive, you cannot be complacent, and you must not become a victim of pressure or of schedules. You must do the job correctly.

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<sup>6</sup> Source: 'Maintenance Human Factors Presentation,' Federal Aviation Administration

**Distraction;** Jobs and life are full of distractions! Distraction can come in the form of thoughts, noise, bright lights, people, radio messages or telephone calls. Eliminate them where possible and where you cannot easily eliminate distractions, then accept them and find new ways to cope.

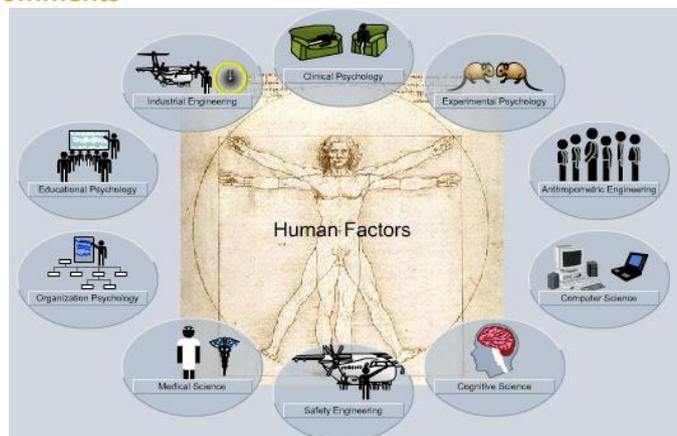
**Lack of Assertiveness;** Assertiveness is a good thing! It means that you speak up when you believe it is necessary. When an assertive worker sees an opportunity, they bring it to the attention of their co-workers or the management. There are times when assertiveness is an absolutely necessary part of work quality and safety.

**Fatigue;** It is a potential problem for many. Fatigue can be a serious on-going ‘chronic’ problem or it may be ‘acute’ - just caused by a few nights of missed sleep. Usually, you make errors because you are fatigued. For example, you may forget to complete a task, you may be unclear in your communication, or you may be temporarily too lazy to do the job correctly. But fatigue is the real problem. When you are fatigued, your physical strength and mental ability are impaired. Fatigue can be managed, but first you must be aware of the risks.

**Stress;** It is a psychological and sometimes physical condition caused by some kind of ‘stressor’. The stressor can be a once-only situation or it can be an ongoing one. For example, a short-term stressor may be a very difficult repair that must be done quickly. Once the repair is completed, the stress goes away. An example of long-term stress could be a divorce situation or other personal problems. Like fatigue, there is short-term stress, called acute stress, and long-term stress, called chronic stress. Whether acute or chronic, stress can affect your life and your work performance. You must deal with it. What are the symptoms of stress? Different individuals may have different symptoms; however, many poor and bad behaviors are reliable indications of stress. Usually you know when you are stressed.

## Put on your “Human Factors Spectacles”

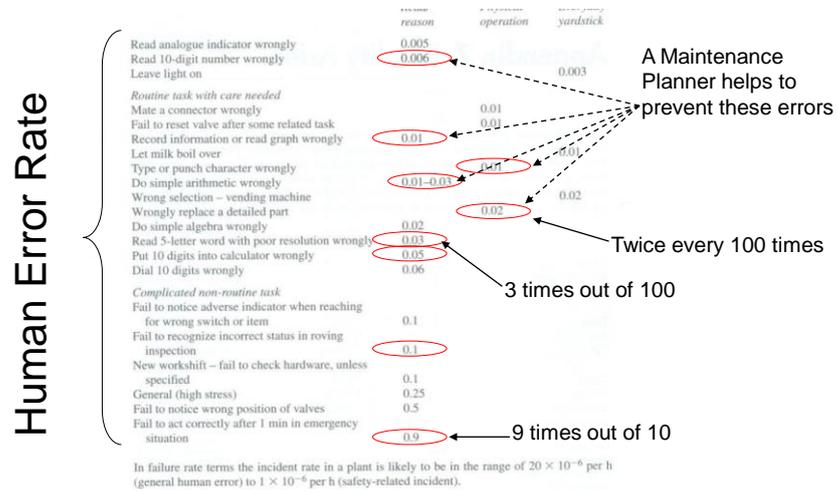
- Sensitivity to human factors
- Knowledge of how human factors affect work and safety
- Objectively examine your world
  - Look at others
  - Look at yourself
  - Look at the environment that surrounds you
- Be willing to make suggestions and comments



Source: 'Maintenance Human Factors Presentation,' Federal Aviation Administration

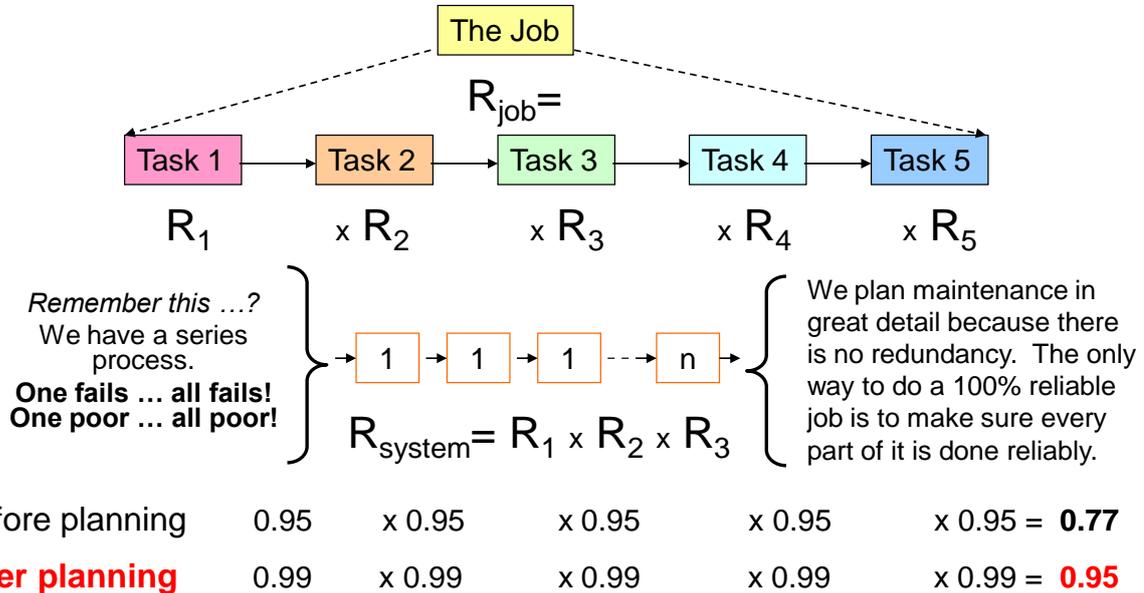
“Putting on the spectacles to look at the world” means being sensitive to human factors, knowledge of how human factors affect work and safety, objectively examining your world, be willing to make suggestions and comments

## Why Maintenance Planning is Critical to the Maintenance Work Quality Control Process



The table shows the chance of things going wrong in a range of situations. Once circumstances become difficult the chance that things will go wrong dramatically rises. Planning the work reduces the likelihood of problems. By developing 3T job procedures to step people through their tasks accurately, by buying the right parts and having them on-hand at the job site, by deciding how to make the work safe before starting, (along with the many other things that a Planner does to prepare ahead of doing the job) you improve the chance of successful outcomes. We know that humans make mistakes. It makes a lot of sense to do everything possible to help people get things right first time.

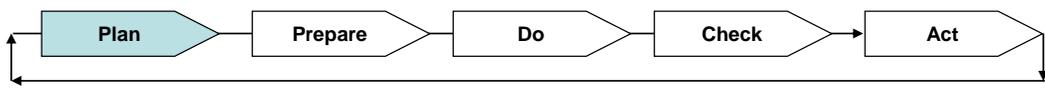
# Planning **Greatly** Improves the Odds of a Series Work Process Being Done Right



## Planning reduces the Human Error Rate

The slide breaks an imaginary job down into five tasks. The tasks form a sequential process. In a sequential process the overall reliability is the multiplication of the individual step reliabilities. If the reliability (the chance of it working right) in one step is low, then the entire process reliability is low. When maintainers and operators do their work they are completing a series of sequential steps. Any wrongly performed step makes the whole job wrong and greatly increases the chance that failure will result. This is the more reason why it is important to plan work carefully and fully – so that the reliability of all tasks is raised towards 100% and hence the job outcome is nearer to 100% quality.

# Included in the Work Planning Process

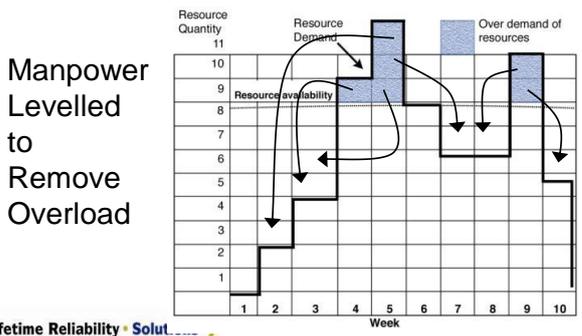
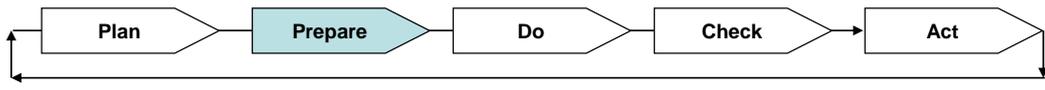


- Site Investigation
- Failure History
- Identify the Required Documentation – dwgs, procedures, etc
- Specifying Important Information to Capture During the Job
- Develop Job Procedure with Required Outcomes & Measures
- Specifying Parts and Materials
- Specifying Subcontract Resources
- Specifying Tools and Ancillary Equipment
- Specifying Human Resources
- Developing the Job Plan and Times
- Setting Job Performance Requirements
- Specifying Job Quality Standards
- Build-in Time for Quality Work
- Costing the Job
- Job Safety



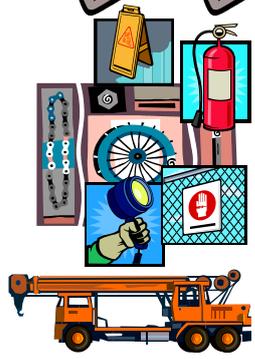
The slide shows the list of tasks that a Maintenance Planner must work their way through when preparing work and developing the Work Pack.

# Organise the Resources to Do the Work



Parts,  
Special  
Tools,  
Safety  
Equipment

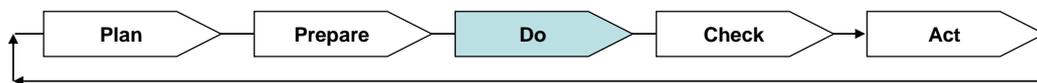
Mobile  
Equipment



Once the work content is planned the next step is to prepare the resources needed to do the work. This involves buying/reserving needed parts, reserving necessary outside services and ensuring there are maintainers available with the right skills to do the work right first time.

Work levelling is performed for two main reasons. The first is to ensure that there is not more work than can be done with the resources available. The second is to ensure the resources you have are not overloaded, i.e. the resources are available when needed. Levelling the work reduces the risk of an error being made trying to meet impossible deadlines. The maintenance backlog is reviewed with the Production people and jobs are selected for planning based on their priority to the business. We want to do the important work that brings most value and bet risk protection to the operation first. The high priority jobs are planned first and locked-into-place in the fixed week schedule to be done as soon as possible under planned and controlled conditions. The Scheduler needs to know the planned time for each job so they can organise the work to be done while maintaining a level workload.

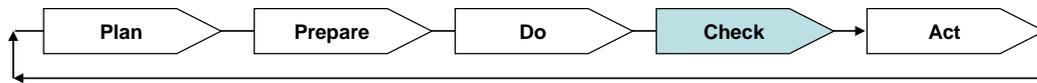
## Starting the Job Right On-Site



- Completed Job Pack
- Safety considerations identified and addressed
- Safe access provided in readiness
- Parts waiting at the job
- Special equipment and tools available when needed
- Mobile equipment at the job
- Preparations Before the Job Starts
  - Isolations
  - Tagging
  - Handover

The slide lists what must be available to the maintainer when they arrive at the work front. Remember that the aim is to maximize the ‘tool time’ when the maintainer adds-value to the operation. Any work that can be done to increase maintainers’ ‘tool time’ is worth doing. It may even be useful to employ a ‘materials handler’ whose job is to keep ahead of the maintainers preparing future work fronts with parts, safe access, encouraging Production to do isolations, etc, just so the maintainers can give maximum value from their skills and knowledge to the business.

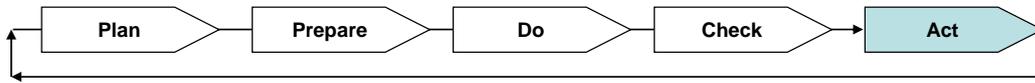
## Include how to Collect Information from Job



- Include information collection into the Standardised Procedure and/or Job Plan
- Request Root Cause Analysis (Creative Disassembly) details
- Find out what would improve the procedure/plan
- Complete any checklists as part of the job
- Take photographs as part of the job
- Collect an accurate and complete record of work done
- Clearly identify all of the parts replaced
- Prove the work was performed right by using suitable measurement and condition monitoring tests after start-up

When the Maintainers are on the job the Planner needs to provide mechanisms to collect relevant and important information about the work done and the condition of the equipment. Build the necessary information to find, and the records to be collected, into the standard SOP and the Job Plan so the maintainers have it at their finger tips. Give the Maintainers the necessary time to gather information and do the data collection in the Job Plan

## Feedback on Planning at the End of the Job



- Calculating True Cost of the Maintenance / Failure
- Job and Workmanship Feedback
- Post-Job Review
- ‘Lessons Learnt’ Meeting
- Continuously Improving the Planning

*When do you know you have done enough planning?....*

*When you know you have done more than enough!*

The Planner has a few more tasks to do once the work on-site is complete.

### *Activity 8 – Standardised 3T Maintenance Planning Procedure*

#### **Standardised Planning**

Use the planning process table in the workbook to develop the standardised work description for each Planning Process Step

You need to set Target, Tolerance, Test for each.

#### *Review and Discussion of Activity 8*

The activity aims to help people think through the details of what to do in a task that will produce the results they require and then lock it into place in their documented procedures.

## 5. Activity 8 – Standardised Maintenance Planning Procedure with 3T Error Proofing

For the planning process steps listed identify the acceptable targets, the tolerance (divided into the ‘good, better, best’ bands) and the test.

Step No.	Task Step Owner	Task Step Name	Full Description of Task	Test for Correctness	Tolerance Range			Record Actual Result	Action if Out of Tolerance	Sign-off After Complete
					Good	Better	Best			
		(3-4 words)	(Include all tables, diagrams and pictures here)							
1	Originator	Job Request	Job request raised by person requiring the work to be done, and includes asset number, asset description, full description of problem/issue to be addressed, their contact details  <i>(Could include the Job Request flow chart here)</i>	Visually check Job Request meets standard example	Meets Job Request example		Meets Job Request example, plus gives history of problem; provides information on symptoms of problem		Return Job Request until conforming to minimum requirements	
	Planner	Checkout Scope of Problem	Go to job site and fully complete Job Scope-Out Sheet	Visually check every Scope-Out Sheet item is addressed	All Scope-Out Sheet fields are completed	All Scope-Out Sheet fields are completed, plus site photos provided	All Scope-Out Sheet fields are completed, plus site photos provided, plus Originator interviewed		Complete all fields in Scope-Out Sheet	
		Identify Work Needed; Safety								
		Collect Relevant Details Together								
		Check Equip History								
		Develop Job Plan								

Step No.	Task Step Owner	Task Step Name	Full Description of Task	Test for Correctness	Tolerance Range			Record Actual Result	Action if Out of Tolerance	Sign-off After Complete
		Identify Parts								
		Identify Resources								
		Cost Job								
		Order Materials								
		Develop Job Procedures								
		Build Work Pack								
		Collect Materials Together								
		Arrange Contracted Services								

## Best Practice Shutdown Focus...

### The top performers recipe...

Thanks to Jim Wardhaugh, UK Consultant (30 years with Shell and Centre of Excellence Leader)

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## Shutdown and Outages Planning

The difference to 'normal' maintenance planning is the scale and intensity of the Production interruption.



Do everything outside of the shutdown that you can.  
**In the shut do only what must be done in a shut.**



Use Project Management methodology to handle the scale of work, to manage the numerous jobs, to communicate with people and to monitor preparation and progress.

***The Workbook contains a minimum Shutdown Preparation Checklist***

Large maintenance shutdowns are complex projects with numerous work fronts. They need to be run and managed like a large project. This requires sufficient personnel be dedicated to

planning and managing the project, followed by the development of appropriate project management systems to prepare for, and to control, the work fronts.

## Minimise the Need for having Shutdowns

- **Manage degradation during operation**
  - Minimise extent of degradation
  - Make mechanism and rate predictable
  - Operate plant well
- **Use unplanned stoppages to do shutdown work**
- **Take reasonable risks and manage them well** by understanding what can go wrong and observing for tell-tale changes
- **Gain credibility with regulators** by having good records and proof that equipment condition meets compliance

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Once you know the rate of degradation it can be trended and estimates made of when the degradation will require action. The rate of degradation is often controllable by operating practices and on-going monitoring and adjustment of relevant factors.

Unplanned stoppages occur for all sorts of reasons e.g. lack of feed, because another upstream plant is down, loss of utilities, etc

Push the shutdown out further when it makes business sense to do so and the risks to plant and safety are controlled.

The Regulators will often accept a 'safety case' to permit a site to vary their regulated equipment maintenance practices from the statutory requirements.

The Regulator will only permit a change to inspection regulatory periods if they are absolutely sure there is not risk by making the change. They will need several years of historic evidence proving that the equipment is behaving, and has behaved, exemplary under your control and management. Your operating and maintenance systems and practices need to clearly show that the statutory equipment is in great condition and has been so for a long time prior requesting the Regulator for special relaxation of the rules to change the maintenance frequency.

## Effective Shutdown Execution

- Integrated planning
  - (Ops, Maintenance, Inspection, Contractor, etc)
  - From feed-out thru to product out

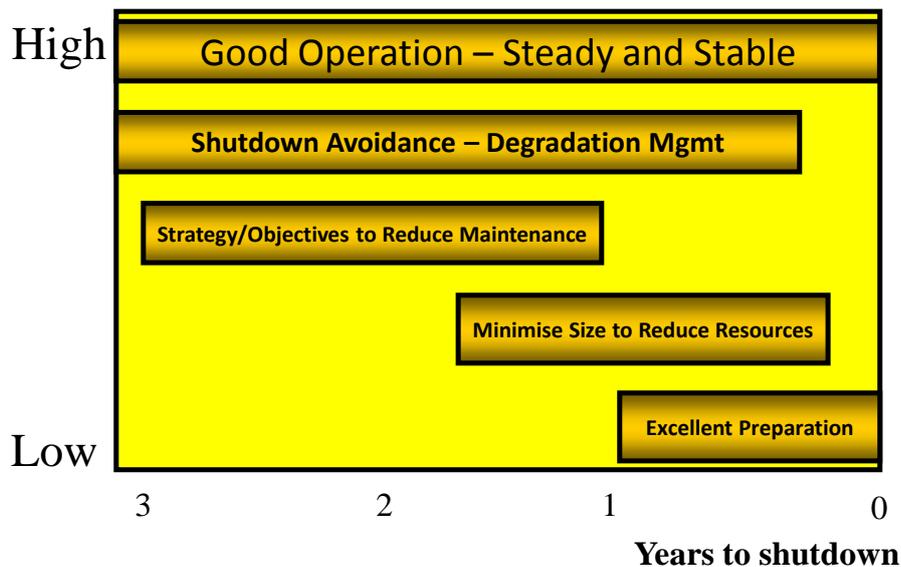


- Detailed plans for critical issues
- Challenging but realistic targets
- Small, competent workforce

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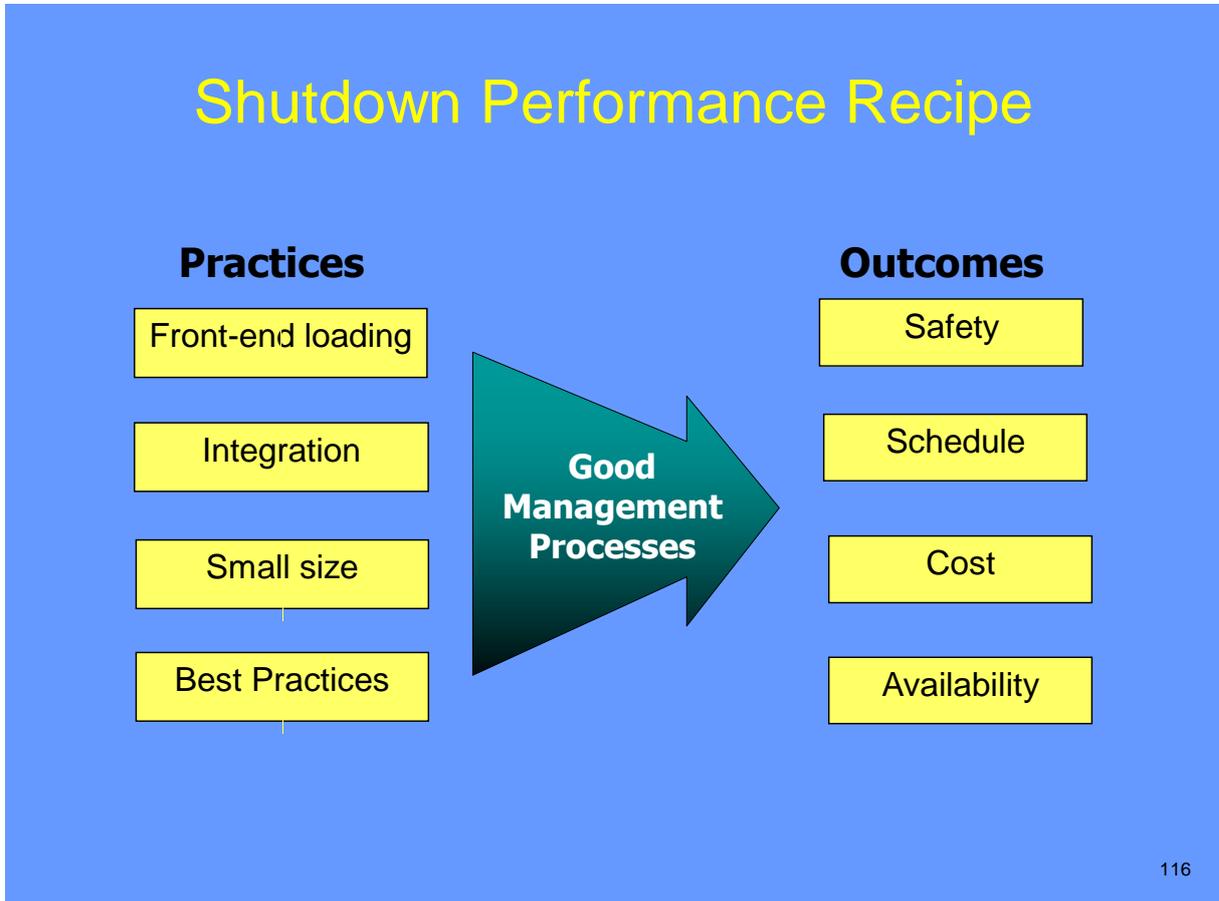
Any action involving a number of diverse people needs face-to-face discussion and agreement if it is to go well. Do not consider meetings a waste of time if they result in better coordination and cooperation. They are a waste of time when no positive actions come from them.

## Influence on Profitability



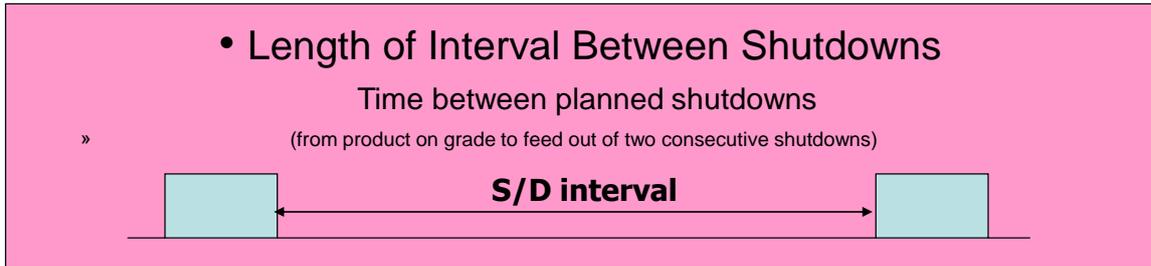
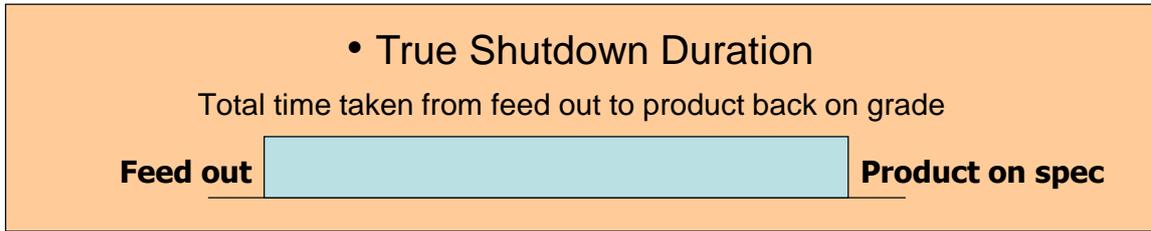
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These five factors can be managed and organised in such a way to maximise operating profit. Good operation aims to deliver steady and consistently in-control processes. Shutdown avoidance aims to reduce degradation. Setting strategy and objectives that maximise profitable operation forces innovations and improvements to be developed and adopted. Minimising the size of the shutdown reduces the resources required and the length of the outage. Managing and preparing the shutdown well means it stays on schedule and is no longer than necessary.



The slide carries the message that if you want good shutdown outcomes you must employ good shutdown management processes and practices. The quality of the end result is only a reflection of the processes used to get to it.

# Shutdown Success Indicators



## Some “best” numbers in Refining

- Crude unit run 68 months (5-3/4 yrs)
- Crude unit “pioneer” run 90 months (7-3/4 yrs)
- Catalytic Cracker run 46 months (3-3/4 yrs)

Source: Alberto Pasqualini refinery - Brazil

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Shell redefined their definition of a ‘shutdown’ to include the time needed to make the plant available and the time needed to return it to full, on-specification production. Both groups – production and maintenance – used the same measure of success, and this forced them to work together in achieving common outcomes.

In Shell the avoidance of shutdowns was encouraged and the length of the period between shuts became an indicator of both production and maintenance successful practice. By keeping plant in good condition and controlling the production processes the length of times between shutdowns tripled and quadrupled, ...and then went even further.

It's now time for you to do some work. Tomorrow you'll go out and scope a job using all the know-how you have. Then come back and I'll help you to build it into a full work pack ready to be passed over for scheduling.

Now you have got me worried. Be patient with me, Joe, I'm still learning.

I know what it's like. I still remember my first days as a maintenance planner all those years ago. You will be just fine. Now is the time for you to test and learn, while I'm still here. Once I go you will have to work through it all by yourself.



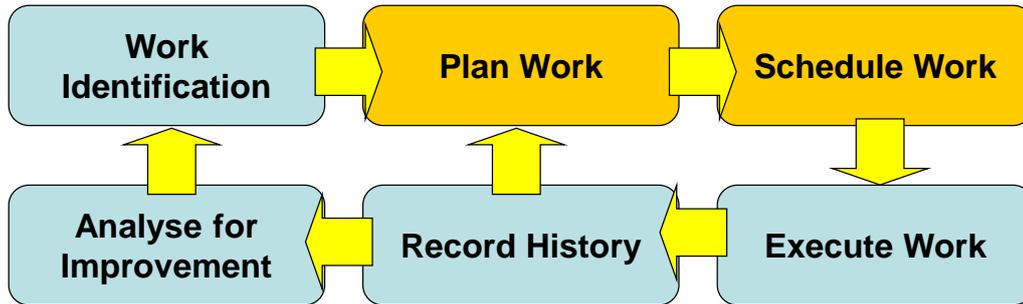
Today's session finishes ...

## End of Day 2

- Planning systems – for office and information management
- Parts purchasing and stores management
- Specifying Work Quality Standards for Reliability
- Project Management – plan/prioritize/control activity
- Human Error and Human Factors
- Work Planning Process – Plan/Prepare/Do/Check/Act
- Shutdowns – use project management approach

# What's on in Day 3

- ‘Cross-hair target’ Game
- Defect Creation and Prevention
- Getting Work into Statistical Process Control
  - Including Standards for Work Quality
    - Key Performance Indicators
    - Scheduling Work to get Done
  - Scheduling Process Requirements



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