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31 Sure Ways to Lower Operating Assets Maintenance Costs and Improve Reliability

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Here is a simple checklist of 31 simple maintenance management tips that you can use to improve your operation. Use it as a guide to start you thinking which maintenance management improvement strategies to use to lower your maintenance and operational costs without spending a lot of money.

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Simple, Quick and Free Ways to Improve Maintenance and Operational Performance

This report starts with a short checklist in the form of 'bullet points' so you can quickly review it. If you wish more detail on any of the 31 maintenance management tips go to the rest of the report and read the section that you want.

The list below is divided into three time scales. The first is what you can do immediately to improve your operation. The second is what to do in the next few months. The third is what to do to get benefits from long term initiatives. Every one of the maintenance management tips work and will give you more reliable equipment, more certain production and lower your maintenance costs.

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Actions for Immediately Improved Results

1. Have a lubrication regime where everything is lubricated when due and you know the right lubricant in the right condition gets all the way to where it should.
2. Have 50% of the plant or maintenance engineer's time spent out working with the plant operators and maintenance trades teaching them engineering and learning from them about the problems they have to work with.
3. Have shaft alignments done on all pumps and gearbox drives including eliminating 'soft foot'.
4. Get to know vendors and supplier's best technical people and get their advice on fixing problem plant.
5. Introduce equipment watch-keeping lists and trouble-shooting check sheets for plant operators and read them regularly to see what they notice.
6. Make plant and equipment choices and selections with a 20 to 25 year time span in mind.
7. Vibration monitor rolling bearings on critical equipment often enough to stop any failures.
8. Ask the operators and maintainers the simplest way they can think of to fix the problem.
9. Get Production and Maintenance Planners, Leading-hands and Supervisors to meet each day and prioritise the work to be done in the coming days and weeks.

Actions for Improved Results That Show Benefits for You in A Few Months Time

1. Start measuring performance with Key Performance Indicators generated from activities and results of the business process itself. Measure both the equipment performance and the business systems' performance. Use that knowledge to continuously improve.
2. Put all Production and Maintenance Supervisors on a compulsory asset management course at diploma level.
3. Establish a basic condition-monitoring regime – process parameter tracking/vibration/oil condition/thermography/'see-touch-hear' inspections.
4. Perform a thorough engineering review of plant changes and upgrades to make decisions based on engineering and business facts. First design and engineer, or model and simulate, or pilot-test plant changes and ideas before putting them into place permanently.

5. Go outside of the company and bring in the training and teaching that your people need to become leaders in their field.
6. Use Maintenance Planners to plan jobs in detail so you get labour efficiency and job quality.
7. Track-down all galvanic corrosion between dissimilar metals in contact and get rid of it, or monitor it closely and trend remaining life.
8. Teach operators how the equipment works and teach your maintenance trades how the production process works.
9. Provide the technical knowledge on plant and equipment your trades need, in a place they can find it fast.
10. Conduct an equipment criticality rating and match condition monitoring to the risk so you identify risk of failure in important equipment and plant.
11. Eliminate the defects - use Root Cause Analysis, 5-Whys, etc on equipment and systems failures and get the problems out forever.
12. Be proactive and imagine problems so you can solve and eliminate them before they happen.
13. Develop ownership, build skills, and build competent people at shop-floor level.

Actions for Improvements That Show You Benefits over the Coming Year or Three

1. Align the Capital Project group's output to the on-going needs of Maintenance and Operations. E.g. ensure all asset and instrument tag numbers have procurement and design information catalogued in individual files; have drawings and manuals numbered so they are easy to access for maintenance; etc.
2. Show and introduce the benefits of world class practices to managers, supervisors and leading hands. Show and introduce Corporate and Senior Managers to world class practices and methods so that can see the benefits to their 'bottom lines'
3. Align Operations and Maintenance efforts through a Production Plan and Schedule that covers both producing product and maintaining equipment well enough to make product.
4. Do all your statutory obligations well with full documentation and excellent procedures and practices.
5. Select the best vendors and suppliers and form a long-term partnership/alliance. This will save time, give you access to good prices, let you use their expertise to solve problems and let you focus on your business.
6. Proactively build flexibility and redundancy into the plant so you have options to address problems quickly. E.g. install tie-ins in readiness to use mobile plant if the installed item fails.
7. Apply Failure Mode and Effects Analysis and Reliability Centred Maintenance on new and old plant and equipment. On new equipment get the vendor to do the FMEA/RCM based on your industry's historical maintenance problems.
8. Select and use equipment that does not breakdown when it fails. Design protection into equipment that stops it breaking if it's overloaded or run wrongly. Use the grade of material that is not affected by the failure mechanism.
9. Buy equipment that can be supported and maintained locally; otherwise you will pay a lot more for parts and be waiting for service

The following section of the report explains each point in greater detail and provides support for the value and worth of doing the activity recommended above.

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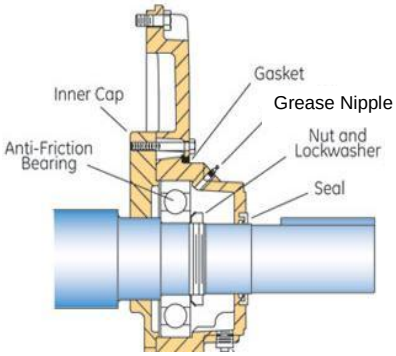
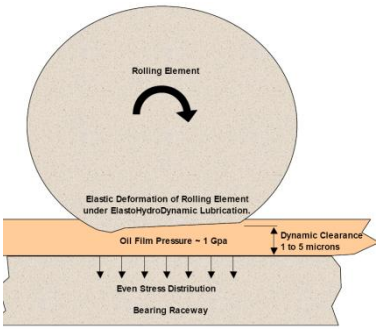
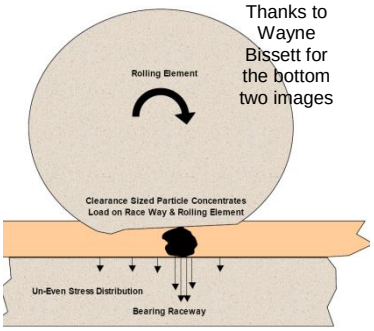
Actions for Immediately Improved Results







Thanks to Wayne Bissett for the bottom two images

1. **Have a lubrication regime where everything is lubricated when due and you know the right lubricant in the right condition gets all the way to where it should.**

   Lubricant in a machine is like the blood in your body–it goes everywhere. When blood is contaminated the contamination also travels everywhere and eventual your vital organs fail. Lubricant, like blood, needs to be clean and healthy. Once it is contaminated by water, dirt, wear particles or any other contaminate it will eventually cause equipment failure.

   The purpose of lubricant is to reduce friction between parts that would otherwise make hard contact, such as roller bearings, plain bearings, gear teeth, gear worm wheels and shafts, along with many other surface contact situations e.g. hydraulic system valves and spools. It requires that lubricant be physically between the two neighbouring parts. It also needs the lubricant to be in a condition of sufficient viscosity (slippery) to hold together so it can keep the parts separated. Temperature changes cause viscosity to change, with hotter temperatures reducing lubricant viscosity and causing it to thin and disappear from between the parts it is supposed to keep separate.

   To protect your machinery ensure that clean lubricant gets fed in-between the parts that need it – be sure the greasing and oiling you do actually separates the parts with fresh lube and does not bypass them. On automatic lube systems regularly prove the pipes are not blocked. When doing hand lubrication prove the lubricant actually reaches the part. Ensure the operating temperature remains below the lubricant viscosity critical value – measure the lubricant temperature and check it against its viscosity graph to prove it is the right temperature range. Ensure lubricant is always clean when it leaves its storage and remains so throughout its working life within a machine – the lube store and lube equipment needs to be 'hospital clean' and lubricant inside machines must be as clean as blood. No water must ever get into lubricant, all dirt and all wear particles of the same size as the lubricant film between two parts must be removed. You will have to filter oil and keep it honey-coloured.

2. **Have 50% of all plant or maintenance engineers' time spent out working with the plant operators and maintenance trades teaching them engineering and learning from them about the problems that the workforce have to work with.**

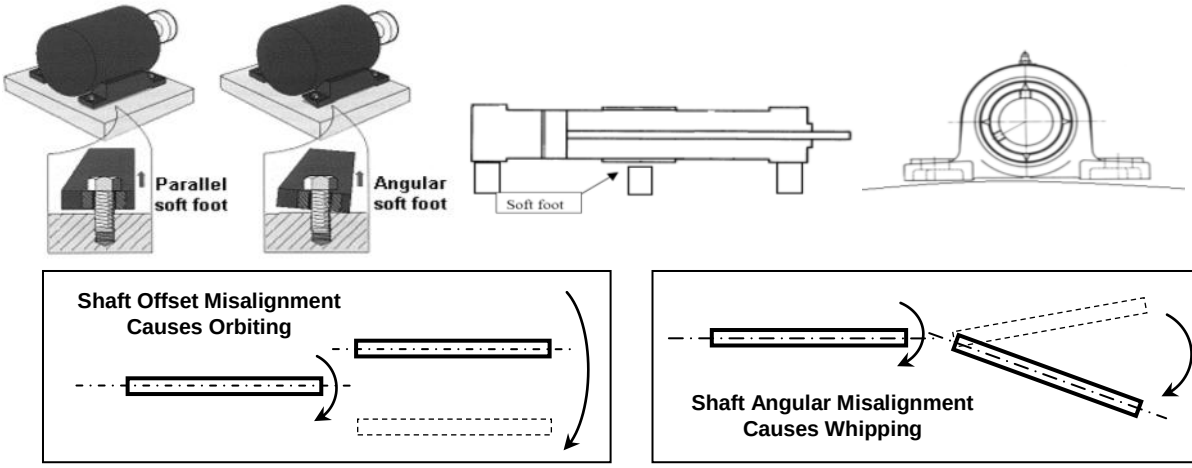
   This tip is all about knowledge transfer and creating teamwork. The maintenance engineer knows about a machine's design strengths and weaknesses and the operators know about the machine's use. The maintenance engineer knows about a machine's materials of construction and the maintainers know about the way the machine is built. Between them all there is plentiful knowledge and know-how to run any production machine reliability and productively – provided the right knowledge gets to the right people.

   The most mobile person in a company responsible for equipment health is the maintenance engineer. It is they that must circulate and create the opportunity to pass right information and knowledge amongst the production and maintenance groups. When correct facts are known by people they will put that knowledge into use and more things start going right, which you will observe as fewer equipment problems, breakdowns and production stoppages.

   An equal benefit to educating operators and maintainers in engineering is the learning made by the engineer of problems that plague the machinery and affect production performance still to be solved. Once a problem is found the engineer works with the operators and maintainers to identify the causes, develop corrective actions, test the effectiveness of the answers and implement those that

are truly effective. To do all the work involved with workforce education, research and development of answers to equipment problems, then the designing and testing of solutions needs the maintenance engineer to be out in the field at least 50% of their time.

3. **Have shaft alignments done on all pumps and gearbox drives including eliminating 'soft-foot'.**



Aligning shafts and removing soft-foot removes distortion and stress from vital machine parts. It is the distortion and subsequent stress of the atomic structure that causes parts to fail. By aligning the shafts the destructive forces generated from orbiting and whipping disappear and the perpetual banging and vibration within the machine reduce and ideally stop. By removing soft-foot the distortion caused to internal parts by deformed frames and housings is eliminated and the parts can move properly, as intended by the equipment designer.

Shaft alignment is best done with laser alignment equipment, but it can also be well done using the reverse dial indictor method if the shafts are close. These methods require training in how soft-foot is surely removed and in the ways to adjust equipment to make shafts come into line when machinery is running at operating temperature.

4. **Get to know vendors and supplier's best technical people and get their advice on fixing problem plant.**

It's impossible for one person to know everything about the design and engineering of all the equipment in even the smallest operation. When problems start to arise with plant and equipment it is important to quickly find lasting answer to them. When a problem reappears often it is clear evidence that the answers which truly fix the problem are not known by the people in the organisation. This is when a relationship with the equipment manufacturer's or supplier's technical specialists will prove to be invaluable.

The vendor's technical specialist knows their equipment the best. They know how it was designed to work, and most importantly, they know the design envelop in which it works reliably. They know what to look for and can pick-out problem causes easily from the confusion.

5. **Introduce equipment watch-keeping lists and trouble-shooting check sheets for plant operators and read them regularly to see what they notice.**

Use plant operators for condition monitoring of their plant and equipment. The human body is blessed with sensitive instruments to listen for noises, tell temperature, fell vibration, detect uncommon odours and for identifying colours and shapes. The human body is a great condition monitoring tool when it is put to use. It means getting operators out of the control room and into the field for 50% of every shift.

You need to turn the chore of doing observation rounds into a fun game. It's very easy for operators to tick check boxes on check sheets without actually having observed the equipment properly. When you develop operator rounds get recorded measurements of what the equipment condition and/or performance observed. Give them inspection instruments like those below and ask

them to note the values taken on the record sheet. To help the operators make good judgment calls also have the 'normal' range of values on the check sheet beside the spot they record their reading. Once the operator sees there is a reading outside of the allowed range they will naturally investigate the problem much more closely.


Stethoscope


Laser Thermometer


Touch Thermometer


Vibration Pen

Someone knowledgeable of the operation and its proper performance needs to review the check sheets every day. These 'second pair of eyes' shows everyone in the operation that the check sheets are important and that careful observation and recording are vital to having well running plant and equipment. Secondly, another expert viewing the readings might find missed problems.

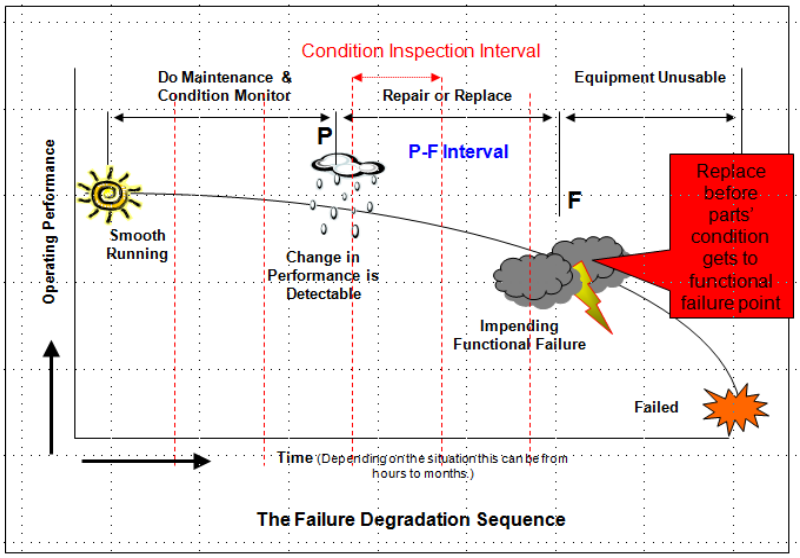
6. Make plant and equipment choices and selections with a 20 to 25 year time span in mind.

Doing repairs on a breakdown is easily ten times the cost of a planned maintenance job to fix the same problem. It's better to do too much preventive maintenance and replace parts well before they fail, and sacrifice operating life, than to repair vital production equipment on failure. Breakdowns cost so much money that it's more valuable to do all possible to prevent them. When you make material selection decisions and parts selection choices select for long, trouble-free operating life.

A small physical asset will most likely be in service for at least 10 years before being replaced. A large, expensive asset could be around for 50 years and more. The perfect outcome is for all assets to never fail and always be available when needed. The right way to look at the reliability of an item of equipment is to have zero failures over its entire operating life. Not once should an item of plant fail while it is in service. If a machine will be in service for 50 years then there ought to be no failures for 50 years. You must still maintain it but your maintenance strategies, which include age replacement, prevent it from breaking down.

By seeking long-term reliability when making engineering choices you minimise costs and downtime. Every breakdown prevented means more operational profit and a more competitive operation. Over the decades aheads that translates into a competitive business that keeps customer's happy and management and staff employed.

7. Vibration monitor rolling bearings on critical equipment often enough to stop any failures.



Vibration Analysis is a condition monitoring technique used to watch the crack behaviour of solid surfaces that move past each other. It includes monitoring roller bearings for signs of crack initiation and growth. The entire purpose of using vibration analysis on roller bearings is to detect failing bearings so you have time to plan for their replacement. It also lets you extend the time to failure by changing the operating conditions and local environment of the bearing. By reducing bearing loads the stresses in the atomic

structure fall. Limiting the load to 80% of design noticeably extends bearing life. Improving lubrication by introducing fresh and clean lubricant is another way to extend life for a time.

To spot when a roller bearing has started to fail it must be checked regularly enough to find the evidence of failure initiation with sufficient life left for you to plan the replacement at a time that minimises production stoppage. Because a VA measurement may be taken wrongly or poorly a small percentage of readings will be incorrect. When selecting the time interval for VA readings you also want to leave time for the next reading to confirm the prior reading and still have time to stop a breakdown. This means you need to fit three inspections between the time when the failure starts ('P' – Potential failure point) and the time the equipment must come-out of service for planned maintenance ('F' – Functional failure point).

The capability of a monitoring technology's 'P-F window of observation' dictates the measuring intervals. If VA gives a 12-week warning P-F window the inspections are done each 4 weeks. If there is evidence of a failure being initiated the inspection frequency is increased in order to quickly confirm a problem is or is not present and to manage the degradation rate to do a planned outage.

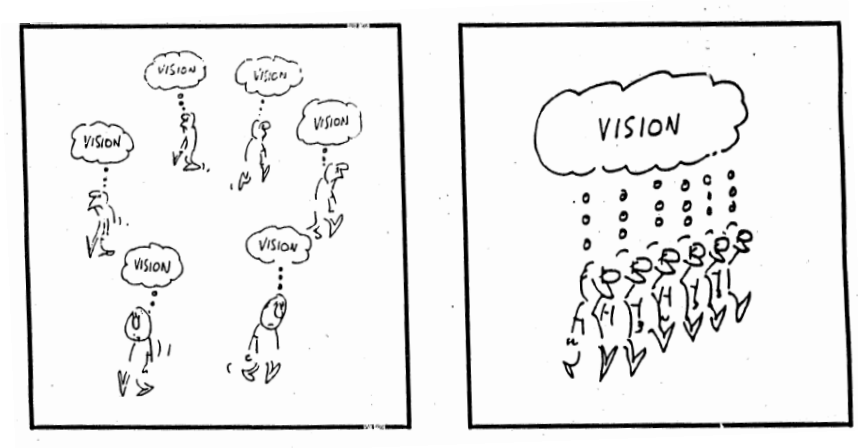
8. **Ask the operators and maintainers the simplest way they can think of to fix the problem.**

People that live with a problem have probably thought a lot about how to solve it. Problem plant and equipment gets looked at closely by its operators and maintainers, they don't like repeatedly doing repairs and wasting time fixing a problem over and over. Being creative they look for solutions and because they know the problem intimately they mentally simulate how the solution will work and its effect on the problem. It's well worth asking them what they would do to fix it.

The added advantage in operator and maintainer solutions is that these people have prior experience in a range of similar situations. They have seen other equipment designs and a other ways to address engineering problems. They also want simple and practical answers that are reliable. They don't want to spend their time doing more work than is necessary. The WIIFM (what's in it for me) factor makes them keen to keep things simple. It's very likely that an operator and maintainer solution will be far less complicated and involved than that from a university qualified engineer. They will also have invested their reputation in their solution and are much more likely to put in a great effort to make it work when implemented.

9. **Get Production and Maintenance Planners, Leading-hands and Supervisors to meet each day and prioritise the work to be done in the coming days and weeks.**

This tip is about intentionally making people communicate and develop common goals, agreed priorities and an understanding of how the day will go. It's about getting people to work together in a planned and coordinated way. It's the first activity of the day.



Call these opportunities for discussion and agreement Daily and Weekly Planning meetings. A structured agenda with time limits and a spot to record short notes of decisions made and actions to do will help make the meetings effective and efficient. People need to see this time as being of great value and worth to them and their work. It must take less than 20 minutes to complete a Daily Planning Meeting well and less than 30 minutes for a Weekly Planning Meeting.

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Actions for Improved Results that Show Benefits in A Few Months Time

1. **Start measuring performance with Key Performance Indicators generated from activities and results of the business process itself. Measure both equipment performance and business systems' performance. Use that knowledge to continuously improve.**

   Measurement is necessary if you want to be sure of where you are. Once you have a measure you can use it to gauge progress and performance. It is important to choose measures that reflect the real situation and that are highly useful in making good decisions to improve the circumstances. In the case of operational plant and equipment the measures need to cover factors affecting equipment reliability and the efficient use of business moneys and resources. Efficiency measures – are you doing things right – are not enough to improve a business. The most important measures of all are those that measure the effectiveness of what you do – are you doing the right things.

   There is no value in being very good at doing unimportant things. In a business that uses machinery, the important things are those activities that keep the equipment healthy and fit for service. Important activities include those that prevent failure. Being world-class at fixing breakdowns is great efficiency, but poor effectiveness. Being brilliant at finding the lowest prices for parts and contract labour sounds like an excellent business benefit, but it would be a poor decision if it caused production problems and downtime.

   When you select KPIs choose a spread of them so you measure both the efficiency of the activity, and the effectiveness and merit of the activity for the business.

2. **Put all Production and Maintenance Supervisors on a compulsory asset management course at diploma level.**

   You can only add value and do better if you know what is valuable and how to do things better. First comes right knowledge and then follows the right decisions. If you want improved operational equipment reliability then everyone working in the operation needs to know how to go about improving equipment reliability. You may even need to train people to thoroughly know the design and engineering requirements. This means making sure people put aside time to learn new facts and information and engaging the necessary resources to provide the right knowledge and skills.

   Production and Maintenance Supervisors are key players in asset management success because they make decisions that affect equipment performance and they decide the allocation of limited skills and resources. They will make better business decisions if they know what is important for asset management and maintenance management success. It's a powerful strategy that will help the people involved (and the business) to perform better, more confidently and more profitably.

3. **Establish a basic condition-monitoring regime – process parameter tracking/vibration/oil condition/thermography/'see-touch-hear' inspections.**

   Condition monitoring is done to warn you of changed behaviour. For machinery you want to be warned of which parts are failing. For a production process you want to be warned which factors affecting operation are degrading. Once you know the condition you can make considered choices.

   Process parameter tracking involves graphing the inputs and/or outputs of an item of plant. Examples are measuring and plotting power usage trends, and recording flows and pressures from pumps and showing them on the pump curve diagrams. They highlight to you when the current performance does not meet the designed performance.

   Machinery vibration measurement, oil analysis and wear particle analysis can give months of warning that machine parts are in trouble. With these monitoring technologies you have fewer breakdowns and your costs reduce because you are able to do planned maintenance at times that suit production.

   Oil analysis checks the chemistry of the oil and additives to see if their properties are still suitable for the operating condition. Perhaps even more valuable is wear particle analysis where the loose particles of solid material in the oil is counted by size ranges – up to 4 micron, 5 to 15 micron and above 15 micron – to warn you how dirty and dangerous the oil is.

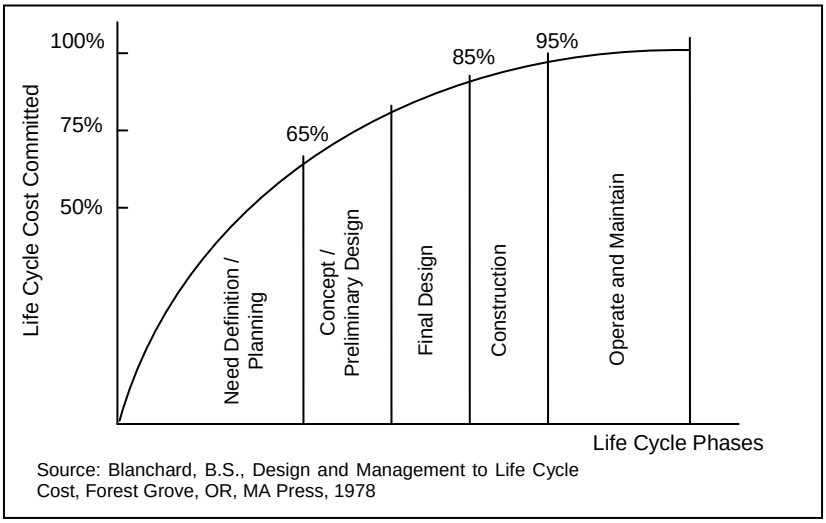
Thermography cameras show temperatures and temperature differences across a piece of plant or equipment. When temperature values indicate a problem you know exactly where the problem is because you see it on the screen and you quickly narrow its causes down to a few possible factors.

'See-touch-hear' inspections use the human body's sensitivity to monitor the plant and its operation. People walk-around and look for changes and new occurrences that should not be, while checking to confirm that the right plant and equipment behaviour is occurring.

4. **Perform a thorough engineering review of plant changes and upgrades to make decisions based on engineering and business facts. First design and engineer, or model and simulate, or pilot-test plant changes and ideas before putting them into place permanently.**

This tip is all about change management control and preventing the waste of time, money and scarce resources on activities that will fail to meet the real business needs, or lead to a future failure of operational plant. Once plant is operating any changes made to it will change the way it behaves and the ways that its operators and maintainers interact with it. When a change is made it needs to work right the first time. It must be absolutely certain that it will improve the performance of the operation.

It has long been known that operational costs are set by the design decisions and equipment selections made during the capital project phase of a facility. Once the choice of production process, operating equipment and installation contractor is made the future costs for an operation are locked into place and become virtually unchangeable. This makes it critical to an organisation's future success that the right business decisions get made during feasibility and detailed design. To maximise the quality of decisions so they reduce future operational risk it is best to put a great deal of effort in planning and proving every change and improvement will truly benefit the business and the way in which it operates before it is made permanent.



Source: Blanchard, B.S., Design and Management to Life Cycle Cost, Forest Grove, OR, MA Press, 1978

5. **Go outside of the company and bring in the training and teaching that your people need to become leaders in their field.**

You need a way to keep your people learning of new and successful ideas. You need a way to get your people to keep coming-up with new and successful ideas. Once your people master their work they will produce masterly results. Continual development values people for the great contributions they can make if given the knowledge and the chance. Go and get experts in their fields and bring them into your company to help make your people experts in their field. This not only applies to managers and supervisors; it applies right down to the lowest levels in a company.

Everyone wants to be known as a person who does a great job. If your people were already great your business would be at the top of your market because it would be producing such incredible results that customers would flock to it. If that is what you want for your operation then build-up the people that are going to take you there.

6. **Use Maintenance Planners to plan jobs in detail so you get labour efficiency and job quality.**

Scheduling is not planning. Putting a note in your diary to catch a plane on-time will not get you to the airport. Making the note in the diary is scheduling, arranging what to pack in your suitcase and how you will travel to the airport to get the plane on-time is planning.

Maintenance Planners must plan and not schedule. They must prepare a job to be successful and prepare the repairer to do the job successfully, right-first-time every time. It needs the Planner to go and see every job for themself and to make a written procedure to do the work expertly. It doesn't mean the Planner must be the one who writes the procedure, it can be done by the technician, but they must ensure a procedure that produces top quality reliability results is available before the job is scheduled. The best procedures are built with the 3Ts – Target, Tolerance, Test.

7. **Track-down all galvanic corrosion between dissimilar metals in galvanic contact and get rid of it, or monitor it closely and trend the remaining life.**

   Galvanic corrosion results when noble and less noble metals are in direct contact or are coupled via an electrolyte (i.e. they are electrically connected together through a liquid). The electrochemical process carries the electrons away from the anode and to the cathode. It is a subtle, creeping process whose destructive effects are often not be seen until failure occurs.

   It is caused by the wrong material design choice, or an installation error, and is solved by using materials close in galvanic voltage potential or using methods that use non-conducting materials so no electrons flow. In an operating plant identification of galvanic cells needs a specific audit to identify suspect materials listed on Bills of Materials or visual inspection of the plant looking for potential cells and measuring the metal remaining on the anode.

   Galvanic failures occur unpredictably, which makes them hated because the failure invariably causes a major breakdown. The rate of corrosion depends on the respective size of anode and cathode (a big cathode and small anode leads to rapid corrosion of the anode), the conducting properties of the electrolyte, the potential difference between metals, and the effectiveness of any sacrificial measures or controls used to prevent the electrochemical process.

8. **Teach operators how the equipment works and teach your maintenance trades how the production process works.**

   Share the knowledge about of how your plant and process works so that everyone can solve more problems, prevent making more problems and become more useful to the business with better engineering and production decisions. Operators need to know how their machines can be failed so they can stop doing wrong things that lead to failure and start doing those operator activities that produce high reliability. Maintainers need to know how the process affects the plant and equipment so they can correctly diagnose problems and feedback the causes to be corrected.

9. **Provide the technical knowledge on plant and equipment your trades need, in a place they can find it fast.**

   Highly reliable plant and equipment needs to be built correctly, installed correctly and operated correctly, all as designed, and not built or used with best intentioned guess work. Every maintenance job needs all the engineering and material details for the item being worked on, along with the design and operating data it needs to meet when working. Unless your tradespeople have the exact data they need with them, and it is unquestionably correct, they will be left to guess what they should do. Once you leave things to luck and human memory there is sure to be failure.

   The technical information must be available to the technician at the job. A hurried person will not bother to check if they are right unless it is easy to do so. Having a great engineering library is good, but if the information on a vital part of a machine is only available in the library few people will bother to go and find it. These days you don't need to have the information on paper, you can make it electronically downloadable so it is accessed when and where the technician needs it.

10. **Conduct an equipment criticality rating and match condition monitoring to the criticality so you identify risk of failure in important equipment and plant.**

    Asset Criticality is an indicator of the business risk that arises from the failure of a business asset. Asset Criticality, also known as Equipment Criticality, uses a risk matrix to identify the severity of the consequences from an asset's failure. Those with higher consequences rate more highly in importance.

ASSET CRITICALITY RATING

The risk level for the asset being assessed is the intersection of the worst consequence known to occur from a failure event and its likelihood to occur

	Safety	No threat	Injuries or ailments not requiring medical treatment	Minor injury or First Aid Treatment Case	Serious injury causing hospitalisation or multiple medical treatment cases	Life threatening injury or multiple serious injuries causing hospitalisation	Death or multiple life threatening injuries
	Hygiene	No threat	Can lead to health issues or ailments not requiring medical treatment	Can lead to health issues or ailments causing a minor injury or First Aid Treatment Case	Can lead to health issues or serious injury causing hospitalisation or multiple medical treatment cases	Can lead to health issues causing life threatening injury or multiple serious injuries requiring hospitalisation	Can lead to health issues causing death or multiple life threatening injuries
	Enviromental	No threat	1) Below licence requirements 2) Contamination contained in immediate plant area and addressed by local workers	1) Within licence requirements 2) Contamination contained within site boundary and addressed with own resources	1) Exceed licence limits 2) Contamination requires mobilisation of external resources	1) Grossly exceeds licence limits 2) Major contamination and local emergency services required	Major contamination and national emergency services required
	Production	No threat	Production capacity reduced for less than 1hour	Production capacity reduced for less than 1 shift	Production capacity reduced for more than 1 day	Total Production stopped for more than 1 day	Total Production stopped for more than 5 days
	Financial	$0>	$1K>	$10K>	$100K>	$1,000K>	$10,000K>
Likelihood of the Event		**No Threat**	**Insignificant**	**Minor**	**Significant**	**Severe**	**Catastrophic**
Historic Scale		**0**	**1**	**2**	**3**	**4**	**5**
Event occurs several times a year	**7**	0	7	14	21	28	35
Event will occur on an annual basis	**6**	0	6	12	18	24	30
Event has occurred several times or more in a lifetime career	**5**	0	5	10	15	20	25
Event might occur once in a lifetime career	**4**	0	4	8	12	16	20
Event does occur somewhere from time to time	**3**	0	3	6	9	12	15
Heard of something like it occurring elsewhere	**2**	0	2	4	6	8	10
Never heard of this happening	**1**	0	1	2	3	4	5

Risk Level
Red = Extreme
Amber = High
Yellow = Medium
Green = Low
Blue = Negligable

Note: 1) Risk Boundary is set at 'LOV' Level
2) Based on AS4360:2004-Risk Management

Once the criticality of an asset is known you match the measures for its protection to its importance to the business. This includes setting suitable maintenance strategy and using operational practices that deliver a necessary level of failure prevention. One of those maintenance strategies is to match condition monitoring technology and methodology to criticality.

An asset's importance may justify on-board monitoring around the clock using highly technical and expensive methods. Or it may be so low in importance that no money for high technology monitoring solutions can be justifiably spent. Not condition monitor any asset means you will have more failures than necessary. When an asset cannot justify a technological monitoring solution you use plant operators and maintainers on routes doing sensory inspections, taking operational measurements and recording/trending performance of those assets.

11. Eliminate the defects – use Root Cause Analysis, 5-Whys, etc. on equipment and systems failures and get the problems out forever.

Highly reliable organizations learn from their problems and then proactively act to prevent them. To solve problems fast you need to draw together relevant information and knowledge. The vast majority of production problems are the same ones repeated repeatedly by different people in different plants or at different times. You should only need to solve a problem once, and then let everyone else in your business use the answer and get what new training they need.

If you are not getting sustained high production performance there are underlying root causes that need addressing. Most often production equipment problems and failures are only symptoms of the real causes. The real causes are hiding deep within an operation's business processes and cultural habits. Until you solve the underlying issues that produce failures, they continue to happen. Determining the real problem is finding the root cause. There are special techniques for determining the root cause of a problem. A simple one for procedural problems is the '5 Whys'. For serious issues Root Cause Failure Analysis is often favoured. For the tens of thousands of defects in your plant and equipment waiting to become failures you use creative disassembly to fix them[1].

12. Be proactive and imagine problems so you can solve and eliminate them before they happen.

Highly reliable organizations do not accept things going wrong. They proactively focus on preventing problems entering their operation and find, then fix, those that remain. They set control mechanisms, standards and checkpoints in place to spot and stop the defects that turn into future failures. They look for what can go wrong before it does and prevent it happening. They put systems into place to get their people to warn of potential problems or hazards and use improvement teams to make the changes that will prevent them happening.

13. Develop ownership, build skills, and build competent people at shop-floor level.

When equipment is built to fine standards that prevent distortion and provide healthy internal conditions it runs smoother and its parts suffer substantially less stress and fatigue. Every part on every machine and piece of equipment in an operation needs standards that guarantee their health. Once you have standards that you can measure, you can prove if a thing is right or not. If you want equipment in your operation at consistently high reliability, the maintenance and operations people need to develop higher work skills and quality practices that they always use. To develop those skills requires setting high levels of excellence and then training people to them. They will develop pride in what they do and take on ownership of the plant's output quality because they control it.

[1] Brown, Peter., Wishaw, Max., 'Precision Maintenance for Engineers' Course, Industrial Training Associates, Perth, Australia, 2000

Actions for Improvements that Show Benefits in the Coming Year or Three

1. **Align the Capital Project group's output to the on-going needs of Maintenance and Operations. E.g. ensure all asset and instrument tag numbers have procurement and design information catalogued in individual files; have drawings and manuals numbered so they are easy to access for maintenance; etc.**

   This tip helps to reduce life cycle costs. During the entire operating life of plant and equipment it is necessary to regularly access design, location and purchasing information about an asset. This information (properly stored and catalogued) is a deliverable of the capital project team and needs to be provided ready for use before commissioning starts. This information is vital during the operating years and the only opportunity to collect it all together is if it is done as part of the project. Once the plant is operating there is not enough time and resources to do the job well and vital information is lost, which means people are forced to guess and so errors start to happen.

2. **Show and introduce the benefits of world class practices to managers, supervisors and leading hands. Show and introduce Corporate and Senior Managers to world class practices and methods so that can see the benefits to their 'bottom lines'.**

   This is more than just explaining to people the values of good asset management and maintenance practices. This is about doing trials and tests on your own equipment with better reliability improvement methods and technologies than you now use. The value of using best practices and best methods is that they improve the performance of the operation by increasing reliability through delivering better work quality and more accurate control of operating performance.

   It is necessary to prove the value of the better methods to senior managers in terms of financial gain so that they publically support the introduction. Making change stick needs proof the change is beneficial, support to do the necessary training and standing-by work process changes until the changes become a normal way of doing business (i.e. stick by it and improve it until it works).

3. **Align Operations and Maintenance efforts through a Production Plan and Schedule that covers both producing product and maintaining equipment well enough to make product.**

   There must be only one Weekly Plan in an operation. If Production has their Plan for the week and Maintenance has their own Plan for the week there is no alignment of effort. When everyone works to the same Plan then it gives the greatest chance that the Plan will be reached.

   The Production Plan must contain all the maintenance work scheduled for each week displayed so that everyone can see what equipment is affected and how long the work will take. Work that involves equipment stoppages will be shown differently to work done when the plant is operating.

   Having one Plan forces people to communicate and discuss options, it forces forethought and preparation to be made ahead of the job, and that guarantees better outcomes when the work is done.

4. **Do all your statutory obligations well with full documentation and excellent procedures and practices.**

   Regulated plant places a legal requirement on a company to make sure the asset does not degrade into a condition that it can kill people. Plant and equipment under regulatory jurisdiction, like cranes and pressure vessels, obligates a company to keep them in excellent condition and have flawlessly recorded proof that the asset is in good health and safe to continue in service.

   Since it is in the operations best interest to look after statutory equipment so they are not forcible shutdown by an Inspector, it is best to use documented procedures that explain exactly what needs to be done so the plant remains safe. These procedures also become proof of work quality and a record showing the operation is meeting its legal obligations.

5. **Select the best vendors and suppliers and form a long-term partnership/alliance. This will save time, give you access to good prices, let you use their expertise to solve problems and let you focus on your business.**

   Getting the right answer to a question that affects the future success of your operation is invaluable. You want to cultivate and harvest the people that know the right answers. Your vendors will do all that they can justifiably do to help you because they know that it will lead to future business. This

means you have an additional resource to use if the vendor sees value in the relationship. By agreeing to a long-term exclusive partnership with a vendor you give them justification to invest their time and effort in your operation. If you get a brilliantly competent vendor they will save you.

6. **Proactively build flexibility and redundancy into the plant so you have options to address problems quickly. E.g. install tie-ins in readiness to use mobile plant if the installed item fails.**

   Redundancy is used to control risk by intentionally duplicating equipment that has poor reliability, or where the consequence of its failure is too catastrophic. When important equipment cannot be permanently duplicated it is useful to provide tie-in points so that mobile or hire equipment can quickly be put into service when the item fails or needs to be taken-of-service. This keeps the plant running while the item is repaired or maintained.

7. **Apply Failure Mode and Effects Analysis and Reliability Centred Maintenance on new and old plant and equipment. On new equipment get the vendor to do the FMEA/RCM based on your industry's historical maintenance problems.**

   FMEA is used to proactively identify equipment risk and RCM is used to proactively identify operational risk. RCM reviews equipment and selects maintenance strategies matched to the operating risk caused by failure. FMEA identifies potential failure modes in machines and determines their effect on the operation of the plant, along with identifying actions to mitigate the failures. Both review methodologies use expert teams to do 'what if' risk analysis on equipment.

   There are two levels at which an FMEA can be conducted. One is to look at the loss of the equipment to identify what failures would cause that to happen. This is the Functional Approach, and has some commonality with RCM. The second method is to look at each part in the equipment and identify what would happen if it failed, and how the failure could be caused. This is the Hardware Approach. The second approach is the more thorough, though requiring more time.

8. **Select and use equipment that does not breakdown when it fails. Design protection into equipment that stops it breaking if it's overloaded or run wrongly. Use the grade of material that is not affected by the failure mechanism.**

   This tip is about designing and redesigning your plant and equipment to prevent disastrous production stoppages. Equipment can be easily and cheaply protected from breakdown by using load protection devices that trip the plant so it cannot be used until the overload problem is solved and it is safe to go back into operation. An example is to use shear pins in coupled drives of machines that can get overloaded and slipping clutches on gearboxes. Another example is to install motor starters that ramp equipment gradually to full load so inertia start-up forces, which can be several times the operating force, are kept low and do not cause rapid deterioration of plant and equipment. A bad start-up can destroy equipment equivalent to several years of normal service.

   Materials of construction can be changed to those that do not suffer from prominent failure modes, like substituting high quality stainless steel for carbon steel in wet environments, or substituting synthetic lubricant for mineral lubricant in hot operating locations.

9. **Buy equipment that can be supported and maintained locally; otherwise you will pay a lot more for parts and be waiting for service.**

   When equipment is purchased you make a decision that will remain in place for decades. That equipment needs to be maintained and serviced throughout those years. If the equipment is not supported locally by competent vendors during its years of service you will suffer long outages from lack of expertise and parts. Even if you purchase spare parts when ordering the original item the time will come when the parts are used up or they have been degraded and are unusable. Then you will need to order them from the original equipment manufacturer, which may be out of business, or will not make the parts for you, or will make parts at exorbitant cost and with delays that suit their production schedule.