CTPM

Understanding
Total Productive Maintenance (TPM)

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TPM was developed in the 1960's in Japan to support the development of the Toyota Production System.

We first heard about TPM in 1989 following the publication of the first English translated Japanese book on the subject.

CTPM was established in 1996 to develop an Australasian version of TPM which it released in 1998.

In 2007 CTPM integrated its enhanced Australasian version of TPM with Lean which we now refer to as TPM & Lean / CI which recognises the unique attributes of our Australasian workplace culture and the critical role equipment reliability plays in operational performance especially in a Lean environment.

TPM & Lean / CI is a Operational Excellence Improvement Strategy focused on engaging and developing the skills of the frontline workforce (Operators and Maintainers) so that they can identify equipment, process and quality problems at the earliest possible time and ensure their prompt rectification. This results, not only in a more stable plant operation but most importantly maximises capacity, minimises costs and creates a safe & productive workplace while minimising Operational Risk.

Background to Total Productive Maintenance (TPM)

TPM had its genesis in the Japanese car industry in the 1960s. It evolved at Nippon Denso, a major supplier of the Toyota Car Company, as a necessary element of the newly developed Toyota Production System, which was originally thought to only incorporate the 2 pillars of Total Quality Control (TQC) or in Japanese language Jidoka, and Just in Time (JIT), supported by Total Employee Involvement (TEI). It was not until 1988, with the publication in English of the first of two authoritative texts on the subject by Seiichi Nakajima, that the western world recognised and started to understand the importance of TPM in supporting the Toyota Production System.

It soon became obvious that TPM was a critical missing link in successfully achieving not only world class equipment performance to support TQC (quality variation reduction) and JIT (lead time reduction through elimination of the 7 wastes), but was a powerful new means to improving overall company performance.

In the early 1990s the implementation of TPM started to rapidly spread throughout the western world, however initially only a limited number of non Japanese companies were able to significantly improve the performance of their manufacturing, processing or mining operations due to the poor initial understanding of what TPM really entailed especially in a workplace culture outside of Japan.

Properly implemented TPM has a major impact on bottom-line results by significantly reducing not only maintenance costs but overall operational costs. Even though there were sufficient examples to demonstrate, many sites struggled to get their implementations to sustain.

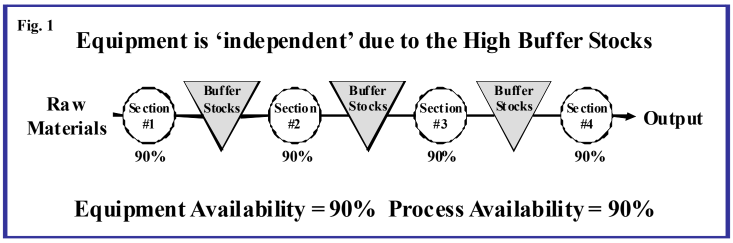
Many sites failed to recognise that TPM, properly implemented, provides the employee engagement foundation required to support Lean along with substantially improving capacity and creating a much safer and more environmentally sound workplace.

To fully understand how TPM should be implemented in a non Japanese workplace, we found it necessary to go back to where it evolved and understand why it evolved and what issues it was trying to address.

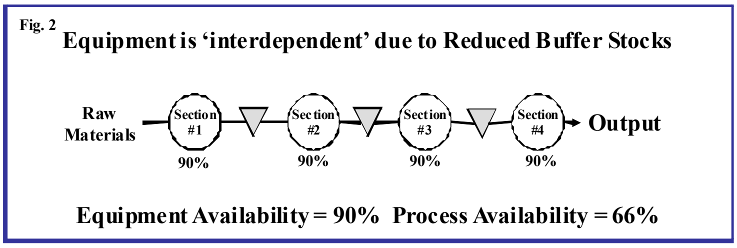
The Evolution of TPM

Back in the 1960s in Japan before the development of the Toyota Production System, high buffer stocks were allowed to develop between major sections of the plant eg cutting, stamping, trimming, assembly, to ensure that if there was a problem with one section of the plant then it would not affect production across the rest of the plant. If one section stopped due to a breakdown then the buffer stocks allowed the other sections to continue provided the breakdown was corrected before the buffer stocks were used up. Hence the role of maintenance was to cost effectively ensure major pieces of plant & equipment were available for an agreed period of scheduled time recognising the buffer stocks would cover the time for maintenance to repair any unexpected downtime events.

Because of the accepted practice of retaining high buffer stocks, most sections of the plant could be considered independent. If the equipment in a section was maintained such that it achieved say 90% availability, the availability of the entire process eg cutting, stamping, trimming, assembly was 90% provided any unexpected downtimes could be corrected before the buffer stocks ran out. If the equipment in a section started to cause quality problems, these would probably be noticed in final quality inspection (eg at assembly) and the cause traced back to the offending section and piece of equipment and corrected by maintenance.



At Nippon Denso in the late 1960s with the introduction of the initial Toyota Production System ideas, the buffer stocks were substantially reduced in their quest for shorter Lead Times and improved quality. Statistical Process Control (SPC) supported by "Quality at Source" was introduced to ensure quality right first time and thus provide maximum customer value through the highest quality at the lowest cost. This was supported by quick responsiveness and superior customer service. Hence in this quest for maximum customer value, buffer stocks were reduced to both reduce Lead Times and force the identification of cost consuming problems. This resulted in individual equipment problems affecting the whole process.



If one section stopped then shortly afterwards the whole process stopped. This made the equipment interdependent. Under these circumstances, the availability of the process became the product of the individual availabilities of each section. Thus, a process involving four sections maintained at 90% no longer had an overall process availability of 90%, but an availability of 90% X 90% X 90% X 90%, or 66%!

Furthermore, as the quality approach changed to "Prevention at Source" by controlling process variables, equipment performance problems were identified much earlier. Conformance and reliability became much more important.

As buffer stocks reduced substantial pressure was placed on the maintenance department to improve process performance. From a maintenance perspective, the maintenance department's performance had not deteriorated, yet demand for the substantial improvement in section availability was overwhelming.

This caused friction between the production and maintenance departments. Production departments demanded former levels of process availability and quicker response times from maintenance, which were often unable to comply due to traditional organisation structures that keep maintenance as a separate function. After much conflict between maintenance and production, engineering were called in to find a solution. They soon realised that mathematically for the four now interdependent sections to achieve their original process goal of 90% availability, their individual availabilities needed to increase from 90% to 97.5%.

The traditional view of maintenance was to balance maintenance cost with an acceptable level of availability and reliability often influenced by the level of buffer stocks, which hid the immediate impact of equipment problems.

In traditional companies, maintenance is seen as an expense that can easily be reduced in relation to the overall business, particularly in the short term. Conversely, maintenance managers have always argued that to increase the level of availability and reliability of the equipment, more expenditure needs to be committed to the maintenance budget. With the onset of substantial availability problems caused by the new way of running the plant, management soon realised that just giving more resources to the maintenance department was not going to produce a cost effective solution.

This conflict between maintenance cost and availability is similar to the old quality mind-set before the advent of Total Quality Control (TQC): that higher quality required more resources, and hence cost, for final inspection and rework. TQC emphasised "prevention at source" of the problem rather than by inspection at the end of the process. Instead of enlarging the inspection department, all personnel were trained and motivated to be responsible for identifying problems at the earliest possible point in the process so as to minimise rectification costs. This thinking was also supported by empowering the operators to reject any input coming to them that was not to the required quality specification and ‘stopping the process’ if they identified a quality issue that stopped them from producing the required quality output.

This did not mean disbanding the quality control department but having it now concentrate on more specialist quality activities such as variation reduction through process improvement and operator quality skills development. This new approach to quality demonstrated that getting quality right first time does not cost money but actually reduces the total cost of operating the business.

To address the drop in availability issue brought about by reducing buffer stocks, this new Quality approach of "Prevention at Source" was translated to the maintenance environment through the concept of TPM resulting in not only superior availability, reliability and maintainability of equipment but also significant improvements in capacity with a substantial reduction in both maintenance costs and total operations costs.

TPM is based on "Prevention at Source" and is focused on identifying and eliminating the source of equipment deterioration rather than the more traditional approach of either letting equipment fail before repairing it, or applying preventive / predictive strategies to identify and repair equipment after the deterioration has taken hold and caused the need for often expensive repairs.

Originally known as Total Productive Maintenance, the words correctly interpreted mean Total (all personnel) Productive (creating greater return on investment) Maintenance (by caring for the plant & equipment so as to maximise its performance and output). To better reflect this correct interpretation the letters TPM now stand for a variety of words such as:

Total Productive Manufacturing; Total Productive Mining; Total Process Management; or even Teamwork between Production and Maintenance.

TPM has developed over the years since its first discovery in 1970. In the first Japanese text book published in Japan in 1982 and translated into English in 1989 (TPM Development Program), there were 5 Activities of TPM that are now referred to as 1st Generation TPM (Total Productive Maintenance). It focused on improving equipment performance or effectiveness only. In a later Japanese text book published in Japan in 1989 and translated into English in 1992 (New Developments in TPM), it was realised that even if the shopfloor were committed fully to TPM and the elimination or minimisation of the "six big losses", there were still opportunities being lost because of poor production scheduling practices resulting in line imbalances or schedule interruptions stopping the regular improvement activities. This is why one of the key platforms for Lean as reported in Jeffrey K Liker's book The Toyota Way in 2004 is 'Stable and Standardised Processes'. Hence 2nd Generation TPM (Total Process Management), which focused on the whole production process, was developed.

Finally in the Japanese text book TPM in Process Industries, published in Japan in 1992 and translated into English in 1994 (some 20 years after its first discovery), it has been recognised that the whole company must be involved if the full potential of the capacity gains and cost reductions are to be realised. Hence 3rd Generation TPM (Total Productive Manufacturing / Mining) was evolved which now encompasses 8 Pillars of TPM with the focus on the 16 Major Losses incorporating the 4Ms – Man, Machine, Methods, and Materials.

At CTPM we have developed an enhanced Australasian approach to applying the principles and practices of TPM & Lean evolved from the Japanese 3rd Generation TPM 8 Pillar company-wide model. Our CTPM model involves 10 Improvement Activities spanning the entire Supply Chain which we have found better suits the Australian and New Zealand workplace culture.

Fig. 3

Evolution of CTPM's 10 Improvement Activities

Japanese 3rd Generation TPM (Company Focus)	10 Improvement Activities of TPM & Lean / CI (Supply Chain Focus)
8. Safety & Environmental Management	1. Safety, Health & Environmental Management
1. Focused Improvement	2. Focused Equip & Process Improvement
	3. Work Area Management
2. Autonomous Maintenance	4. Operator Equipment Management
3. Planned Maintenance	5. Maintenance Excellence Mgmt
5. Early Equipment Management	6. New Equip / Area / Process Mgmt
6. TPM in Admin & Support Departs	7. Support Depart Excellence Management
	8. Value Stream Management
4. Education & Training	9. People & Leadership Development
7. Quality Maintenance	10. Process Quality Management

CTPM Est. 1996 CTPM

The 3 key enhancements involved changing the order of the activities (safety to #1); adding 2 Activities – Work Area Management (enhanced 5S) and Value Stream Management to cover the entire Supply Chain and address stabilising the production plan using flow logic; and changing description of activities to simpler language.

An important outcome of this new approach to equipment management which is now supported by many success stories throughout the world in a variety of industries, has been that senior management have realised that TPM is both strategically important for a world competitive business, and that TPM cannot be implemented by the maintenance department alone. TPM is a company-wide and supply chain focused improvement initiative involving all people associated with the site / company.

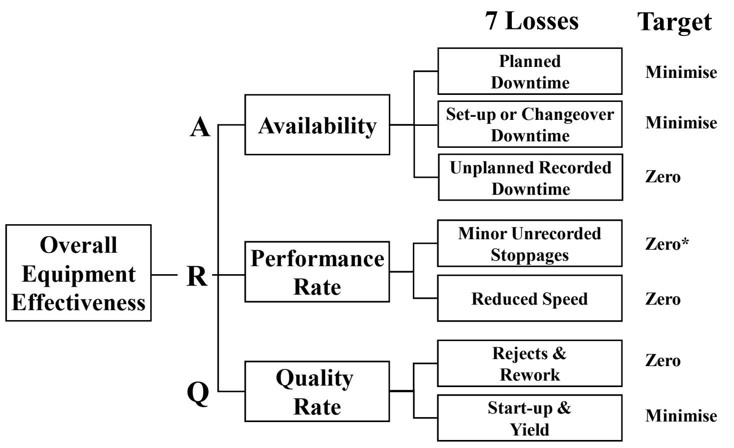
Although each enterprise may approach TPM in its own unique way, most approaches recognise the importance of measuring and improving Overall Equipment Effectiveness along with the need to reduce both operational and maintenance costs in an environment that promotes on-going Continuous Improvement.

Understanding the Importance of Overall Equipment Effectiveness

Many companies who recognise the important role equipment and process performance have on bottom-line results are turning to the measure which drives TPM called Overall Equipment Effectiveness (OEE) which incorporates not only Availability but also Performance Rate and Quality Rate. In other words, OEE addresses all losses caused by the equipment: not being available when needed due to planned downtime, set-up downtime and unplanned recorded downtime; not running at the ideal or theoretical rate due to reduced speed or minor unrecorded stoppage losses; and not producing first pass, within specification output due to rejects & rework or start-up & yield losses. A key objective of TPM is to cost effectively maximise Overall Equipment Effectiveness through the elimination or minimisation of all losses. A simple model outlining these losses is shown in Figure 4.

Fig. 4

Overall Equipment Effectiveness Model



The aim of the 7 Losses is to capture all possible losses that could be improved including such Planned Downtime as meal breaks, maintenance periods etc

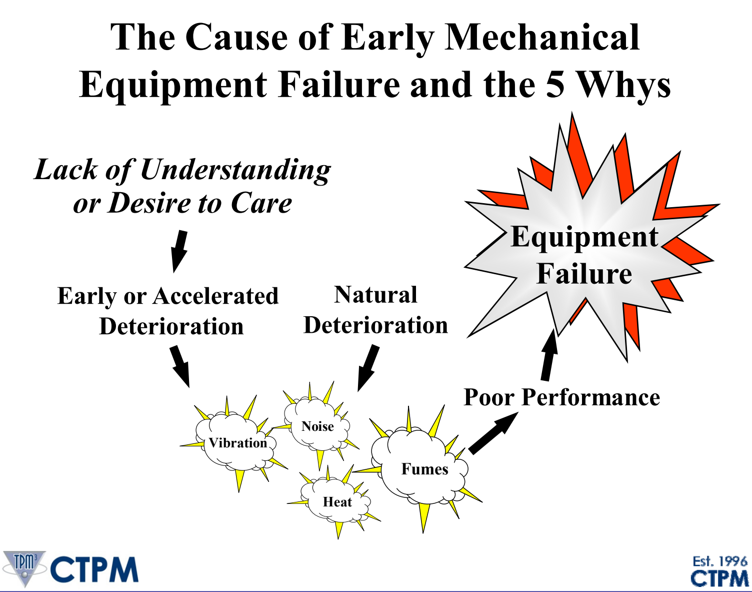
**Minor Unrecorded Stoppages should ultimately become zero as they become automatically recorded*

When many organisations first measure Overall Equipment Effectiveness it is not uncommon to find they are only achieving around 40% - 60% (batch) or 50% - 75% (continuous process) whereas the international best practice figure is often reported to be +85% (batch) and +95% (continuous process) for Overall Equipment Effectiveness. In reality we have found that best practice OEE performance is very dependent on the way we run our plants (eg whether planned maintenance or changeovers can be conducted outside production hours, the number of changeovers required for local marketplace requirements etc) resulting in OEE targets being specific to the site, however we still often find that ***there exists at many sites the opportunity to increase capacity / productivity by 25% - 100%.***

Understanding the Cost Impact of Failure

TPM significantly reduces operational and maintenance costs by focusing on the Root Cause of Failure through the creation of a sense of ownership by the plant & equipment operators, maintainers and support staff to encourage "Prevention at Source". To help understand the thinking behind TPM we need to investigate what causes failure.

Fig. 5



Most of us have heard of the concept of the ‘Root Cause of Failure’ and the tool most commonly used to assist in the search for the root cause – the 5-Whys. The 5-Whys is a technique of asking why 5 times recognising that statistically it has been shown that after 5 ‘whys’ you are most likely to be at the root cause. In the work place we rarely get to the root cause because we are too busy reacting to the symptoms of our problems. However, unless we get to the root cause we will always have problems reappearing.

What is the root cause of failure? Often, before mechanical failure we can have poor performance, prior to poor performance we may get early indicators such as vibration, noise, heat or fumes coming from our equipment. This can be caused by either natural deterioration (reached its expected life) or early or accelerated deterioration (see Figure 5).

What do we mean by ‘Early or Accelerated Deterioration’? This is where a piece of equipment or part of a piece of equipment wears out quicker than is expected. That is, its life is shortened because its natural deterioration is accelerated.

Let us look at the failure mechanisms of the parts that make up our plant & equipment. Most pieces of mechanical equipment in our plants can be broken up into 3 broad categories:

	Structural Items	**Wear Items**	**Working Items**
Part	Frame Housing Casing	Wear Plates Pump Impellers Table Rolls	Transmissions Hydraulics Pneumatics
Failure Mechanisms	Corrosion Erosion Fatigue Damage	Dependant on throughput **Note:** the higher the OEE - the shorter the life	Governed by the Laws of Physics

From the above table we can see the different failure mechanisms for the three different categories of items. It is worth noting how TPM will actually reduce the life of your wear items due to the increase in throughput as your OEE increases some 50% or more.

Our main interest however, is with the Working Items. These by far make up the majority of items that need maintenance attention and contribute most to our overall maintenance spend. So let us understand the impact of the laws of physics on our working parts.

If, for example, I were to rub my hands together for the rest of the day what is going to happen? I will get very sore hands as they get several layers of skin rubbed off. To stop this from happening I would need to apply some form of lubrication to act as an interface between my hands.

Hence, proper lubrication provides an interface between moving surfaces, and a key role of lubrication is to be a sacrificial wear element. That is, the lubrication wears out as the moving surfaces interface with it. This is why it is recommended that we replace the oil in our cars at say every 10,000 km. This is not because the oil is dirty, even though it may look dirty it is continuously filtered and clean. The reason for replacement is that the oil has worn out.

Accelerated deterioration occurs when:

- lubrication is not present;
- lubrication is incorrect for the application;
- lubrication between surfaces is forced out due to overload;
- lubrication wears out; or
- lubrication becomes contaminated.

Who has ever seen an operator “blow down” his equipment with compressed air, or hose it down with water? What is this process doing to the equipment? More than likely the operator is forcing contamination into the equipment without even realising it or caring about it. This contamination is a primary source of early or accelerated deterioration.

Many studies have been conducted to determine the impact of early or accelerated deterioration. Let us consider the situation of the working parts of your equipment. If you were to plot say the 30-year history of the actual life of a part that normally fails after 12-months would you get a straight line? In most studies the result is a normal distribution where the part fails for the majority of the time at 12-months however on other occasions it may fail early or later often with a range of some 6-months either side of the 12-month majority. If we were to introduce a periodic or preventive maintenance plan for this part what would be our strategy. Obviously if we were to replace the part after 12-months we would still have a significant number of failures. If we were very conservative we could replace the part every 6-months. This would significantly reduce the failures however we would have very high maintenance cost. So what is the answer?

This is where TPM becomes so important. TPM is based on the precepts of:

- understand what causes the variation in component life;
- reduce or minimise the variation in component life; then
- look to improve.

Under this approach the first task is to identify what is causing the variation. Studies conducted by the Japanese Institute of Plant Maintenance and companies like DuPont and Tennessee Eastman Chemical Company have shown that 3 major physical conditions make up some 80% of the variation. These physical conditions are:

- Looseness
- Contamination
- Lubrication Problems

The elimination of these three conditions is known as "establishing Basic Equipment Conditions". Once "Basic Equipment Conditions" have been established we find our normal distribution curve squashes up some 80% and moves to the right thus significantly increasing the life of our parts.

In his book, TPM in Process Industries, Suzuki raises the important issue when he states:

"Implementing a periodic / preventive maintenance system before establishing basic conditions - when equipment is still dirty, nuts and bolts are loose or missing, and lubrication devices are not working properly - frequently leads to failures before the next major service is due.

To prevent these would require making the service interval unreasonably short, and the whole point of the preventive maintenance program would be lost.

Rushing into predictive maintenance is equally risky. Many companies purchase diagnostic equipment and software that monitors conditions, while neglecting basic maintenance activities.

It is impossible, however, to predict optimal service intervals in an environment where accelerated deterioration and operating errors are unchecked."

Impact of Multi-Skilling on Basic Equipment Conditions

Although multi-skilling has often been successful in creating a more flexible workforce, experience now highlights that while personnel move from equipment to equipment, or area to area, they lose the motivation to seek out basic equipment problems or defects which if left unchecked, will cause failure in the future (see Figure 5). The Operators often demonstrate a lack of care for the equipment because they know they will soon be moved to another area or piece of equipment.

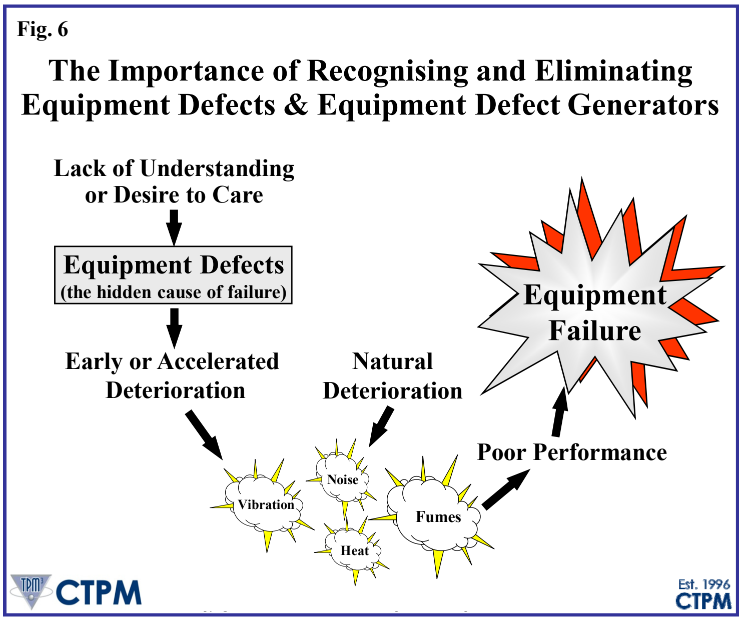
An Area Based Team approach, which promotes the development of Base Skills, Team Skills and Mastery Skills, provides a means to achieve both flexibility and ownership within the workplace. Correctly formed Area Based Teams involving 4-8 Operators including a working Frontline Leader, create an environment where personnel can come to recognise the benefits for themselves to learn both the proper way to operate their equipment as well as how best to care for their equipment by maintaining “Basic Equipment Conditions”.

TPM implementation experience has shown that there is a definite relationship between failures and “Basic Equipment Conditions” – no looseness, no contamination, and perfect lubrication. Our experience with multi-skilling is that it takes away ownership and the motivation for Operators to ensure Basic Equipment Conditions.

Without the framework of effective Area Based Teams where team members can develop the Base Skills required to operate all plant and equipment within their Team’s Area of Responsibility to ensure team flexibility as well as developing their Mastery Skills to become the expert at caring for, and detecting any defects that might develop in their equipment, operational and maintenance costs will always be high.

Equipment Defects – The Hidden Cause of Failure

The key driving objective of TPM is to eliminate or minimise, not just reduce the equipment losses. To achieve this, TPM is an on-going journey to excellence that challenges our mind-sets. One such important challenge is the traditional mind-set that focuses on either actual or potential failures or breakdown and largely ignores equipment defects that can be the hidden cause of failure (see Figure 6).



Equipment defects or imperfections with our equipment are subtle and not always obvious. They "flow" into our plant & equipment due to various reasons: poor initial design or changes to the initial design requirements of our plant & equipment due to output requirement changes; the way we operate our plant & equipment and the environment we operate our plant & equipment in; imperfections in the maintenance materials we use and the way we carry out our maintenance activities; and last but not least, as a consequence of any failures which occur to our plant & equipment. They are often difficult to identify and correct because they are traditionally accepted as the norm. Equipment defects play a major part in causing "losses" in equipment performance.

TPM implementation experience has shown that there is a definite relationship between failures and equipment defects in that most failures can be traced back to equipment defects. In a TPM environment, the aim is to focus on equipment defects so as to eliminate the occurrence of failures and early deterioration. This focus on equipment defects has a large bearing on the way everyone in the company needs to become involved with TPM. All personnel need to ask the question: "are my actions focused on avoiding defects or merely addressing the issues associated with defect removal". Being able to identify and correct equipment defects and then find their source so they can be avoided in the future is a major ingredient in the process of implementing TPM.

Using Operator Equipment Management Improvement Activity to induce Change

Operator Equipment Management is about "caring for equipment at the source" so as to ensure the "Basic Equipment Conditions" are established and maintained to allow the successful implementation of planned preventive and predictive maintenance to be successfully administered by the Maintenance department. Ultimately Operators become responsible for the Overall Equipment Effectiveness of their plant & equipment through a "root cause" approach to defect avoidance.

It is not a simple exercise to create an Area Based Team environment that promotes ownership with Base Skill flexibility and Mastery Skill for TPM. Changes take time. A systematic approach, supported by a robust process, needs to be adopted to allow the changes to be implemented at a rate commensurate with the organisation's evolving culture.

Although implementation of Operator Equipment Management involves 4 stages covering 7 defined steps spanning some 2-3 years, it needs to be specific to the situation and plant environment. The final goal of achieving mature equipment-competent Operators is for the Area Based Teams to be responsible for the Overall Equipment Effectiveness (OEE) of their plant & equipment. This does not mean Operators carry out all maintenance activities, but that they are responsible for knowing when they need to carry out the simple defect avoidance and maintenance service work themselves and when they should call in maintenance experts to repair problems, which they have clearly identified.

The Relationship between Traditional Maintenance and TPM

Many traditional approaches to maintenance assume ‘Basic Equipment Conditions’ (no looseness, no contamination and perfect lubrication) are mandatory, and where Operators skill level, behaviour and training is of a high standard. Unfortunately in most manufacturing and mining operations these ‘Basic Equipment Conditions’ and operator skill and behaviour levels do not exist thus undermining the basis of any traditional maintenance approaches.

For this reason, the application of TPM as a company-wide / supply chain focus improvement strategy is highly advisable to ensure:

- ‘Basic Equipment Conditions’ are established; and
- ‘equipment-competent’ Operators are developed,

before attempting a major investment in developing traditional maintenance practices. Failure to do this in an environment where Basic Equipment Conditions and Operator error are causing significant variation in the life of your equipment components will block your ability to cost effectively optimise your maintenance tactics and spares holding strategies.

The other key difference between traditional maintenance and TPM is that reliability is promoted as a maintenance improvement strategy whereas TPM recognises that the maintenance function alone cannot maximise reliability. Factors such as Operator ‘lack of care’ and poor operational practices, poor ‘Basic Equipment Conditions’, and adverse equipment loading due to changes in processing requirements (introduction of different products, raw materials, process variables etc), all impact on equipment reliability. Unless all personnel become actively involved in recognising the need to eliminate or reduce all “losses” and to focus on ‘defect avoidance’ or ‘early defect identification and elimination’, failures will never be cost effectively eliminated in a manufacturing or mining environment.

Conclusion

It should be acknowledged that a TPM implementation is not a short-term fix. It is an on-going journey based on changing the work area then the equipment so as to achieve a clean, neat, safe workplace through a “PULL” as opposed to a “PUSH” culture change process.

Significant improvement should be evident within six months, however full implementation can take many years to allow for the full benefits of the new culture created by TPM to be sustaining. This time frame obviously depends upon where a company is in relation to its quality and maintenance activities and the resources being allocated to introduce this new mind-set of equipment management.

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Ross, who is Wollongong based, founded CTPM in 1996 after more than 20 years of manufacturing and operational experience covering maintenance, production, operations and executive roles along with 5 years of international consulting experience. Ross has been actively involved with Lean since 1985 and the application of TPM since 1990. In 1998 he developed and launched CTPM’s Continuous Improvement Methodology. He is recognised as Australasia’s leading authority on TPM and Continuous Improvement. He is currently assisting sites throughout Australia, New Zealand, Indonesia, Thailand and China to strive for and achieve Operational Excellence.

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