Improving Coal Mining Production Performance Through the Application of Total Production Management

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ABSTRACT

This paper describes the application of the Total Productive Management (TPM) technique as a performance improvement initiative for a coal mining operation. It discusses the objectives of TPM, with the driver for improved production performance being the Overall Equipment Effectiveness (OEE) of the equipment or process, and with the development of "ownership" as the behavioral approach to equipment management and continuous improvement through cross-functional and area-based teams. It illustrates the concept of equipment management as defects management.

The scope for application of TPM to the coal mining industry is immense. The harshness of the operating environment can be a major generator of equipment defects, and a current paradigm in the industry accepts these defects as an unavoidable outcome defining maintenance costs in this environment. However recent benchmarking studies have highlighted that maintenance costs per operating hour in some mining operations are more than double the vendor's estimate of "best practice". The paper refers to these studies which also compare maintenance costs of fixed and mobile plant and equipment to "best practice" outcomes in comparable process industries.

The ultimate goal of any operating strategy must be to translate results to the bottom line through adding revenue from increased volume and quality of operations output, better safety performance, and reducing costs of production through lower operating and maintenance costs. These lower costs result from removal of defects generators, improved maintenance planning, and identification and reduction of hidden operating costs resulting from poor equipment maintenance. The paper discusses methods of evaluating the progressive improvements brought about by a successful TPM strategy to achieve this goal in a highly visible format to provide the incentive to both management and the workforce to push on for more improvement.

Finally the paper outlines the minesite procedures required for successful implementation of TPM to sustain these desired results for all stakeholders. It suggests that TPM can be integrated with existing business improvement initiatives by structuring these other minesite programmes (safety, cost reduction, restructuring, capital replacement, etc.) into the "Eight Pillars of TPM" framework as part of the overall business plan. Resulting interface redundancies can then be identified and eliminated, and a timeline developed for effective implementation of the overall minesite initiatives programme.

INTRODUCTION TO THE TPM PROCESS

TPM As A Business Improvement Initiative

Total Productive Management (TPM) is a proven concept of equipment management for maximising capacity, productivity, quality, employee morale, safety and bottom line results.

Like the Quality movement, TPM had its genesis in the Japanese car industry in the 1970's. However, it has only been in recent years since the late 1980s that TPM has started to rapidly spread throughout the western world, significantly improving the operational areas of initially manufacturing and now mining industries. TPM has evolved as a vital and necessary response to the need to develop a competitive advantage by substantially improving capacity through enhanced plant and equipment performance along with output quality, while significantly reducing not only maintenance costs but

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overall operating costs. Successful implementation of TPM has resulted also in the creation of safer and more environmentally sound workplaces.

For change to be sustainable, it requires the focus of a tangible and effective driving mechanism. TPM applies the principles and practices of quality management, especially "prevention at the source", but focused on plant and equipment rather than on customers as in TQM. TPM uses Overall Equipment Effectiveness (OEE) as the driver that focuses the TPM initiative and provides the vehicle for sustained continuous improvement, with all employees becoming involved in preventing defects from developing in plant and equipment. Defects are identified at the earliest possible time so that they can be removed in a cost-effective manner before they lead to deterioration in overall equipment or process performance. TPM challenges the traditional approach of "I operate, you fix".

An important outcome of this new approach to equipment management, supported by many success stories throughout the world in a variety of operational industries, is that TPM cannot be implemented by a maintenance department alone. TPM is a company wide improvement initiative involving all employees. Changes now occurring within the Australian coal industry with the establishment of workplace agreements and the overhaul of work practices, provide the environment for the implementation of TPM to become strategically important for a globally competitive coal mining operation.

Objectives

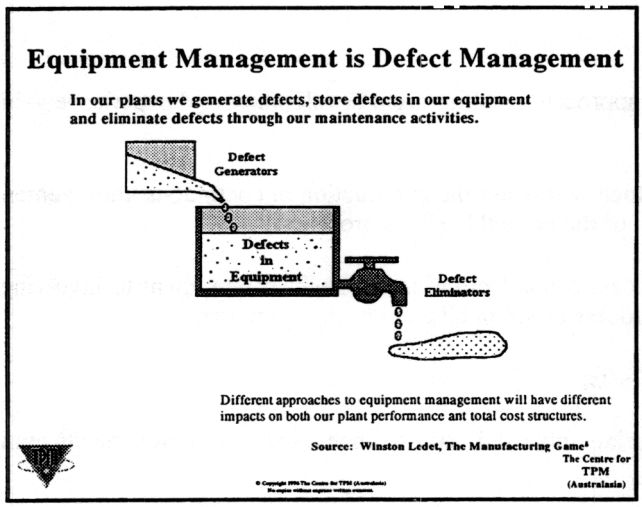
Although each enterprise may approach TPM in its own unique way, most approaches recognise the importance of measuring and improving Overall Equipment Effectiveness (OEE), and the need to create a sense of ownership by the plant and equipment operators, maintainers and support staff to encourage prevention at the source. The three main objectives of TPM are defined as:

- to maximise the Overall Equipment Effectiveness (OEE) through loss analysis;
- to develop Ownership of equipment through area-based teams; and
- to promote Continuous Improvement through area-based and cross-functional teams.

Equipment Management as Defect Management

Defects are generated and "flow" into plant and equipment due to various reasons, some of which are:

- the poor initial design, or subsequent changes to the design parameters due to output requirements changing;
- the method and practices adopted in operation of plant and equipment and the environment in which operations are carried out;
- the imperfection in maintenance materials and spares as sourced from stores or imparted during handling or assembly; and
- the consequences of any failures which occur within the plant or equipment.



Source: Kennedy (1997).

Fig. 1 - Defect management

The principle of identifying equipment management as defect management, as depicted in Fig. 1.1, was developed by Dupont and is embodied in the Manufacturing Game (Lidet 1994). Defects are "stored" in the plant and equipment and progressively eliminated through maintenance activities. An "overflow" results in breakdown. The "level indicator" of defects to trigger planned maintenance activities is the outcomes of inspections, condition monitoring, etc. However different approaches to equipment management in controlling this system will have different impacts on both the plant performance and total cost structures.

The basic principle of TPM is the recognition and elimination of these defects AND the defect generators (as the root causes of failure) which lead to accelerated deterioration resulting in poor performance and ultimately in plant and equipment failure. These activities of recognition and elimination are carried out by the miners, plant operators and maintenance personnel as cross functional and area based teams.

A Paradigm Shift To An Operator-Ownership Environment.

Over the past ten years we have seen the pendulum of change in the coal industry swing towards a multi-skilled workplace. However as companies have gone through this experience, the importance of the issue of "ownership" has become apparent. Through bitter experience, many companies have now come to realise that the pendulum may have swung too far. Without a sense of "ownership", employees tend not to care for equipment. Although multi-skilling has been successful in creating a more flexible workforce, experience now highlights that, while employees move from equipment to equipment, or area to area, they lose the motivation to seek out basic equipment conditions problems or defects which, if left unchecked, will cause failure in the future.

An area-based team approach that promotes the development of both base skills and mastery skills provides a means to achieve both flexibility and ownership within the workplace. Correctly formed area-based teams create an environment where employees recognise the benefits for themselves in adopting the proper way to operate their equipment and 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 these basic equipment conditions of correct lubrication, no contamination, and no looseness.

This focus on equipment defects has a large bearing on the way that everyone at the minesite becomes involved with TPM. Defects are often difficult to identify and correct because they are traditionally accepted as the norm. All employees need to adopt the attitude of questioning whether their individual actions are focused on avoiding defects or merely addressing the issues associated with defect removal. The paradigm shift required by management and all employees at the mine is to accept that they are able to, and want to, identify and correct equipment and process defects and then find their source so that they can be avoided in the future. This paradigm shift is a major ingredient in the implementation of the TPM process.

So, again, it is fundamentally important to realise that TPM is not a maintenance management technique but is a process that is applied throughout the total mine organisation as a framework for the application of business improvement initiatives.

The Eight Pillars of TPM.

The Centre for TPM (Australasia) approach, resulting from development and experience gained over the past five years, is based on:

- establishing a structure which will foster the introduction of continuous improvement techniques and the adoption of those techniques as part of the normal business processes;
- recognising that TPM success stems from a management commitment to involving all employees to assess and question equipment and process losses in all areas of the operation;
- challenging existing mind-sets;
- setting in place the appropriate tools and skills to ensure that the improvements made are sustained and expanded over time.

The "Eight Pillars of TPM" that form the framework supporting this process are:

- Focused Equipment & Process Improvement;
- Operator Equipment Management;
- Maintenance Excellence;
- Education & Training;
- Safety & Environmental Management;
- New Equipment Management;
- Process Quality Management; and
- Administration & Support Systems Improvement.

These Pillars of TPM interact in a polychronic way to form a support structure to underpin and promote the improved performance of the whole company through the TPM process. To successfully apply the principles of TPM, management and the workforce must realise and mutually accept that these Pillars require the whole company to be involved to take advantage of the significant gains that can be achieved.

The first five Pillars are most commonly applied in the operating process during the initial stages of the TPM Implementation Plan. As the culture of the workforce changes and equipment effectiveness improves, the remaining three Pillars complete the supporting loop to ensure the perpetuation of the improvement outcomes in the operating process. The application of the five initiating Pillars in a coal mine environment is discussed below.

APPLICATION OF TPM TO THE COAL INDUSTRY

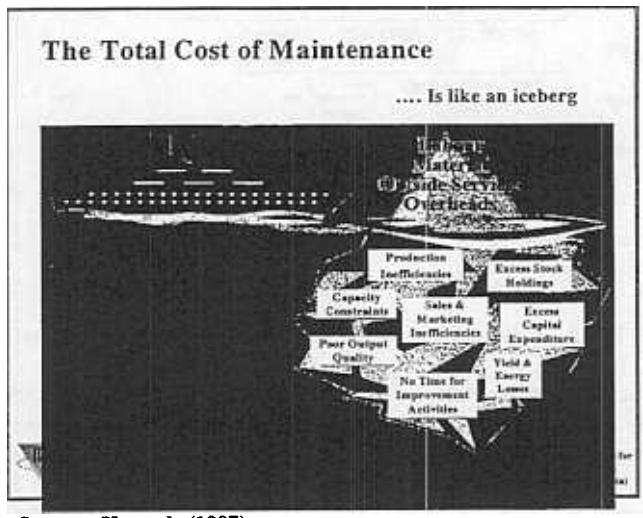
Scope for Application.

The scope for application of TPM to coal mining is immense. The harshness of the operating environment in most coal mining operations is a major generator of defects. And the coal mining industry paradigm accepts these defects as the unavoidable outcome of this environment. This attitude results in loss of productivity due to

- equipment failure or other unplanned stoppages, both recorded and unrecorded;
- equipment in a mining operation or a coal washing plant process idle while waiting on set-up time for, or availability of, critical equipment; and

- reduced output or increased waste due to equipment or processes operating below OEM specifications.

These losses also result in, or at least reinforce, the lowering of workforce morale due to frustration in malfunctioning equipment, and the resulting outcomes of absenteeism, poor safety performance and industrial unrest.



Source: Kennedy (1997).

Fig. 2 - The hidden costs Of poor equipment management

The current paradigm also results in maintenance strategies that incur major costs to the operation. Fig. 2 illustrates the exposure of the operation to those costs, both exposed and hidden, associated with consequences resulting from poor equipment management. A recent benchmarking study in maintenance practices in the mining industry by Strategic Industry Research Foundation (SIRF) (Holmes, 1997) has highlighted that, in over 50% of the mines included in the study, the maintenance costs per operating hour were more than double the equipment vendor's estimate of "best practice". Also the cost of maintenance of mobile equipment, ignoring consumable costs, was up to one third of the capital value of the fleet. This compares with expenditures on maintenance in best practice process industries of between 1% and 3% of capital value. The maintenance cost, again ignoring consumables, of mine fixed plant tended to be in the range of 2.5% to 6.5%, compared to best practice for comparable process plant of 3% or in the range of 3% to 4% in exceptionally difficult circumstances.

Another outcome from the SIRF benchmarking study was that, contrary to the currently accepted belief that age of equipment, mine conditions and equipment vendor are the predominant factors defining maintenance costs, these were of second order importance compared with the factors of work practices and culture at the site.

TPM Framework In A Coal Mining Operation.

The production losses for an item of equipment, such as a dragline or longwall face system, or a production process operating at a mine, such as a truck and shovel fleet or a coal washing plant, can be represented, on a time related basis, by a block diagram relating available time to the effects of loss categories as shown in Fig. 3. Overall equipment effectiveness is defined as the ratio of value adding time, after accounting for all losses, to scheduled production time expressed as a percentage. Although in continuous operations, planned maintenance time is included in scheduled operating time, in non-continuous operations this activity is excluded to remove the mechanism of skipping planned maintenance to improve OEE.

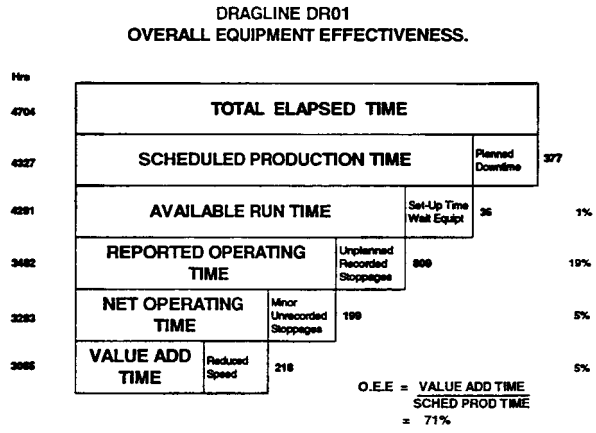
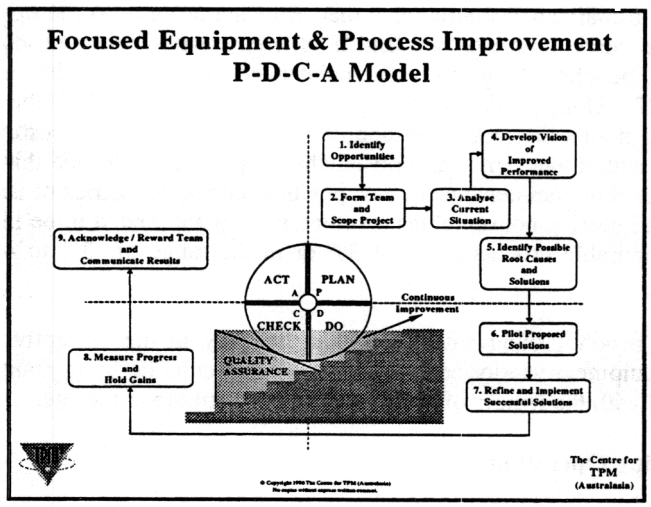


Fig. 3 - Production Losses – overall equipment effectiveness

The **Focused Equipment and Process Improvement Pillar** is normally the starting point for a TPM implementation programme, focused on strategically important equipment or process. The procedure, as illustrated in Fig. 4, involves the establishment of the "current situation" from continuous recording of losses or by sampling, and the identification and analysis of losses identified using first, second and third level pareto charts. Solutions are developed for the reduction of losses, and the resulting improvement of OEE, by cross-functional teams using root cause analysis and PDCA cycle techniques. Following trials, refinement, and implementation of successful solutions, each cross-functional team is disbanded. The task of achieving further gains to OEE, by continuous improvement techniques applied to that equipment or process, is handed over to the relevant area-based team.



Source: Kennedy (1997).

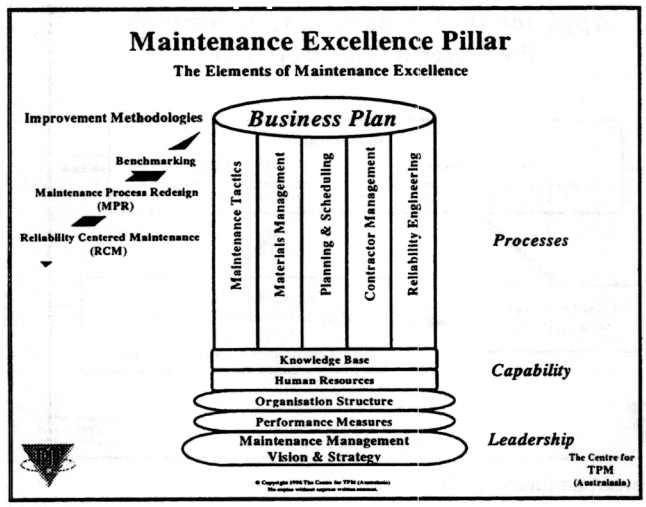
Fig. 4 - Focused Improvement & Process Improvement Model

The Leadership Team, consisting of mine management and TPM co-ordinator, provides the mandate for each cross-functional team, reviews and accepts the solutions, agrees to ongoing performance reporting and improvement activities, and recognises and rewards the contribution of those involved in the improvement of the OEE. This process is repeated, as required, at the instigation of the Leadership Team, with the objective of continually improving the level of OEE for the equipment or process over time.

The **Operator Equipment Management Pillar** is introduced at the appropriate time to achieve a self-managed equipment-competent workforce. Operator equipment management is about "caring for equipment at the source" so as to ensure that the basic equipment conditions – correct lubrication, no contamination, and no looseness – are established and maintained. This is a staged implementation by area-based teams consisting of operators and maintainers for equipment or process areas. These stages might be as follows:

- Recognising equipment defects and making improvements so as to achieve Basic Equipment Conditions;
- Understanding equipment functions and mechanisms so as to achieve Zero Breakdowns;
- Understanding the relationship between production and basic equipment conditions so as to achieve Zero Production Defects; and
- Managing the workplace so as to achieve Zero Accidents.

This does not result in a take-over by operators of the maintenance function. However operators become responsible for knowing when they need to carry out the simple defect avoidance and maintenance service work themselves, and when they should call in the maintenance experts to repair problems which they have clearly identified.



Source: Kennedy (1997).

Fig. 5 - Maintenance excellence pillar.

The establishment of this shared task zone provides the maintenance organisation at the minesite with the time to focus its resources on the **Maintenance Excellence Pillar** to optimise reliability and equipment management support. As illustrated in Fig. 5, this involves the application of leadership, capability and maintenance management processes, together with maintenance planning and improvement methodologies such as reliability centred maintenance (RCM), maintenance process redesign (MPR) and benchmarking, to move the level of maintenance management along the "best practice" continuum towards maintenance excellence. Without the foundation of a clear and well-communicated maintenance management strategy supported by an appropriate organisation structure, human resources and knowledge base, the introduction of TPM almost always fails.

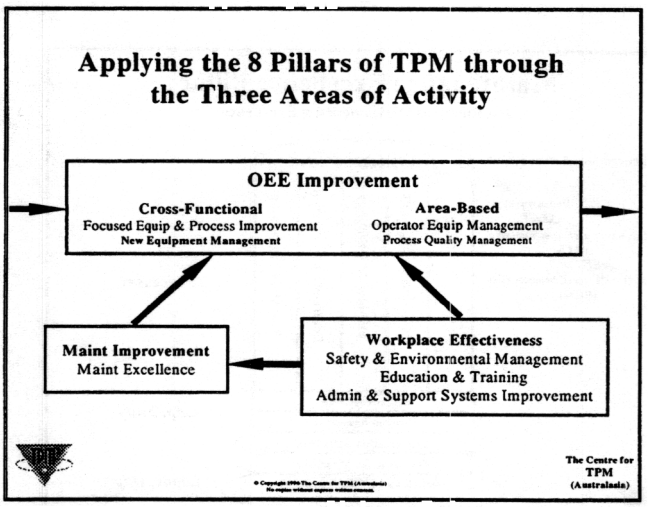
Implementation of the **Education and Training Pillar** supports the progress of these other Pillars, and requires a significant commitment to education and training both to challenge mind-sets and impart new skills. TPM is a "new way of working" for an organisation, focusing on the importance of equipment management for the success of the company. This Pillar ensures that this focus is clearly understood and held by all employees and including management. Following initial awareness workshops for all employees, TPM training should then be achieved, wherever possible, through "dirty education" processes where you "learn as you do" on the job.

The **Safety & Environmental Management Pillar** employs the resulting change to the behavioural approach of the workforce culture and also the safe work environment resulting from the improved basic equipment condition state of plant and equipment.

The other three Pillars are introduced at the appropriate time. These eight Pillars of TPM are applied to the overall business through the three areas of implementation activity that, as shown in Fig. 2.5, are OEE Improvement, Maintenance Improvement, and Workplace Effectiveness.

Current Progress in Introduction of TPM in Australian Mines

Although TPM is well established in the manufacturing industry throughout the western world, little information is available that describes the application and/or results of a TPM program implemented at mine sites in Australia or overseas. While many minesites in Australia have introduced some of the techniques described in this paper, either separately or as part of a previous TQM programme, with varying degrees of success, the author is unaware of any operations fully employing the TPM framework. However some pilot programmes are in progress and interest in TPM has been indicated by a number of mining companies that have attended TPM workshops run by The Centre for TPM.



Source: Kennedy (1997).

Fig. 6 - Areas of implementation activity

As an example of the outcomes achievable, the following improvements were observed by the author at Oaky Creek Mine in Central Queensland during implementation of particular techniques in the early 1990s as described below:

- Focused Equipment and Process Improvement (cross-functional teams) and Operator Equipment Management (area based teams) techniques applied to gateroad development resulted in a 65% improvement in metres per unit shift achieved in Maingate 4 over previous maingate development rates in the No.1 Colliery, after cross-functional team project outcomes, and attention to ongoing improvement by the area based teams.

- Operator Equipment Management techniques applied through area based teams in the coal preparation plant resulting, in part, to an increased throughput of 8% to a record output from the plant.

Some North American mines have in the past had considerable success through commitment to techniques and working practices that are now embraced by the TPM Pillars. These include US mines at Cyprus Twenty Mile Coal Company, Colorado, Western Fuels Association Deserado Mine, Colorado, Sabine Mining Company, Texas, Homestake Gold Mine, South Dakota, and in Canada at Syncrude Canada, Alberta. All of these operations rank among the most successful and highest productivity mining operations in the region.

EVALUATING THE SUCCESS OF TPM STRATEGIES

The focus for improvement activities in TPM is the trend of the OEE of the equipment or process considered. Run charts of OEE will provide trends or patterns of improvement over a specified period of time. This technique is useful in providing the teams, and the workforce at large, with a comparison of OEE before and after implementation of a solution, to measure its impact, and celebrate in its success. Progressive changes in Pareto Charts are also useful in showing progress in a highly visible format that provides incentive to push on for more improvement.

Other means of measuring the success of a TPM strategy, in terms of the changes in effectiveness of the overall operation, include the progressive review of the company's rating on operations innocence-to-excellence and maintenance innocence-to-excellence matrices developed by The Centre for TPM. The level of progress in organisational change is similarly gauged by progressive ratings on a culture innocence-to-excellence matrix using repeated employee surveys.

The success of a TPM strategy will translate to the bottom line through increased revenues from greater operations output, better safety performance, and reduced costs of production. Production cost reductions are achieved through lower maintenance costs (resulting from removal of defects generators), improved maintenance planning, and identification and reduction of the hidden costs of poor equipment maintenance. The continuous improvement techniques employed in the TPM process lend themselves to the establishment and charting of KPIs for measuring the progress in the critical success factors identified as affecting the achievement of these goals for the business enterprise.

TAILORING THE TPM PROCESS TO INDIVIDUAL ORGANISATION NEEDS.

A major characteristic of the TPM process is its flexibility of implementation. The order of introduction of the first five pillars and the variety of techniques applicable to the process provide the means of tailoring the application of TPM to suit the individual needs of a coal mining operation.

However some issues should be seen as underlying the introduction of TPM in any situation. Recent feedback suggests that the implementation model that works best involves the initial introduction of the process into a small number of targeted pilot areas within the mine operation as a learning experience, and for familiarisation of the management and workforce with TPM principles and techniques. The process is then cascaded progressively across the operation based on the early successes gained and the learnings achieved in those pilot areas by all stakeholders. Experience has also reinforced the need for a sound strategy in place to address the employee relations aspects of the implementation of TPM, including enterprise agreements, or similar understandings with the workforce, which include support for the process. This is of critical importance to demonstrate the strong commitment of management, from the CEO down, which is essential to the cultural changes involved in TPM. It is also essential in defining an agreed position with the workforce when issues arise which threaten the process, or the integrity of those employees involved in pilot schemes.

The minesite procedures required to successfully introduce TPM so that it will be sustained, and will achieve the desired results for all stakeholders, involve three main phases:

- Awareness and Preparation

  Creating a critical mass of initial understanding within the organisation for the need and potential impact of TPM, determining an appropriate implementation strategy, and motivating participation to move forward.

- Assessment and Planning

  Identifying the "stake in the ground" and the most appropriate implementation methodology outlining the potential benefits, costs and resources required, drafting a realistic implementation plan with measurable milestones, and gaining senior management commitment together with that of a sufficient number of other relevant stakeholders.

- Implementation

  Finalising the implementation plan and assigning initial resources, executing the plan with continuous feedback and regular reviews, and promoting the success to encourage progress so that expectations are realised.

However the methodology used must be flexible enough to ensure that the key issues of "how do we get all employees to contribute and participate in TPM", and "how do we ensure that TPM is integrated into existing business improvement initiatives" are adequately addressed. The Centre for TPM (Australasia), based in Wollongong, NSW, provides information exchange, training and consulting support to achieve these outcomes.

One common reason put forward as to why TPM has not been introduced at a minesite is the current time and resource commitment to other improvement strategies. A suggested approach to implementing TPM to overcome this problem is to structure other minesite programmes (safety, cost reduction, restructuring, capital replacement projects, etc.) into the TPM Pillars framework as part of the overall business plan, remove identified interface redundancies, and develop a timeline within that framework for effective implementation of the overall minesite initiatives programme.

CONCLUDING REMARKS

TPM implementation is not a short term fix for an ailing maintenance programme or a non-performing coal mine operation. TPM is a company-wide business improvement initiative involving all employees. Like Quality, it is a continuous journey. Experience gained in Australia and overseas indicates that 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 sustained. Suitable business planning horizons must be adopted to allow this to occur.

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