CHAPTER 8 PREDICTIVE MAINTENANCE

8.1. Chapter Overview

This chapter presents the facilitation of preventative and predictive maintenance strategies by considering the integrated asset management system that provides access to monitoring and diagnostic information. Predictive maintenance, based on the asset management system that provides accurate monitoring and diagnostic information is the focal point of Electrical/Instrumentation maintenance activities.

This chapter describes the predictive maintenance that is conducted by means of the integrated asset management solution as discussed in preceding chapters. This is the last block in the second stage of the SAMI asset health triangle, presented below in Figure 89.

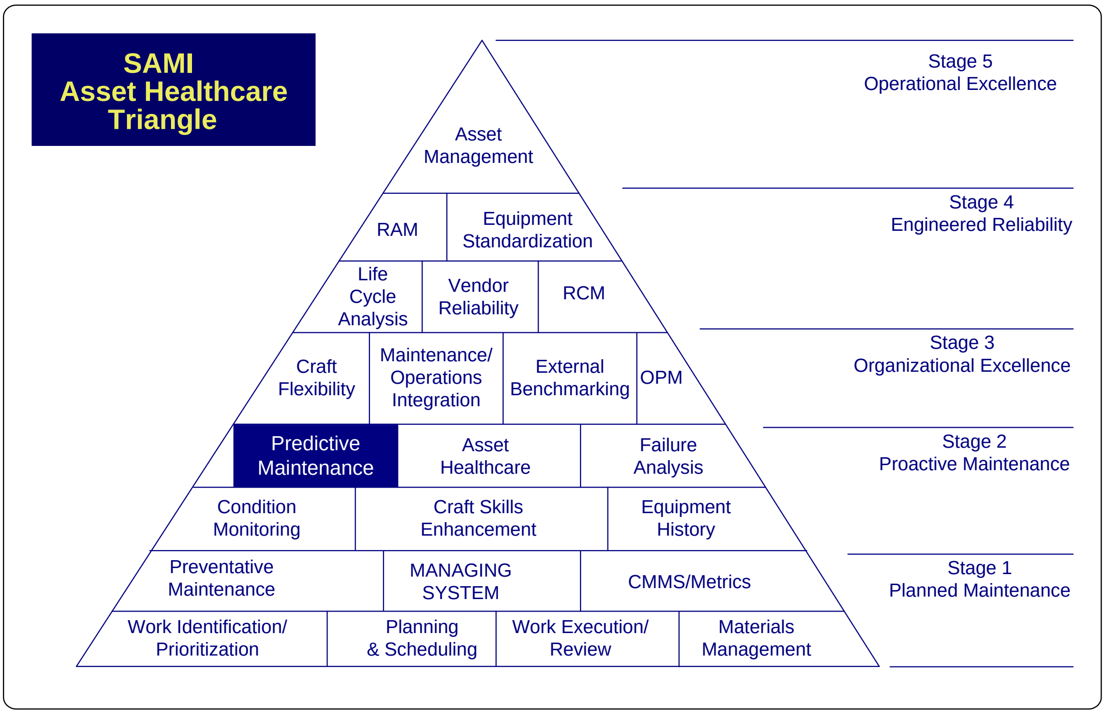

Figure 89: Predictive maintenance

8.2 The Context of Predictive Maintenance

In modern process industry plants, management continually strives to reduce production costs, an estimated one-third of maintenance expenditures are wasted. Maintenance averages fourteen percent of the cost of goods sold in many industries (Mobley 2002), making it a prime target for cost-reduction efforts. According to a DuPont report, "The largest single controllable expenditure in a plant today is maintenance, and in many plants the maintenance budget exceeds annual net profit". Optimizing the return on maintenance is now a key strategy for most process plants.

8.3 Maintenance Approaches

The lack of a considered maintenance strategy, results in evidence of the following patterns in plant operations and maintenance (Moubray 2003):

- Equipment failures that result in lost production and expensive repairs.
- The equipment failures occur repeatedly.
- Maintenance schedules are identical for similar equipment, regardless of application or economic impact.
- No maintenance standards or best practices exist.

A good maintenance strategy can address the above-mentioned symptoms and can improve process operations and maintenance actions whilst simultaneously reducing costs. An effective maintenance strategy can in fact be as important to the business results as the quality program.

The majority of maintenance strategies are based on one or more of four basic maintenance approaches namely (Moubray 2003):

- Reactive Maintenance
- Preventive Maintenance

- Predictive Maintenance
- Proactive Maintenance

The requirements or function of the control systems maintenance group in Solvents must be reviewed before the different approaches to maintenance can be discussed. The main function of the control systems maintenance group within the Sasol Solvent environment is to maintain the integrity, reliability and safe operation of all instrumentation, control systems and emergency shutdown systems on the three plants. This complex operational environment requires a specific approach for every different equipment category.

Ideally the plant management process must move away from reactive maintenance and towards proactive maintenance. By moving from one strategy to the next must be managed so that plant up-time is close to or 100 percent, safety is adhered to at all times and that environmental problems are kept to a minimum. Figure 90 below presents a graphics depiction of the requirements for the approaches namely Reactive, Preventative, Predictive and Proactive Strategies as discussed in Joubert (2006). The four approaches are discussed individually

The approaches to maintenance strategy, as presented above indicates that failures need to be properly managed in order to prevent serious production losses, and optimize production, reduce maintenance costs and ensure compliance to safety, health and environmental requirements (Sasol 2005).

Figure 90 shows that when a plant uses reactive maintenance failures and production losses are at the extreme left of a continuum where improved maintenance strategies start with time based maintenance. One of the most important aspects of such a managed process is that of maintenance strategy setting – deciding what maintenance to do, when and how often. Various strategies are combined to set up the maintenance plans for the maintenance of the Sasol Solvents facility.

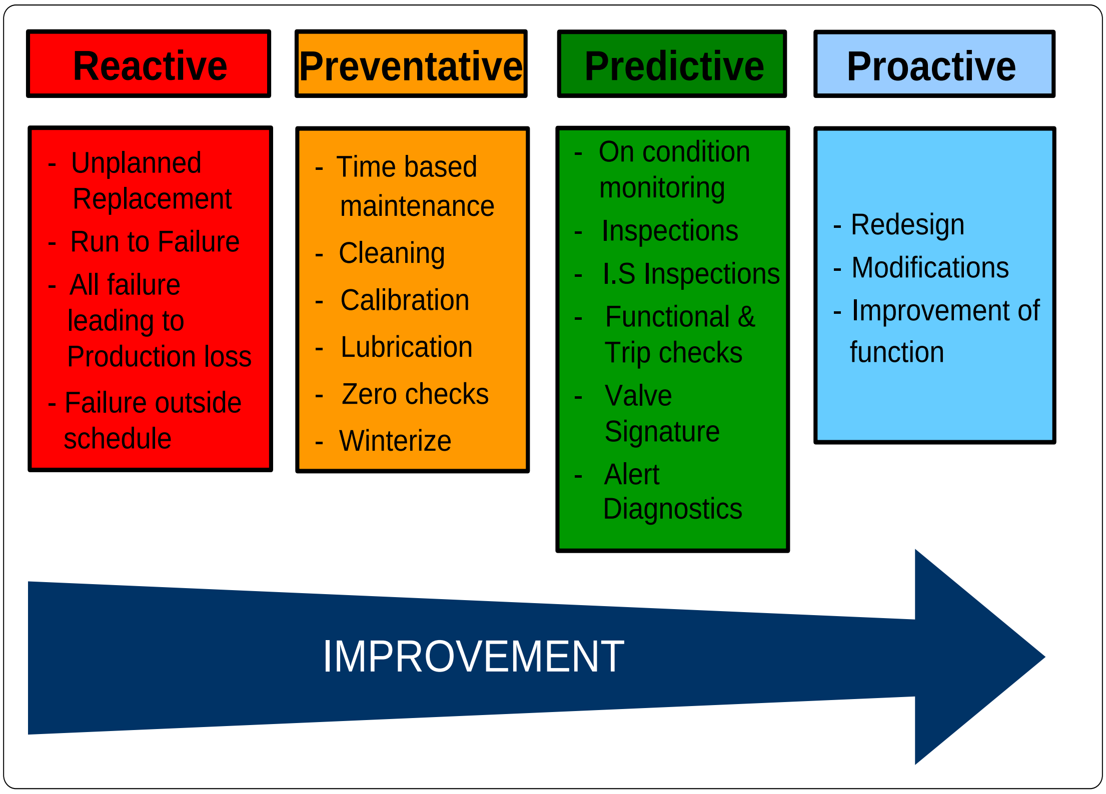

Figure 90: Maintenance strategy approaches

Predictive maintenance requires that on-condition monitoring and alert diagnostics are put into place. The technology that allows field devices to provide real-time systems diagnostics that can interface with a user friendly platform for diverse equipment data obtained from valve signatures and alert conditions. The interface designed and implemented at the Sasol Solvents Site required a considerable effort during this project and allowed plant personnel to move from preventative to predictive maintenance.

Plant operations managers need to make the required investment so that state-of-the-art technology and skilled human resources can enable maintenance strategies to become predictive in nature. Once predictive maintenance strategies are in place the shift to pro-active strategies is an easily obtainable business objective.

8.4 Maintenance Strategies

8.4.1 Reactive Maintenance

The oldest maintenance approach is **reactive**, or "run-to-failure". Equipment is used until it breaks and on failure the equipment is inspected and repaired or replaced as required (Moubray 2003).

Companies that rely on reactive maintenance strategies alone, find that they are faced by the following consequences:

- **Costly downtime.** Equipment fails with little or no warning; the production process therefore could com to a complete halt until replacement parts arrive, resulting in lost revenue.
- **Higher maintenance costs.** Unexpected failures can increase overtime labor costs, as well as expedited delivery of replacement parts.
- **Safety hazards.** Failure with no warning could create a safety issue with the failing equipment or other units that might be affected.

Reactive maintenance can be appropriate under certain conditions for a limited number of non-critical and low cost equipment that is considered to hold little or no risk of collateral damage and will not result in lost production. It's important, to make sure that downtime as a result of non-critical equipment failure will not have a ripple effect and negatively influence more critical equipment and processes.

It is alarming to consider that currently, the majority of maintenance strategies (refer to table 11) remain reactive in nature (Emerson 2005). The implications of a reactive approach include unplanned replacement of equipment and unscheduled failures that disrupt profitable plant operations. Failures due to a reactive maintenance approach often result in loss of production. In addition, unscheduled failures can lead to an even greater number of failures on control systems and equipment.

Table 11: Maintenance strategies comparison

	1988	2004	Best Cost
Reactive	55%	55%	10%
Preventative	30%	31%	25-35%
Predictive	10%	12%	45-55%
Proactive	5%	2%	5-15%

The reactive approach to maintenance requires that personnel must be equipped to deal with breakdowns on a daily basis, by means of effective planning and work execution system. In terms of the reactive approach, some equipment will be run to failure. Failure data will be captured on SAP, and analyzed to determine the effectiveness of preventative and condition based maintenance (Sasol 2006).

8.4.2 Preventative Maintenance

The **preventive** maintenance philosophy is also known as **time-based** or **planned** maintenance. The goal of preventative maintenance approach is to maintain equipment in a healthy condition. Selected service and part replacements are scheduled based on a time interval for each device - whether it needs it or not.

Preventative maintenance is also typically used on non critical equipment, although there are some situations where reactive maintenance may be satisfactory, especially when there is no history of performance problems and the equipment is not associated with a critical loop (Honeywell 2005).

As part of a typical preventative approach, transmitter calibrations may be performed every six months in critical areas. Although this approach may uncover possible problems, the majority of preventative check-ups are unnecessary because the tests are performed on healthy instrumentation.

Figure 91, presented overleaf indicates how preventive maintenance is related to the equipment-failure cycle.

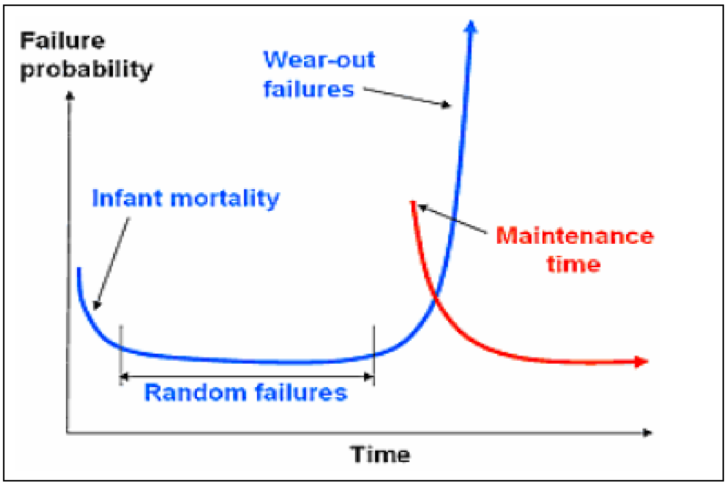

Figure 91: Equipment-failure cycle

The equipment failure cycle starts with a high probability of premature (infant) failures that result from manufacturing or installation errors. The probability of failures remains constantly low until the equipment begins to wear out. Preventive maintenance is scheduled to take place before the probability of failure increases significantly due the equipment run-time exceeding the estimated healthy life-time of equipment (Sasol 2006).

In reality, the maintenance schedule is rarely optimal. Time-based preventative maintenance is typically carried out too soon, which increases costs and decreases reliability (because the failure cycle again begins with a higher rate because of maintenance errors). Or the preventive maintenance comes too late, increasing the risk of wear-out failures. To time the maintenance correctly, you need to know the actual equipment condition and be able to predict the failure point (Sasol 2006).

Disadvantages of depending solely on the preventive approach include (Sasol 2006):

- **Wasteful -** Equipment or components may be replaced prematurely, while they still have plenty of useful life left.
- **Inventory costs -** A larger inventory is typically needed to support a preventive maintenance program.
- **Application-dependent wear often ignored -** In light wear applications, equipment may receive excessive and unneeded maintenance. In severe wear applications, equipment may receive insufficient maintenance. In addition, identical equipment in different applications may require different maintenance intervals.
- **No complete prevention of failures -** A misalignment could be causing bearing wear, creating a possible failure before the next scheduled maintenance.

While preventive practices can be an important part of your maintenance strategy, there's a growing need to include predictive and proactive maintenance as well. Scheduled maintenance will be carried out on specific equipment, and will be scheduled on SAP. These inspections will be carried out on a daily, monthly, yearly, and three yearly periods, depending on the criticality of the piece of equipment or system, the safety integrity level (SIL rated) of the control loops; government inspection requirements and Sasol standards based on experience and historical data from the asset management system (Sasol 2006).

Calibration, cleaning, lubrication and zero checks of equipment forms part of the scheduled maintenance. Winterization is also an action to prevent changes to process. Opportunity maintenance may also be done in this type of maintenance. All the maintenance is based on time / schedules activated by SAP.

8.4.3 Predictive Maintenance

In predictive maintenance, equipment condition rather than time intervals determine the need for service. Online condition monitoring helps identify when wear-out risk begins to increase and predict when failure is likely to occur. This approach can save time and money because it enables maintenance staff to correct the problem before the equipment actually fails. Downtime and repair costs caused by unexpected failure are avoided as well as the costs and lost production caused by unnecessary preventive maintenance (Sasol 2005).

Advanced predictive maintenance programs frequently modify the definition of a failure. Traditionally, a failure is defined as the point where the equipment breaks down and is no longer available for production. A more appropriate definition is that the equipment is no longer able to produce the right quality at the right production rate and the right cost. At this point, the plant is losing profitability and maintenance should be considered (Sasol 2005). .

Predictive maintenance techniques can be applied to all critical pieces of equipment capable of broadcasting information about their condition (i.e., intelligent devices). Critical equipment not having smart instrumentation can be covered by preventive maintenance-applying historical performance data to extend the intervals between scheduled maintenance periods.

There are two focus areas namely Condition based monitoring and Inspections. Condition monitoring will be used where applicable. Typical vibration monitoring on compressors will be done as well as on-line monitoring of the data from the different pieces of equipment. The inspections will include scheduled inspections, Intrinsic Safe (IS) inspections, functional and trip and alarm checks and daily plant inspections done by artisans. Valve signatures and alert diagnostics will be used on the more modern plants with the asset optimization solutions being planned and implemented.

8.4.4 Proactive maintenance

While predictive maintenance uses online condition monitoring to help predict when a failure will occur, it doesn't always identify the **root cause** of the failure. That's where **proactive maintenance** comes in. Proactive maintenance relies on information provided by predictive methods to identify problems and isolate the source of the failure (Sasol 2006).

Take the case of a pump that has periodic bearing failures. A condition-monitoring program may apply vibration sensors to the bearings, monitor the bearing temperature, and perform periodic analysis of the lube oil. These steps will tell when but not why the bearings are failing.

Proactive maintenance might add laser alignment and equipment balancing during installation to reduce bearing stress, lowering failure rates and extending bearing life. But it will also take the next step to find the sources of failures — for example, looking at cleaning procedures before tear-down to see if contamination during rebuild is a root cause for early bearing failures (Sasol 2006).

By determining these root causes and acting to eliminate them, it can not only prolong the life of the equipment. Many seemingly random failures will be eliminated and avoid repairing the same equipment for the same problem again and again. Whenever a failure occurs too often on any type of equipment, it is assumed that there is a need to modify the process or equipment. These problems can be modified working through the change management process (MOC).

If the modification is not working, engineering out the problem must then be considered. The relevant process and engineering staff will be called for a meeting to discuss the problem and give solutions that will be implemented as soon as possible.

8.4.5 Choosing a strategy

For most plants, the best maintenance strategy combines several or all of these approaches. The combination that will be chosen will both affect and be affected by work processes, expertise, technology and management.

The right mix will differ from plant to plant, as well as for different types of equipment. Generally, the more critical the process, the more expensive the equipment, the higher the potential for collateral damage, the more the maintenance practices move toward predictive and proactive strategies (Sasol 2006).

8.5 Maintenance Plans

Based on the above strategies, maintenance plans is developed for the equipment and control systems at the three different plants on the Solvents site. Maintenance plans developed will be worked into work orders, which will be available on SAP. SAP is utilized for planning and scheduling of maintenance actions. All work must be initiated by means of notifications (defects obtained from fault alerts generated by the integrated asset management system) and this work goes through a planning process.

8.6 Maintenance Procedures

Maintenance procedures address the safety aspects and the actual work that must be done. Each maintenance procedure is captured in a general procedure that addresses competencies of people working with instrumentation, responsibilities and authorities. The procedure is worked through by all artisans and signs that he /she understands the contents of the procedure. The legal appointed personnel also familiarised themselves with each procedure and the contents thereof. These procedures are made available electronically on the Asset Manager as discussed in chapter seven.

8.7 Change Management

Moving from a reactive to a more predictive maintenance strategy does not come easy if this was the mode being operated in for a few years. One of the aspects covered in the action research steps is the resistance to change from management and maintenance staff. Managers look at budgets and costs and are very sceptical about the integrated solution since it hasn't been implement elsewhere in a plant similar to the plants in the Solvents environment. Would the integrated solution bring the benefits as predicted at what cost from Sasol's side?

Maintenance staff looks at additional work and the unfamiliar field of equipment and systems. The following issues were raised by maintenance staff:

- New technologies being installed and used differently from old 4-20mA technology.
- Different plant control systems – training takes too long and complicated to operate.
- New asset management systems like AMS and Asset Manager software running on a PC – new learning curve and used to work with HART hand held device – different work methodology.
- Use of valve diagnostics to determine valve status – additional work during shutdown.
- Don't understand the different bus topologies and technologies.

How are heads turned and attitudes changed? The change management model from the book 'Culture change for leaders' was used to address the issue of change. The book stated the following: "Leaders are the catalyst for change in any organisation".

The following model in figure 92 is used to explain the change management process that was followed.

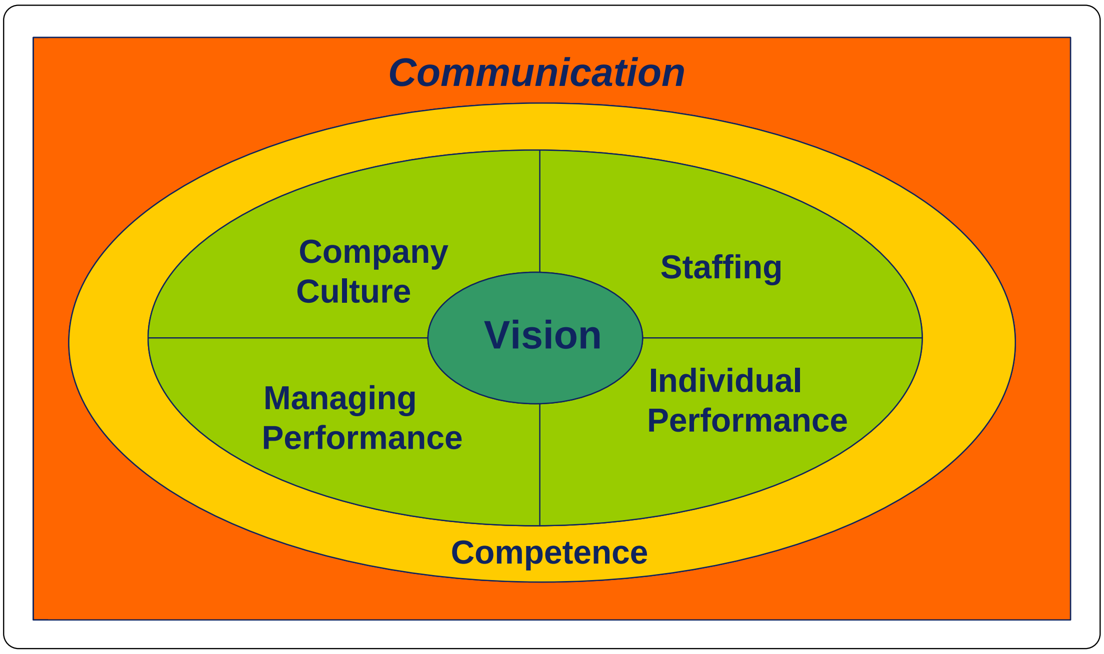

Figure 92: Change management model

A common vision was determined (Joubert 2005):

> "***We set the world benchmark, by responsibly managing & optimizing E&I assets, by balancing people skills with a development program.***"

Referring to the model it was necessary to use the vision to address the four quadrants.

8.7.1 Company culture

Addressing the company culture was crucial for top management to buy into the proposed solution and convince them of the possible benefits. This was achieved with lots of discussions and using the virtual machines (see 2.13) to demonstrate the functionality and the proposed integrated solution (Claassen 2005). The preliminary tests that were done, was used to show some benefits using some of the technology proposed in the final solution.

8.7.2 Correct staffing

The next step was to produce the correct staff for operating the new systems. The artisans and specialist artisans were already in a two year training process that was driven by me and the maintenance manager to achieve the correct staff with the correct experience and knowledge of the different systems.

8.7.3 Individual performance

With a skills development training program that consisted of external training from vendors and suppliers being implemented, it was possible to monitor individual performance on the different areas of the plant where the new technology was used. Training was also given on Wednesdays to enhance communication about the technologies and work processes.

8.7.4 Performance management

Managing the performance of all the maintenance staff and the flow of the proposed project execution for implementing the integrated solution was another crucial aspect that needed to be solved. Some of the implementation was going faster than other parts and this was crucial to manage the different time lines. Certain parts of the program such as the roll-out of the software was faster executed that the training to use the systems. Part of the changes was to implement small changes and not the normal conventional way of doing a full cycle project. This would have a major impact on the implementation of the integrated asset management solution on the live plants effecting production and logistics (Claassen 2005).

All of the above steps were done to ensure that the core competencies were developed and maintained. These competencies would be used to achieve the stated vision. Communication was the most crucial aspect of the model implementation. Everybody was kept informed of the implementation and the progress. One point to mention was that it was very important to the team of maintenance staff assisting in the project to give the smallest acknowledgement and to communicate the small wins to everybody.

Lao Tzu said:*" the best change is what the people think they did themselves."*

Claassen (2005) made the following statement:

> "*To change culture in an organization you have to re-program employees. Your leaders are the computer programmers and your computer analyst is your HR officer. Programming can only take place with good communication between the programmer and the computer (employees). The computer analyst must measure the effectiveness of the change."*

8.8 Benefits

Implementing the proposed integrated asset management solution on the Solvents plants it was necessary to evaluate the benefits achieved. These benefits are as follows:

- Superior return on assets.
- Significant reduction of maintenance and operating costs.
- Reduction of unplanned downtime.
- Abnormal situation avoidance according to the ASM Consortium.
- Creation of higher level knowledge in workforce.
- Empowering maintenance work force.
- Prevented five plant trips, ± R12 million (USD 2.35 mil).

- In shutdowns valve diagnostic capabilities on control valves was used to determine which valves should be removed from the plant. Only 40 valves out of 350 were removed and saved R1.2 million (USD 0.13m). Valve signatures of all installed control valves, when they left the suppliers factories are in the history folders in the Asset Manager package. The current valve signatures are compared with the blue prints from the factory for each shutdown (Joubert 2005).
- Detected faulty or poorly optimised valve positioners (Saved R2.1 million (USD 0.32m).
- Audit trail on instruments (changes captured). Important for Management of Change – SAFETY.
- Quick download of settings when changing transmitters – Save artisan time.
- More effective, focussed maintenance – Less break down maintenance and more planned maintenance = Reduced maintenance cost.

From figures 93 and 94 the benefits achieved using the integrated solution are shown. This info is retrieved from SAP to monitor the trends in the different maintenance strategies.

From the graph it indicates the decline in reactive maintenance after the installation and implementation of the integrated solution. Preventative maintenance is going done and the predictive maintenance is increasing. The estimated cost saving in the reactive maintenance component is in the region of R77 000 (USD $11000) per year (Joubert 2005).

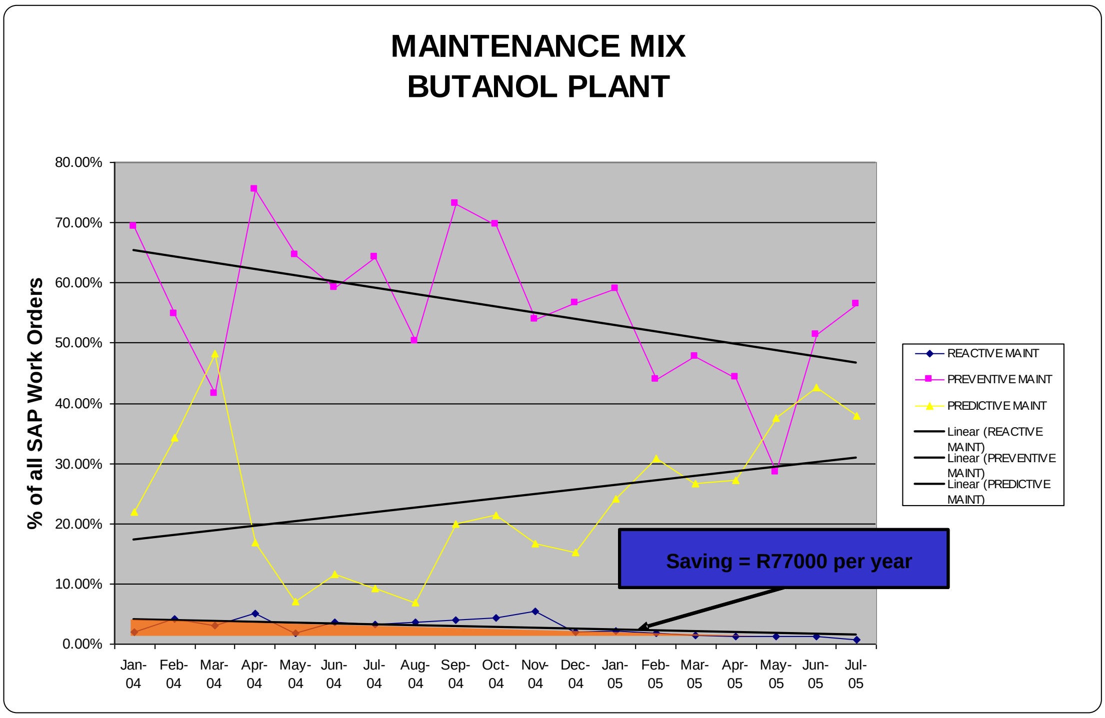

Figure 93: Maintenance mix on the Butanol plant

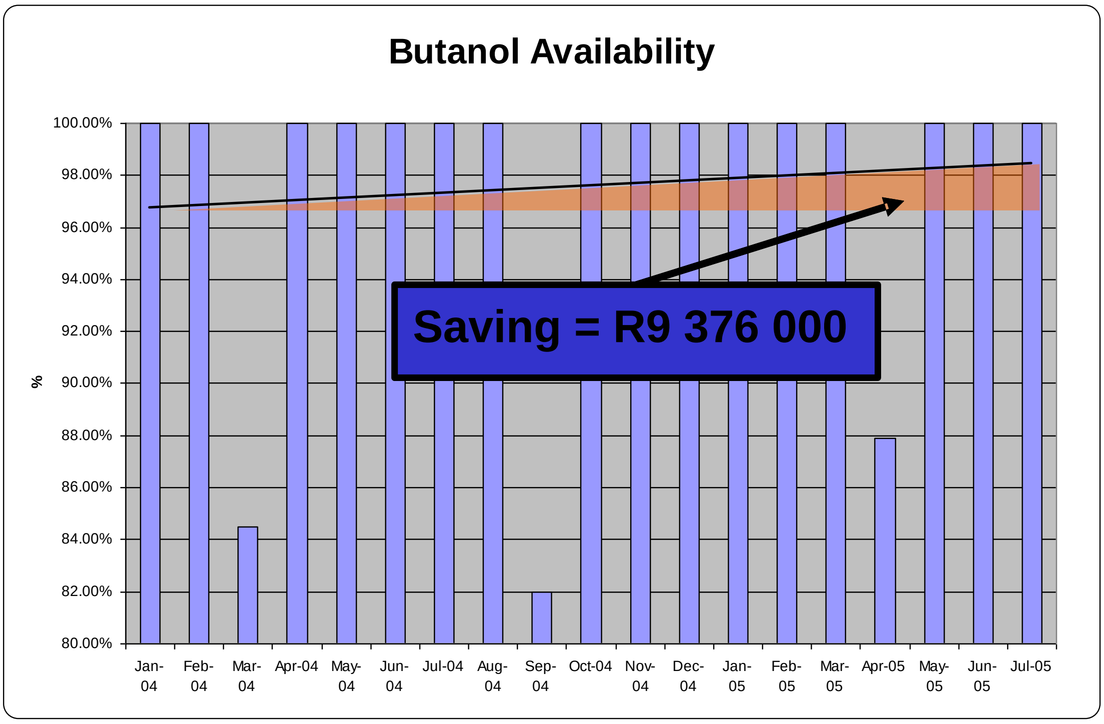

Figure 94: Plant availability on the Butanol plant

After the installation of the integrated asset management solution, the plant availability started increasing. This produced longer plant uptimes, higher production figures and better optimized plant operations. From figure 94 the plant availability for the Butanol plant is shown. Over a period of a year an estimated saving of R9.376 mil (USD $568 000) was achieved (Joubert 2005).

8.9 Conclusion

By implementing a total integrated asset management solution and managing the change control to get maintenance and process personnel competent, it is possible to move from reactive maintenance to predictive maintenance. The integrated solution will increase reliability by combining embedded diagnostics from all plant systems and smart field devices. It will dramatically reduce the time required, in the region of 40 to 60 percent, to identify and resolve system and device faults and abnormal conditions. Optimizing all the control loops on the plant will add to the reliability and produce more consistent production rates and ensuring longer periods of plant availability. It also increase user performance (safety and effectiveness) while reducing the annual training budget.