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Informed Maintenance Planning

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The starting point for improving maintenance planning is the establishment of a maintenance policy which embraces a work flow system, various techniques in monitoring reliability and work practices, and anticipates plant problems rather than reacts to them. This means that the company has a commitment to sustaining an information base which requires accurate data collection, effective management and timely disbursement of reports. The planning has to be reasonable, considering the level of available resources and the speed with which they may be dispatched.

1. Introduction

There are two primary tasks associated with maintenance management: planning the optimum schedule of work and ensuring that the effort has been effective. It would be reasonable to suggest that the more intensive effort is associated with the first area of work: it has to be responsive to both business objectives of the plant and the current integrity of the equipment. Planning has to incorporate a variety of task types from breakdown work, preventative maintenance and survey work, [1]. In addition, it has two modes: planning for overhauls and day to day tasks required for operating plant. Hence planning absorbs a large portion of time for personnel ranging down from the maintenance manager, the planning group and the trades staff who are responsible for executing tasks.

Maintenance is necessary as a function of design issues, the onset of damage mechanisms, sensitivity to operations and generally determining the risk for a desired service life to be cut short. These issues are relevant to improving the planning process so that problems are anticipated. This provides a proactive approach rather than a reactive approach. Proactive planning will ensure timely warning on the need to provide capital for plant improvements and the possibility that a facility will not deliver the required performance at some time in the future. It is this sense of anticipation which represents the step forward of modern maintenance planning over the primarily responsive approach adopted in the past.

2. Maintenance Improvement Model

A program for the improvement of maintenance within a company is set out in Figure 1. The objective of this program is to provide a means by which the assets of the company are operated and maintained with the knowledge of their current and expected future capability, [2]. There are three lobes to the process: condition-based maintenance, strategic planning for the assets and optimisation of maintenance to suit production.

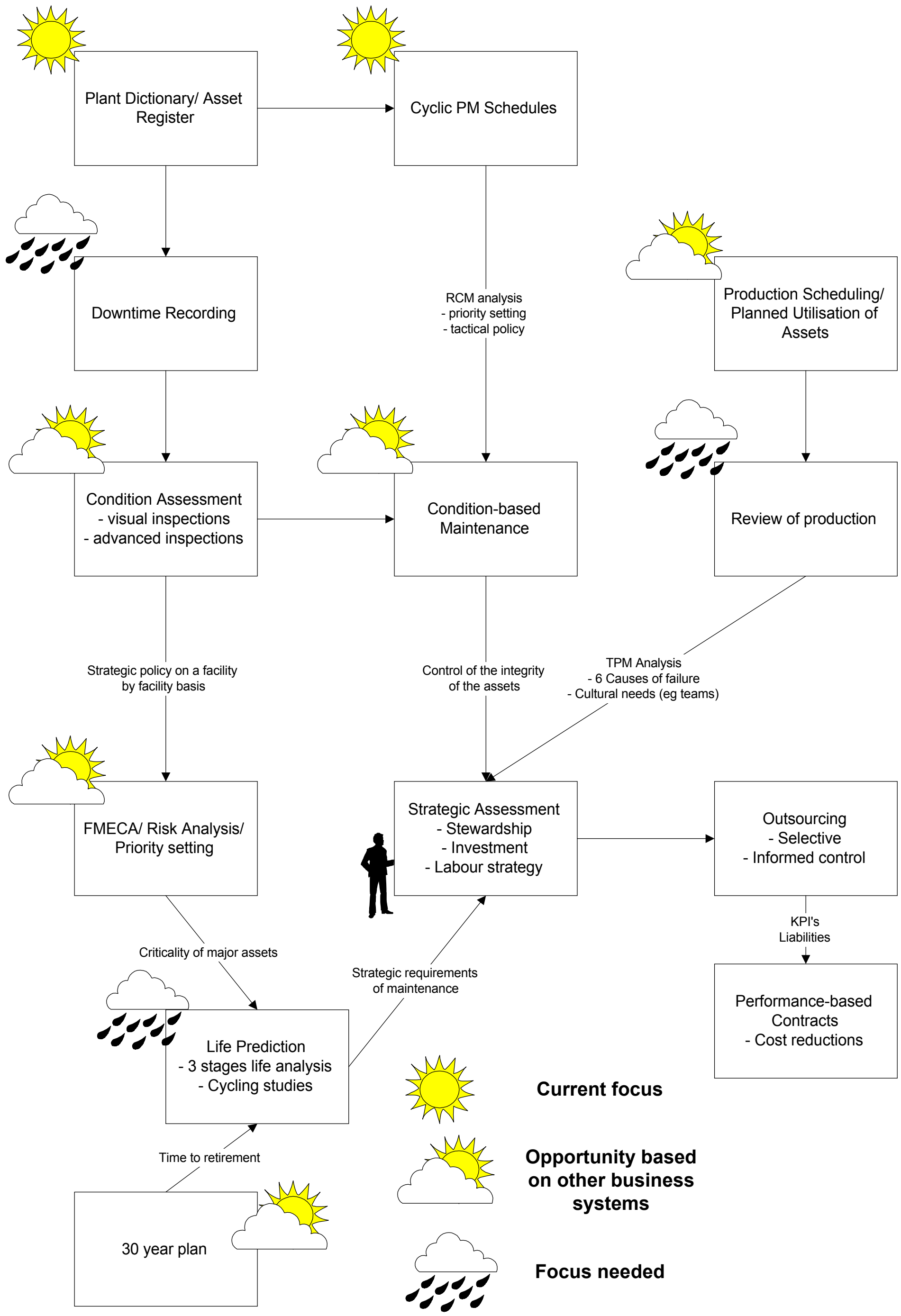


Figure 1 Maintenance Improvement Strategy

Ideally one would like to do everything at once, but no company can sustain more than about four or five improvement tasks at any one time. As a consequence, a company needs to move to elements of condition-based maintenance first, then to adopt improvements in each of the other two lobes, and then to take stock of their future management of their assets. There is no clear advantage in whether to progress the strategic lobe or the production optimisation lobe before the other.

The condition-based maintenance lobe has two paths incorporated in it. The left hand path following downtime tracking and inspection strategies are primarily focused on operations staff better understanding the capability of the equipment which they control. The right hand path is for the maintenance staff to analyse their performance and to improve their planning. Reliability-centred maintenance is a powerful, risk-based technique [3] which we employ in the right hand path to reduce the total amount of maintenance undertaken. But we also recognise that it is only possible to achieve this by improving the surveillance of the plant so that problems which would normally be prevented by a greater preventative maintenance program, are anticipated and corrected before downtime arises.

The strategy behind Figure 1 is that it shows the dependency of activities. For example, condition-based maintenance cannot be imposed on a site which practices reactive maintenance without first setting up a comprehensive, cyclic preventative maintenance program. In addition, maintenance performance improvement is only possible when a mechanism which is the equivalent of a work order allows effective information capture. An inspection system should not be rolled out prior to the establishment of a downtime tracking system, without running the risk of creating unnecessary inspections and missing others which would prevent failures such as have arisen in the past.

3. Strategic Goals versus Day to Day Management

There are two levels on which maintenance planning is undertaken: the strategic level and the day to day organizing of maintenance tasks. The strategic planning of maintenance is concerned with whether or not the equipment which makes up the facility will meet both its current requirements and those set for the long term. Hence strategic planning requires an appreciation of the business requirements and the manner in which operations will degrade the plant, [4]. For example, if it is forecast that the facility will produce smaller batch sizes and that a greater degree of flexibility will be demanded in the future, then strategic planning has to accommodate possible increases in the maintenance budget due to accelerated wear out from change overs and stoppages. Alternatively, if it is determined that the facility is becoming less efficient than corresponding plants elsewhere in the company, then strategically it would be intelligent to reduce the maintenance expenditure and tolerate a possible deterioration in the equipment. This may be partially offset as the throughput reduces as more efficient plant elsewhere picks up more of the production burden.

The vision for one maintenance group in a medium-sized manufacturing company is:

To provide a cost effective and efficient maintenance service by changing the focus from the existing reactive service and evolving into a proactive, predictive, preventative maintenance service.

This vision will suffice while this group progresses from a cyclic maintenance program into a condition-based maintenance approach to planning. As the group grows in its capability and in its confidence of what is can achieve, then the vision will expand. The end vision for a maintenance provider may read something like:

To ensure that the assets of the company will be reliable. This will be achieved by anticipating deterioration and addressing its root cause by technical means and education of company personnel. The timing at which these actions will be initiated will be set through a mature financial appreciation which takes into account the optimum time at which items may be removed from service.

This vision statement sets out the primary purpose, how it will be achieved and when. The relevant who for this statement is the maintenance group for whom this is the vision. The relevant what (has to be done) is left for more detailed strategic documents.

The day-to-day objectives of maintenance requires work to be grouped into two categories: maintenance and plant improvement, [5]. The distinction needs to be made in order to differentiate the costs of retaining equipment in its working condition as compared to improving the process. The types of work which need to be tracked on a daily basis includes:

Unplanned work: Any work arising that has not been included in a schedule of work. This includes breakdowns, requests for operator assistance and opportunistic work undertaken while the trades person in the vicinity. In some cases this work does not attract a production stoppage penalty, but all categories represent periods when the timing of the work is not controlled.

Planned work: This will include preventative maintenance tasks (which prevent a breakdown), predictive maintenance inspection (to determine condition of equipment) and scheduled overhaul work, all of which form a schedule of work. Labour and parts are prepared in advance in order to complete these tasks.

Capital Improvement: Work which requires managerial or corporate approval of funds. This work may fall outside of the maintenance contract and therefore a tendering process may be in place to win the work. There may also be a requirement to carry out justifications and design work as part of the preparation to tender.

Plant improvement: Any works that require capital expenditure to the limit of authorisation of the plant managers or equipment upgrades as part of an ongoing improvement program. This work may take the form of a project that has been developed by operations staff and would generally be completed by the maintenance provider. These projects can sometimes be experimental and it is therefore important to clarify the scope of work as recorded on the work order.

Raising and acquitting a work order is a key to the success of the maintenance process. Although the system can be fast tracked to complete urgent work the loop must be closed in order to capture all of the required information that will allow the management team to make value judgements as to the integrity of the equipment. Another key issue in the tracking of data via the work order system is that of finances. It is not only important to invoice the correct value to the owner but also to be in a position where the maintenance provider can measure his performance and apply suitable improvement programs.

4. Work Flow Systems

The fundamental strategy is first of all influenced by whether or not breakdowns may be tolerated. While all breakdowns are undesirable, there is an added investment required to ensure that they absolutely never happen. For the majority of industrial facilities this investment is not warranted in terms of the business objectives. A grading of industrial facilities would look like:

99.9% - high investment justified by financial return
90% - best practice service facility
80% - best practice manufacturing facility
60% - average performance facility which is not world class
40% - poorly performing facility

The rankings may be interpreted as follows: if a facility has a reliability such that its maximum utilisation level is between 90 and 99.9%, then it equates to a best practice service facility such as a sewage pumping station or a power station. Note that we use the term utilisation level and not more common terms such as availability or capacity factors. This allows us to include setup times but not idle times when there is no demand for the product or service. The reason for this is that there is no guarantee that a low demand unit receives the maintenance investment necessary for it to operate at higher levels of utilisation.

We note that the industry standard for costs of work is as follows:

$$Cost\ of\ Breakdown = 3 \times Cost\ of\ PM = 9 \times Cost\ of\ PDM$$

where *PM* is preventative maintenance and *PDM* is predictive maintenance. This rough approximation is based on the fact that Breakdown work includes cost of lost operation, premium time rates and possibly urgent purchase of material. The PM work covers the cost of material (possibly up to 60%) as well as labour plus the cost of access, whereas PDM is largely a labour cost.

If we consider the strategy of maintenance, then we may form the table below to collate the necessary information linked to a strategic outcome. Following the gathering of this information we then need to consider the following questions:

1. Do we have a well managed work flow system which captures the necessary data to provide the information required in the above table?

2. Where are we spending our money and do we need to reallocate the resources?
3. Do we sufficiently audit our capital spending such that we are investing in the future of the equipment and not overcoming the mistakes of the past?

Past experience	*Future prospect*	**Strategy**
Downtime rate Plant condition Work order history		1. Improve utilisation 2. Recover integrity 3. Optimise planning
	Production expectations New technology Life assessment	4. Target equipment 5. Capital planning 6. Capital planning

In the first instance we need to map a work flow system by which we can measure and hence manage the process, [6]. It is the first step towards firming up what data needs to be captured, at what stage it is trapped and where it ends up. An example of a proactive maintenance work flow system is laid out in Figure 2. There are three types of work identified in this system, which follow the categories discussed in the previous section:

1. Work over which there is no control of the timing
    - Equipment failure
    - Partial loss of availability which has to be regained
    - Failure of return to service
    - Secondary damage which needs to be immediately rectified
2. Planned work over which there is control of the timing
    - Cyclic preventative maintenance procedures
    - Cyclic inspection requirements which require the plant to be off line
    - Cyclic requests for condition monitoring with the plant on line
    - Corrective actions which result from either secondary damage associated with a failure or identification of a problem on the plant
    - Completion of an outstanding piece of work which could not be completed earlier due to resources, access, lack of spares, etc.
3. Plant improvement work which will lead to an integrity upgrade, a production enhancement or the elimination of a potential risk. Typically this work can wait until a suitable time such as an outage.

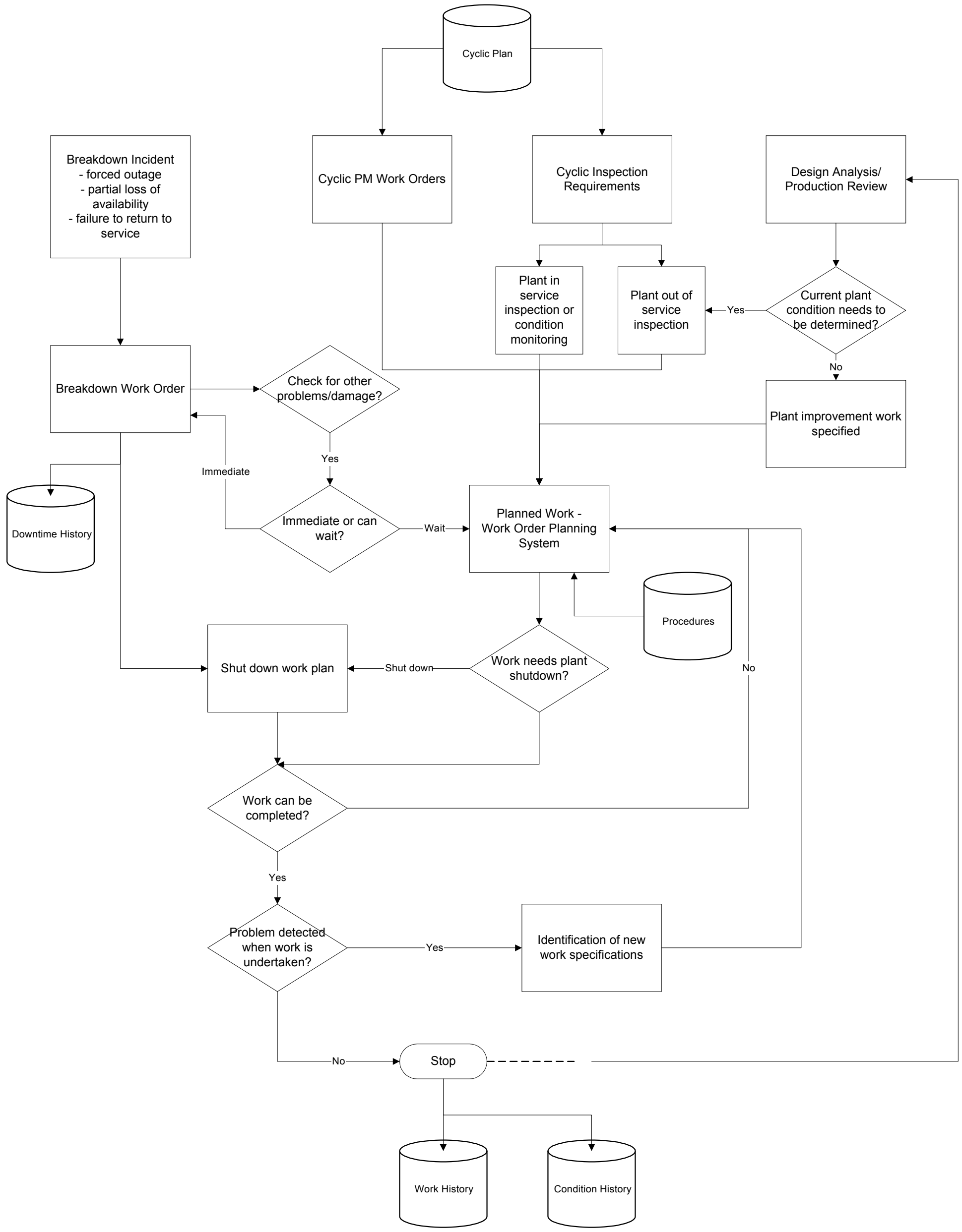


Figure 2 Maintenance Work Flow

No condition monitoring or plant inspection activity should be carried out unless there is a specific work order, naming the timing of the activity, is released. The maintenance system cannot contain the information resulting from the activity but the incidence of the activity has to be logged in the maintenance system.

We may distinguish between a number of information systems which have different purposes:

System	Content	Purpose
Maintenance System	Cycle times for standard activity Work procedures Logging of work order activity	Manage and log the work effort invested into the plant.
Downtime (Partial Loss of Availability) System	Log incidences of loss of reliability/availability	Identify equipment-based threats to the business.
Plant Condition History	Record the results of inspections and condition monitoring activity	Relate the condition of the plant and identify areas of possible weakness,

A plant item may be considered to need attention if:

- The maintenance system identifies that we are spending too much money on it.
- The downtime system identifies frequent failures there.
- The plant condition history identifies that its condition is degrading at too rapid a rate.

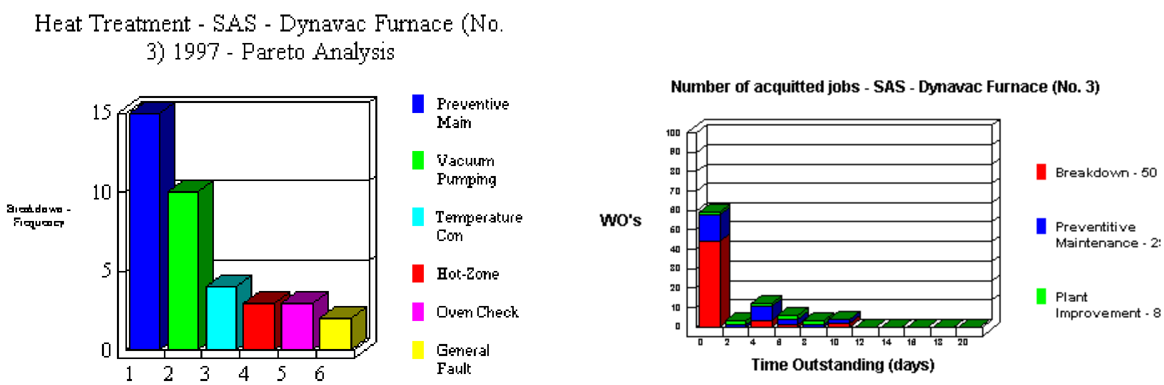
It is not possible to combine or integrate these systems since their underlying philosophy is quite different: they have a different purpose, the timing in which data is collected is fundamentally different, different staff classifications enter the data, and the data may well be analysed by different groups with different objectives.

Measurements in a predictive maintenance context are collected to identify the current condition of the equipment and to forecast the time for optimum replacement. As such a single measurement has value in meeting the first objective but little value for the second. Hence the maximum value of data is realised when measurements can be analysed as a group collected over time and in comparison across plant locations. This provides specific obligations on the management of condition monitoring and plant inspection data. The data must be held in a manner which allows the trending of the data to provide an impression of what the future will hold. The data must be objective in order to allow comparison; hence inspection results cannot be solely comments but must have some form of quantification. No measurement is made without first identifying the analysis which it will feed, the outcome from that analysis and the decision support such analysis would provide.

5. CMMS Feedback

Improvement processes combine both a field or plant activity and a back-up information activity, typically conducted through the computerised maintenance management system (CMMS). The second item is as important as the first in order to ensure that improvements are documented, information flows and decision making is informed, [7]. This ensures a cultural improvement plus the success of improved communications. If people expect to have certain information supplied to them, breakdowns in the communication flow will generate attention on trouble spots which are indicative of more fundamental problems such as neglect or waste through repetitive work.

A comparison of downtime and maintenance performance data is shown in Figure 3 for a heat treatment furnace. The data spans about 10 months and does not include about 10 cyclic maintenance work cards, some of which are carried out on a monthly basis.



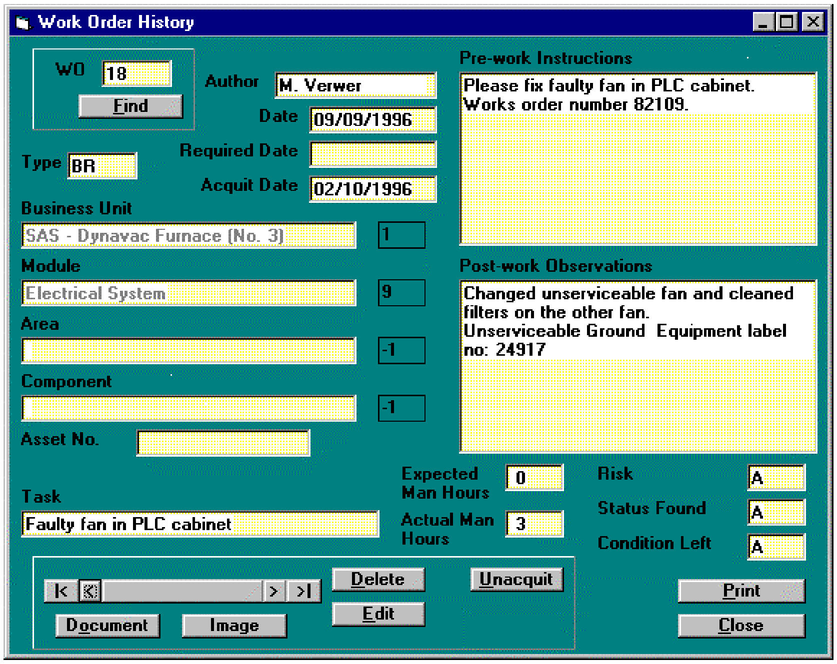
Downtime analysis *Work order response performance*

Figure 3 Analysis of SAS Dynavac furnace

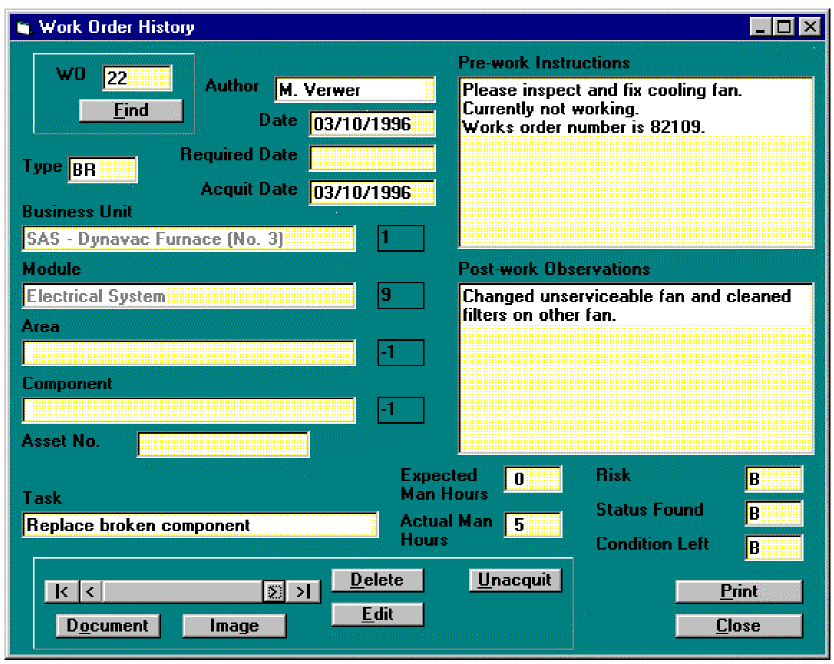
There are some clear mismatches between the data: for example, 35 downtime incidents were recorded but 50 breakdown work orders were logged. We expect that the downtime data is reasonably correct but we may be missing some very brief incidents, or equally likely we are seeing evidence of repeat visits to the same failure. The data is providing us with a basis for further investigation.

The balance of PM to breakdown work order is not satisfactory, but the scheduling of PM's is also poor with 15 PM's being blamed by operators as preventing the use of the asset. The downtime analysis is owned by production staff and gives substance to their observations in a meeting with maintenance staff. On the other hand, the work order performance analysis put forward by maintenance shows how they are providing resources and an analysis of the details of each work order will demonstrate how they are currently addressing the downtime problems recorded by production.

If we consider a history record for two breakdowns which occurred on this machine within one month of each other we gain further insight into the maintenance performance.



Breakdown on 9/9/1996



Breakdown on 3/10/1996

Figure 4 Breakdown work order samples

The furnace operates in a gritty environment so fouling of the filters is a reasonable expectation. If the two cards are compared, it took some time for the maintenance providers to respond to the September 1996 failure and the work was actually discharged one day prior to the October failure. This job was attended to and acquitted on the same day the problem was registered.

In both cases the risk to the plant was minor:

September breakdown - Risk A: No risk to plant operations
October breakdown - Risk B: Exposure to risk if another component fails

The second job required 5 hours to fix. It is not known whether or not this includes travel time to the job which is an issue since the furnace is located on a large jet base. In looking at the record of what was done, in both instances the filters were cleaned on other fans. This may be taken as an example of competent practice, but in fact suggests that the preventative maintenance program is lacking: why aren't the filters of these fans cleaned before the fans fail? Why weren't all of the filters of all fans on this furnace cleaned when attending the September breakdown? In other words, where is the planning role working to prevent a breakdown call out, particularly when a heads up was provided that filters were dirty during the September call out? This is not the fault of the trades person, but rather the planning system associated with caring for this unit.

At this particular site, the type of information provided above has been given to the superintendents of the production process which uses the furnace. As these middle managers are educated in the system, there is an expectation that they will lead inquiries such as the questions raised above. Similar to many modern CMMS's, the information I snow available to the company, but a system is required to exploit it.

The elements of such a system include:

1. Production own the downtime data and meticulously record failure events, being particularly careful to log the reason for downtime.
2. Production attempt limited inspections, in keeping with their technical expertise, but raising their awareness of the condition of the assets that they use.
3. Production move to a greater sense of ownership of the assets, demanding more detailed information from maintenance regarding the condition of their equipment and the service provided by maintenance.
4. Maintenance review the history of their performance, particularly focusing on breakdown attendance. Where could work have been anticipated?
5. The two groups jointly review the inspection program in the light of information raised under items 2 and 4.

There are two key terms here: <u>stewardship</u> for production and <u>client service</u> for maintenance. Both terms set obligations on each party.

6. Control of Personnel Dispatch

There are many sources of internal waste associated with maintenance. These include:

1. Travel time to and from a job
2. Additional travel time to collect spare parts/tools necessary for a job
3. Waiting for access to a machine/site
4. Wasted time due to lack of knowledge - design information, correct procedure, appropriate diagnosis of a problem

Much of this waste can be eradicated through the employment of a planned maintenance route which encompasses a list of the following:

- Path along which the trades person must travel
- Prepared list of spares and tools
- Provision of detailed instructions and access to support documentation

By implementing this approach, a maintenance provider will optimise the use of their trades people. If the maintenance routes are not planned then the trades person will rush from one job to the next with the outcome that less time is available for diagnosis plus the guarantee that the repair represents a permanent fix.

The key person in the maintenance chain is the equivalent to the planner who is responsible for allocating tasks and planning the work. Hence this position has to be formed on behalf of the operations client so that a person can direct maintenance traffic throughout a facility.

Work can be allocated on the basis of three parameters:

1. Criticality of equipment
    - Agreed levels established in the contract
    - Subject to alteration due to changes in operations
2. Risk outcome - outcome if work is not done
    - Human safety, environment, availability, minor hazard
    - Statutory requirements
3. Potential to batch a job with other necessary work
    - Function of the location of resources
    - Minimise internal waste

A dispatch model needs to be established for an organisation which suits the manning structure and the allocation of responsibilities between, for example, different groups who provide a maintenance function.

7. Conclusion

The starting point for improving maintenance planning is the interface between operations and maintenance, to identify sources of uncertainty which would adversely affect the planning and execution of maintenance tasks. In particular the focus needs to be on the capability of the two groups to work together to reduce the maintenance costs.

In one study conducted in a medium-sized manufacturing company, four primary problems were identified:

1. Lack of accountability in raising requests for maintenance
2. The need to provide an overview of the maintenance system which is in place
3. Demonstration of the optimisation of maintenance tasks and the sustaining of this effort in the future
4. Inventory management and the need for identifying appropriate availability of spare parts including the reduction of both on-site stock and the reliance on overseas suppliers.

The answers to these problems are straight forward systems which have had reasonable success in other manufacturing environments, both in Australia and overseas, and which have been described in this paper.

The paper specifically addressed the management of maintenance work plus the need for ensuring the accuracy of downtime tracking. This is not a device to be used for the advantage of either operations or maintenance, but the vital supply of technical information upon which a proactive maintenance system may be based. The discrepancies between the records in the two systems is the focus of a meaningful discussion which will improve maintenance planning.

While data has to be collected to improve decision making, it has to be delivered within effective reports which suit various levels of readership. The presentations made in thsis paper were pleasing to the eye and relied on both graphics and a blocked layout of comparable information. The ability to scroll through such information and providing access by operations managers to the details will improve leadership in maintenance improvement by the people who will benefit the most: operations.

Acknowledgments

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