Case Study
Implementing Preventive Maintenance at a speciality paper mill

Expanded from a paper presented at a paper industry Best Practice Maintenance Conference

A pragmatic solution

Every maintenance improvement programme is different. Each enterprise contemplating change is faced with a unique combination of needs, opportunities, obstacles, and constraints. These include considerations of plant availability, reliability, product quality, available resources, affordability, urgency, embedded culture and legacy systems. Any improvement programme setting out to bridge the gap between the existing and desired future states is obliged to take account of the particular prevailing factors.

This paper is an account of one such rapidly implemented, quick payback, pragmatic solution to a business-threatening maintenance problem.

Background

A major expansion

During the 90s a major specialist paper manufacturer announced plans to build one of the most advanced paper machines in the world at one of its existing mills. The nearly £40m investment would consolidate the company's position as a leading supplier in the global market. The highly automated mill extension would include computer controlled paper machinery, fibre 'stock' preparation and chemical make-up area and an effluent treatment plant returning potable quality water to the local river. The new facilities would increase the company's production capacity by 60%.

At the time, the world-wide tempo of paper industry investment was low and paper technology and equipment vendors were eager to supply on very favourable terms, not least of which was short delivery period. Following a rapid build, the project moved into start-up just two years after kick-off.

Crisis – unreliability threatens

Having eliminated the 'day one' problems with major equipment, the mill's engineering team turned their attention to the more general failures affecting the plant. Sudden failures were occurring regularly for a wide variety of causes, for example, blocked filters, loose drive belts, bearing seizures, etc. These incidents were seriously jeopardising production and profitability.

A year into start up the reliability situation with the new facilities was becoming intolerable for the business. The equipment and systems had been well engineered, but preventive maintenance (PM) was needed in order to realise the benefits of the high reliability designed into the plant. To achieve the required plant uptime and product quality, the mill's management directed that a PM programme be implemented without further delay. The organisation didn't have the resources to cope with such a project and so a further decision was taken to implement the required solution using specialist outside resources.

Shire Systems, the organisation's computerised maintenance management system (CMMS) supplier of long standing, was consulted for advice. Shire Systems assigned a Maintenance Consultant from the professional support team with specialist knowledge of process plants to evaluate the situation on the ground.

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Turnkey service needed

A manufacturer's competitiveness and profitability depends directly on the availability and reliability of mechanical plant and equipment. Plant availability and reliability are outcomes of the maintenance process. The mill's new facilities needed a comprehensive PM plan for the new facilities to achieve the budgeted production volumes and product quality. Safety, health and environmental (SHE) compliance imperatives would also be assured by the PM plan.

A suitable PM plan was to be defined, loaded into the CMMS and periodic PM routines scheduled to provide a level PM workload over the year.

The 65m long paper machine viewed from the operating floor

Besides ensuring the required running performance of the plant, the adopted PM plan had to be affordable and 'manageable'. The new PM workload should ideally be within the capacity of the existing maintenance crew and, during the transition period of implementation, should not disrupt the responsive service that the maintenance department also had to provide to their production colleagues. The programme would be phased in area by area, with the full plan operational within six months.

As the organisation's management were aggressively pursuing higher added value and the elimination of waste, they didn't want their staff to be involved with over-the-shoulder monitoring or other 'waste work' in connection with the PM project. They demanded a self-directed, value-added service from their services provider, Shire Systems. After completion of a secrecy agreement, Shire Systems personnel would be given free access to the plant, its records and drawings and required to get on with the job. All decisions on PM philosophy and procedure were to be approved by the paper mill's engineers; otherwise minimum distraction of the organisation's staff was essential.

A scoping study was carried out and an outline solution proposed. This was agreed for rapid implementation on a turnkey basis. Progress meetings would be held every 3 weeks during the course of the project.

First define the maintenance strategy

A manufacturing organisation's *asset* strategy establishes, within affordable costs, the targets for asset availability and performance - and ensures the organisation is aligned to business goals *(Figure 1)*. It is part of the enterprise's business strategy and its correct formulation is the responsibility of senior management.

The paper company's targets for availability, performance and affordability in respect of the new facility were quite clear – but before developing the preventive maintenance plan, a consistent strategy for maintenance first had to be established. An agreed approach to the following was required:

- Assurance of equipment fitness for purpose
- Basic care of the equipment inventory
- Maintenance of business-critical equipment
- User involvement in equipment care

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Figure 1

Rational maintenance strategy and actions cascade directly from the enterprise's business goals

Assurance of equipment fitness for purpose

General considerations

It is clear that each item of equipment should be adequate for purpose, that is, capable of discharging its 'mission' in the overall production scheme. In many organisations this is not the case in practice.

Equipment incapable of performing adequately can enter service as a result of wrong initial design or selection. Properly selected equipment can subsequently become inadequate for purpose as a result of changes made to the manufacturing process - or its own use-related deterioration.

Note: Proper 'early engineering' of plant additions and modifications is essential for enterprise performance. New and modified equipment should be considered as a potential 'Trojan horse' of latent failures waiting to emerge in service and disrupt the business.

One of the first actions of any PM implementation should be to identify and initiate a remedial plan of action for 'rogue' equipment – items with unacceptably high failure rates or other performance inadequacy. These items usually require a design change, major refurbishment or complete replacement in order to cope with their mission in the manufacturing process.

The chosen strategy

The few items of 'rogue' equipment in the new facilities were identified and dealt with by design change. Other 'day one' problems caused by construction errors were also progressively eliminated.

As the facilities were new, there were no items of equipment that had lost process capability as a result of advanced deterioration.

Basic care of the equipment inventory

General considerations

In industry, a significant number of plant failures occur because equipment is being abused in some way.

Equipment abuse is generally not 'deliberate', but it nevertheless occurs as an outcome of inept operating and maintenance practices. Careless practices include poor lubrication, neglecting to clean equipment and ignoring of evident equipment defects and distress.

The plant failures resulting from abused equipment, and the consequent work of repair, are part of a vicious circle of self-sustaining, 'self inflicted' maintenance. This approach to asset management adds no value whatsoever to an enterprise's money-making or customer satisfaction processes.

Elimination of self inflicted failure events is the number one priority of any rational maintenance programme. This involves setting up an asset care programme that will deliver the baseline state of 'non-abuse' – by initiating a programme of basic care, tender loving care (TLC), for all equipment.

Besides careful operation, the basic care activities are: lubrication, cleaning, surveillance to detect early signs of equipment distress and deterioration - and then, of course, early repair. These activities are of paramount importance and underpin the availability and reliability of all plant and equipment.

Note: If basic care is not sufficient, both the frequency of failure and its resulting adverse effects will escalate. The bulk of maintenance activity will then be concerned with rectifying the consequences of equipment abuse, not management of the process of natural deterioration. Entropy is inevitable, but abuse is avoidable and must be eliminated. The 'fix it' mindset must be replaced with one of 'care for it'.

The chosen strategy

It was agreed that all equipment would receive planned basic care. This would include an inspection by the maintenance department at least once a year. When an operate-to-failure policy was decided for a 'non-critical' item, this would definitely not mean 'ignore and abuse-to-failure'!

Maintenance of enterprise-critical equipment

General considerations

Basic care alone will not deliver the plant availability and reliability needed to achieve the business goals. There has to be an additional overlay of targeted preventive maintenance tasks which counter functional failure of critical items of equipment.

These critical items are known as 'maintenance significant' and their failure must be controlled to avoid intolerable consequences for the enterprise. The consequences of failure include threats to throughput, quality, safety and environmental compliance, and excessive cost of repair – particularly when a failure can propagate to cause collateral damage to other items and property.

An asset should therefore receive maintenance attention not just in consideration of its failure characteristics, but in proportion to the scale of the potential threat to the business that failure would cause. Nowadays, deriving the maintenance plan for an asset from consideration of intolerable failures is the domain of RCM, Reliability Centred Maintenance. This, however, is a resource-intensive method and demands a considerable amount of time to implement for a complete production facility.

The chosen strategy

The facility, and particularly the paper machine itself, had very few duplicated (redundant) systems and therefore the great majority of equipment items could automatically be considered 'critical' to a greater or lesser extent. The degree of criticality of individual items depending on:

- Whether the item is in the production main cycle or an auxiliary cycle, whether its operation is continuous or intermittent and, if continuous, whether it has functions that are interruptible without immediate and serious business impact.
- The quality, safety and environmentally critical functions the item must provide.

These factors would be evaluated for each system and its constituent parts. Besides the intensity of pro-active maintenance, the classification would also determine whether the PM tasks which needed to be carried out with the system off-line would be scheduled on a 'shutdown' or 'opportunity' basis. Shutdown maintenance would be minimised.

The limitations placed on affordable resources and time-to-complete ruled out full blown application of RCM. Nevertheless, the basic RCM principles of failure modes and effects analysis and countermeasure task selection would be adopted when deciding the maintenance plan for the new facility.

User involvement with equipment care

General considerations

It's now generally accepted that maintenance is a cross-functional process. Active involvement of equipment users in equipment care activities is a prerequisite for world class standards of plant reliability and product quality. This approach was spearheaded by the petrochemical industry with its multiskilling initiatives and the assembly-type industries with their TPM programmes. User-executed (operator) care and maintenance is generally known as autonomous maintenance, or 'automaintenance'.

These programmes seek to demolish the notorious 'brick wall' that has historically divided the production and maintenance departments in manufacturing industries, and which have compartmentalised their respective roles and responsibilities. The key outcome of these programmes is increased plant availability and reliability, providing a plethora of benefits to the enterprise: better throughput, product quality, safety, unit costs, morale, etc.

The chosen strategy

At the mill, production and maintenance were indeed compartmentalised, but production managers agreed that change was necessary. The production groups accepted that they should be actively involved in the equipment basic care tasks. However, they could not commit themselves to implementing a firm programme of autonomous equipment checking routines in the short term because they felt that they were too pressed with the optimisation of the production processes on the new plant. This created a dilemma - in the interim period, until all operator care schedules were eventually in place, should the high-frequency checking be allocated to craftsmen?

Surveillance checks carried out by craftsmen would require a significant increase the maintenance department's manhour budget for PM and send the wrong message to the plant operators. Their effect would be to discourage operator engagement with the equipment – the very opposite of what is required for plant reliability. They could be seen to institutionalise the separation of the operator from the care of his equipment and sustain the 'brick wall' between production and maintenance. It was decided to avoid allocating high frequency inspection tasks to the craftsmen. After all, the maintenance plan was being compiled for the next decade - it must look forward to the desired future state.

Two favourable considerations would mitigate any adverse effects in the short term until the operators could be released for autonomous maintenance training:

- The maintenance department's lubrication team was constantly in the plant and in touch with the equipment. They were already reporting equipment defects found in the course of their work. They could increase their vigilance and carry out plant surveillance in a more structured way.
- Except for a limited number of assets needing exceptional attention, the plant was robust and the lower frequency PM routines carried out by craftsmen would provide the major contribution to the necessary plant reliability improvement during the period.

The course of action was clear. Full credit would be taken in the maintenance plan for production department's commitment to autonomous maintenance and high frequency surveillance routines would not generally be allocated to craftsmen.

Taking a wider view

Maintenance is a very complex process of interrelated activities. It's always wise, and very profitable, to contemplate improvement initiatives on a broad front. Focusing too narrowly on one area can result in overlooked opportunities or threats. Whenever a particular change is planned, other lateral improvements should also be identified and incorporated when that they can be implemented without too much difficulty. They often support the main thrust or provide valuable enhancements to the strategic outcome.

A general review of the current maintenance situation at the mill was initiated. An audit of current practice compared with appropriate best practice was carried out considering 20 elements of performance *(Figure 2)*. As a result, other affordable, non-disruptive initiatives that could be rapidly implemented were identified and executed in parallel with the PM project.

Betterment initiatives included best practice lubrication and bearing management, condition monitoring, better accessibility for maintenance and enhancements to the CMMS and technical information system.

Deciding and installing the PM Plan

See the figure in Attachment 1, *'Devising the Plan of Maintenance Tasks – a morass of information'*.

General policy

Process-centred maintenance plans

It was decided to adopt a process-centred maintenance approach. PM plans would be targeted at asset 'systems'. All care and maintenance tasks required to sustain the basic state of the target system and its business-critical functions would be contained within each plan.

A system is a group of interconnected equipment which function together to provide a capability important from a production process viewpoint. For example, a liquid storage system - this could include the tank, mixer and drive assembly, pumps and drive assemblies, auxiliary items, pipework, electrics, instrumentation and controls, etc.

Note: Process-centred maintenance plans are essential for achieving optimal maintenance and business performance. They promote increased understanding of the equipment in its process context - and higher quality maintenance outcomes are delivered as a result. Clustering equipment into unit operation systems also reduces administration burden and increases craftsman productivity.

Integrating disparate information systems and task groups

Considerations

Most manufacturing organisations have a multiplicity of disparate, equipment-related information systems for the control of various aspects of their asset population. Each of these separate systems is the source of different maintenance tasks. These separate systems have evolved for historical reasons, for example, enactment of applicable health & safety legislation and flavour of the month maintenance, quality or loss control initiatives.

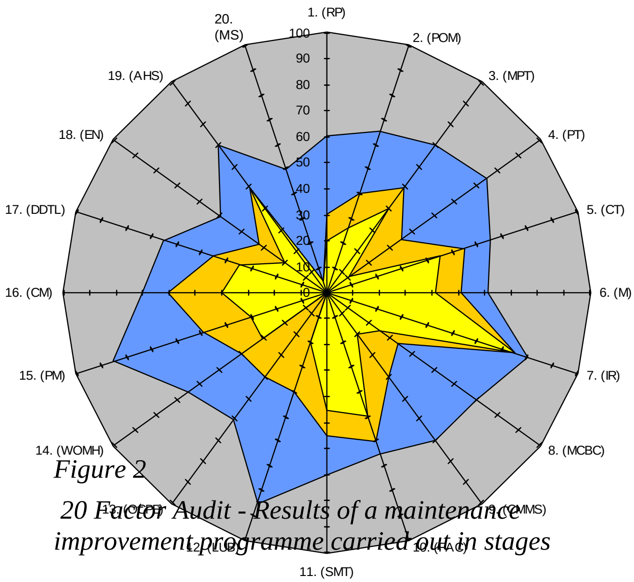

Figure 2

20 Factor Audit - Results of a maintenance improvement programme carried out in stages

The situation at the mill was typical. For the PM plan to be comprehensive, care and maintenance tasks had to be incorporated from various sources. Separate task groups already existed in connection with the following:

- Lubrication
- Pressure systems
- Ventilation systems & COSHH
- Flammable gas systems
- Hygiene
- Environmental compliance
- Radio-active sources
- Lifting gear
- Safety devices and equipment
- Fire protection equipment
- Quality critical instrument calibration

Maintenance efficiency and effectiveness will increase when the maintenance task groups of the various disparate systems are integrated together. Ideally the CMMS should hold and administer all the care and maintenance tasks for an enterprise's assets.

The required speed of implementation demanded a fit for purpose solution - full integration was a nice to have. It was decided that the various task groups would be evaluated and, depending on their nature, would either be linked or integrated in the PM plan in the CMMS.

Note: Complication increases when specialist contractors participate in the PM programme, for example, when they are used for bearing condition monitoring, thermography of electrical switchgear, testing of ventilation system efficiency, etc. The task groups associated with these contracts are often insufficiently defined and tracked in an enterprise's own record systems.

On-condition checks

As a fundamental maintenance philosophy, it was decided that when a major off-line routine was due on a system, it should always be preceded by an on-line examination of the equipment group immediately before bringing it off-line for maintenance. For systems containing a significant rotating machine, this would include an 'on-line and loaded' bearing condition evaluation. These requirements would be specified in the preamble to the off-line PM routine. The standard task listing in the PM routine would be ratified or modified, depending on the outcome of the on-line checks.

Synchronising lubrication events

The lubrication tasks were already set up in a dedicated computerised lubrication management system provided by the lubricants supplier Mobil. To enable a speedy implementation of the overall PM plan, it was decided to keep the Mobil information system. However, the lubrication system and the maintenance management system needed to be cross referenced in some way to keep them in synch. This was particularly necessary for the 'off-line' lubrication tasks, that is, oil changes and bearing grease repacks. In addition, a change could conceivably be made to the task plan in one system and the other system not updated. It was decided to provide linking 'memos' within the principle PM routines signalling engineers to check the item's lubrication record and current status before beginning the particular PM routine.

Pressure systems schemes of work

Pressure system technical files had been prepared for the mill by a firm of consulting engineers, but the schemes of work were not entered in the CMMS. Again, in order to speed up implementation of the PM programme, it was decided not to immediately include them in the PM plan being developed, but to reference the pressure system schemes of work in the PM routines of the affected systems. Routines would include a 'memo' to refer to the status of the pressure systems checks. Over time the schemes of work will be transferred over to the CMMS.

Minimise the PM workload

To counter the natural tendency to over-specify PM, it was decided to adopt a deliberate bias towards minimising PM – a 'just adequate' plan to deliver the availability and reliability demanded by the business goals.

Compiling the plan of PM tasks

The PM plan was compiled in stages. Although presented as a sequence of steps, in practice there is considerable iteration in parts of the process:

- Analyse the systems, assemblies and parts – define the assembly hierarchy of the facility
- Analyse the failures associated with the system parts – historical and potential failures and consequences
- Decide the PM tasks – identify the failure countermeasures for each system part
- Assemble the PM routines – allocate task frequency and executor. Separate into on-line and off-line groups
- Validate the routines and estimate the resource needs
- Enter routines in the CMMS
- Schedule the routines
- Define the 'routes'

Analyse the systems, assemblies and parts – unravelling complexity

Using process flowsheets and P & ID schematic drawings, the facility's unit operations and processes were analysed and the constituent systems identified.

For each system, schematic and assembly drawings were used to define the hierarchy of subsystems, assemblies, sub-assemblies and components. These assembly hierarchies provided a representative model of the facility, unravelling its complexity and revealing all the candidate parts for maintenance *(Figure 3)*.

Note: It is essential for all new or unfamiliar items of equipment whose performance is critical to the enterprise to carry out assembly analysis to identify the maintenance-demanding parts. When the maintenance-demanding parts are left to identify themselves by in-service failure it will take years to fully define the PM plan and will cost the business very dearly in business disruption – loss of prime quality throughput, high maintenance costs and SHE violations.

The system hierarchy was reconfigured into a listing of assemblies and components in logical sequence - the various branches of the hierarchy following each other in order of priority. The listing 'goes with the flow', that is, following the path of energy transfer or material transformation in the system.

amount of time. However, it is absolutely essential to produce them as they provide the ***framework*** *on which the maintenance task plans and their sibling routines are built.*

Analyse the failures associated with the system parts

This involved a series of steps:

Identification of potential failures

Identifying failure-prone parts from logical engineering analysis is the crucial first step in defining reliability-centred PM tasks.

By studying the parts assemblies and their context of operation, the parts prone to failure and their likely failure modes were deduced by engineering judgement.

Note: Parts prone to failure are those having relative motion, exposed to fluids with corrosive components or particulate matter, subject to vibration, shock or thermal cycling, with a

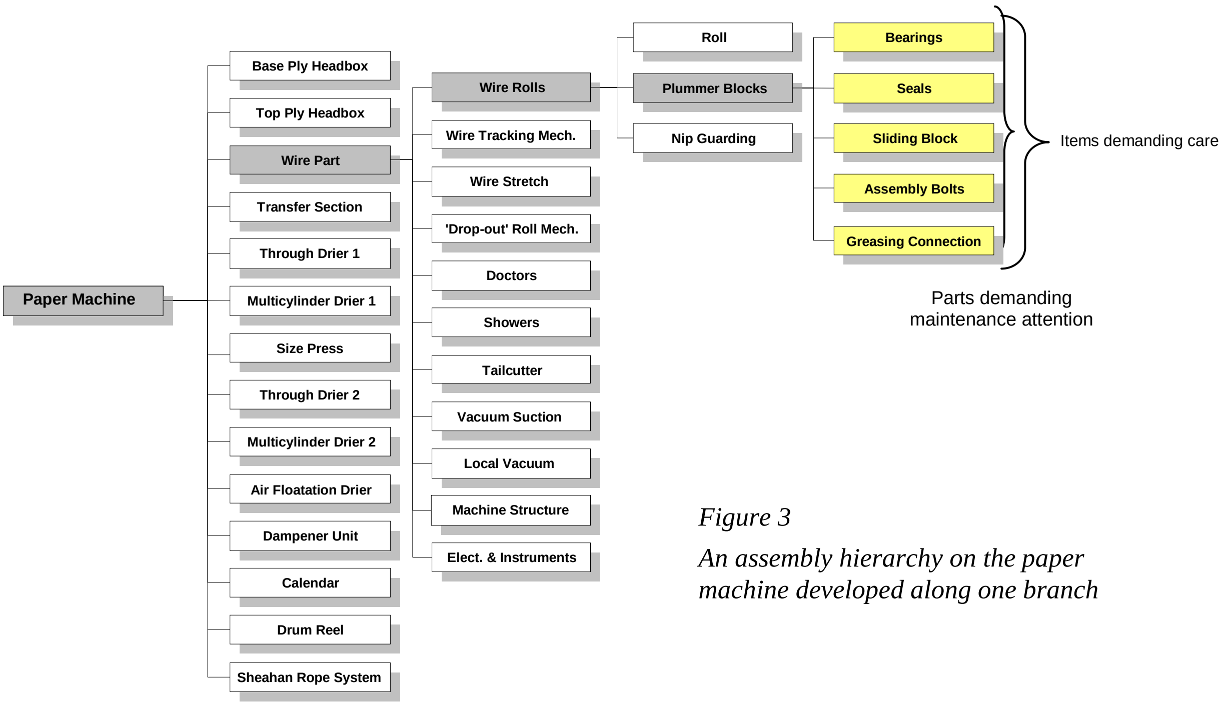

Figure 3

An assembly hierarchy on the paper machine developed along one branch

480 systems were eventually identified for the new facility. These were comprised of over 2200 defined items of equipment.

Note: Developing these hierarchical models and component/part sequences takes up a significant

critical internal shape or finish, fragile items which are mechanically cleaned or exposed to the risk of user-initiated mechanical damage, etc.

Inspection of the current state of equipment

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To gain an understanding of the operating context and how the equipment was actually 'holding up' in service, each system was visually inspected to find out the general condition of its parts and whether accelerated deterioration was occurring due to the operating environment or operating practices. Any evidence of operational difficulties was recorded, for example, tell-tale signs of 'hammering' to release sticking parts or blockages, frequent access to internals, missing fasteners, 'make-do' modifications and additions carried out since commissioning.

The knowledge gained was used to earmark vulnerable parts and as a basis of discussion with the maintenance and production teams.

Review of history records

The available records of equipment failure and repair were reviewed and used to confirm and update the failure profile of parts - and identify worthwhile PM tasks.

Maintenance group experience

The craftsmen and maintenance supervisors that were most knowledgeable about the equipment were interviewed. Their personal experience and opinion was used to confirm and update the failure profile of parts and identify worthwhile PM tasks.

Note: Craftsmen must be involved in deciding the PM plan for reasons of motivation and role evolution as well as task accuracy. Active involvement in the PM decisions builds ownership and enthusiasm. It also feeds the process of craftsman empowerment - thereby enabling the role of supervisors to evolve from job supervision to job planning.

Production group experience

The equipment operators and production supervisors were interviewed about their personal experiences and opinion of the equipment. They gave information about their equipment's behaviour freely and enthusiastically, identifying the parts that particularly affected operability and the needed quality functions.

For the highly critical systems on the paper machine, the assembly hierarchy was used to guide the discussion of performance item by item - to ensure that no known snag was overlooked.

Note: Operators and production supervisors know the plant best of all. Even when autonomous maintenance is not officially practised, most operators carry out small fixes on their equipment. They are most conscious of the plant's 'quality functions' and most familiar with the states of 'partial failure to function' (when a function is degraded but not completely lost). They know the points of equipment unreliability and operational inadequacy.

Items demanding regular attention

Decide the PM tasks

All the information gained by analysis, inspection and interview was assessed. An initial list of maintenance countermeasure tasks were defined for the parts of each system in consideration of the nature of failure, likelihood of failure, impact on the enterprise and the method of earliest distress detection.

Note: The failure of a system or asset is initiated by the failure of a single component part. The effect of the failure can be localised and minor - or it can have a wider effect, involving collateral damage, with major and even of fatal consequences.

In line with the policy of minimised PM, on-line condition checking tasks were identified as a priority. Production intrusive and expensive machine disassembly checks were avoided wherever possible.

The task list was decided in a number of stages:

Manufacturer's recommendations

Manufacturer's recommendations were compared with the plan of maintenance tasks derived by analysis and operating experience and any overlooked tasks were added. Warranty-critical tasks later considered to be unreasonably onerous and adding little to system reliability would be re-evaluated after expiry of the warranty period.

Although the plant had been provided with extensive manufacture's documentation, it was of very variable quality, particularly between Scandinavian, continental European and UK providers.

In general, manufacturer's manuals tended to be of limited use. Their main value was in providing disassembly and assembly instructions and information on parts, but they rarely provided information of a standard that could readily be used for compilation of an effective maintenance plan. Besides giving an incomplete list of tasks, their inconsistent structures and lack of a logical sequence made them hostile to incorporation in the PM plan – which aimed at a standardised, user-friendly format.

Note: Except for some specialist technology providers, few manufacturers really understand the operating context and the particular performance requirements of their equipment - even less appreciate and address the needs of the reliability-conscious maintainer in their O & M manuals.

Lubrication

The Mobil lubrication schedule of off-line tasks were referenced and aligned with related PM tasks in the plan.

Quality functions

Additional checks necessary for process reasons were added to the task plan, in particular countermeasures against failure of quality critical functions. Besides the requirements for intrinsic quality of the paper web, stringent hygiene standards also applied due to the paper product's end use.

Assuring quality functions by maintenance countermeasures is part of QFD (Quality Function Deployment).

Compliance with legislation

When any system contained parts that were subject to specific regulatory checks, these were referenced in the plan.

Assemble the PM routines

PM routines are the means by which the PM plan is applied in practice. The PM plan for a system is can be considered as a 'folder' of PM routines.

A routine is a bundle of care and maintenance tasks to be carried out together at a defined frequency by a designated 'executor group' on a target system. Routines are divided into 'on-line' and 'off-line', depending on whether they must be completed with the target system in an energised or de-energised state. The routine frequencies are standard fixed calendar periods – subject to normal scheduling tolerances. For user-friendliness and ease of administration, each routine's reference number identifies its parent plan, executor, frequency and the system's required energisation status.

A total of 158 discrete and generic PM plans of multiple routines were defined. The standardised structure and format of the routines makes them user-friendly and easy to revise.

It is fairly straightforward to decide which tasks are to be included for each candidate part in the PM plan for a system – it's deciding the application interval, or frequency, that is more demanding. The interval is chosen such that successive applications of the task would be likely to detect or offset potential failures before they can give rise to functional failures. The task is allocated to the standard frequency routines that will deploy it at the decided interval. In line with the 'minimise PM' philosophy, PM tasks were deferred to lower frequency routines, unless a higher frequency application rate was judged imperative to achieve the plant availability and reliability demanded by the business plan.

In use, routines are optimised by adding or subtracting tasks – effectively reassigning them to a routine of a more appropriate frequency. In this respect, a PM routine can also be considered as a 'clipboard' of the failure preventing tasks judged appropriate at the particular point in time.

For any system, the lowest frequency routine is considered the 'parent' routine in the folder of routines. It may be annual, or longer. It contains the roll-up of all tasks in the higher frequency routines. *It is useful to list all system parts in the parent routine, even when no task is to be immediately attached to it, then the maintainer knows that this is not an oversight but a considered decision for 'no PM'.*

Within routines, standard clusters of tasks were provided for general parts, such as fabricated equipment and pipework. For example, checking the condition of valve glands, stroking of valve spindles and inspection of fasteners and pipe supports. These were easily to include in the routines. Such tasks are often omitted to the detriment of system reliability when PM plans are equipment rather than process system-centred.

Note: Unnecessary tasks in routines allocated to craftsman can add up to significant extra costs. On the other hand, the on-line surveillance checklists allocated to operators should be as comprehensive and detailed as the time available for their compilation allows!

Validating the routines and estimating the resource needs

Each routine was validated in its final draft form. An acceptance session with the responsible maintenance supervisor was held at the location of the target system. The workscope was reviewed and the logic of the task sequence tested by going through the routine's task list in reference to the actual physical equipment. After ratification of the routine, the size of crew and time needed to complete each routine was estimated and used to update the cumulative manhours total for the PM workload.

Entering the routines in CMMS

The group of equipment items making up each maintainable system were grouped together in the CMMS under the identification number of the system's prime item of equipment. The prime item is known as the 'root tag'. The finalised routines were entered in the CMMS attached the 'root tag' in each system.

This was for administration of the PM plan only, as event history must always be recorded against individual items of equipment to enable root-cause failure analysis to be carried out.

Scheduling the routines – minimising 'shutdown' maintenance

The maintenance routine workscopes were scheduled as either 'shutdown' maintenance or 'opportunity' maintenance. For reasons of proper job co-ordination, routines with different executer groups but the same frequency on a particular system were triggered for simultaneous issue and execution.

Shutdown PM workscope was to be carried out during the fixed frequency production 'shuts' – the outages necessary for replacement of consumable parts on the paper machine, process cleaning and product type changes. The PM routines were scheduled evenly, according to their manhour content, over the number of available days in the 'shuts' programmed for the year.

Note: In process plants, especially those with frequent planned shutdowns, the in-house maintenance crew tends to be sized on the basis of shutdown workload. As any maintenance engineer knows, the amount of 'new' work emerging at the start of and during a shutdown usually stretches the available resources to the limit. It is therefore incumbent on the maintenance planners to resist the inclusion of any planned work in a shutdown's workscope unless it absolutely can't be done at any other time.

Any system that could conceivably be maintained on an opportunity basis was excluded from the shutdown workload. Candidates for opportunity maintenance were standby systems, systems used intermittently in the production cycle or which could be interrupted because of inherent buffer capacity or 'tolerance' in the upstream or downstream processes.

Opportunity maintenance routines were loaded in the CMMS and scheduled evenly over the year according to the number of running days programmed for the paper machine.

Defining the 'routes'

Lists of on-line routines that could be quickly executed and completed in succession by a single craftsman were compiled into 'routes'. The routines were sorted into a logical order of execution according to the geographical layout of the paper mill site.

With this type of multiple equipment routine, any 'fix' that would take longer than 10 minutes or would require spare parts other than consumables should generally be avoided. The craftsman can note the condition and raise a separate work request for its correction.

Other considerations

Equipment identification labelling

To allow the quick identification of the target system, the physical equipment must be clearly labelled. This saves both time and error and is hugely cost-effective.

It was decided that, for each system, a printed label would be prominently displayed at the system location. The label would state the ID Number of the root tag, its description and a list of maintainable assemblies included in the system. The labels were printed from a PC and laminated to increase their durability.

Autonomous maintenance routines

The vast majority of equipment in the new facility is very robust. The notable exception is the Finishing Area. Here the paper reeler-slitter and robotic systems are extensively automated with relatively delicate mechanisms which demanded a different care philosophy from that of the rest of the facilities.

To avoid operating problems, these items need good surveillance and daily checking and cleaning. The Finishing Area equipment is amongst the most critical in the mill and the production department agreed to implement an autonomous maintenance programme. A list of autonomous care tasks was compiled and issued to the Production Department. Maintenance supervisors delivered the necessary training to the production operators.

Specialist contractor routines

PM programmes on particular categories of equipment were already being carried out by specialist contractors. Specialist contractors applied their own PM plan and routines and these were not recorded in the CMMS. Equipment in this category included boilers, large gas burners, large ventilation systems and fixed fire protection installations.

System assembly analysis and task listing was completed for some of the equipment maintained by specialist contractors. However, the derived plans were not necessarily the same as those of the contractor. Contractors have therefore been asked to supply details of their schemes of work and these are being reviewed. After being validated and ratified, they will be included in the overall PM plan in the CMMS.

Electrical & instrumentation routines

Generic routines were provided for instrument and control systems. Loop checking and calibration tasks and frequencies will be customised over time in consultation with the mill's Technical Manager and production management in consideration of quality critical functions.

All motors above 1.4 kW, together with their auxiliaries, cabling and control gear were tracked as individual systems in the PM plan.

Providing 'enough' information in the PM routines

The information in the routine and task narratives focused on the needs of the craftsman. In addition to the task instructions, brief explanatory notes, cautions and warnings, were provided as appropriate.

There can be some uncertainty about the amount of information that should be provided within a maintenance routine. How much should be taken for granted as trade or plant general knowledge? There are four important considerations in this regard:

Quality

Routines must be brief, yet specify the maintenance tasks and job precautions unequivocally. The task list and essential instructions should not be left open to interpretation. When correct action is really imperative, more rather than less information should be given - even when this could appear pedantic.

Note: Craftsman performance is directly proportional to the availability of good data and information systems

Diligent craftsmen welcome pertinent information and do not view its supply as *disparaging. Routines are not just instruction lists, but maps, signposts and guides. They must be written from the point of view of what the craftsman needs to know and would like to know. When the reason for a particular task is obscure, a brief explanation should be given.*

Safety

When there was a hazard arising from the job 'context', for example, confined space entry, danger of falling arising from incidental removal of floor-plates or handrails, dangerous substances in equipment internal spaces, etc, safety instructions were included and reference made to any special permit requirements. Universally applied lock-off and permit to work regulations were taken 'as read'.

Co-ordination

Routines often require co-operation between different executor groups. Where applicable, this was signalled in the preamble to the respective routines, even though associated routines were scheduled for simultaneous action. Any liaison arrangements could then be properly organised before work actually started. For example, the annual PM carried out on a critical gearbox with a flange-mounted motor generally requires co-operation between the two Mechanical and Electrical executor groups.

Documenting and retaining the organisation's knowledge base

An organisation's knowledge base must be electronically or paper documented to ensure that it can be retrieved at will by any authorised person. The maintenance routines are part of this knowledge base. Routines should include all known information pertinent to each task applied to the target part in a specific context of operation. As a corollary, tasks and routines must be updated to reflect latest available information.

Note: When writing a routine, to ensure all context information is included, it is useful to imagine that the routine is to be assigned to a competent individual, but one who does not necessarily have detailed knowledge of the plant.

Avoiding routines becoming too 'routine'

Efficiency demands that the maintenance process be systematised and maintenance routines carried out systematically. However, this does not mean carrying them out in a bureaucratic or mindless way. There is a need for continuous review of the PM workload with critical evaluation of the maintenance cost versus manufacturing benefit trade-off.

Routines should be subjected to a 'sanity' check each time they are activated, and after their execution. Continuous critiquing and feedback from the craft crew and engineers was encouraged - 'if in any doubt shout'.

For the new facility this was particularly important as the plant's actual failure profile was still unfolding. It was essential to continuously review the routines against latest experience. As plant experience and understanding has increased, engineers have developed more confidence in interpreting equipment condition from on-line checks. This has allowed production-disruptive and expensive internal inspections to be deferred.

Note: When craftsmen are in disagreement with the appropriateness of routines they will develop an indifference to preventive maintenance. Plant reliability is achieved when preventive maintenance is approached with the diligence that only a real belief in the system can bring.

And, it should not be forgotten, maintenance interval optimisation remains the holy grail of PM!

Launching the routines

In operation at the mill, the Maintenance Controller extracts the PM routines for the current period and discusses them with the maintenance supervisors responsible. One engineer is generally in charge of the PM work and another the corrective work carried out during a shutdown.

When a major routine is issued, the Maintenance Controller and a maintenance supervisor carry out preliminary checks on the target system before assigning the routine to the craft crew for execution. These preliminary checks include the following:

- Review any outstanding work requests for repairs and modifications
- Review the job history of the system's component items, especially in the period since the last application of the routine
- Review the lubrication status of equipment
- Review the inspection status of pressure systems, work equipment, ventilation systems, etc
- Visit the system and establish its current condition and operating performance with the users, including the period trend in operating pressure, flow, temperature, pressure, etc, as applicable
- Arrange for 'on condition' checks, including bearing vibration and temperature, thermography, oil analysis, etc, as applicable. Review trends from the records
- Assess the system's current global status and needs and assign the off-line routine for craftsman action with task updates and additional special instructions, as applicable

A successful outcome

The new facilities' reliability and downtime is no longer a threat to production and the line speed and production rate has progressively increased. The PM workload is being carried out without any growth in manpower resource; in fact the overall maintenance manhour trend is now

The paper finishing area

downwards.

Savings in energy and raw material efficiencies add to the increasing benefits. In less than a year since kick-off of the PM project, preventive maintenance has increased plant uptime by 15% - allowing the production of additional paper volumes valued at several millions of pounds.

The mill's Chief Engineer, was particularly struck by the effect the new system had on his team: 'We used to bring the paper machine down for maintenance only to have it fail again after start up. This was really demoralising, now this doesn't happen like before. The men are dedicated and enthusiastic. They are totally committed to pro-active maintenance. I've realised that fitters don't like working in the chaos of a reactive environment and this can be a prime reason for them looking to change jobs'.

The Maintenance Controller gives his assessment of the results in the period: 'Plant reliability has improved, call outs have dropped from 2 a night to 2 a week, Production are much more caring about the plant and morale is improving'.

The implementation has resulted in winners all round. Management is satisfied. Production staff is content. Engineers have more time to give to continuous improvement tasks. Craftsmen enjoy the more organised work and close involvement in decision making. To outside parties, the PM programme demonstrates a management focus on quality and safety. External quality auditors from the company's highly demanding customers are impressed.

The maintenance improvement project at the paper mill was not a TPM or RCM 'banner' type initiative, but a pragmatic maintenance solution to a serious business threat. The basic principles of plant reliability were applied consistently within the constraints of affordability and rapid delivery. The project meetings held every 3 weeks were crucial to maintaining the pace of progress.

Demolishing the brick wall dividing production and maintenance

Looking to the future

In manufacturing industry the notorious 'brick wall' dividing the production and maintenance departments and compartmentalising their roles and responsibilities, was placed there by organisational design. It's a legacy of 'functional thinking'. The developments in manufacturing science over the last quarter of the 20th century have shown it to be a costly anomaly.

In the new millennium 'systems thinking' is imperative for survival in the global market. Added value and interconnectivity of activities are the driving issues. Production and engineering groups have no choice but to form a manufacturing alliance and work as one team, sharing the equipment care and maintenance tasks on a *rational* basis.

In reality, the wall resists demolition. It has been reinforced by culture – which perpetuates custom and practice, and plant unreliability – which inevitably polarises the production and maintenance groups in a stand off of mutual accusation and condemnation.

Poor reliability is disruptive and viciously undermines the development of a respectful, mutually supportive relationship between maintenance and production departments. It is the first issue to address in the move to cross functional maintenance and increased manufacturing performance. With equipment-intensive process plants, a reasonable level of plant reliability must be reached before users become disposed to carrying out autonomous maintenance. ***Plant reliability is a pre-condition for harmonious change***.

This level of plant reliability has now been reached at the mill. The implementation of the PM plan has reduced plant failures and the aggravation they cause; the production and maintenance teams have been brought closer together. Maintenance planning meetings have introduced the opportunity for increased communication and co-operation. The production managers have a positive attitude towards autonomous maintenance.

Whilst simple tasks, like changing filters, are being handed over to the production group, early detection of developing defects by '5 senses' inspection must be developed further. This will require intensive operator training - but it will deliver the next breakthrough in plant reliability.

A process of evolutionary change is being applied at the mill. The brick wall is being demolished - brick by brick.

<END>

Case Study

Implementing Preventive Maintenance at a speciality paper mill

Attachment 1

Devising the Plan of Maintenance Tasks...

a morass of information