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THE APPLICATION OF HOSE MANAGEMENT IN MINING

Paulo Roberto Pereira

ABSTRACT: In a surface mining operation the unscheduled downtime due to hose can reach up to 37% of the entire unscheduled downtime for a prime mover hydraulic shovel. Reliability Based Maintenance Programs are more effective at improving fleet availability and Total Cost of Ownership. In this regard, correct process management is a fundamental building block of any successful machine reliability centered maintenance program. This can be expressed as well as the correct management of the application of the machine components, the quality and capability of the human resources involved, the comparative acquisition costs of those components and more importantly the comparative operational performance of those components. The main objective is to quantify the economic value that a reliability centered component maintenance program will bring to the operation in increased safety, machine availability and productivity, environmental compliance and total cost of ownership. This paper will present what this program, called Hose Management Program, looks like for flexible hose assemblies, its applications and the value that it has brought to some mine operators around the world.

RELIABILITY CENTERED MAINTENANCE – AN OVERVIEW

Reliability Centered Maintenance (RCM) is a process to ensure that assets continue to do what their users require in their present operating context (Moubray, 1997).

It is generally used to achieve improvements in fields such as the establishment of safe minimum levels of maintenance, changes to operating procedures and strategies and the establishment of capital maintenance regimes and plans. Successful implementation of RCM will lead to increase in cost effectiveness, machine uptime, and a greater understanding of the level of risk that the organization is managing.

John Moubray (1977), characterized Reliability-centered Maintenance as a process to establish the safe minimum levels of maintenance.

Reliability centered maintenance is an engineering framework that enables the definition of a complete maintenance regime. It regards maintenance as the means to maintain the functions a user may require of machinery in a defined operating context. As a discipline it enables machinery stakeholders to monitor, assess and recommend the working regime of their physical assets. This is embodied in the initial part of the RCM process which is to identify the operating context of the machinery, and write a Failure Mode Effects and Criticality Analysis (FMECA). The second part of the analysis is to apply the "RCM logic", which helps determine the appropriate maintenance tasks for the identified failure modes in the FMECA. Once the logic is complete for all elements in the FMECA, the resulting list of maintenance is "packaged", so that the periodicities of the tasks are rationalized to be called up in work packages; it is important not to destroy the applicability of maintenance in this phase. Lastly, RCM is kept live throughout the "in-service" life of machinery, where the effectiveness of the maintenance is kept under constant review and adjusted in light of the experience gained.

RCM can be used to create a cost-effective maintenance strategy to address dominant causes of equipment failure. It is a systematic approach to defining a routine maintenance program composed of cost-effective tasks that preserve important functions.

The important functions (of a piece of equipment) to preserve with routine maintenance are identified, their dominant failure modes and causes determined and the consequences of failure ascertained. Levels of criticality are assigned to the consequences of failure. Maintenance tasks are selected that address the dominant failure causes. This process directly addresses maintenance preventable failures. Failures caused by unlikely events such as non-predictable acts of nature will usually receive no action provided their risk (combination of severity and frequency) is trivial (or at least tolerable). When the risk of such failures is very high, RCM helps the user to consider changing something which will reduce the risk to a tolerable level.

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The result is a maintenance program that focuses scarce economic resources on those items that would cause the most disruption if they were to fail. For mobile equipment failure of certain components will always be severe enough to cause that piece of equipment to be down often in an unscheduled basis. Therefore, there is an immediate detrimental impact (severe) to the performance of that equipment and by extension to the operation in which that equipment is involved. This is true for hose assemblies on any piece of equipment

RCM emphasizes the use of Predictive Maintenance (PdM) techniques in addition to traditional preventive measures. By establishing testing parameters for component it is possible to define "useful lives" for items which not necessarily means their ultimate life but the recommended durability of that component in a lab setting. By combining this durability with the ability to monitor the lab parameters in the field a "predictive" replacement schedule can be produced by the maintenance personnel

RELIABILITY CENTERED MAINTENANCE - EVOLUTION

Since the 1930's, the evolution of maintenance can be traced through three generations. RCM is rapidly becoming a cornerstone of the Third Generation, but this generation can only be put in perspective in the light of the First and Second Generations.

The First Generation

The First Generation covers the period up to World War II. In those days industry was not very highly mechanized, so downtime did not matter much. This meant that the prevention of equipment failure was not a very high priority in the minds of most managers. At the same time, most equipment was simple and much of it was over-designed. This made it reliable and easy to repair. As a result, there was no need for systematic maintenance of any sort beyond simple cleaning, servicing and lubrication routines. The need for skills was also lower than it is today.

The Second Generation

Things changed dramatically during World War II. Wartime pressures increased the demand for goods of all kinds while the supply of industrial manpower dropped sharply. This led to increased mechanization. By the 1950's machines of all types were more numerous and more complex. Industry was beginning to depend on them.

As this dependence grew, downtime came into sharper focus. This led to the idea that equipment failures could and should be prevented, which led in turn to the concept of preventive maintenance. In the 1960's, this consisted mainly of equipment overhauls done at fixed intervals.

The cost of maintenance also started to rise sharply relative to other operating costs. This led to the growth of maintenance planning and control systems. These have helped greatly to bring maintenance under control, and are now an established part of the practice of maintenance.

Finally, the amount of capital tied up in fixed assets together with a sharp increase in the cost of that capital led people to start seeking ways in which they could maximize the life of the assets.

The Third Generation

Since the mid-seventies, the process of change in industry has gathered even greater momentum. The changes can be classified under the headings of new expectations and new techniques.

Evolution of Maintenance Expectations as shown in Figure 1.

New techniques

There has been explosive growth in new maintenance concepts and techniques. Hundreds have been developed over the past fifteen years, and more are emerging every week.

Figure 2 shows how the classical emphasis on overhauls and administrative systems has grown to include many new developments in a number of different fields.

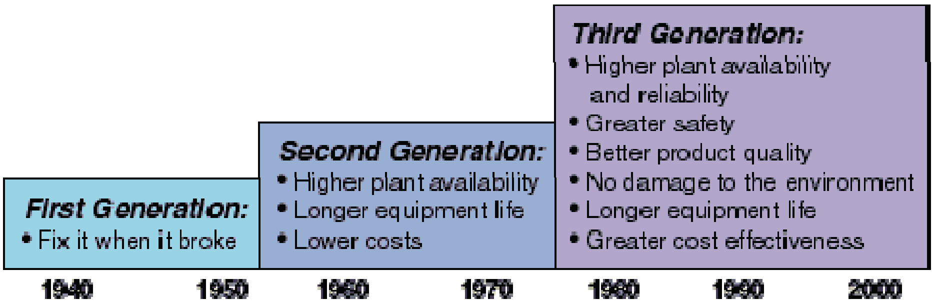

Figure 1: Evolution of maintenance expectations

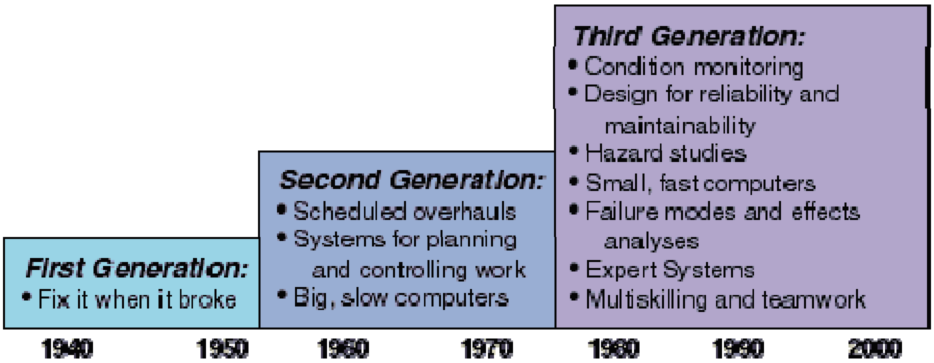

Figure 2: Evolution of maintenance technologies

The new developments include:

- decision support tools, such as hazard studies, failure modes and effects analyses and expert systems
- new maintenance techniques, such as condition monitoring
- designing equipment with a much greater emphasis on reliability and maintainability
- a major shift in organizational thinking towards participation, team-working and flexibility.

A major challenge facing maintenance people nowadays is not only to learn what these techniques are, but to decide which are worthwhile and which are not in their own organizations. If we make the right choices, it is possible to improve asset performance and at the same time contain and even reduce the cost of maintenance. If we make the wrong choices, new problems are created while existing problems only get worse.

The challenges facing maintenance

In a nutshell, the key challenges facing modem maintenance managers can be summarized as follows:

"To select the most appropriate techniques to deal with each type of failure process in order to fulfill all the expectations of the owners of the assets, the users of the assets and of society as a whole in the most cost-effective and enduring fashion with the active support and co-operation of all the people involved."

RCM provides a framework which enables users to respond to these challenges, quickly and simply. It does so because it never loses sight of the fact that maintenance is about physical assets. If these assets did not exist, the maintenance function itself would not exist. So RCM starts with a comprehensive, zero-based review of the maintenance requirements of each, asset in its operating context.
All too often, these requirements are taken for granted. This results in the development of organization structures, the deployment of resources and the implementation of systems on the basis of incomplete or incorrect assumptions about the real needs of the assets. On the other hand, if these requirements are defined correctly in the light of modem thinking, it is possible to achieve quite remarkable step changes in maintenance efficiency and effectiveness.

Hose Assemblies and RCM – The need for a Hose Management Program

The Hose Management Program seeks to address the third generation of Maintenance Expectations as listed in Figure 1 with the following techniques:

a) Condition monitoring, where hose condition both external and internal are closely monitored
b) VEVA (Value Engineering/Value Analysis) for greater system reliability and maintainability
c) Hazard studies enabled by systematic inspections, tracking, condition monitoring and engineering analysis of the data collected
d) Root cause and effects analysis supported by the build-up of experience and investigation of failures. This will also help establish a site specific standard of systems criticality and a reliability based hose replacement
e) Expert systems that support traceability of hose assemblies
f) Multiskilling and team work between end user and supplier team which are crucial for the successful implementation of the program

To extend on the above and explain the hose assembly performance relationship to RCM and the need for a well designed and implemented Hose Management Program the 7 RCM Expectations above as they pertain to Hose Assemblies are discussed as follows:

1) What is the item supposed to do and what are its associated performance standards?
   Hose assemblies convey power through the dynamic action of pressurized hydraulic fluids which enable a piece of machinery to perform its basic operating functions of loading, ripping, digging, hauling, drilling or grading. The performance standards are derived from the various industry bodies that establish standards for hose assemblies such SAE, ISO, DIN and MDG 41 to name a few.
2) In what ways can it fail to provide the required functions?
   Hose assemblies can fail in several ways depending on the application in which they are installed. They can fail by internal effects such as manufacturing defects, poorly designed hose / coupling interface, continuous pressure impulse spikes above working pressure, temperature spikes and by external effects such as poor crimping, twisting, external cover abrasion, cuts, or gouges. The program tracks hose assemblies from cradle to grave thereby identifying when the hose fails and what was the failure mode.
3) What are the events that cause each failure?
   Many events cause these failures but most are related to manufacturing processes, crimping practices, installation practices and engineering practice. Analysis of each failure will help to recommend the right product that will ensure from the beginning the highest possible reliability for a particular hose assembly.
4) What happens when each failure occurs?
   Usually, when a hose assembly fails on a piece of mining equipment the equipment is out of service immediately after the failure. Although the frequency will vary, from a mining operator's perspective the severity is high and immediate. Additional risks that are involved are severe injury to the operator and potential complete loss of the piece of equipment due to a fire for example. In addition, the environmental consequences of a failure might be severe depending on which hose assembly fails. Usually, the cost of the hose assembly that fails pales in comparison with all the other costs that are involved with a failure
5) In what way does each failure matter?
   Each failure matters because it will affect to a greater or lesser extent the profitability pyramid of a mining operations described in Figure 3:

Every one of the sub-pyramids can have an economic value associated with them and in conjunction changes in them will lead to incremental positive or negative cash flows in a given mining operation.

1) What systematic task can be performed proactively to prevent, or to diminish to a satisfactory degree, the consequences of the failure?
   The most proactive action an operator can take to prevent or diminish to a satisfactory degree the consequences of failure is to take an Applications Engineering approach. This approach involves studying the hydraulic system on the machine and prescribing the right hose assembly component for that application. In addition, Application Engineering helps with the serviceability of the machine when it comes the time for Hose Assembly fabrication, replacement while also helping with the cost of the machine's Bill of Materials
2) What must be done if a suitable preventive task cannot be found?

Time and answers to questions 1 through 6 will help build a database of well documented cases that will help the user to establish maintenance principles and a body of maintenance tasks (preventative and/or predictive) where correct remediation is not immediately obvious. So, this body of information is the essence of the Hose Management Program.

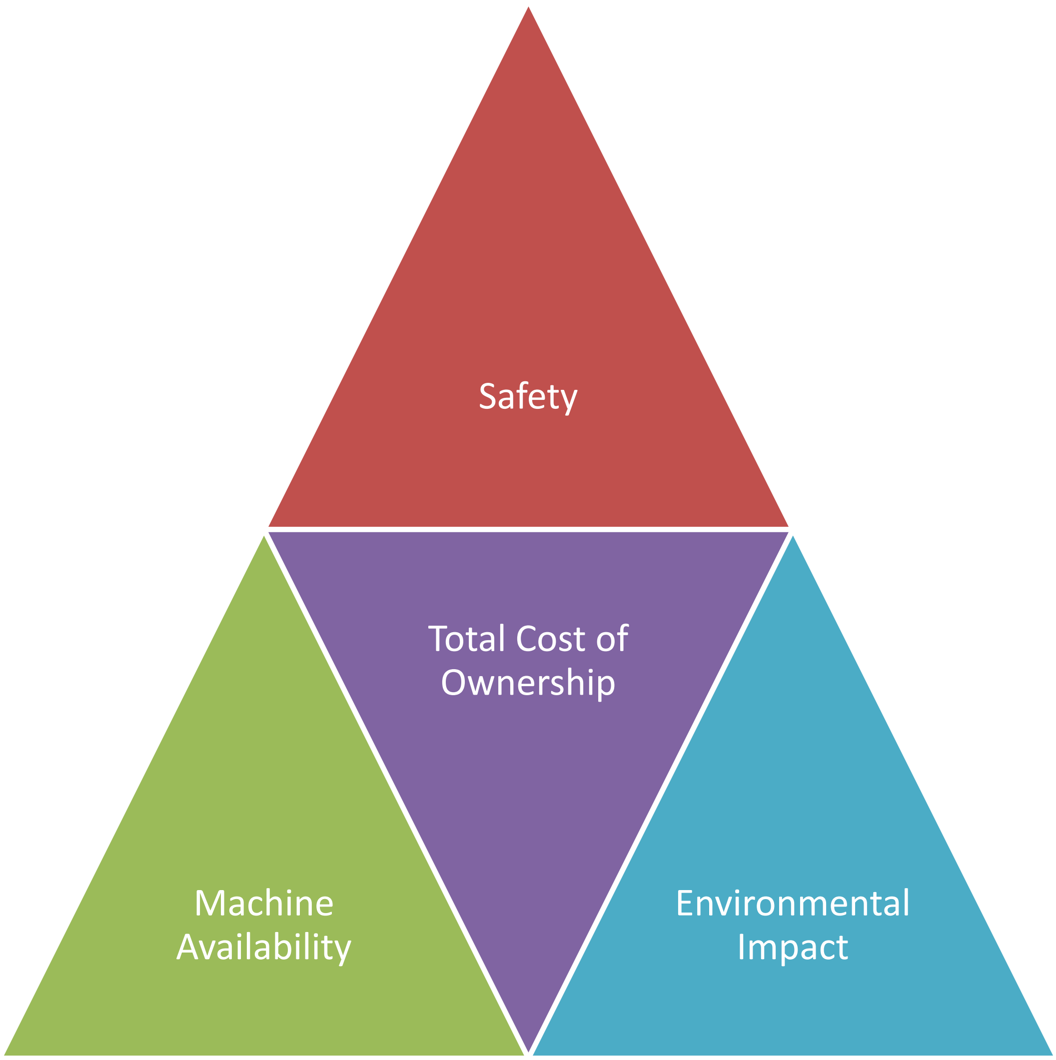

Figure 3: Profitability pyramid

Key Components of the Hose Management Program

1) Key performance Indicators to be determined at the beginning of the implementation of the program
2) High performance products that will enable a significant reduction in undesired outcomes
3) Product application engineering analysis that will optimize hydraulic systems
4) Hose assembly tagging and tracking to track the lifecycle of every hose assembly
5) Internal Condition Monitoring and engineering analysis of selected hydraulic circuits
6) External Condition Monitoring of hose assembly conditions
7) Risk analysis based on hose assembly function and location on a given piece of equipment
8) Reliability Based Replacement Alerts based on condition monitoring

APPLICATIONS OF THE HOSE MANAGEMENT PROGRAM

By applying some or all of the components of the Reliability Based Hose Management program as described above it has been possible to produce the following results at several different types of mining operations described in Figure 4:

Mine Type	Area of Improvement	Equipment Type	Quantifiable Improvement After Hose Management
UG Hard Rock Mine	Mean Time Between Failures	One boom Jumbo	206% Improvement
UG Hard Rock Mine	Mean Time Between Failures	One boom Jumbo	240% Improvement
UG Room and Pillar Coal Mine	Total Cost of Ownership	Continuous Miner	Reduction in Hose and couplings expense
Aggregates Mine	Mean Time Between Failures	Mining Fleet	33% Increase in Fleet Availability
Surface Coal Mine	Total Cost of Ownership	Large Hydraulic Shovel Boom Hoses	Reduction in Hose Acquisition Cost
Surface Coal Mine	Mean Time Between Failures	Hydraulic Shovel Boom Hoses	20% to 40% longer life.
Mining OEM	BOM, Assembly Time	Haul Truck	Reduction in the BOM Cost

Figure 4: Hose management field examples

Relation between the cost of a hose assembly and the cost of downtime

An idea of the relationship between the cost of downtime for selected mining operations and the cost of a hose assembly on a given machine are presented in two examples shown in Figure 5

Surface Gold Mine Heap Leach
- **Cost of Hose Assembly: up to $840.00**
- **Content per Machine: up to $25,000**
- **Lost production per hour of downtime on a prime mover: $77,000/Hr**
- **Spot Gold Price at 1,300/oz**

Surface Coal Mine
- **Cost of Hose Assembly: up to $1,100.00**
- **Content per Machine: up to $40,000**
- **Lost production per hour of downtime on a prime mover: $27,000/Hr**
- **Spot Price of Coal at $7.53/metric ton**

Figure 5: Relative values of downtime, content per machine and hose assembly pricing

CONCLUSIONS

The paper discusses Reliability Based Maintenance applied to Hose Assemblies and shows the results produced by applying one or more components of a Reliability Based Hose Management Program in several mining operations around the world departing from a time based maintenance program to a condition based maintenance program. This new approach in hose assembly maintenance has shown significant improvement in Mean Time Between Failures, Reduction in the Total Cost of Ownership and improvement in Mobile equipment Fleet availability. The main factors determining the success of mining operations were discussed and it is shown that the acquisition cost of a hose assembly is insignificant compared to the value of downtime of a major piece of equipment in any mining operation.

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Moubray, J. 1977, Reliability Centered Maintenance, 2nd Edition, Published, April 1997, *by Industrial Press*, ISBN: 0831130784.