EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH
ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE

# CERN - ST Division

ST-Note-2003-038
20 January 2003

## ST-HM EQUIPMENT CONSOLIDATION

Ingo Rühl, Antonino Calderone

**Abstract**

In general all kind of equipment must be maintained if it is to fulfil its function for a useful life. This can be achieved using one of the four key maintenance strategies - on failure maintenance, fixed time maintenance, condition based maintenance and design out maintenance. Each of these strategies has a place within an optimised maintenance plan. The first three maintenance strategies are mostly applied and implemented in the various ST maintenance plans. The fourth strategy in contrast, design out maintenance (also referred to as equipment consolidation / replacement), is rather applied in an ad-hoc strategy than in an organised way. This paper shall outline the general factors that must be considered in order to implement design out maintenance. Furthermore this paper shall demonstrate a possible approach for the application of design out maintenance regarding transport and handling equipment.

Presented at the 6th ST Workshop
Thoiry, France, April 1 – April 3, 2003

## 1 INTRODUCTION

Maintenance designates all the activities (technical, administrative, and management) designed to keep or to return an **asset** to operating condition.

From day one, equipment and plant must be maintained if it is to fulfill its function for a useful life. This can be achieved using one of the four key maintenance strategies[1]:

### 1.1 On-Failure Maintenance (Corrective Maintenance)

The maintenance is done when the equipment has failed to fulfill its function.

### 1.2 Fixed Time Maintenance (Preventive Maintenance)

The equipment maintenance is based upon fixed time – either calendar based, actual hours in operation, or the number of equipment cycles carried out.

### 1.3 Condition Based Maintenance

The equipment maintenance is based upon its known condition.

### 1.4 Design Out Maintenance

Design, or redesign, equipment to eliminate the root cause of failure and resulting failure modes so as to eliminate or minimize the need for maintenance. When it comes to design out maintenance or equipment consolidation or equipment replacement we are basically talking about 'Repair vs. Replace'.

**In our experience, the repair vs. replace decision is generally not well understood nor implemented in most organizations.** This paper puts forwards the principles upon which effective repair vs. replace decisions should be based, discusses some of the practical issues frequently encountered in applying these principles, and then makes some suggestions about how to improve repair vs. replace decisions.

### 1.5 Maintenance plan

Each of these strategies has a place within an optimized maintenance plan, but the distribution of the mix will depend upon many factors, including:

- The equipment to be maintained,
- The operational context – both in terms of Production and the Prevailing environmental conditions,
- The maintenance resources available,
- Health and safety compliance,
- General Practicalities,
- Costs.

[1] Note: Many differing terms are used to describe the various strategies!

## 2 EQUIPMENT LIFE CYCLE

The standard model to display the typical life cycle of equipment is the bathtub curve:

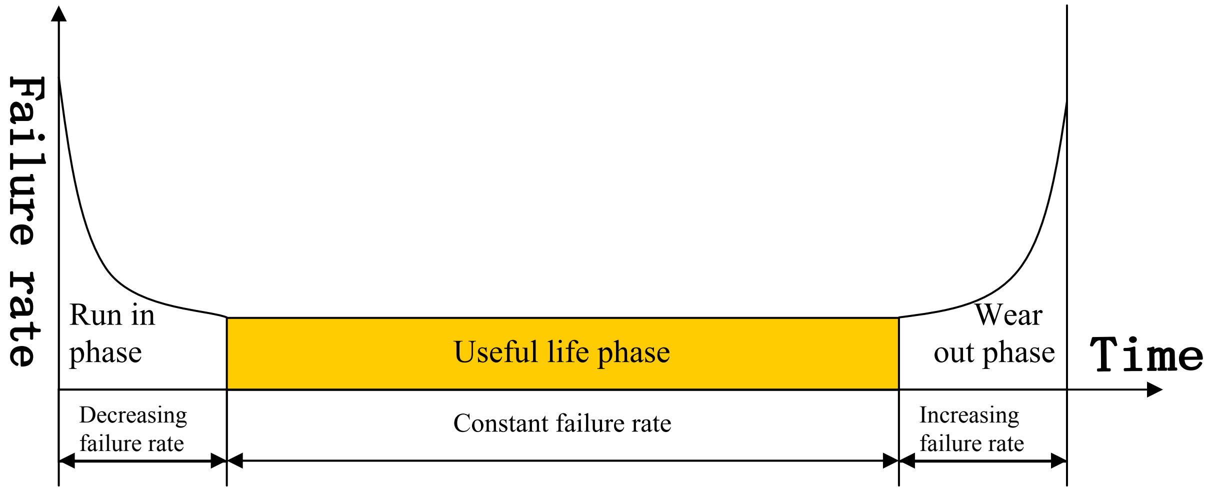


**Figure 1:** Bathtub Curve

The typical 'Bathtub' curve illustrates the classic profile of failure rate against time for equipment. Although it cannot be applied in general for all equipment it does correspond very well to the equipment maintained by the ST division.

The ST maintenance plans does respect the run in phase as well as the useful life phase but there is no or hardly any design out phase for equipment reaching the life cycle end.

## 3 ST-HM EQUIPMENT

The ST-HM equipment is divided into two main groups and also maintained by two different maintenance contracts.

### 3.1 The 'Road' transport equipment as trucks, trailers, utility vehicles etc.

Table 1 shows the entire CERN transport vehicle park of which ST-HM is in charge for maintenance.

| *Pos.* | *Vehicle type* | *Number* | *Average age [years]* |
|---|---|---|---|
| 1 | DS - Divers | 20 | 20.9 |
| 2 | ELE – Electrical forklifts | 23 | 15.8 |
| 3 | ELT – ICE forklifts | 28 | 16.0 |
| 4 | GR – Mobile cranes | 3 | 13.2 |
| 5 | PL – Utility vehicles (>3.5 t) | 16 | 14.7 |
| 6 | RR – Road trailers | 18 | 23.0 |
| 7 | TG – Electrical pallet trucks | 36 | 19.1 |
| 8 | TR – Road trucks | 10 | 18.5 |
| 9 | VU – Utility vehicles (<3.5t) | 67 | 9.6 |
| 10 | MA – Agriculture vehicles | 4 | 27.5 |
| 11 | JA – Garden vehicles | 40 | 16.8 |
| 12 | V99 – Garden vehicles (Reserve) | 12 | 13.9 |
| 13 | VM - Mopeds | 118 | 17.9 |
| *14* | *Total* | *395* | *17.5* |
| **15** | **Total (Pos. 1 - 9)** | **221** | **16.8** |

**Table 1**: CERN transport vehicle park

The high average age of equipment is due to the fact that there was hardly any investment for the renewal of the transport vehicle park after the LEP installation.

The fact that CERN vehicles are generally exonerated from technical control was hiding the fact that many vehicles are obsolete and does not correspond to today's health and safety regulations. Since last year the CERN vehicles undergo the technical control on a voluntary base but all vehicles that were presented had to be taken out of service. So far only a small number of vehicles were presented since the preparation of each vehicle takes a lot of time and already major investments that are not foreseen in the actual budgets.

In 2003 the renewal of some strategic equipment is foreseen in the limits of the available budget as for example the procurement of a new mobile crane that will replace the two old mobile cranes (>15 years). In addition, the contribution of the LHC machine and the Experiments will enable us to overhaul and/or replace obsolete equipment and to procure new equipment that fulfils the requirements for the transport of delicate machine and detector equipment.

Please note that the total required budget for the renewal of vehicles in 2003 as shown in table 2 is not yet fully allocated.

| *Pos.* | *Vehicle type* | *Reasons / Remarks* | *Cost est. [CHF]* |
|---|---|---|---|
| 1 | Mobile crane 35 t | Replacement of two existing mobile cranes due to non-reliability. Too much investment for repairing the old ones. | 300'000 |
| 2 | Road truck 6x6 | This new truck shall replace CERN truck n° 402 (age 17 years) in case of breakdown. CERN truck n° 402 is currently the only one able to taw the Nicolas trailer 100 T, which will transport the cryodipoles, and the Nicolas trailer 60 T. This truck will be used full-time for the transport of cryodipoles and it is essential for transport operations to have another truck for the Nicolas trailer 60 T. | 170'000 |
| 3 | Telescopic semi-trailer flattened | This type of semi-trailer is adapted to all types of loads: high (low centre of gravity), long (until 17 m) and heavy (until 40 tons). This semi-trailer shall replace the Trabosa trailer and allows a transport of a cryodipole in case of a breakdown of the Nicolas trailer 100 T. | 250'000 |
| 4 | Plate truck 4x2 | This truck shall replace the trucks Ford n° 328 and 329 which are out of service. These dimensions (7 m, 10 T of payload) cover most of the loads to be transported. | 120'000 |
| 5 | Plate truck 4x2 with rack or hatchback | This vehicle is intended to replace the old Unimog trucks (age 24 years). These dimensions (7 m, payload 10 T) cover most of the loads to be transported. The rack or hatchback allows a loading the with a pallet truck. | 160'000 |
| 6 | Frontal electric forklift truck 5 T | This forklift truck shall replace the forklift truck n° 662 due to non-reliability. It shall comply with the new safety requirements relating to handling activities on the slopes. | 120'000 |
| 7 | Semi-trailer payload 25 T | This semi-trailer will be dedicated to the transport of long loads for LHC project (ex: QRL, DFBs, etc.) and of many machine elements (ex: converters, DQR, DQS). | 150'000 (LHC budget) |
| 8 | Semi-trailer payload 25 T | This semi-trailer will be dedicated to the transport of fragile loads for experiments. It shall be equipped with a particular suspension system to attenuate vibrations and efforts generated on the transported pieces. | 200'000 (Experiments budget) |
| 9 | 5 utility vehicles | Renewal of the utility vehicle park (< 3.5 t). | 100'000 |
| **Total** | | | **1'570'000** |

**Table 2**: 'Road' transport equipment priority list for consolidation

In addition, ST-HM will work out an equipment renewal plan that takes in consideration the near and future requirements. The aim is to keep a much smaller transport vehicle park and to rent equipment that is only used now and then. For the remaining equipment park in 2007 a renewal plan as for the CERN car pool but with a longer replacement period of up to 10 years could be considered.

### 3.2 The lifting and handling equipment

The 3395 lifting and handling equipment includes electrical and ICE forklifts, electrical and mechanical hoists, electrical tunnel vehicles, gantry cranes, auxiliary lifting equipment, working and lifting platforms, overhead traveling cranes etc.

The most of the equipment has specific life time cycles but of the 3395 lifting and handling equipment that is currently listed in the maintenance plan of ST-HM the 326 overhead traveling cranes in service represent the most important and most strategic part since there is hardly a back-up solution possible.

*3.2.1 Overhead travelling cranes*

In table 3 all overhead travelling cranes are listed that were commissioned more than 30(!) years ago.

| *Pos.* | *Overhead travelling crane* | *Building* | *Capacity [t]* | *Commissioning date* |
|---|---|---|---|---|
| 1 | HHLPR3 | 151 | 30 | 1957 |
| 2 | HHLPR4 | 150 | 20 | 1957 |
| 3 | HHLPR5 | 150 | 20 | 1957 |
| 4 | HHLPR23 | 250 | 10 | 1960 |
| 5 | HHLPR24 | 250 | 10 | 1960 |
| 6 | HHLPR27 | 101 | 10 | 1961 |
| 7 | HHLPR30 | 251 | 10 | 1961 |
| 8 | HHLPR31 | 251 | 10 | 1961 |
| 9 | HHLPR36 | 156 | 10 | 1962 |
| 10 | HHLPR39 | 157 | 40 | 1963 |
| 11 | HHLPR40 | 352 | 40 | 1963 |
| 12 | HHLPR57 | 103 | 5 | 1965 |
| 13 | HHLPR60 | 7 | 3.5 | 1965 |
| 14 | HHLPR63 | 163 | 20 | 1965 |
| 15 | HHLPR67 | 157 | 20 | 1965 |
| 16 | HHLPR74 | 169 | 20 | 1967 |
| 17 | HHLPR75 | 358 | 50 | 1967 |
| 18 | HHLPR84 | 180 | 60 | 1968 |
| 19 | HHLPR89 | 129 | 1.5 | 1968 |
| 20 | HHLPR90 | 129 | 1 | 1968 |
| 21 | HHLPR91 | 180 | 40 | 1968 |
| 22 | HHLPR113 | 377 | 10 | 1969 |
| 23 | HHLPR114 | 378 | 10 | 1969 |
| 24 | HHLPR142 | 183 | 30 | 1971 |
| 25 | HHLPR500 | 867 | 30 | 1973 |
| 26 | HHLPR501 | 867 | 15 | 1973 |
| 27 | HHLPR502 | 867 | 15 | 1973 |
| 28 | HHLPR514 | 869 | 7.5 | 1973 |
| 29 | HHLPR515 | 869 | 7.5 | 1973 |
| 30 | HHLPR517 | 868 | 7.5 | 1973 |
| 31 | HHLPR518 | 868 | 7.5 | 1973 |

**Table 3**: Overhead travelling cranes > 30 years

It would be too easy and not correct to claim that in general all those overhead travelling cranes commissioned more than 30 years ago are at the end of their life cycle. Several more aspects have to be taken in consideration especially the mechanism group of a crane according to the FEM standards. The FEM classification takes in consideration the:

- Average hook path HW [m],
- Hoisting speed V [m/min],
- Cycles/hours ASP,
- Working hours per day AZ.

These values are required to calculate the average operating time group per working day:

**tm** = (2*HW*ASP*AZ)/(60*V)]

The operating time group **tm** in combination with the 'estimated' load spectrum defines the four FEM mechanism group of hoisting equipment:

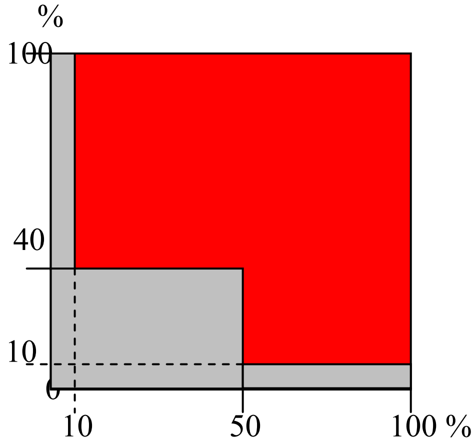


**Figure 2:** Light

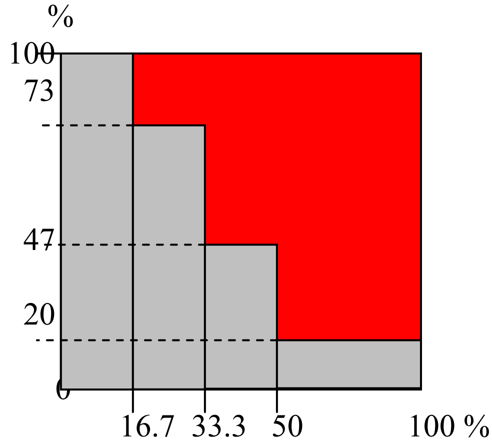


**Figure 3:** Medium

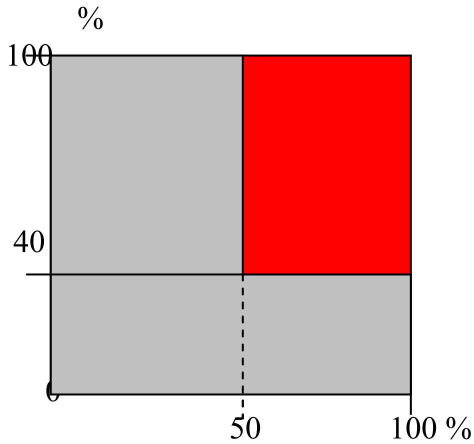


**Figure 3:** Heavy

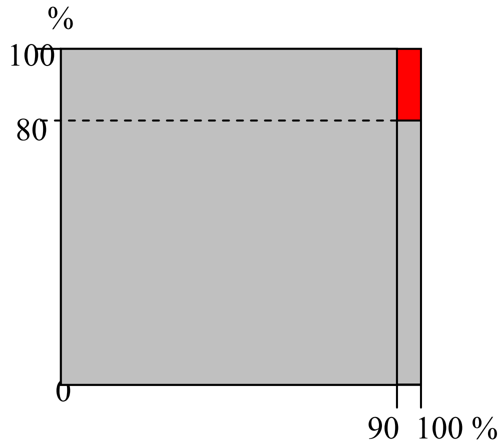


**Figure 4:** Very heavy

Each of the four spectrum classes is divided into four subgroups – 1Bm, 1Am, 2m and 3m. Unfortunately these data are not or hardly available for the older cranes – neither in the equipment documentation nor in the specifications.

For cranes commissioned before 1990 only the running hours were registered in the best case, which makes the calculation of the life cycle status difficult if not impossible. Since 1990 basically all new cranes are equipped with a kind of 'black-box' that registers the running time and lifting spectrum and calculates automatically the remaining lifetime.

Hence, the statement that the cranes commissioned more than 30 years ago reaching the end of the lifetime cycle contains always a kind of uncertainty.

Considering the failure rate two main causes are possible:

1. The electrical failure rate counts for more than 80% of the breakdowns. This can simply be explained that the life time cycle of electrical components is by far less than the mechanical life time cycle. The breakdowns are often recurrent but of short duration. Also some cranes that were commissioned not more than 15 years ago cause already major electronic problems and will require design out maintenance in order to increase reliability.
2. The mechanical failure rate is considerable lower, less than 20%, but can have as a consequence long downtimes. Mechanical breakdowns are mostly unpredictable even with 'modern' analyse tools.

### *3.2.2 Overhead travelling crane consolidation project*

A 10-year consolidation plan could be established based on the known and/or estimated parameters as run time, load spectrum and also based on a safety assessment due to the fact that the safety standards changed considerably during the last 30 years.

The extent of the design out maintenance will then depend also on the foreseen future use of the crane, the spare part supply from the crane manufacturer if still existing or an alternative supplier.

Crucial point of design out maintenance is as so often the available budget. Since we are basically talking about 'Repair vs. Replace' when it comes to design out maintenance we also talk about 'Long time small investments vs. Short time big investment'.

The standard maintenance plan of the most ST maintenance contracts covers only the four standard maintenance service levels [MSL] but not the fifth MSL for equipment consolidation. The available budget for the fifth MSL is just sufficient to treat a few major breakdowns but does not allow a consequent equipment consolidation. But since the equipment is getting less and less reliable more and more budget resources must be taken out of the four MSL in order to cover the more and more occurring fifth MSL work. As a consequence less preventive maintenance can be afforded, which will have a negative impact in the long run.

The following standard terms on which a consolidation project can be established must be accepted and understood in order to set up a proper ST consolidation plan:

### *3.2.3 Life Cycle Costing*

Life Cycle Costing is a process of estimating and assessing the total costs of ownership, operation and maintenance of an item of equipment during its projected equipment life. Typically used in comparing alternative equipment design or purchase options in order to select the most appropriate option.

### *3.2.4 Economic life*

Economic Life is the total length of time that an asset is expected to remain actively in service before it is expected that it would be cheaper to replace the equipment rather than continuing to maintain it. In practice, equipment is more often replaced for other reasons, including: because it no longer meets operational requirements for efficiency, product quality, comfort etc., or because newer equipment can provide the same quality and quantity of output more efficiently.

### *3.2.5 Return on Assets*

Return on assets is an accounting term. The relative merits of various accounting standards, how assets should be valued (book value, replacement value, depreciation rates and methods etc.), and differences between tangible and intangible assets are of the interest for accountants as well as for maintenance engineers. In practical terms, as it impacts on maintenance, Return on Assets is the profit attributable to a particular plant or factory, divided by the amount of money invested in plant and equipment at that plant or factory. It is normally expressed as a percentage. As such, it is roughly equivalent (in principle) to the interest rate that you get on money invested in the bank, except that in this case the money is invested in plant and equipment.

In addition to the above terms each project leader should take in consideration the logistic support analysis if the project requires reliable transport and handling means:

### *3.2.6 Logistic support analysis (LSA)*

Logistic support analysis is a methodology for determining the type and quantity of logistic support required for a system over its entire lifecycle. Used to determine the cost effectiveness of asset-based solutions.

### *3.2.7 Overhead travelling crane priority list for consolidation*

The following overhead travelling cranes (table 3) require urgently a consolidation program. The list is non-exhaustive, full equipment analyse is under way and a proper design out maintenance plan will be established.

| *Pos.* | *Crane* | *Bldg* | *Com. date* | *Reasons / Remarks* | *Cost est. [CHF]* |
|---|---|---|---|---|---|
| 1 | HHLPR3 | 151 | 1957 | Intensive use of cranes foreseen for the installation of LEIR. | 1’400’000 |
| 2 | HHLPR4 | 150 | 1957 | | |
| 3 | HHLPR5 | 150 | 1957 | | |
| 4 | HHLPR36 | 156 | 1962 | Crane is worn out and shall be replaced completely. | 150’000 |
| 5 | HHLPR84 | 180 | 1968 | Heavily used cranes -in the past and at the present. Crane manufacturer does not exist anymore, no more spare parts available, recurrent electrical problems. The replacement of the lifting trolleys and the electronics was requested already several time but never realised due to the lack of budget. Risk of major delay for ATLAS if a mechanical breakdown occurs. | 1’200’000 |
| 6 | HHLPR91 | 180 | 1968 | | |
| 7 | HHLPR500 | 867 | 1973 | Worn out due to the heavy utilisation during 30 years. Requires over proportional maintenance efforts. No more spare parts available. Proposal to replace the entire mechanical and electrical equipment by keeping only the bridges. | 500’000 |
| 8 | HHLPR501 | 867 | 1973 | | |
| 9 | HHLPR502 | 867 | 1973 | | |
| 10 | HHLPR560 | TCC8 | 1979 | Although only in service since 1979 the electrical equipment is worn out and has to be replaced completely. | 250’000 |
| 11 | HHLPR570 | 921 | 1981 | Intensive use foreseen for the TI8 and CNGS installation. Non-reliable electrical equipment. No more spare parts available. Urgent replacement of electronics required. | 500’000 |
| 12 | HHLPR572 | ECA4 | 1981 | | |
| **Total** | | | | | **4’000’000** |

Table 3: Overhead traveling crane priority list for consolidation

## 4 CONCLUSION

Instead of finishing in a lengthy conclusion just as a reminder the following key points from this paper:

- Repair vs Replace decisions have expensive consequences, yet are often made without full and proper analysis – "rules of thumb" are often inappropriate.
- The appropriate tool for accurate decision-making is to use a Life Cycle costing approach….
- …but accurate data is often not available to support this decision tool
- The most accurate decision model is useless, without effective management control to ensure that it is being appropriately applied.

## Bibliography


[1] Malcolm J. Wallace, *Essential Tools for Optimized Maintenance Performance* (Wolfson Maintenance, Manchester, 2000)

[2] Sandy Dunn, *Maintenance Outsourcing – Critical Issues* (PRicewaterhouse Coopers, 2000)

[3] Harvey H. Kaiser, *Maintenance Management Audit* (Applied Management Engineering, USA, 1991)

[4] Bernard T. Lewis, *Facility Managers Operation and Maintenance Handbook* (McGraw-Hill, USA, 1999)

[4] Repair vs. Replace - Key concepts for better decision-making (Sandy Dunn, Asian Maintenance in Mining Conference, Lombok, Indonesia, 1999)