ST

Maintenance Management Standard

Chapter 8 : Preventive Maintenance Foundation

Corporate Cement Industrial Performance

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LafargeHolcim

Content

1. Introduction

This chapter of the manual will deal with the concept of Preventive Maintenance, the main components thereof and two of the most crucial (and basic) activities within Preventive Maintenance: walk-by inspection and lubrication. In addition, the link to SAP-PM will be discussed as part of a successful management of Preventive Maintenance activities. This chapter matches the scope of the MAC Foundation element Preventive Maintenance #1. Condition monitoring techniques would then correspond to the MAC Advanced element Preventive Maintenance Level #2 (e.g. oil analysis, vibration analysis, Non-Destructive Testing) and will be further described within Chapter 9, Advanced Preventive Maintenance.

2. Preventive Maintenance in a plant

2.1 Preventive Maintenance role

Preventive Maintenance deals, by definition, with all tasks that are performed at predetermined (fixed) intervals. This includes all inspection types, measurement and data gathering and scheduled component replacement.

Preventive Maintenance is a key component on any successful Maintenance strategy within LafargeHolcim. Clearly defined Roles and Responsibilities within the Maintenance organization will facilitate the management, planning, scheduling and execution of the Preventive Maintenance Routines (PMR's), which account for a considerable part of a plant annual maintenance activities, especially in terms of man-hours required.

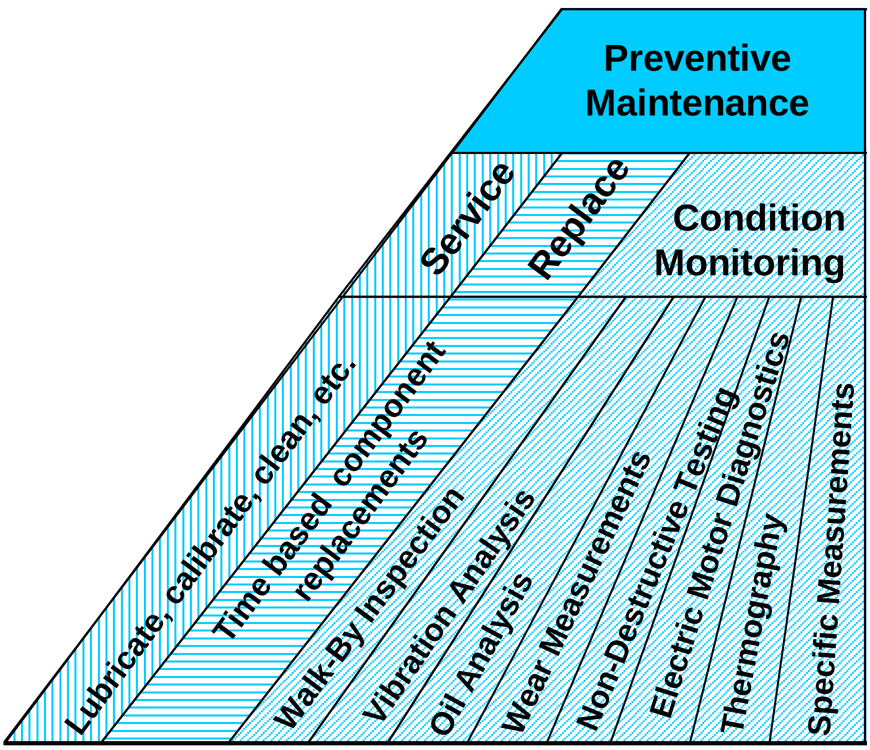


Figure 1 **Detail of activities corresponding to Preventive Maintenance.**

It is therefore one of the key functions of Preventive Maintenance to perform the required inspections, servicing, Condition Monitoring techniques and to report any findings (via notifications or Work Requests) to the Corrective Maintenance function to be addressed.

2.1.1 Preventive Maintenance optimization

The Preventive Maintenance function must assure that all Preventive Maintenance tasks are aligned throughout the plant, in order to avoid duplications and that wherever possible Condition Monitoring tasks are replacing time based activities.

This Preventive Maintenance optimization includes then the following:

- Walk by inspection (all Maintenance and Production Check Sheets): the actual content of the inspection check sheets must be validated and stream lined according to the specialty performing the walk-by inspection
- No duplication between Condition Monitoring and downtime inspections. For example, if a motor connection box is being scanned for loose contacts with a thermal camera, then there should not be a scheduled **time based** re-tightening task of those same connection lugs. Other examples include time based replacement of components whose condition is being monitored through a specific technique.
- Standardize Preventive Maintenance Routines (PMR's) by equipment type throughout the plant. Common equipment such as bucket elevators, belt conveyors, and vertical mills should have the same Maintenance inspections and tasks defined, no matter where in the cement plant it is located. However, in some plants this condition is not fulfilled and therefore a bucket elevator in the Raw Meal area has different Maintenance tasks than one at the Cement Grinding area. Whereas it is true that some inspection frequencies need to be adjusted based on the material conveyed (i.e. clinker/cement dust are more abrasive than raw meal, demanding shorter inspection intervals), the majority of tasks should be the same in every case.
- No duplication of task between different disciplines. It can be found especially in inspection check sheets that certain activities (such as overall vibration and temperature level of an electrical motor) are being performed by technicians from every specialty (e.g. mechanical, electrical, lubrication, preventive maintenance and production). In order to optimize the usage of resources, the specific inspections must be assigned to the relevant specialty only. The personnel performing the inspections must be competent enough, in order not to resort to 'everybody does the inspection to assure that someone is detecting the problem'.
- Justify and optimize the fixed time replacement of components. Sometimes it is more economical to replace a component (or complete equipment) on a time basis than to spend resources on monitoring its condition. While this holds true for lower criticality equipment, the replacement frequency must be defined according to the expected service life of the specific application and how likely it is to have a failure as function of time (i.e. for age related and not random failures). Special care must be taken with time based replacements that are defined in case of accelerated wear instead of finding the root causes to the problem. It is therefore the responsibility of Preventive Maintenance to analyze the underlying causes for a time based replacement and to provide a documented justification for these tasks (economical and technical) and to investigate further on Condition Monitoring or other possibilities (e.g. re-design) to try to eliminate a non-justifiable time based replacement task. The resulting replacement strategy should be reviewed regularly for optimization purposes.

2.1.2 Preventive Maintenance follow-up on requested corrective work

An efficient Preventive Maintenance function cannot limit itself to just performing inspections and data gathering; the main outcome from the PMR's must be work requests (notifications) in order to correct any deviation that might have been detected. This has to be accomplished in a concise and timely way, in order to support the responsible for taking the desired action (e.g. bearing replacement, V-belt pulley replacement), which is often performed by personnel outside from Preventive Maintenance.

It is nevertheless the responsibility of Preventive Maintenance to make sure that:

- The recommended action is planned within an adequate time frame. Tracking the progress of the notification in the SAP-PM system and double-checking during Planning meetings that the corresponding Work Order has been scheduled.
- The recommended action is properly performed, providing technical support in terms of required adjustments on components, proper re-lubrication procedures and other parameters to verify the proper execution of the corrective work. The involvement level will depend on the skills of the technicians and supervisors performing the corrective work.
- The recommended action restored the equipment to the desired condition. This includes vibration and temperature measurements after a bearing replacement, shaft alignment or fan balancing (to quote some examples. The time spent on these activities should be charged to the original corrective work order). Only after these verifications have been performed and provided a satisfactory result is the

responsibility of Preventive Maintenance fulfilled. Afterwards, periodic monitoring (through PMR's) can be resumed until the next time a deviation is detected and the notification cycle starts again.

Preventive Maintenance is responsible as well for other analytical tasks, which will assure a continued long term operation of the plant equipment. Downtime analysis, Root Cause Failure Analysis, FMEA and Reliability Analysis are some of the tools leaded by Preventive Maintenance.

2.2 Preventive Maintenance techniques

There are many different techniques that can be applied in a plant as part of a Preventive Maintenance strategy. It is crucial to understand that more often than not, the simplest tools when well applied will deliver an amazing degree of benefit related to their cost.

It is therefore considered as cornerstones for an effective Preventive Maintenance a proper walk-by inspection program (with participation from Process/Production, Mechanical and Electrical Maintenance) as well as an adequate lubrication management.

These elements will then act as a sound basis for more advanced condition monitoring techniques, such as oil analysis, vibration analysis, thermography, etc.

Lubrication and walk-by inspection will be described within this chapter, whereas the rest of techniques are presented in Chapter 9, "Advanced Preventive Maintenance," of this manual.

2.3 Administrative work

In order to minimize the administrative work involved in PMR's management, the resulting workload must be evenly distributed (balanced) throughout the year and the SAP-PM module (or Computerized Maintenance Management System, CMMS, in use) must be properly configured to allow the automatic generation of all work orders.

3. Preventive Maintenance Routines (PMR's)

A Preventive Maintenance Routine (called PMR in abbreviated form), is a task performed at predetermined intervals, in order to check the current physical condition, to reduce probability and/or impact of a failure in operation, or to maintain a desired level of performance of an equipment.

This definition includes all periodic measurements performed as Condition Monitoring, whereas the resulting actions (e.g. alignment, fan balancing) would be considered as Planned Corrective Maintenance (PM01 in SAP) and not as PMR's (PM02 in SAP).

The PMR's can encompass scheduled replacement of components (e.g. oil filter after 8'000 hours operation), notwithstanding the actual condition of the component (i.e. a bearing is replaced every major outage, whether it could still have worked longer or not).

It must be said that the PMR's for component replacement have to be avoided, as long as a Condition Monitoring activity can be implemented without incurring in higher costs than just performing the component replacement. Sometimes the time based component replacement is just a way of masking unsolved problems (i.e. piston pump replacement every year due to wear, instead of solving the oil contamination problems that are wearing down the pump).

3.1 PMR intervals

For industrial equipment running continuously (e.g. cement plant, on a 24 hour a day, 7 day a week basis or 24/7), the PMR's will be performed based on calendar days and not operating hours. This can be explained by the fact that the planned stops of equipment are scheduled on a calendar basis and therefore the equipment will not be available for Maintenance anyway when the operating hours are reached. It is thus simpler to handle the PMR's on a weekly frequency and multiples of 7 days; more details on this will be covered under heading SAP-PM PMR Management in this chapter.

3.2 PMR content

The following are the main elements that should be included on any PMR.

- ACS: Equipment must be clearly identified
- Description: Meaningful title for a set of tasks (will help when setting the PMR's in the SAP-PM system)
- Frequency (Weeks): Indicates how often the PMR will be performed.
- State of the equipment: Stopped or running. Although this can be inferred from the inspection, it is never enough to mention it (especially for safety reasons)!
- #: Task number within a Work Order
- Task: This is the essence of the PMR, where the instructions will be given on what to do and how to do it!
- Estimated time: Will depend a lot on the local resources, accessibility, skills level, equipment type. It is crucial for planning purposes.
- Trade: What skills/training is required in order to perform the PMR

Some advices regarding the task description for any PMR:

- Be as clear and specific as possible: Use verbs such as measure, grease, sample, tighten
- Avoid the word 'check', e.g. 'check weld seams'; check exactly what? What is the desired condition?
- Clearly indicate what the outcome of the inspection should be: A measurement, crack detection, etc.
- Provide acceptance criteria (limits) whenever possible (e.g. 50 mm thickness, 2% elongation, 0.5 % relative ovality)
- For complex tasks, refer to a specific job plan (formal procedure Standards & Specifications heading), under chapter Planning and Scheduling on the Manual. All procedures should be readily accessible to the technicians for reference.

3.3 Sources of information for PMR's

The main sources of information for PMR's that can be referred to are the following:

- Manufacturer manuals
  - A preventive maintenance schedule is usually included (as a chart).
  - In most cases, it is too general and has to be enhanced
  - Important values for adjustments and measurements are one of their main contributions!
- Existing PMR's for the same type of equipment (LafargeHolcim Portal, plant records)
  - Standard PMR's for main equipment (kiln, clinker cooler, ball mill, vertical mill and roller press) are available on LafargeHolcim Portal, CoP Maintenance
  - These PMR's are not meant to be used as "Copy & Paste!"
  - Adjustment is required for specific type of equipment (e.g. Loesche VRM vs. Pfeiffer) and actual acceptance values need to be added (allowable wear, thickness, etc)
  - Provided an efficient set of PMR's for a particular type of equipment is already available at the plant, it can be used as basis for a new equipment
- In addition adjust accordingly:
  - Inspection type: There are obvious differences (chain vs. rubber belt bucket elevator);
  - Acceptance criteria: Chain elongation will not be the same if the manufacturer differs (e.g. Aumund vs. Rexnord); even measurement procedure might vary!
  - Inspection frequency: Material being handled, operating hours, temperature are all factors that might require an adjustment of frequency
- Equipment history and personnel experience: equipment history provides a whole array of useful information:
  - Modifications done to the equipment:
    - Type of bearing lubrication might have been changed (from grease to oil) ➔ Change lubrication routine!
    - New design of liners ➔ Adjust wear measurement frequency!
    - Fan recently equipped with VFD ➔ Develop corresponding routines and eliminate old ones (e.g. old damper was removed)

- Known behavior of equipment
  - Normal vibration level exceeds 5 mm/s ➔ vary acceptance criteria
- Changes in operating conditions
  - Kiln shell thickness sharper decrease because of new alternative fuels
  - Increased wear on clinker cooler plates because of extra production
  - VRM hydraulic system leakages due to higher operating pressure (to cope with extra production)

- FMEA’s (Failure Mode and Effect Analysis)
  - Failure Mode and Effect Analysis is a very useful tool to fine-tune and enhance the PMR‘s for an equipment
  - It demands a bigger, concerted effort from the plant personnel (multi-disciplinary teams)
  - A comprehensive FMEA database is currently available on LafargeHolcim Portal
  - FMEA’s can be developed as well as part of Reliability Analysis

3.4 Other factors influencing PMR’s

Feedback from your technicians: Make sure they understand the tasks. Especially for newcomers, a supervisor should perform key PMR’s together with the technician to double-check results (e.g. girth gear axial and radial runout)

- Ask your technicians for feedback on the PMR instructions: are all tasks included?
- Are descriptions detailed enough?
- Are there tasks that he/she is performing that are not listed on the PMR, but that should be?
- Are there superfluous or non-applicable tasks?

Training: As mentioned under the last point, make sure your technicians are skilled enough in order to execute the PMR‘s. Training can be made internally and on the job!.

Check downtime Paretos for evidence of missing PMR‘s. This can prompt a PMR revision; maybe frequency needs to be readjusted or a task is missing. Root Cause Failure Analysis (RCFA) can support this decision.

3.5 Key PMR’s

The Key PMR’s comprise the most important PMR’s that every cement plant and grinding station should perform (for other industries, please refer to the applicable ones). These PMR’s are sometimes neglected, despite the fact that they can have a tremendous impact on availability and maintenance cost.

For each PMR, there is a specific procedure that has been developed, explaining in full how to perform it and more importantly, how to make decisions based on the results.

Equipment / PMR	**Recommended Frequency**[1] [week]	**Comments**
Electrical installations		
Check the resistance of the grounding systems	48	may be regulated by country law
Motor Control center (MCC)		
Thermography inspection of MCC's	24	
High voltage switchgear		

[1] Frequency to be adjusted according to equipment condition and wear rates and according to the maintenance requirements defined by the OEM

Thermography inspection of switchgear and cable connections	24	
Medium voltage switchgear		
Thermography inspection of switchgears	24	
Parameter check and functional test of protection relay incl. recording of reaction time	96	
Insulation test	48	
Transformer		
Thermography inspection of the transformer	24	
Oil analysis on oil filled transformers and on load tap changers	48	6 part Basic test and DGA, Furan analysis every 5 years until transformer is 25 years old, then every year
Insulation test and Polarization Index measurement on dry type transformers	48	
Low voltage switchgear		
Thermography inspection of switchgears	24	
Parameter check and functional test of protection relay incl. recording of reaction time	96	
Motors >= 250 kW		
Thermography inspection on motors	12	
Off-line test for motors Electrical motor diagnosis (EMD)	48	
On-line tests for motors Electrical motor diagnosis	only if issues have been detected	
Steel - bin, tank, silo		
Shell thickness on critical steel silos	16	
Stack, chimney		
Shell thickness on stacks	16	
Belt conveyor		

Belt conveyor rubber belt hardness measurement	48	85 Shore A: order 90 Shore A: replace However consider also results from visual inspection and X-ray monitoring
Additional for steel cord belt conveyors: X-ray or eddy current testing on steel cords	5 years	Decrease frequency with increasing age
Bucket elevator		
Bucket conveyor rubber belt hardness measurement	48	
Measurement of chain elongation	48	2% maximum (in general)
Chain or belt alignment	48	
Ultrasonic test for crack detection on drive shaft	48	
Ball mill		
Measure wear of the mill diaphragm	12	
Measure wear of the mill liners	4	
Visual inspection of the mill head	24	
Magnetic particle / Dye penetrant test / Ultrasonic on mill head	48	
Magnetic particle test of dye penetration on mill shell weld seams	48	
Mill trunnion bearing play and condition	24	Clearance measurement between trunnion and bearing
Cyclone		
Shell thickness on cyclones (corrosive environment)	16	
Emergency power generator		
No-load run of emergency power generator	4	
On-load test with thermography	48	Load to be connected to the switchgear
Fan		
Wear measurement of the impeller	Kiln area: 48w Other areas: 12w	
Ultrasonic test for crack detection on drive shaft	48	For main process fans
Girth Gear Drive (kilns and mills)		

Backlash measurement	48	
Tooth root clearance	48	
Visual inspection of teeth surface	48	
Spray pattern check	2	
Temperature distribution over flank width	1	Maximum delta temperature of 3°C along the flank
Measure axial and radial run-out of girth gear	48	
Gyratory crusher		
Wear measurement of shell / liners	12	
Grate cooler		
Ultrasonic test for crack detection on drive shaft	48	
Frame alignment	48	
Gap management (between grate plates and lateral)	48	Vertical gap (clearance) between grate plates is 1.5 mm, gap between side castings and grate plates (side clearance) is approx. 3.0 mm (cold clearance)
Wear measurement of the plates	48	
Hammer crusher		
Wear measurement of hammers	48	
NDT (MT or PT) test for crack detection of rotor hubs	144	
Horomill		
Wear pattern on roller	12	
Wear measurement pattern wear ring	12	
Impact crusher		
Ultrasonic test for crack detection of the drive shaft	144	
Wear Measurement of the roller discs, liners	1	
Kiln		
Visual inspection of axial thrust collar of roller shaft	1	
Roller shaft bearing play	48	

Visual inspection of axial thrust roller system	2	
Ovality measurement	24	
Relative movement (creep)	1	Between 10-15mm/rev; Maximum 30mm/rev
Migration (axial movement)	1	
Axis alignment	48 (cold), 144 (hot)	
Shell thickness measurement	48	
Magnetic particle test on kiln shell weld seams	48	Especially on sections with diameter transition
Wear measurement on tire / rollers: rectilinearity	48	2mm max (concave or convex)
Wear measurement on rollers: Conically of roller	48	5mm max
Ultrasonic test for crack detection on tire	48	
Ultrasonic test for crack detection on roller shaft	48	
Preheater		
Wear measurement of the refractory (concrete and bricks)	48	
Pan conveyor		
Pan conveyor chain elongation	48	
Chain alignment	48	
Ultrasonic test for crack detection on drive shaft	48	
Reclaimer		
Measure elongation of the chain	6	
Roller mill, vertical roller mill		
Ultrasonic test / Magnetic particles test for crack detection of the pull rod and piston rod	48	
Wear measurement pattern on rollers	12	May also be shorter depending on the material to grind
Ultrasonic test for crack detection on roller	48	
Wear measurement on separator blades	8	
Wear measurement pattern table	12	May also be shorter depending on the material to grind

Wear measurement of the table liners	4	
Roller press		
Wear measurement on roller	4	
Fuel tanks		
Shell thickness on fuel tank	16	
Critical Drives		
Vibration monitoring of critical drives	2 to 4	
Oil analysis on critical gearbox, bearings and hydraulic systems	4 to 24	

4. Walk-by inspection

Walk-by inspection is defined as an inspection carried out **with the equipment in running condition**, using four out of the five human senses (eyesight, listening, smell, touch plus common sense!) in addition to simple tools (infrared thermometer, vibrometer) and aided by a check sheet.

For LafargeHolcim purposes, the walk-by inspection is radically different from 'visual inspection' and should not be mistaken. The visual inspection is part of the Non-Destructive Testing (NDT) and is performed with the equipment stopped.

Features

As can be inferred from the definition previously introduced, the walk-by inspection has the following features:

- It is inexpensive, since only manpower and minor tools are required. Whereas in some countries the labor costs are one of the main factors of the total Maintenance cost, there is seldom the need to hire any new personnel in order to implement the walk-by inspections, i.e. existing resources are better utilized.
- It is simple: the walk-by inspection can be easily completed by experienced personnel, with sound basic knowledge and a good dose of common sense. It is key that a well developed check sheet is used.

4.1 Checksheets

The inspection check sheet is the main tool to be used during the walk-by inspections. A well designed check sheet allows a thorough inspection, since the inspector does not have to rely on his/her memory to inspect all machines on the assigned route, nor on what to inspect. In addition, the check sheet captures all relevant feedback that can later be either turned into notifications (in case of detected anomalies) or recorded for trending purposes.

Therefore, a check sheet should feature the following:

1. Clear instructions: It must be clear what each task is, whether visually inspecting oil level or measuring a bearing temperature. The use of the term ‘check’ should be avoided or at least complemented (e.g. visually check welding seam for cracks).
2. Target condition: Always indicate what the acceptable condition should be like; use a figure whenever possible (e.g. 4.5 bar pressure, 55 °C bearing temperature). In this way, the comparison of the actual value against the target value allows an immediate detection of an anomaly that demands further action. In addition, the magnitude of the deviation will determine the priority of the follow-up measures.

   Where no figures can be used, it is recommended to provide hints on assessing proper function: for example, belt cleaners should always be in contact with the belt.

3. User friendly layout: The layout of the check sheet itself should be easy to fill in for the inspector and it should be based on anomaly detection, i.e. after the inspection, the supervisor or person responsible for the notification should be able to identify at a glance where deviations from the desired condition have happened. This can be accomplished using a column to identify, whether a Notification is needed or not (otherwise, if a technician reports “Bolts loose” only, it is unclear whether he managed to solve the issue or is still pending)

   Another relevant feature is space for comments, since other information not accounted for in the check sheet may be key for troubleshooting and further analysis.

4. Logical sequence: The equipment to be inspected must be listed starting from the highest and farthest point in the plant (e.g. bucket elevator drive) and follow the least complicated path throughout the plant in order to complete the inspection. This can result in equipment from different areas (e.g. pre-homo silo dedusting fans and pre-heater cyclones) being included in the same check sheet in order to save time and effort for the inspector. Note that the idea behind starting at the farthest point is to maximize the chances the inspection will be completed in case the inspector had to interrupt the job due to an emergency or other unforeseen circumstance (e.g. had to immediately notify a Maintenance supervisor in case of an extremely high temperature bearing)

Some examples of check sheets are shown below, where the above mentioned points are illustrated:

Condition Equipment	**Yes/No**	**Target value**	**Actual value**
Is the system properly sealed - from dust pickup to stack outlet? Gaskets in good condition?			
Is the compressed air clean and dry? (Condensates evacuated from filter bowl)			
Record compressed air pressure at diaphragm valves feed line (5-6 bar)		**5-6 bar**	
Watch the cleaning sequence for a full cycle. Are all valves activating properly?			
Does the air pressure return to target value after each pulse on the cleaning sequence?		**5-6 bar**	
Is the pressure drop through the bag filter less than the target value (13 mbar)?		**13 mbar max**	

Figure 2 Sample check sheet, showing task description, task completion, target value and actual value.

Equipment	Yes/No	Notification needed?	Comments
Is the conveyor belt worn out (fabric visible or only thin layer of rubber remaining, deep grooves, holes, patches, cracks in rubber, etc)?			
Is the belt splice damaged?			
Is the belt properly aligned? (Is it running centered? Any evidence of belt rubbing against frame?)			

Figure 3 Sample check sheet, where columns for Notification needed and Comments have been added

The following example illustrates a way of reducing the amount of text and the effort to fill in the template.

HAC code	Activity	Punto mant.	Normal range	OK	Not OK	Remarks
211BC1	Measure	Reducer temperature	max 70 C			
	Inspect	Belt scraper condition	touching belt			
	Inspect	belt tracking	aligned			
	Inspect	belt splices	not torn			
	Inspect	belt condition	no cuts			

Figure 4 Sample check sheet where the amount of writing is minimal (just for remarks)

It can be noted that in the check sheet of figure above, there is no space for writing the actual value of the reducer temperature. Although the inspector is provided with a heat gun, the idea behind is not to record data that will not be trended; therefore, the inspector would have to enter the actual temperature value **only if it exceeds the alarm value**. This measure certainly simplifies the execution of the walk-by inspection and can be certainly applied to all those items where no trend is required (e.g. compressed air pressure on jet pulse dust collectors: if the pressure is beyond the acceptable range, it just has to be re-adjusted but no trend is required).

It must be clear that the goal is to create check sheets that demand the least writing effort for the technician, without sacrificing the quality of the information contained therein. Another important consideration is to eliminate the paperwork generated by check sheets as much as possible. For this purpose, the following two headings will discuss two different options on how to accomplish this. Plants are strongly encouraged to apply the described methods to reduce the amount of print-outs of check sheets.

Check sheets in SAP-PM

The examples shown in the previous section refer to tables that are not easily realized in SAP-PM. In order to solve this problem and at the same time to shorten the length of the respective Work Order, the check sheets has to be created in another application (e.g. MS-Excel) and linked to the Work Order through the DMS (Document Management System) functionality of SAP. Therefore, the actual work order will only make a reference to the corresponding check sheet (i.e. the actual machines and points to inspect are not included as part of the long text of the Work Order operation) but with the advantage that the check sheet is always linked to SAP, which is very valuable in case of modifications to the check sheet (a single document to modify).

For daily inspections, this allows having a plasticized print-out that the technician can take to the field, make remarks with a whiteboard (or other erasable) marker and re-use it the following day.

Of course, in case the plant wishes to keep written records, this can always be accomplished through a print-out of the corresponding check sheet.

Paperless check sheets

A relatively new way to eliminate the need to carry 'paper' check sheets out in the field is the use of Personal Digital Assistants (PDA's). Some plants within the LafargeHolcim Group have implemented this tool for their walk-by inspections. The inspection route is created as a MS-Excel or Word document, uploaded in the PDA and handed over to the inspector. After performing the job, the inspector downloads the completed check sheet and the responsible supervisor scans it for anomalies. The resulting document can be electronically stored for further reference; values to be trended can be copied directly from the check sheet to the appropriate database. An example of how one of these check sheets looks like is presented below:

361-LQ1 MAIN DRIVE LUB SYSTEM												
Is the oil flow less than 6.0*100 Lpm?		7		7		7.8		7.8				7.5
Range : between 6 and 8*100 Lpm												
Is the motor temperature over 70 C?												
Motor pump 1 (circulation oil)		47		47		46		44				53
Motor pump 2 (high pressure)		58		61		53		56				64
Motor pump 3 (high pressure)		50		55		47		53				57
Motor pump 4 (high pressure)		55		54		49		52				56
Motor pump 5 (high pressure)		49		52		45		48				54
Motor pump 6 (high pressure)		57		56		50		55				59
Motor pump 7 (send oil to heater)		32		33		49		51				58

Figure 5 Check sheet in MS-Excel used with PDA's.

This idea can be easily linked with the concept of check sheets integrated in the DMS (as commented on the previous section), since the format can be exactly the same.

In addition to the fact that typing/transcription mistakes are avoided, the usage of PDA's has had a boosting effect on the image of the inspector and his motivation, since this kind of gadgets conveys a 'high-tech' impression and can certainly eliminate needless paperwork. Another advantage is the fact that the PDA makes it easier to assure that the inspector has actually taken the check sheet out in the field (the same cannot be said of print-outs).

Despite the sensitivity of electronic devices not designed for industrial use, the PDA's have proven durable in the cement plant environment. Special casing can be as well provided, to avoid damages by shock/falls and dust.

There is specific 'add-on' software that allows synchronization between a PDA and the SAP-PM module. For the time being there is no proven solution within LafargeHolcim yet.

4.2 Organization of walk-by inspection routes

Equipments to be inspected must be listed on a 'logical' order that matches the actual layout of the plant (which does not necessarily correspond to the process flow). The whole idea is to avoid that the inspector climbs up to the top of the bucket elevator, goes afterwards to the bottom of the silos and then returns again to an upper level and comes down again. This logical order has to be tested in the field and optimized. For better results, it is suggested to start the route with the higher most and farthest point within the plant section (in case the inspector has to interrupt the route, it would be easier to resume it being closer to the workshop or workplace).

Relevant safety instructions and a list of tools must be mentioned at the beginning of the route. Bear in mind that the tools to perform the walk-by inspection should be limited to the scope of the inspection, i.e. the technician should not carry a full set of heavy wrenches or electrical contact cleaner fluid or any other material that will not be used during the inspection.

Another advantage of the optimized inspection routes is the reduction in number of resulting Work Orders and the ensuing administrative work.

4.3 Production and Maintenance Check sheets

One common mistake observed at different LafargeHolcim sites is the creation of identical walk-by inspection check sheets for Production and Maintenance personnel. These check sheets should be substantially different, due to the time available and the respective set of skills of the technicians performing the inspection.

Whereas a certain level of redundancy on main equipment (kilns, mills) is desired, both Maintenance and Production must actively engage on the design of the check sheets and assure that both parties know what the other is supposed to be inspecting!

In the case of Production, the focus should be on **symptom detection**. The Production personnel is present on a permanent basis and therefore a daily (or even once per shift) walk-by inspection can be organized for them. However, this should not take them away from their other duties and must be a much shorter route than the one for Maintenance personnel. This inspection should be simple to perform and its scope should be to verify that the equipment can keep running during that particular shift (i.e. no immediate threat to operations). Items to look for are mainly spillages (of lubricant or process related material), oil levels, noise, temperature and vibration at main drives, tracking (alignment of belt conveyors); it is crucial to concentrate on indications that may vary at short notice and which may disrupt the productive process.

It is not expected that problems detected during a Production walk-by inspection be solved by the technician performing the inspection (unless they are very simple); it is rather the notifications the expected outcome.

For Maintenance inspections, the focus must be set on **cause detection**. The inspection must therefore be more detailed and looking forward to detect deviations at the earliest possible stage (measurements and comparison against target values). In the example of a belt conveyor, it is not enough to notice that there is a spillage; the idea is rather that the Maintenance technician makes sure a spillage cannot happen, i.e. condition of belt skirting, wear and adjustment of belt scrapers. This entails a more comprehensive inspection, which can be performed less often than the one from Production (e.g. weekly instead of daily).

In addition, the Maintenance inspector should display the following traits:

1. Safety aware: Safety comes first! The inspector should never risk him/herself in order to perform the inspection.
2. Inquisitive: An inspector should always try to dig a little more on the root cause than just reporting an anomaly
3. Pragmatic: Small issues should be solved there and then instead of writing a notification (e.g. loose bolt)
4. Intimately familiar with the equipment: A skilled inspector will be able to pick up small differences on noise, heat or vibration being generated by the equipment
5. Keep all senses open: Information needs to be perceived from as many sources as possible; different stages of a problem can then be estimated (a hot and vibrating bearing vs. just a vibrating bearing)
6. Thorough and systematic: All inspection points on equipment have to be covered and all equipment on the route (check sheets)

4.4 Execution of walk-by inspections

4.4.1 Tools

Besides the check sheets, there are other simple tools that an inspector can carry out in the field to perform the job. The whole idea behind is that the inspector can already report more accurate details and possible root causes of a detected problem, aiding thus the planning process of the follow-up actions (i.e. a deeper analysis is required or there is time enough until the next scheduled vibration analysis).

- Flashlight: although it seems basic, little can be accomplished without a proper illumination level.
- Temperature gun (pyrometer, infrared thermometer): useful for temperature measurements, especially those in accessible locations when the equipment is running. As long as the measurements are performed with the same emissivity factor for a given point, a temperature variation can be easily picked-up (although the absolute values may be shifted by several degrees).
- Pen Vibrometer: more reliable than a hand measurement, the overall vibration value can already give a good insight on the severity of the problem. In addition, vibration can be measured and reported on different directions as additional input for more in depth analysis. The pen vibrometer is a handy tool for quick checks but not for troubleshooting, where a full vibration spectra analyzer will be required.

4.4.2 Visual aids

Visual aids (or marking of gauges) are an easy and simple way to boost the effectiveness of any walk-by inspection. If every important gauge in the plant is already showing the acceptable range of operation, even unskilled workers can immediately recognize when the range is exceeded and give warning to the responsible individuals for further action to be taken.

The recommended process for implementation of the visual aids can be summarized as follows:

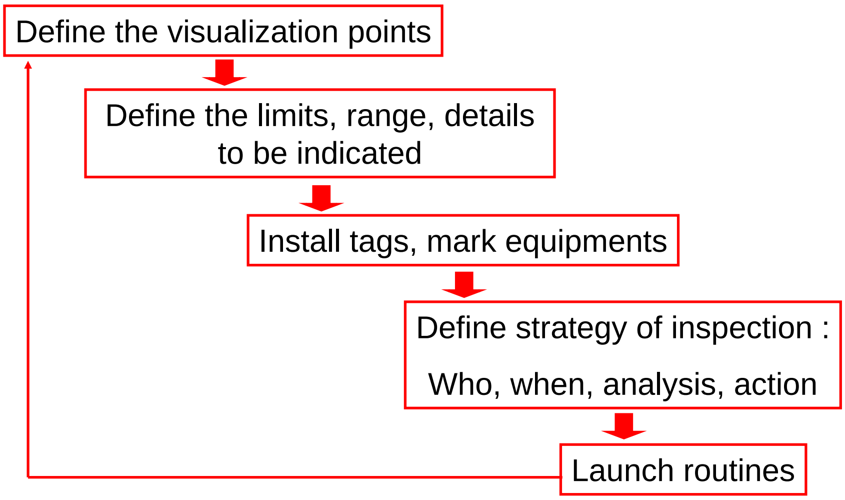


Figure 6 Process for implementation of visual aids

- Define the visualization points: all gauges to be marked (i.e. manometers, thermometers and others) must be identified and listed.
- Define the limits, range, and details to be indicated: for each gauge, the normal operation range has to be defined. This is one of the lengthiest parts of the whole process and involves working together with the Process Performance Engineer and the Central Control Room operators. There will be cases where a maximum or a minimum level suffices, whereas for others a full range is required.
- Install tags, mark equipments: there are several ways to accomplish this, from crude paint markings on the gauges to specially coated transparent covers. Some of the available options are shown in the following pictures. The key point is that the markings must be readily visible and the type of marking should take into consideration the surrounding environment, to assure the longest useful life possible.

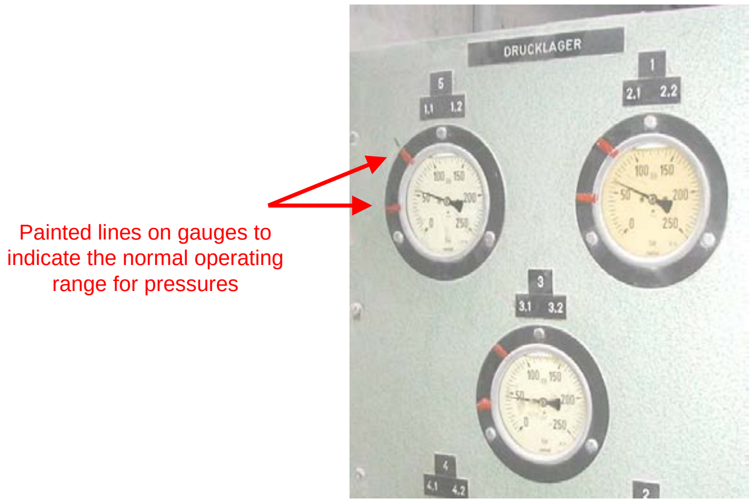


Figure 7 Marking of pressure gauges (manometers) with painted lines. Easy solution that works well on clean environments, such as hydraulic rooms.

Figure 8 Easy to read marking of gauges, showing acceptable ranges with color coding.

The case illustrated presents several advantages:

1. The ranges are very clearly indicated and it is easy for any worker to tell when the needle exceeds the allowable range.
2. The color code already provides an idea of ‘desirable ranges’ (green color), where the impact of the variable being out of range is not as drastic as with the ‘allowable ranges’ (red color), where any deviation from the range warrants immediate action. For example, the temperature reading for cooling water is shown in green color, where the non-compliance with the range will eventually affect the oil temperature (since the oil is being cooled by the water), but may not have an immediate adverse effect. On the other hand, it is critical that the oil temperature does not exceed the upper range, since this affects the equipment reliability and therefore quick action must be taken if this happens. Likewise, the oil flow may be restricted at too low temperatures, due to the increase in viscosity. This condition needs to be addressed as well, since it may cause increased wear in the equipment.
    - Define strategy of inspection: once the gauges are properly identified, there must be inspection routines that include all of these points. Frequency of inspection, as well as responsible for performing the inspection have to be defined, as per the guidelines laid out in heading “Production and Maintenance check sheets”.
    - Launch routines: the next step after defining the inspection routes is to launch them. This means communicating them to the technicians that will perform them and provide a hands-on training on the usage of the check sheets where the particular gauge to inspect is included. The feedback from the technicians has to be consolidated and integrated in order to improve the inspection route.

5. Lubrication management Concept

Lubrication is more complex than only adding grease or changing oil to the machinery. It has many diverse activities such as lubricant selection, lubricants storage, handle, preservation and proper application. Considering the importance and impact of proper lubrication a proper lubrication strategy must be devised and executed.

Under the scope of the LafargeHolcim’s lubrication strategy it is recommended to centralize the lubrication roles and responsibilities in the Preventive Maintenance department. The main objective is the alignment and standardization of:

- Selection and application of lubricants
- Scheduling and execution of the inspections and services
- Lubricants sampling and analysis interpretation

Core roles and responsibilities of the lubrication team are:

- Creation and management of lubrication chart
- Update of lubrication and inspection routines in management system according with PMR's management.
- Planning, schedule and execution of the inspections and lubrication routines (re lubrication , sampling and oil replacements).
- Carry on specific equipment inspections to identify and report: Oil leakages, temperature variations, lube pattern and consumption on pinion drives, operation of centralized systems, condition of filter elements, safety and maintainability issues
- Assuring proper inventory levels, storage and handling of lubricants
- Assuring safety and working conditions of warehouse, workshop and lubrication tools
- Assuring proper disposal of lubricants and recording according to OH&S and environmental requirements
- Coordinate the contact with suppliers for
  - Optimizing the performance of lubricants
  - Training and new develops
  - Discussing oil analysis results

The following topics will be discussed more in detail as part of the lubrication management concept and can be considered as the basis of the lubrication program as they are the main inputs to build the lubrication chart.

1. Lubricant properties
2. Selection and application
3. Lubrication and re-grease frequencies
4. Lubrication and re-lubrication methods

5.1 Lubricant properties

A lubricant is a complex combination of chemicals that is formulated to provide specifically defined performance properties. There is not yet any universal lubricant to satisfy all requirements, a considerable reduction in lubricant types can be obtained in most cases by using multi-purpose lubricants. Standardization can simplify stock levels, also reduce confusion on oil applications and achieve a lower purchase price.

The process to get different variety of lubricants for industrial application is:

Oil bases from different refinement treatment are mixed (maximum two) in order to get the viscosity and quality required.

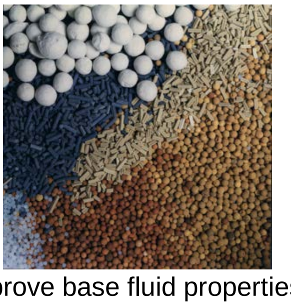
Characteristics of lubricant are complemented adding different type of additives according with necessity for application and kind of service.

Base Fluid

- Make up most of the lubricant
- Determine the fundamental properties of lubricant

+

Additives



- Improve base fluid properties
- Protect the base fluid
- Protect the equipment.

Figure 9 Oil composition

The following table shows a summary of the different applications and oil characteristics

Industrial oils	anti oxidant rust inhibitor	foam inhibitor	Demulsifies	Anti Wear additive	EP-additive
Circulating oils (C)	X	x	x		
Hydraulic oils (H, HL, HLP)	X	x	x	x	
Gear oils (CLP)	X	x	x	x	x
Compressor oils (VB, VC, VDL)	X	x	x	x	
Grease	X			x	x

Additives

A chemical substance added to a petroleum product to impart or improve certain properties. Common petroleum product additives are: antifoam agent, anti-wear additive, corrosion inhibitor, demulsifier, detergent, dispersant, emulsifier, EP additive, oiliness agent, oxidation inhibitor, pour point depressant, rust inhibitor, tackiness agent, viscosity index (VI.) improver.

Additives are chemistry compounds that have the ability to improve the natural properties of the lubricant. Finished oils contain 15 to 25% additives to :

- reinforce some of the base oil's properties,
- give the base oil properties that it does not have naturally.
- Each family comprises several types of molecule, which are chosen by the designer in accordance with the performances to be delivered by the finished lubricant.

Additive	**Engine Oils**	**Automatic Transmission Fluid**	**General Purpose Oil**	**Hydraulic Oil**	**Industrial Gear Oil**	**Automotive Gear Oil**	**Grease**
Detergents	▤	▤					
Dispersants	▤	▤					
Anti-Oxidants	▤	▤	▤	▤	▤	▤	▤
Rust Inhibitors	▤	▤	▤	▤	▤	▤	▤
Anti Wear	▤	▤		▤	▤	▤	▤
E.P. Agents					▤	▤	▤
VI Improvers	▤	▤			Some	Some	
Pour Point Depressants	▤	▤	▤	▤	▤	▤	
Anti Foam	▤	▤	▤	▤	▤	▤	
Dyes		▤					▤
Friction Modifiers	▤	▤					

Figure 10 Application of different additives

5.2 Selection and application of mineral lubricating oils

Selecting oil is primarily based on the viscosity required to provide adequate lubrication for rotary elements at operating temperature. The viscosity of oil dependent of temperature, viscosity becoming lower as the temperature rises. The viscosity-temperature relationship of oil is characterized by the viscosity index. For rolling bearing lubrication, oils having a high viscosity index (little change with temperature) of at least 95 are recommended.

ISO Viscosity Grade	Midpoint Kinematic Viscosity mm²/s at 40°C (104°F)	Kinematic Viscosity Limit mm²/s at 40°C (104°F) Minimum	Kinematic Viscosity Limit mm²/s at 40°C (104°F) Maximum
ISO VG 2	2.2	1.98	2.42
ISO VG 3	3.2	2.88	3.52
ISO VG 5	4.6	4.14	5.06
ISO VG 7	6.8	6.12	7.46
ISO VG 10	10	9.00	11.0
ISO VG 15	15	13.5	16.5
ISO VG 22	22	19.8	24.2
ISO VG 32	32	29.8	35.2
ISO VG 46	46	41.4	50.6
ISO VG 68	68	61.2	74.8
ISO VG 100	100	90.0	110
ISO VG 150	150	135	165
ISO VG 220	220	198	242
ISO VG 320	320	288	352
ISO VG 460	460	414	506
ISO VG 680	680	612	748
ISO VG 1000	1000	900	1100
ISO VG 1500	1500	1350	1650
ISO VG 2200	2200	1980	2420
ISO VG 3200	3200	2880	3520

Figure 11. ISO Viscosity grades

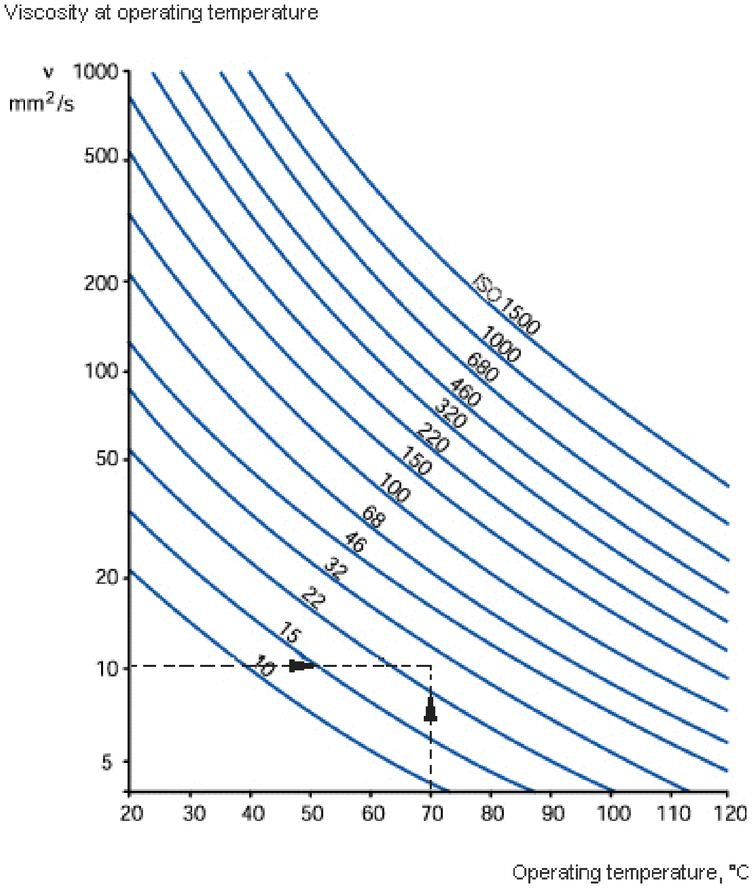


Figure 12 Kinematic viscosity at reference temperature

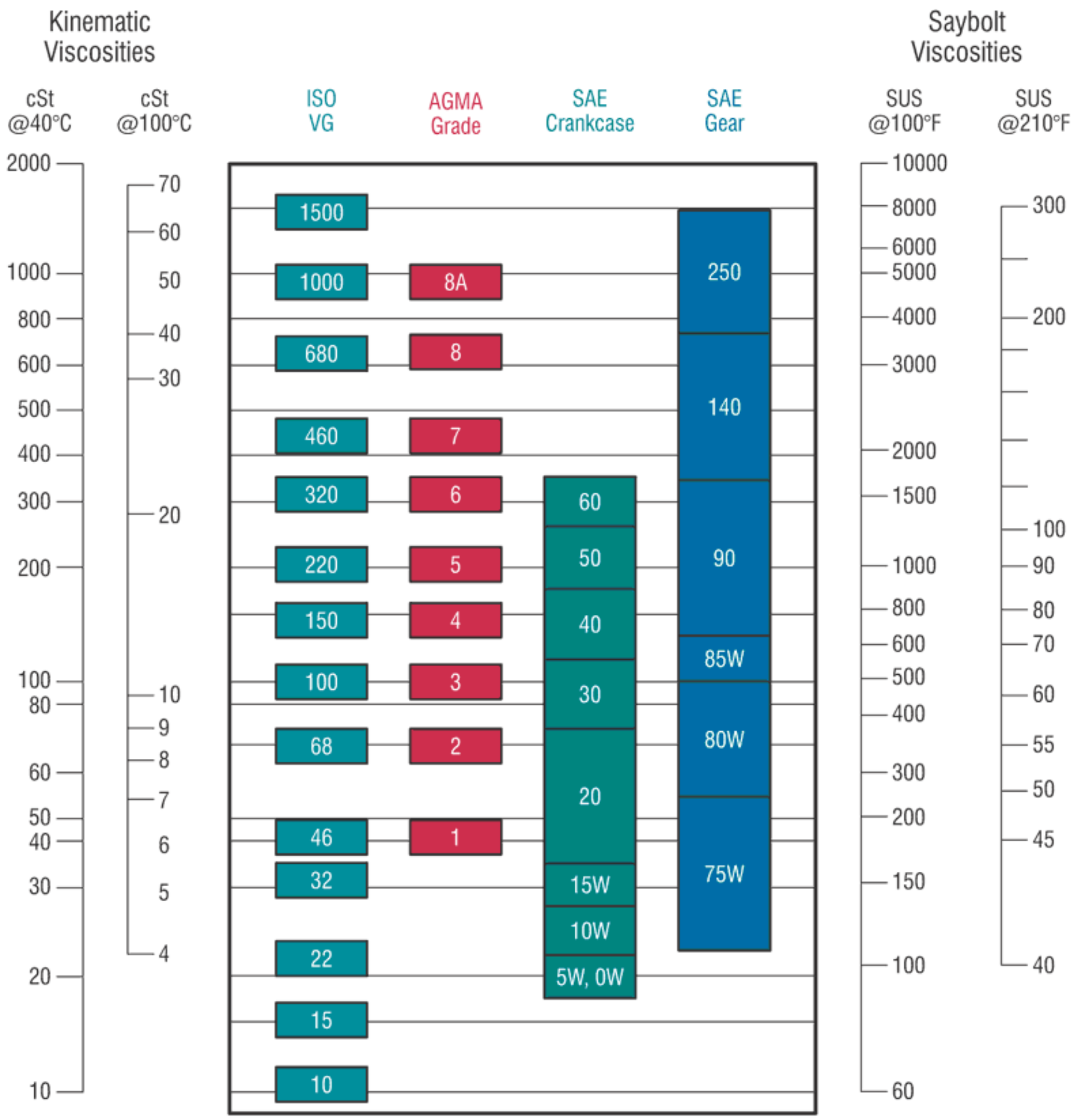


Figure 13 Equivalence chart for oil viscosities

The lubricant lubricates the machine via a combination of physical and chemical mechanisms. The lube tech must understand both the lubricant and the lubrication mechanisms that enable friction and wear management. Additional factors have to be considered for a suitable lubricant selection, such as specific running conditions like temperature, load compared to design limits, etc.

Under those considerations some types of lubricant had been developed and classified accordingly their application and requirements.

L-AN – DIN 51501	Mineral oils with normal requirements used in forced-feed and circulation lubrication. The oil temperature of the oil dripping out of the friction point may not exceed 50°C.
B – DIN 51513	Dark bituminous mineral oils with good adhesive proprieties. Applications: gear drives, sliders, wire ropes, slide ways, etc., where a high viscosity of the lubricating oil is not desirable.

Circulation Oil

C - DIN 51517	Non-ageing mineral oils without additives. Primarily used for circulation lubrication. Meet higher requirements than lubricating oils L-AN.

CL – DIN 51517 Additivated mineral oils to increase anti-corrosive and anti-ageing properties. Primarily used for circulation lubrication. According to their viscosity, these oil types show good low and high temperature properties.

Application: compressors, hydraulics, gearings, rolling and plain bearings with circulation lubrication.

Gear Oil

CLP – DIN 51517 Additivated mineral oils to increase anti-corrosive and anti-ageing resistance and to reduce wear in the mixed friction zone. Used for dip-feed and circulation lubrication, when requirements made on wear protection are extremely high.

H – Hydraulic fluids

HL – DIN 51524 Additivated mineral oils to improve anti-corrosion and anti-ageing properties.

HLP – DIN 51524 Same as hydraulic oils HL plus additional additives to reduce wear due to fretting corrosion in mixed friction zones.

Compressor oil

K – DIN 51503 (Refrigerator oils). Mineral oils or oils composed of allied hydrocarbons to lubricate and cool refrigerating machine compressors.

VB, VC and VDL – DIN 51506. Mineral oils with or without additives for the use in air compressors with an oil lubricated pressure chamber, without injection cooling. The oil can be also used in vacuum pumps.

Turbine Oil

L-TD – DIN 51515 Additivated lubricating oils with improved anti-corrosion and anti-oxidation properties. To be used for the lubrication and control of steam turbines, stationary gas turbines or machines driven by these, such as generators, compressors, pumps and gears.

Z – DIN 51510. Pure mineral oils primarily used for steam-driven sliding parts of steam engines with a steam inlet temperature less than 380 C.

5.3 Selection and application of synthetic lubricating oils

Lubricating oils Base on Ester Oils

Ester oils are the result of a reaction of acids and alcohols with water splitting off. There are many types of esters, all of them having an impact on the chemical and physical properties of lubricants. In the past, these lubricating oils were mainly used in aviation technology for the lubrication of aircraft engines and gas turbines as well as gear systems in pumps, starters, etc.

Ester oils have a high thermal resistance and excellent low temperature behavior. In industrial applications, rapidly biodegradable ester oils will gain importance because it seems possible to achieve the same efficiency as with polyglycol oils by selecting appropriate ester base oil.

Certain ester oils may exhibit low hydrolytic stability. Hydrolysis is the cleavage of the ester into an alcohol and an acid in the presence of water. Ester lubricants need to be hydrolytically stable because they are often exposed to humidity in use. In practice, hydrolysis may be a less serious problem than commonly reported. The hydrolytic stability of an ester depends on:

- The type of ester used
- The type of additives used
- How the ester was processed
- The application

Lubricating Oils based on synthetic hydrocarbon oils

Synthetic hydrocarbons are similar to mineral hydrocarbons in their chemical structure. They have nearly identical properties relating to their compatibility with sealing materials, disposal, reprocessing and miscibility with mineral oils. The main advantage is their excellent low temperature behavior. It is possible to manufacture food-grade lubricants for the food processing and pharmaceutical industries with SHC base oils using special additives.

Lubricating oils based on Polyglycols

These lubricants ensure especially low friction coefficients, which make them suitable for gears with a high sliding percentage (worm and hypoid gears). With the appropriate additives, they provide excellent antiwear protection in steel/bronze worm gears, and have a good extreme pressure performance. In gear systems, higher polarity polyglycols allow greater interaction on the metal gear surface. This gives polyglycols mild extreme pressure performance even without additives.

Polyglycol oils may have a negative impact on sealing materials and may dissolve some paints. At operating temperatures above 212°F (100°C), only seals made of fluorinated rubber or PTFE are resistant. Before using PAG oils in production applications, it is advisable to test compatibility with paints, seals and sight glass materials.

Miscibility with mineral oils is limited; mixtures should therefore be avoided. Polyglycols are neutral toward ferrous metals and almost all nonferrous metals. If the application has a loaded contact with one component consisting of aluminum or aluminum alloys (rolling bearing cages containing aluminum), there may be increased wear under dynamic load (sliding movement and high load). In such cases, compatibility tests should be conducted. If a worm gear is made of an aluminum bronze alloy, polyglycols should not be used because the reaction in the load zone could result in increased wear.

5.4 Lubricating greases

Grease lubrication is used wherever oil lubrication is not possible or not necessary. They are used especially when the product must remain localized in a mechanism, for example, when the possibilities for re-lubrication are limited or not economically viable. Greases adhere well to sliding surfaces and provide efficient protection from ingress of dust, dirt and water. Their major disadvantage is increased internal friction.

Greases are cohesive lubricants whose composition and product features are designed to reduce friction and wear over the widest possible temperature ranges and time spans.

Grease is composed of:

THICKENER (5-20%) + LUBRICATING OIL (75-95%) + ADDITIVES (0-15%)

Although greases do not have the cooling and cleaning qualities of liquid lubricants, they do offer other advantages, which are under certain conditions, preferable to that of oil. The majority of greases are used for roller bearings and sometimes for plain bearings, transmissions and open gears.

Thus, grease can be used :

- To keep contaminants (dust, impurities, water, corrosive gases, etc...) from reaching lubricated parts.
- To avoid dripping and undesired loss of the product
- To reduce the frequency of lubrication. The grease stays in place and thus guarantees lubrication for long periods. This is why intervals between maintenance can be longer for greases than for oils.
- For intermittent operations. Because grease remains in place during periods of inactivity, its use is preferable to that of oil in the case of frequent machine starts.
- When machine parts are heavily worn, grease permits prolonged use of worn parts which normally use oil.
- To reduce noise caused by machine wear, thanks to a thick film of grease.
- In order to use certain solid additives of exceptional lubricating ability which mix well with grease, but do not mix with liquid lubricants.

Thickeners	**Main Advantage(s)**
Metal Soaps (Ba, Li, Ca)	*multipurpose*
Bentonite (Clay) / Silica	*high temperature*
Aluminum Complex	*high temperature*
Plastic (PE, PTFE, FEP)	*high temperature*
Polyurea	*vibration, sealed for life*
Barium Complex	*extreme pressure*
Calcium Complex	*water resistance, corrosion protection*
Solid Lubricants	**Reason for Use**
Graphite	*anti-wear*
Zinc Oxide	*white colour*
Calcium Carbonate	*anti-rust, EP*
Molybdenum Disulphide (“Moly”)	*anti-wear, load-carrying*

Figure 14 Application of grease thickeners and solid lubricants

Miscibility

If it becomes necessary to change from one grease to another, the miscibility or the ability to mix greases without adverse effects should be considered. If incompatible greases are mixed, the resulting consistency can change dramatically so that bearing damage e.g. due to severe leakage, could result.

Greases having the same thickener and similar base oils can generally be mixed without any detrimental consequences, e.g. lithium thickener/mineral oil grease can generally be mixed with another lithium thickener/mineral oil grease. Also, some greases with different thickeners e.g. calcium complex and lithium complex greases, are miscible with each other.

Table 1. Grease Compatibility

	Aluminum Complex	Barium	Calcium	Calcium 12 Hydroxy	Calcium Complex	Clay	Lithium	Lithium 12 Hydroxy	Lithium Complex	Polyurea	Sodium	Calcium Sulfonate
Aluminum Complex	-	■	■	●	■	■	■	■	●	■	■	■
Barium	■	-	■	●	■	■	■	■	■	■	■	▼
Calcium	■	■	-	●	■	●	●	▼	●	■	■	N/A
Calcium 12-Hydroxy	●	●	●	-	▼	●	●	●	●	■	■	N/A
Calcium Complex	■	■	■	▼	-	■	■	■	●	●	■	●
Bentone (Clay)	■	■	●	●	■	-	■	■	■	■	■	■
Lithium	■	■	●	●	■	■	-	●	●	■	■	●
Lithium 12-Hydroxy	■	■	▼	●	■	■	●	-	●	■	■	●
Lithium Complex	●	■	●	●	●	■	●	●	-	■	■	●
Polyurea	■	■	■	■	●	■	■	■	■	-	■	■
Sodium (Soda Base)	■	■	■	■	■	■	■	■	■	■	-	■
Calcuim Sulfonate	■	▼	N/A	N/A	●	■	●	●	●	■	■	-

▼ Borderline Compatibility ● Compatible ■ Incompatible N/A - Not Available

Figure 15 Compatibility of greases

Unfortunately, there is no truly "universal" grease, which can be applied to the multitude of industrial, automotive and marine uses. Certain top-quality modern greases can satisfy up to 75% of these needs, but for the other 25%, several different and specific greases are necessary. This list is long. The choosing of grease requires, detailed technical information concerning use and the know-how of a specialist.

The NLGI, "National Lubricating and Grease Institute" classes lubricating greases according to their consistency. Consistency is divided into "grades", represented by the following numbers: 000, 00, 0, 1, 2, 3, 4, 5, 6 Each grade corresponds to a range in which the consistency of the grease should be situated, which is determined by the penetration of a cone into the grease. The result is then expressed in 1/10 mm. The deeper the penetration, the lower the number: a NLGI 000 grease is thus less consistent than a NLGI 2 and represents a high degree of penetration.

5.5 Lubrication and Relubrication Methods

Re-greasing

Rolling bearings have to be re-lubricated if the service life of the grease is shorter than the expected service life of the bearing. Re-lubrication should always be undertaken at a time when the condition of the existing lubricant is still satisfactory.

The life expectancy of grease depends on several factors, such as the type of grease, speed and operation temperature of the bearing. The environmental and sealing arrangement also plays a part. For small ball bearings, service life is often so long that re-lubrication is unnecessary. Bearings lubricated for life fitted with shields or seals are suitable in these situations.

Re-lubrication period

The re-lubrication intervals (tf) for bearings on horizontal shafts under normal and clean conditions can be obtained from diagram 1; as a function of type of bearing, rpm and internal diameter of the bearing.

The re-lubrication interval (tf) is an estimated value, valid for an operating temperature of 70 °C, using good quality lithium thickener/mineral oil greases. When bearing operating conditions differ, adjust the re-lubrication.

At bearing temperatures over 70 °C (160 °F), the re-lubricating interval should be reduce by half for each 15 °C (27 °F) of increase in temperature. Intervals may be extended for temperatures under 70 °C (160 °F).

It is necessary to re-lubricate more frequently in applications where there is a risk of heavy contamination. The same applies to bearings in wet environments. For that consider to divide the total amount of grease by the frequency, in order to keep the same quantity and avoid increase over greasing and consequently high temperature on bearings.

For bearings in vertical shaft position the intervals obtained from the diagram should be halved.

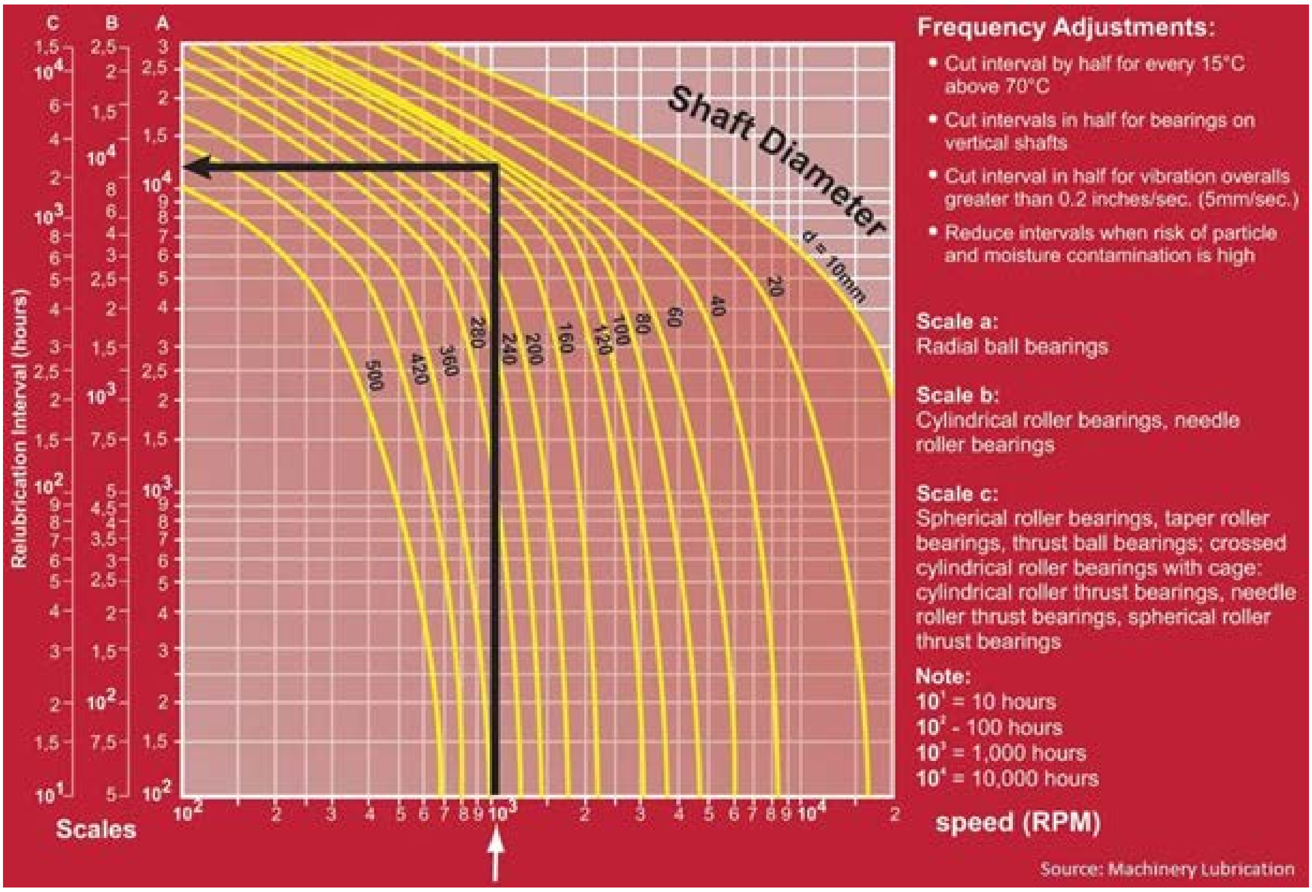


Figure 16 Relubrication frequency chart

Re-lubrication quantity:

Suitable quantities for re-greasing from the side of a bearing can be obtained from formula:
Gp = 0,005 D B

and for re-greasing through the bearing outer or inner ring from formula:
Gp = 0,002 D B

Where:

Gp= grease quantity in grams

D=bearing outside diameter in mm

B= total bearing with in mm (the corresponding dimension for thrust bearings is H)

Lubrication Systems Maintenance

Simple manual operation of the system will determine if the power resource is operating efficiently. In the case of pneumatic or hydraulic operations, a pressure gauge on the power source will confirm operating pressure.

The next phase of the system PMR inspection is to check the level of lubricant in the supply reservoir. This check should include a visual examination of the lubricant for contamination in cases where the lubricant is open to the atmosphere during transfer and handling. If the system uses filters, strainers or screens, they should be checked periodically for contamination build-up or blockage, and cleaned.

In the control area of the system, the timer should be checked to assure that the predetermined time settings have not been altered. All electrical controls and terminals should be visually checked for cleanliness and tight connections. Electrical components should be contained inside a panel that can be closed and latched to provide protection from atmospheric condition and to protect plant personnel from system malfunctions. During manual operations of the system, check system pressure and compare to previously determined normal operating pressures.

Checking any lubricating system at the pump/reservoir/control panel location is a necessity, but does not assure that the lubricant is being delivered to the lubrication point. It means only that the heart of the system is in good operating condition.

The next step is to check the distribution system. Ruptured, plugged or kinked piping and tubing can make some portions of the system inoperative while other portions are operating efficiently. This condition can lead the control systems and warning devices to indicate satisfactory performance through the system, when in reality, some machinery points are not being lubricated.

The best way to assure that all lube points are being properly serviced is to visually check each header, secondary lube line, and lube line from the metering device to the lube point. This is, in many cases, a time consuming and difficult task, and consequently is not performed. As a result of skipping this step of the PMR check, a malfunction in the header and distribution lines is discovered only when the machinery fails.

Finally, the system is not fully operational unless each metering device is individually checked to assure proper operation. Most metering devices have a visual indicator for this purpose. Those devices that do not have a visual indicator can be checked only by loosening the distribution line from the metering device, operating the system and visually checking for operation of the valve. This is a time consuming and often overlooked portion of the PMR check, but is also an important aspect.

5.6 Lubrication Chart

As was addressed at the beginning of this chapter an adequate knowledge of the previous topics:

1. Lubricant properties
2. Selection and application
3. Lubrication and re-grease frequencies
4. Lubrication and re-lubrication methods

is fundamental to develop the lubrication chart, which is the basis of the lubrication program.

The lubrication chart consists in a template where all relevant information is gathered:

- Equipment and specific lubrication points
- Type, designation and amount of lubricant applied
- Identification of activity type and the corresponding frequency

LafargeHolcim

Lubrication Chart

Plant: ____________________
Revision Date: ____________________

			Lubricant					Application Method	Lubricating Points		ACTIVITY TYPE FREQUENCY											
											Inspection Points				Grease		Oil					
ACS	Equipment Description	Element to Lubricate	Type of Lubricant	Comercial Designation	Technical Designation	Quantity	Unit of Measurement	Application Method	No. of Lube pt	Fitting	Oil Level	Grease Level	Oil Filter	Breather	Regreasing	Regreasing [g]	Oil Sampling	Oil Analysing Company	Oil Change	Oil Filtration	Comments	ROUTE

Figure 17 Example of lubrication chart

All basics and theoretical knowledge explained at the beginning of this chapter now is consolidated in the lubrication chart which is an essential tool to structure and build lubrication PMR’s for:

- Services
- Inspections
- Cleaning
- Re-greasing or oil top-up
- Grease or oil replacement
- Sampling

The PMR’s set up shall be carried out according to the description in sections Preventive Maintenance Routines (PMR’s), Work Load balancing and PMR’s Management in SAP-PM, within this chapter.

5.7 Lubricant handling

Contamination can be defined as any unwanted substance or energy that enters or contacts the oil. Contaminants can come in a great many forms; some are highly destructive to the oil, its additives, and machine surfaces. It is often overlooked as a source of failure because its impact is usually slow and imperceptible.

This means that contaminants can not only cause a breakdown in the health of the lubricant (and thus a failure in the lubricant’s ability to perform efficiently), but will also interact with the moving surfaces to cause wear, leading to component failure. Adhesion, abrasion and corrosion of component surfaces will typically result from oil contamination as will poorly specified or unhealthy lubricants.

In a study conducted by the bearing manufacturer SKF, over 50% of bearing failures are the result of improper lubrication

- 34.4% - Inadequate Lubrication
- 19.6% - Contamination
- 18.6% - Other
- 17.7% - Installation errors
- 6.9% - Overload
- 2.8% - Storage and Handling Errors

The oil introduced to a machine should be of appropriate quality given the demands of the application, and should be stored and handle properly before serving it to that. For that reason, is necessary to keep in mine some basic rules during lubrication handle.

5.8 Lubrication Storage

Oxidation occurs in all oils that are in contact with air, including stored lubricants. The base oil and additive combination affects the rate of oxidation, and the presence of the thickener in grease can increase the degradation rate. But the environmental and storage conditions have the greatest influence on the rate at which the lubricant degrades. Increasing the temperature at which the lubricant is stored by 10°C doubles the oxidation rate, which cuts the usable life of the oil in half. The presence of water, usually introduced as a result of temperature variations, increases the rate of oxidation.

Frequent agitation of the lubricant incorporates air into the oil. This increases the surface area contact between air and the oil, increasing the rate of oxidation. Agitation also serves to emulsify water into the oil, increasing its catalytic effect on the oxidation process. The storage container itself can affect the rate of oxidation. A poorly prepared steel drum can expose the oil to iron, which catalyzes the oxidation process. Of course, the use of no reactive (plastic) containers or drum liners eliminates the metal catalyst affect on oxidation.

Product	Maximum Recommended Storage Time
Lithium Greases	12 months
Calcium Complex Greases	6 months
Lubricating Oils	12 months
Emulsion Type Fire-Resistant Fluids	6 months
Soluble Oils	6 months
Custom Blended Soluble Oils	3 months
Wax Emulsions	6 months

Figure 18 Recommended storage time limit

5.8.1 Addressing Health, Safety and Environmental Issues

It is worth requesting a Materials Safety Data Sheet for each lubricant to keep in the storeroom for quick reference, and more importantly, for the lubrication technician to check before handling the lubricant.

The area will require adequate drainage for catching spillage or leakage, and environmental concerns must be considered.

5.8.2 Tips

The next points are some tips to keep in mind because they are known to affect the lifetime of the lubricants

- Increase the temperature at which the lubricant is stored by 10 °C doubles the oxidation rate. Presence of water, usually introduced as a result of temperature variations
- The shelving should allow the barrels to be stored on their side, with the openings (bungs) at three and nine o'clock to ensure an airtight seal
- Label and tags on the containers and location should be placed
- Usage of proper racking allow easy disposal
- Drop oil containers avoid oil spillages and unsafe conditions
- Warning signals are needed to communicate the possible risks
- Fire extinguishers must be available
- Use different deposits with hermetic covers for type of oil. Label them specify the type of oil. Also usage proper tools is recommendable into the workshop for disposal
- Proper handle during application is needed in order to maintain insulate the lubricant as much as possible
- Procedures, information work, journal should be shown in the workshop.
- Material Safety Data Sheet for each lubricant must be available in the store room as quick reference and handle for lubrication technician, also in the medical service.
- Smoking and eating must be prohibited in this area.

Figure 19 (left) Battery of drums connected to a single desiccant breather filter. Assuming a clean environment within the lube workshop, filter rating of 25 µm is required for the breather.

Figure 20 Fresh oil is filtered and transferred to a bulk storage (tote), fitted with desiccant breather filters. This is an improvement from the previous figure, since the oil is ready to be taken out to the field in a cleaner condition

Figure 21 Labeling of lube workshop.

Wrong position

Figure 22 FIFO (first in, first out) for oil consumption.

Look for position of drum bungs at 3' and 9' o'clock

5.9 Oil Consumption Ratio (OCR)

The Oil Consumption Ratio is an important performance indicator when it comes the measuring and evaluation the overall lubrication situation / performance of the plant. The OCR is the ratio of how much oil is added to the system in a period (normally a year) to the actual volume of fluid the system holds; thus:

$$\text{Oil consumption ratio} = \frac{\text{Total volume of oil replaced}}{\text{Total volume of oil installed}}$$

The preventive maintenance responsible is the owner of this indicator as according to the LafargeHolcim standard organizational setup lubrication is under his responsibility. The oil consumption ratio is to be tracked on yearly base

Note that for the OCR, a value in a range of 0.45 to 0.85 can be considered good practice.

For the calculation of the volume of oil installed, all capacities bigger than 5 liters shall be taken into consideration. As a base, the information as documented in the plant lubrication chart shall be used. Note that mobile equipment as e.g. trucks used in the quarry shall not be considered for the calculation.

6. Work load balancing

The work load of the maintenance department basically consists of preventive maintenance activities, corrective maintenance and although the main objective is not to have them, usually there are emergencies. The proportion between them depends on several factors, in order to manage and optimize the resources required for all maintenance activities (work force, third party services, spare parts, etc.) it is essential to have an effective control of all of them.

The amount of PMR's is defined by the requirements to maintain the overall condition of equipment, prevention and early detection of failures. A key issue is to justify the PMR's required to satisfying those requirements and approaching plant targets (KPI's) with the lowest cost.

The purpose of this chapter is to show the process to balance the work load of the PMR's in order to provide a constant work load of preventive maintenance activities and also to appoint some specific considerations.

6.1 Concept

Considering the big amount of PMR's of a plant and the required resources for the execution, mainly the work force, it is necessary to balance this workforce requirement in order to have a constant work load of PMR's. This is a key issue in the case of a maintenance strategy based on frequency.

It is proven practice that with proper implementation and the effective execution of PMR's and corrective maintenance, the required workload for emergencies and corrective maintenance tends to decrease.

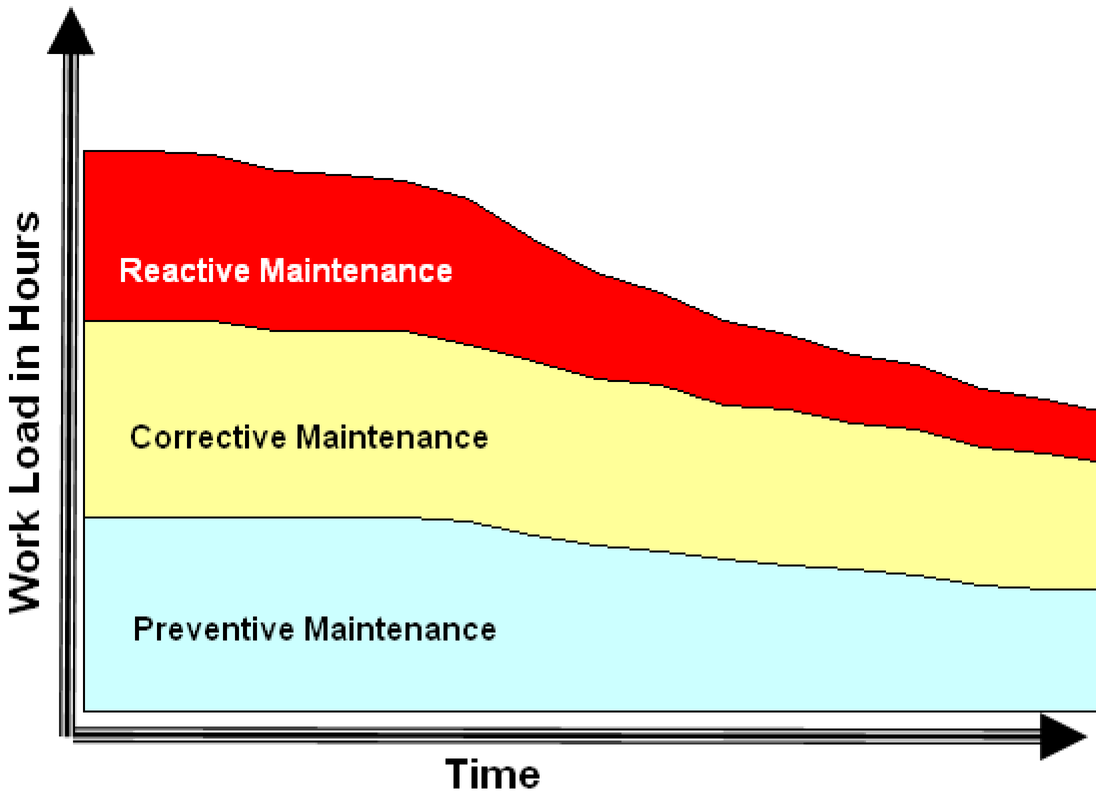


Figure 23 Maintenance work load distribution.

6.2 Maintenance shutdowns schedule

First of all it is necessary to settle a schedule for the maintenance shutdowns of each area or production line according to the annual production and maintenance plan and obviously this calendar must be aligned with the KPI’s targets.

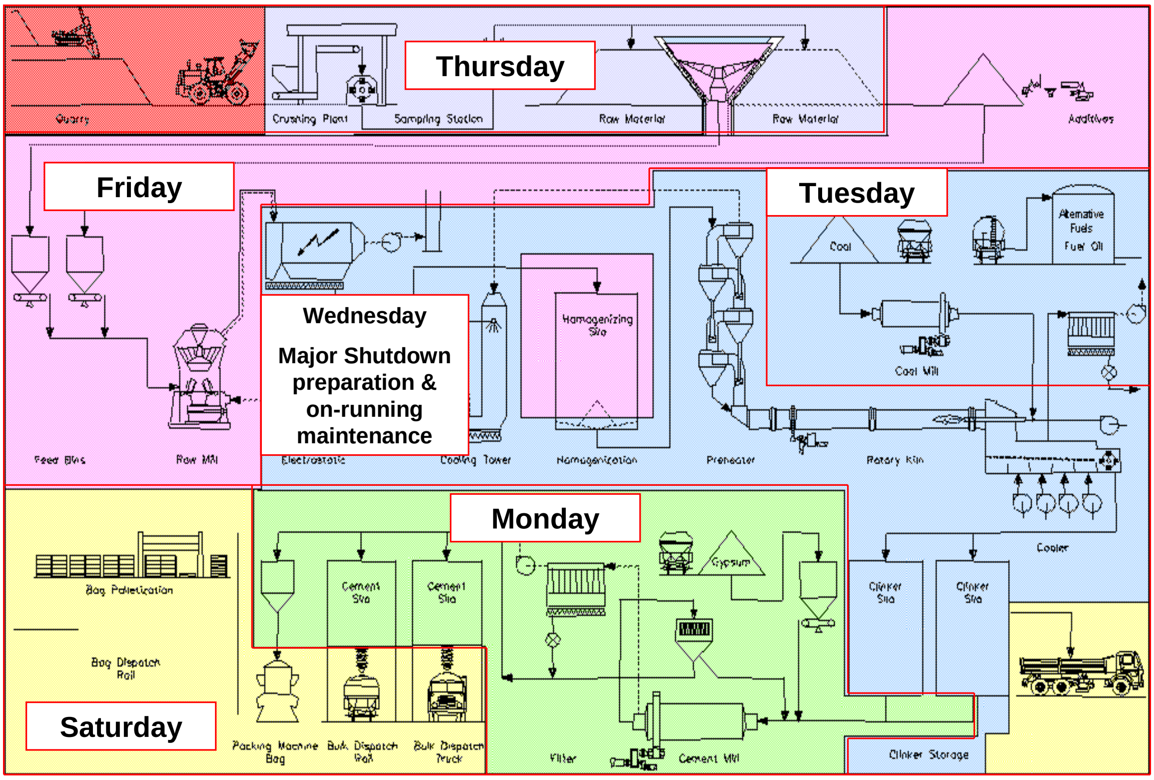


Figure 24 Definition of the areas for weekly / monthly maintenance

Be aware that this process is applied for the weekly / monthly maintenance shutdowns, on running maintenance and housekeeping, nevertheless maintenance shutdowns for kilns and others major shutdowns should be appointed on this schedule.

The maintenance shutdown schedule should be updated and published at least to production and maintenance departments in order to inform and coordinate the plant operations.

MAINTENANCE SHUTDOWN SHEDULE									
WEEK	FROM	TO	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	D
1	01.01.07	07.01.07	HOLIDAY	PET COKE	KILNS	CRUSHING	CEMENT 1	DISPATCH	D
2	08.01.07	14.01.07	CEMENT 5	AFR	KILNS	CRUSHING	RAW MEAL PREP.	DISPATCH	D
3	15.01.07	21.01.07	CEMENT 4	PET COKE	KILNS	CRUSHING	HOUSEKEEPING	DISPATCH	D
4	22.01.07	28.01.07	CEMENT 5	AFR	KILNS	CRUSHING	RAW MEAL PREP.	DISPATCH	D
5	29.01.07	04.02.07	CEMENT 4	PET COKE	KILNS	CRUSHING	CEMENT 1	DISPATCH	D
6	05.02.07	11.02.07	HOLIDAY	SHUTDOWN K 2	SHUTDOWN K 2	SHUTDOWN K 2	SHUTDOWN K 2	SHUTDOWN KILN 2	D
7	12.02.07	18.02.07	SHUTDOWN K 2	SHUTDOWN K 2	SHUTDOWN K 2	SHUTDOWN K 2	SHUTDOWN K 2	SHUTDOWN KILN 2	D
8	19.02.07	25.02.07	SHUTDOWN K 2	SHUTDOWN K 2	SHUTDOWN K 2	SHUTDOWN K 2	SHUTDOWN K 2	SHUTDOWN KILN 2	D
9	26.02.07	04.03.07	SHUTDOWN K 2	SHUTDOWN K 2	SHUTDOWN K 2	SHUTDOWN K 2	SHUTDOWN K 2	SHUTDOWN KILN 2	D
10	05.03.07	11.03.07	TC	AFR	KILNS	CRUSHING	RAW MEAL PREP.	DISPATCH	D
11	12.03.07	18.03.07	CEMENT 5	PET COKE	KILNS	CRUSHING	HOUSEKEEPING	DISPATCH	D
12	19.03.07	25.03.07	HOLIDAY	CEMENT 4	KILNS	CRUSHING	RAW MEAL PREP.	DISPATCH	D
13	26.03.07	01.04.07	TC	PET COKE	KILNS	CRUSHING	CEMENT 1	DISPATCH	D
14	02.04.07	08.04.07	SHUTDOWN CEM 5	SHUTDOWN CEM 5	SHUTDOWN CEM 5	SHUTDOWN CEM 5	SHUTDOWN CEM 5	SHUTDOWN CEM 5	D
15	09.04.07	15.04.07	CEMENT 4	PET COKE	KILNS	CRUSHING	AFR	DISPATCH	D
16	16.04.07	22.04.07	TC	AFR	KILNS	CRUSHING	RAW MEAL PREP.	DISPATCH	D
17	23.04.07	29.04.07	CEMENT 5	PET COKE	KILNS	CRUSHING	CEMENT 1	DISPATCH	D
18	30.04.07	06.05.07	SHUTDOWN K 1	HOLIDAY	SHUTDOWN K 1	SHUTDOWN K 1	SHUTDOWN K 1	SHUTDOWN K 1	D
19	07.05.07	13.05.07	SHUTDOWN K 1	SHUTDOWN K 1	SHUTDOWN K 1	SHUTDOWN K 1	SHUTDOWN K 1	SHUTDOWN K 1	D
20	14.05.07	20.05.07	CEMENT 5	AFR	KILNS	CRUSHING	RAW MEAL PREP.	DISPATCH	D
21	21.05.07	27.05.07	CEMENT 4	PET COKE	KILNS	CRUSHING	CEMENT 1	DISPATCH	D
22	28.05.07	03.06.07	TC	AFR	KILNS	CRUSHING	RAW MEAL PREP.	DISPATCH	D
23	04.06.07	10.06.07	CEMENT 5	PET COKE	KILNS	CRUSHING	HOUSEKEEPING	DISPATCH	D
24	11.06.07	17.06.07	CEMENT 4	AFR	KILNS	CRUSHING	RAW MEAL PREP.	DISPATCH	D
25	18.06.07	24.06.07	TC	PET COKE	KILNS	CRUSHING	CEMENT 1	DISPATCH	D
26	25.06.07	01.07.07	CEMENT 5	AFR	KILNS	CRUSHING	RAW MEAL PREP.	DISPATCH	D

Figure 25 Example of a maintenance shutdown schedule

6.3 Work load balancing process

Basically the process consist on create a template to list and distribute all PMR's in a certain period (one year as minimum) and adjust the sequence of them in order to balance the workforce requirements. Outsourced PMR's also should be listed but not included in the countering of workforce requirement unless personnel are required as part of the staff or for preparation and equipment testing. This template also offers an overview of all the operations and is helpful to detect if some activities will block between them and also to optimize the use of the workforce.

The process to build the work load balancing template is explained in the following Figure.

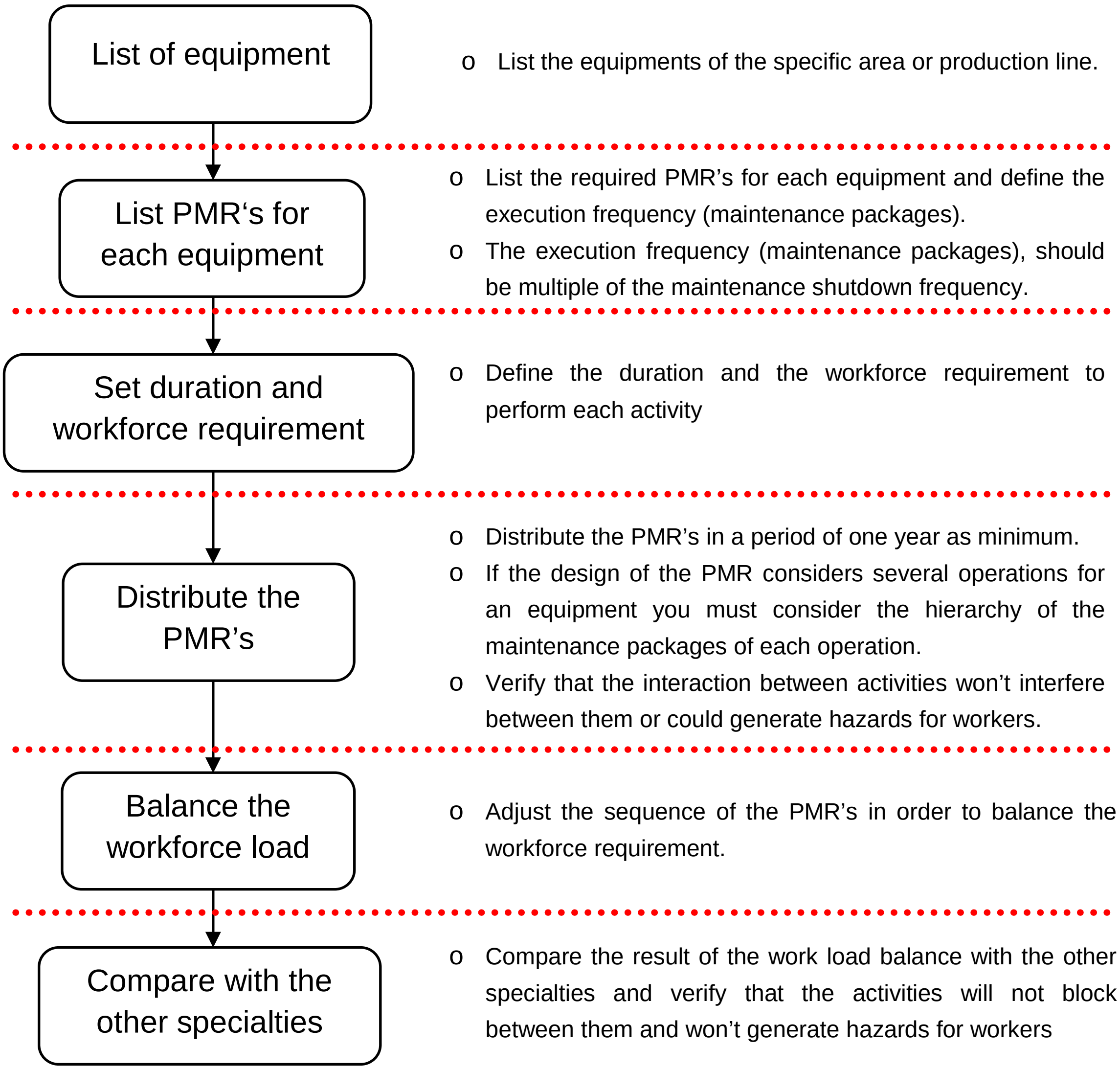


Figure 26 Work load balancing process

It is recommended to create a template for each area and for each specialty (mechanic, electric and lubrication) and then compare them in order to identify if some activities are repeated or if any activity have a negative impact on other. Remember that the result of this work are operations that will performed on field, in which people and many other resources are involved, so that many considerations, mainly safety, should be made during the process and it is better if they are done since the beginning, so take your time and always work on team.

	Mechanical Maintenance: Raw Meal Prepararion Area					2-Dez-05	16-Dez-05	30-Dez-05	13-Jan-06	27-Jan-06	10-Feb-06	24-Feb-06	10-Mrz-06	24-Mrz-06	7-Apr-06	21-Apr-06	5-Mai-06	19-Mai-06	2-Jun-06	16-Jun-06	30-Jun-06	14-Jul-06	28-Jul-06	11-Aug-06	25-Aug-06	8-Sep-06	22-Sep-06	6-Okt-06	20-Okt-06	3-Nov-06
Ubic.técn.		Freq.	Duration	No. Per	M hrs.	Week number:																								
						0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48
321-EC1	Mechanical service	6W	8	2	2	16			0			16			16			16			16			16			16			16
321-EC1	Chain elongation measurement	3M	2	1	2	2						2						2						2						2
321-EC1	Annual service	1Y	8	3	24				24																					
321-EC2	Mechanical service	6W	8	2	2		16			16			16			16			16			16			0			16		
321-EC2	Chain elongation measurement	3M	2	1	2					2						2						2						2		
321-EC2	Annual service	1Y	8	3	24																				24					
321-MB1	Mechanical service	1M	8	3	24	0		24		24		24		24		24		24		24		24		24		24		24		0
321-MB1	Runout and backlash measurements	1Y	8	2	16	16																								16
321-MB1	Wear measurement (liners and diaph. plates)	3M	4	2	8	8						8						8						8						8
321-MP1	Cleaning of cooling system and filters	3M	8	2	16				16						16						16						16			
321-MP1	Coupling inspection and re-grease	6M	8	2	16				16												16									
321-MP2	Cleaning of cooling system and filters	3M	8	2	16		16						16						16						16					
321-MP2	Coupling inspection and re-grease	6M	8	2	16								16												16					
321-SP1	Mechanical service	2M	8	2	16	16				16				0				16				16				16				16
321-SP1	Inspection of internal bearing and feeding air-slide	1Y	8	2	16									16																
321-SP2	Mechanical service	2M	8	2	16		16				16				16				0				16				16			
321-SP2	Inspection of internal bearing and feeding air-slide	1Y	8	2	16														16											
321-ULA	Cleaning of cooling system and filters	3M	4	2	16						8						8						8						8	
321-ULB	Cleaning of cooling system and filters	3M	4	2	16						8						8						8						8	
321-VE3	Mechanical service	3M	7	2	14			14						14						14						14				
321-VE3	Wear measurement	6M	7	2	2			14												14										
341-CP1	Mechanical service	6M	8	2	16												16												16	
341-VE1	Mechanical service	3M	3	2	6						6						6						6						6	
341-GU1	Mechanical service	3M	5	2	10						10						10						10						10	
			Work force req. in Hours			58	48	52	56	58	48	50	48	54	48	42	48	66	48	52	48	58	48	50	56	54	48	42	48	58
			Work force req. in Pers.			7	6	7	7	7	6	6	6	7	6	5	6	8	6	7	6	7	6	6	7	7	6	5	6	7

Figure 27 Example of a template created for work load balance of PMR's

Before starting with the execution of the activities, the work load balance should be submitted to the Maintenance Manager in order to budget and assure the availability of resources required to attain with the execution of all PMR's.

Work load balancing is also a prerequisite of loading PMR's in SAP and regarding to this it is very helpful for the definition of many inputs for SAP such as:

- type of maintenance strategy
- maintenance packages (frequencies)
- hierarchy of the maintenance packages (notice: remember this when task list creation)
- parameters and design of the task list (number of operations, sequence of activities, duration, workforce requirement, frequency of operations, etc.)
- definition of the call date for scheduling the maintenance plan (according with the maintenance shutdown schedule).
- definition of the type of maintenance plan

The template is also used as a dead line monitor to verify the correct scheduling and also can be helpful for analysis and optimization of the preventive maintenance and to prior evaluation of the impact of futures changes.

7. PMR Management in SAP-PM

The purpose of loading and scheduling PMR's in SAP is the automatic generation of work orders for preventive maintenance activities at specific dates; this is a key input for the master maintenance plan. However you have to travel towards several transactions to obtain the expected results (see dashed area in Figure 28).

> In this section it is assumed that the work load balancing of PMR's has been done. You have to be aware of the quantity of work orders the system can generate in case of misunderstanding.

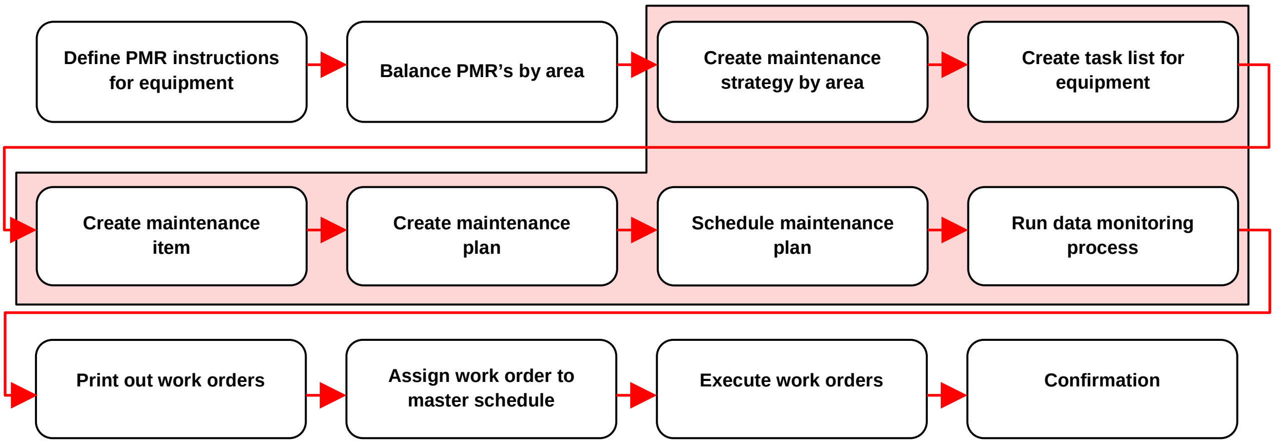


Figure 28 Preventive Maintenance Management Process

The following types of maintenance plan are available in SAP:

- **Strategy-based maintenance plans**:
  The maintenance strategy defines the number of packages and their frequency.
- **Single cycle plan**
  Maintenance cycle can also be directly defined in the maintenance plan. This maintenance plan corresponds to a strategy-based maintenance plan with exactly one time based or counter-based package. In case, you do not need to create a strategy or assign operations in the task list to this specific package. The total work contained in the specified task list is called up.

7.1 The Preventive Maintenance Process in SAP-PM

Preventive Maintenance	**SAP PM**	**Purpose**
PMR Database Eq/functional Location Frequency Task Time Resources Workload Balancing	Maintenance Strategy	To define PM on Time Based Or counter* based For a process area or per plant To define packages (frequency)
	Tasks	Description of PM activities Resources (Labour+ Materials)
	Maintenance Item	Information for work order header (Function location, Equipment, Work center, cost center, order type and activity type
	Maintenance Plan Scheduling	To provide scheduling information

The first concept to understand is the terminology used in the preventive maintenance program and the meaning of them when the work order is created, the following pictures describe it:

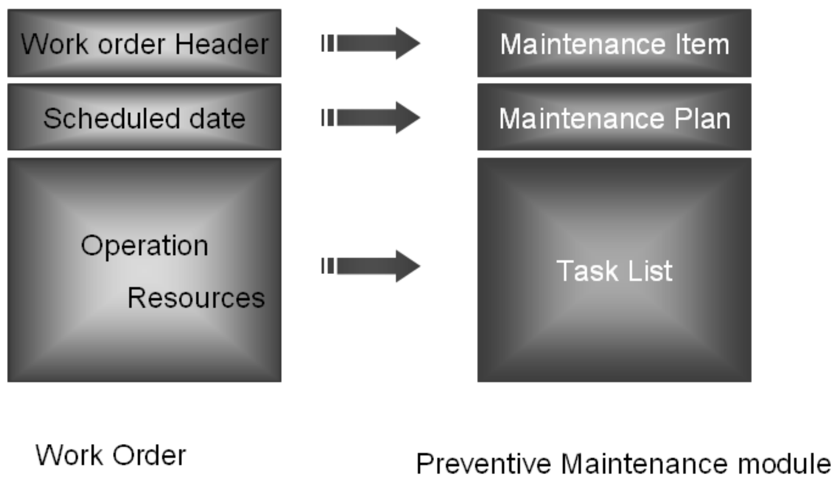


Figure 29: Work order element in the SAP preventive maintenance program

It is essential to understand how the process of preventive maintenance in SAP-PM is defined. Basically the process consist on creating a database which contains all PMR's, organized in such way they expected to be executed on field and according with the previous design and work load balancing. All data and parameters are organized and interact in SAP-PM as is shown in the following figure.

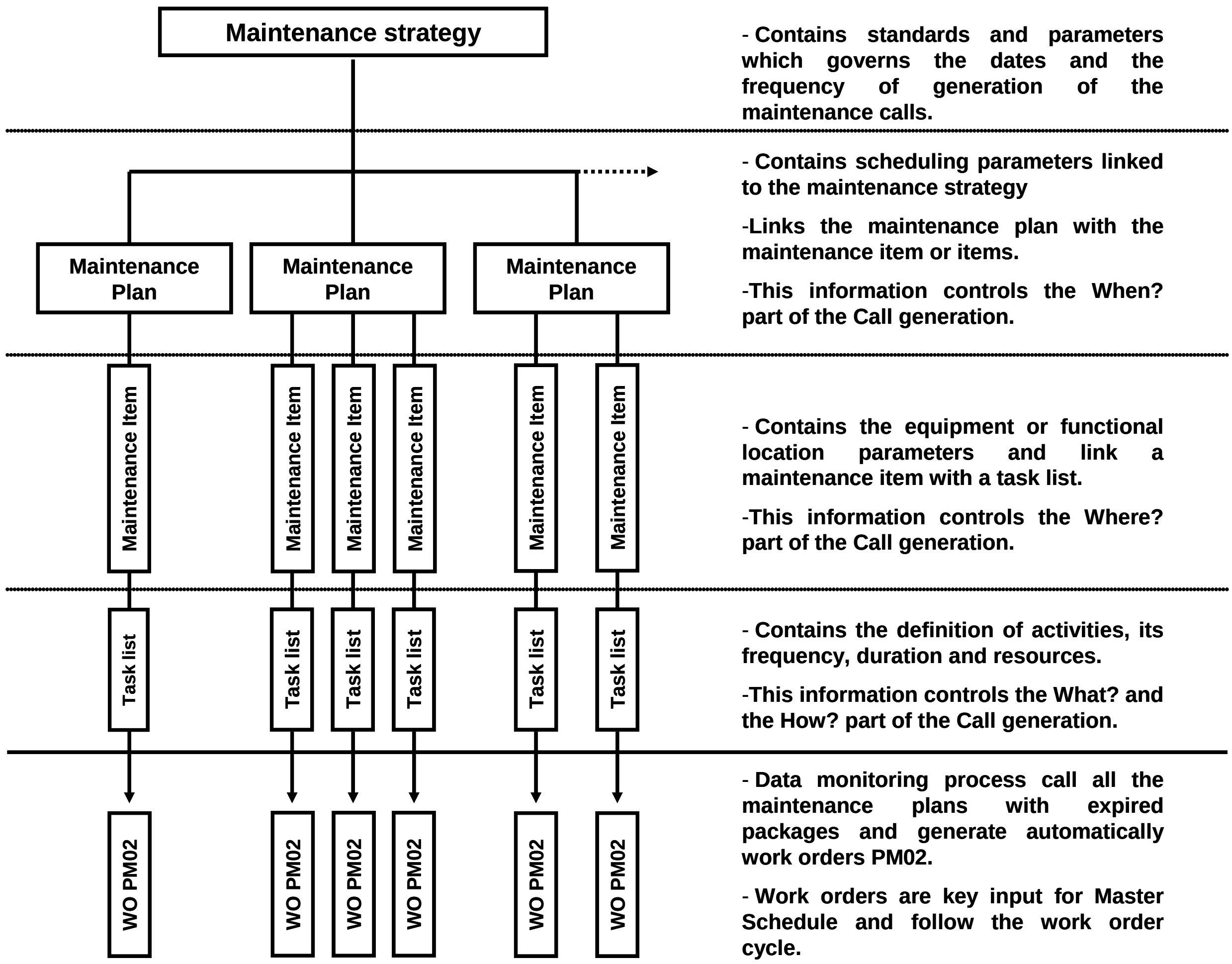


Figure 30 Preventive Maintenance database in SAP-PM

7.2 Maintenance Strategy

7.2.1 Definition

In the Maintenance Strategy are defined the standards and parameters which governs the dates and the frequency of generation of the maintenance calls. This standards and parameters are the following:

Strategy header (name and description)

Scheduling parameters (call horizon and offset)

Scheduling Indicator and Strategy unit (measurable units used to determine the dates for the maintenance calls)

Maintenance packages (definition of the packages, its sequence and its hierarchy)

Name: Always start with Plant ACS code

Strategy Unit: Always *day* or *week* for Time strategy

Call Horizon: *80%* for time strategy

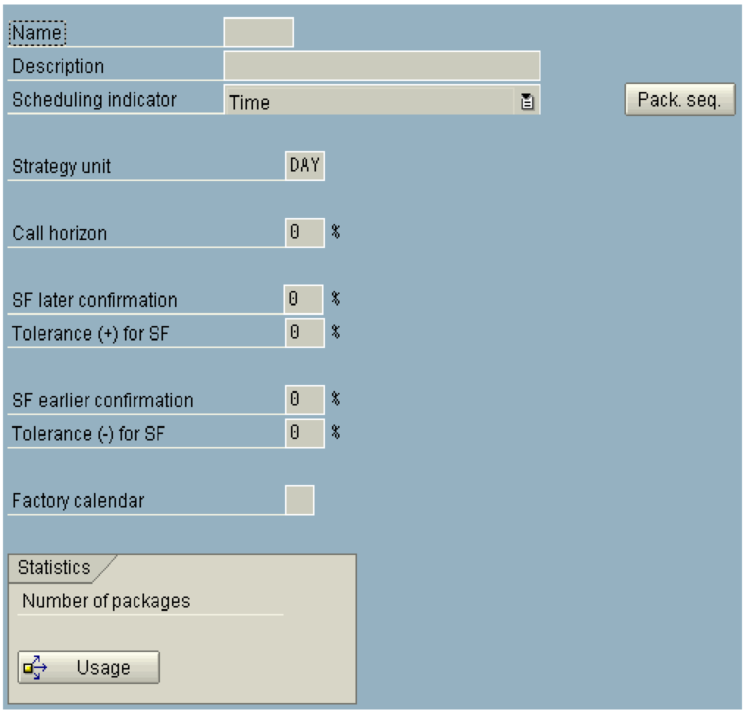


Figure 31. Maintenance strategy screen

The Maintenance Strategy is a required field throughout SAP Planned Maintenance. It is required in:

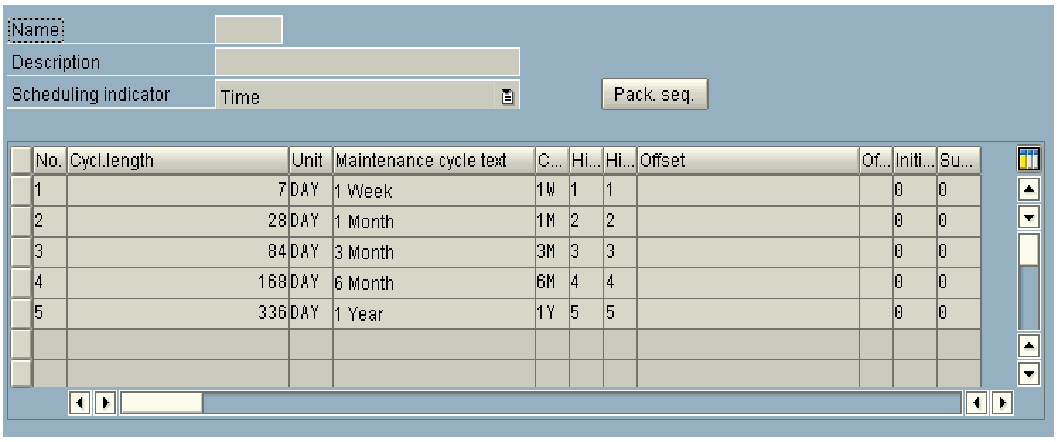
- Task List,
- Maintenance Item,
- Maintenance Plan.

Strategy must be defined at plant level under the responsibility of the Preventive Maintenance manager.

7.2.2 The Maintenance Packages

Maintenance packages define the frequency at which specific operations are executed. Maintenance packages are assigned to the operations in a task list. Packages are based on measurable units such as Time (days) or on Performance (Operation hours, wearing millimeters, Tons produced, etc.).

On a Maintenance Strategy based on frequency, Maintenance Packages are defined by all the frequencies defined in the prior Work Load Balance of PMR's.



Name
Description
Scheduling indicator: Time
Pack. seq.

No.	Cycl.length	Unit	Maintenance cycle text	C...	Hi...	Hi...	Offset	Of...	Initi...	Su...
1	7	DAY	1 Week	1W	1	1			0	0
2	28	DAY	1 Month	1M	2	2			0	0
3	84	DAY	3 Month	3M	3	3			0	0
4	168	DAY	6 Month	6M	4	4			0	0
5	336	DAY	1 Year	1Y	5	5			0	0

Figure 32. Maintenance package definition screen

It is possible to define a hierarchy for Maintenance Packages (as is shown in Figure 32), this is very useful to reduce the amount of operations and work orders management; nevertheless you must be aware of the hierarchy definition to avoid blocking packages unnecessary.

In the following example the packages are Hierarchical. If at the same date e.g. the 1M+3M tasks are ready only the 3 M is released

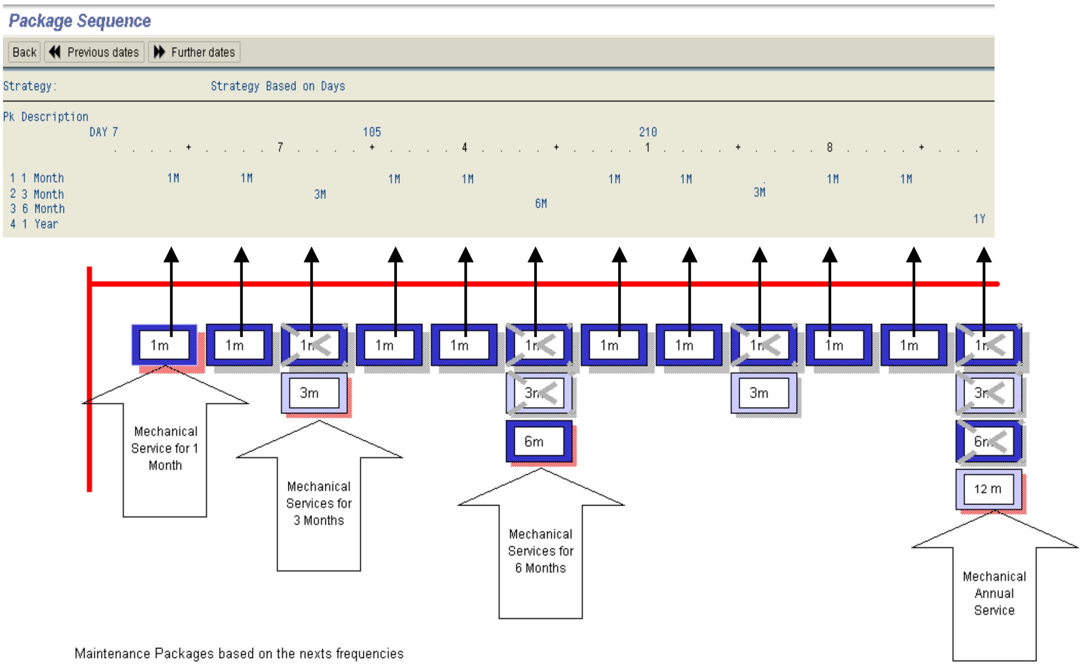


Figure 33 Package sequence and hierarchy.

7.3 Task List

Maintenance task lists describe a series of individual maintenance activities. These can be used to standardize recurring activities, plan them more effectively, and save time when creating maintenance orders and maintenance plans.

In the Plant Maintenance system, maintenance task lists can be used for routine, preventive and corrective maintenance work Task lists also specify which spare parts and tools are required for operations and the time needed to perform the work.

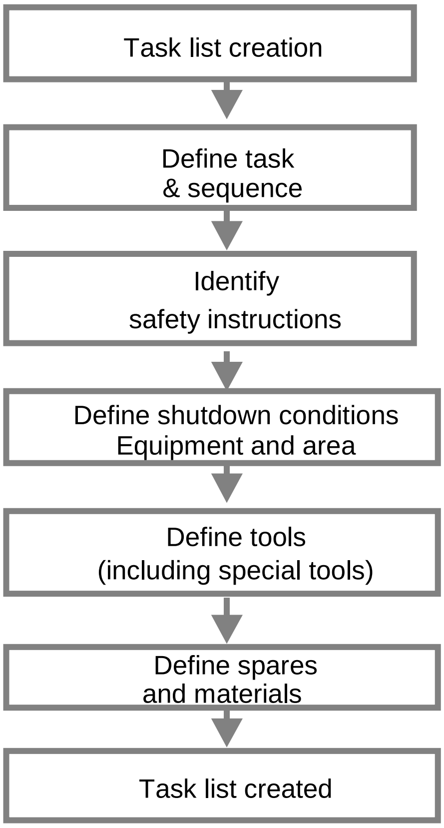


Figure 34 Task list creation

In SAP three types of task lists exist the recommendation is to use the following rule:

- Functional Location task list: to be used as standard procedure for corrective maintenance work. These task lists will be assigned to the PM01 work order. A naming convention must be defined for each plant.
- Equipment task list: Should not be used
- General Task List: for all preventive maintenance procedure. A naming convention must be defined for each plant.

Condition Monitoring Techniques		Example	Level for Work Order	Task List	Code
Lubrication	Greasing route	All routes with greasing and quantity of grease	Area/Line	General Task List	LUB
	Oil and grease replacement	Fixed time replacement of oil for small GB - No oil analysis performed	Equipment	General Task List	OIL
	Oil Sampling & Analysis	Sampling analysis of oil of main equipment	Area/Line	General Task List	OIL
Condition Monitoring	Walk By inspection	Maintenance walk by inspection	Area/Line	General Task List	WBI
	Vibration route	All routes used for Vibration analysis with data collector	Area/Line	General Task List	VIB
	Thermography	Routes for thermography analysis	Area/Line	General Task List	THM
	EMD	Either static of Dynamic measurements	Functional location Level 5 / Equipment	General Task List	EMD
	NDT	VT, PT, MT, UT, E Current	Functional location Level 5	General or Functional Location Task List	NDT
	Equipment specifc measurement	Shell test, lead wire, Run out etc	Functional location Level 5	General or Functional Location Task List	Equipment HAC in 2 digits
	Downtime Inspection	Visual inspection, calibration, cleaning, replacement, adjustment or services	Functional location Level 5 / Equipment	General or Functional Location Task List	Equipment HAC in 2 digits
	Wear mesurement	Liners, thickness, elegation, hardness…	Functional location / Equipment	General or Functional Location Task List	Equipment HAC in 2 digits

Figure 35 : Definition of task list by condition monitoring techniques

Naming convention for preventive maintenance task list:

Always start with Plant ACS code in 2 digits (i.e. AL for Altkirch; GV for St Genevieve) and use the code from the table above

7.3.1 Maintenance task list structure

The following assignments are made in the **task list header**:

- Planner group, this planner group are specific for the task list, the recommendation is to have the same setup than for the work order process.
- Maintenance strategy,
- and a series of other parameters
- Note that task list header will never appear in the work order text.

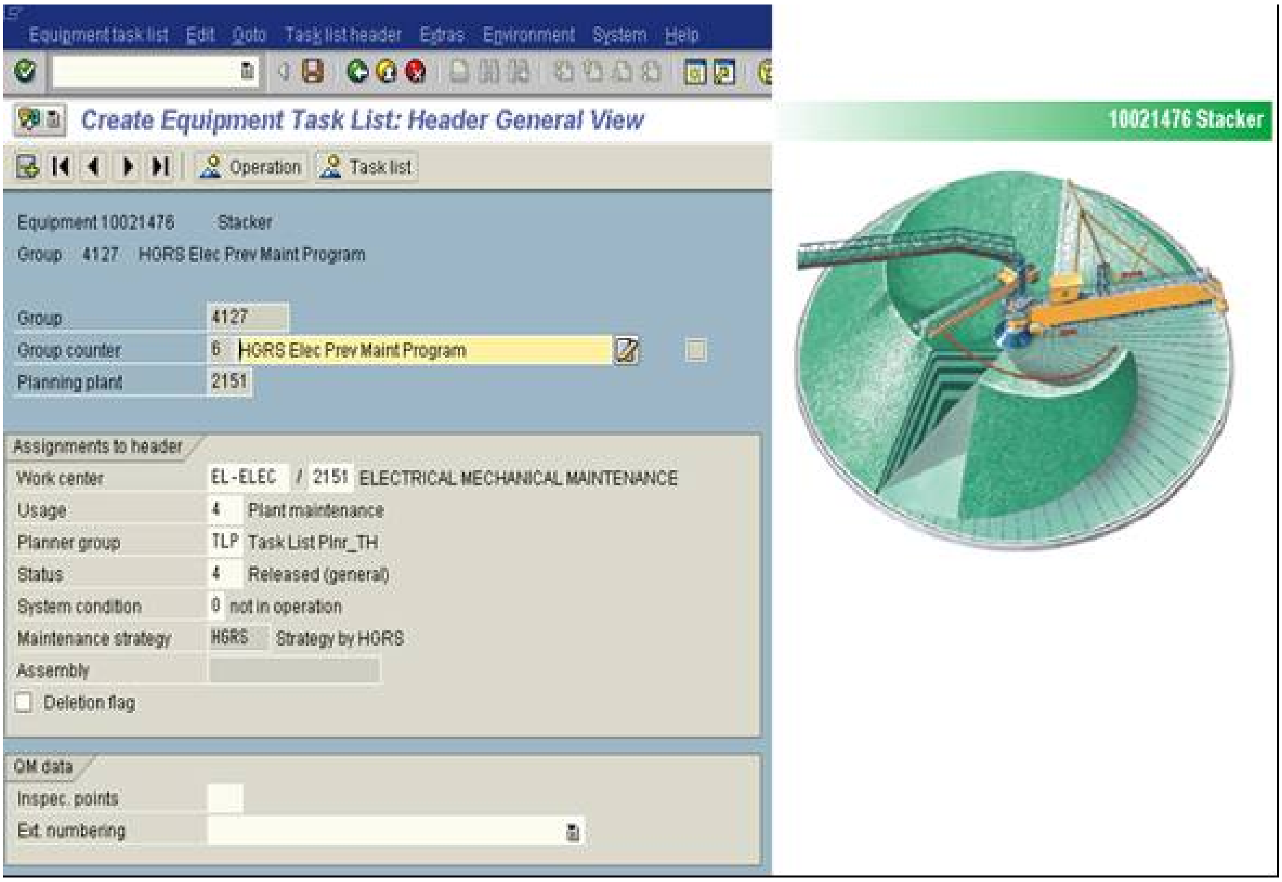


Figure 36 Task List Header

The following assignments are possible for **operations**:

- The operations are expressed in such way they describe the frequency, and the function
- The personnel (work center) needed and the duration of the executions is also defined in this step

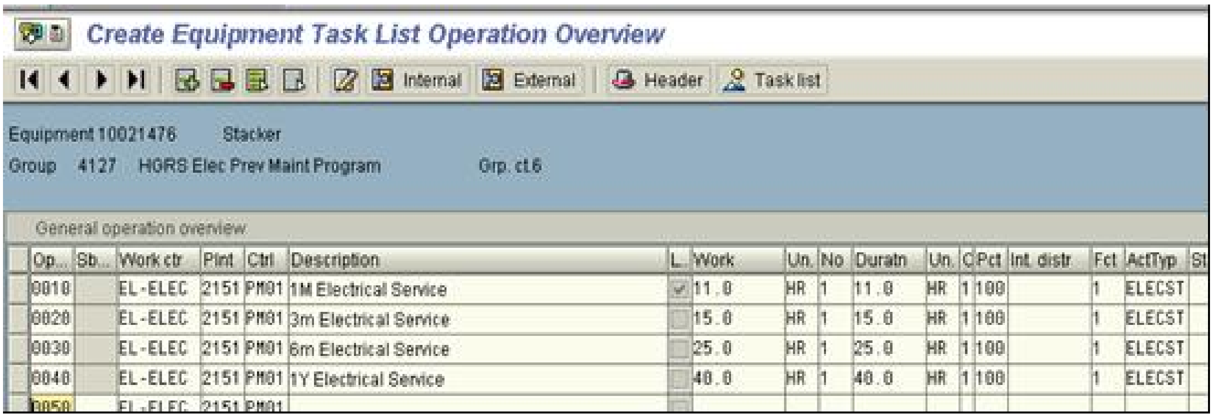
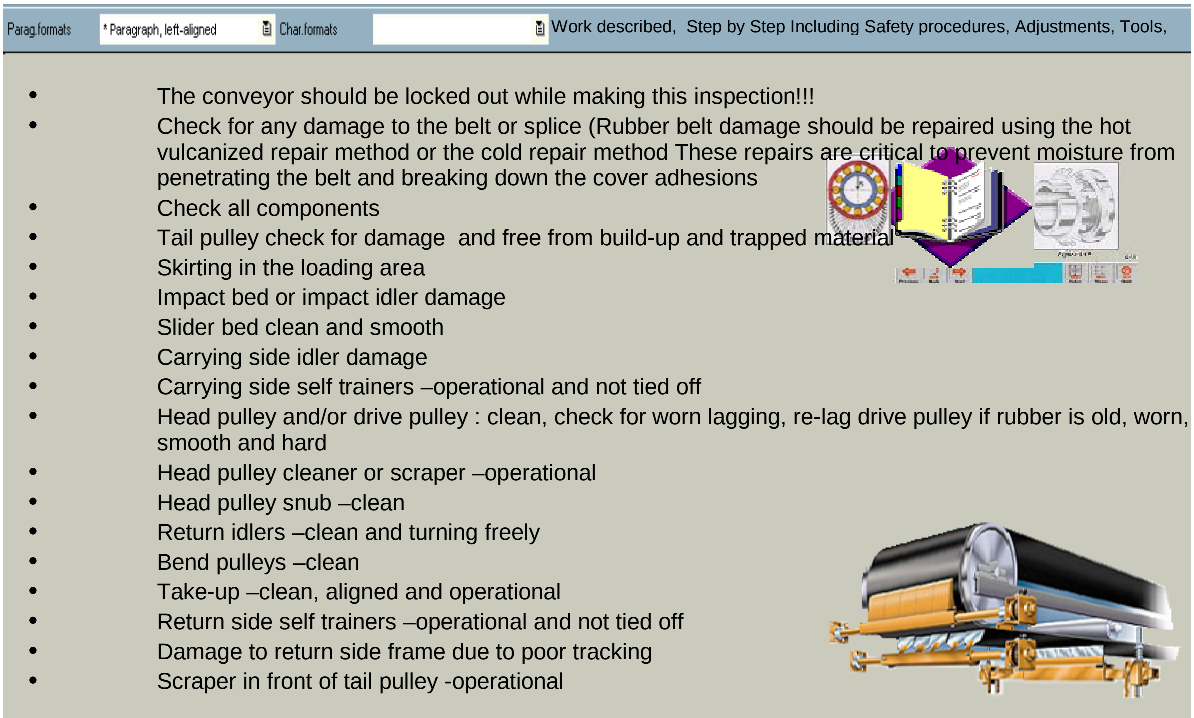


Figure 37 task List Operation Overview

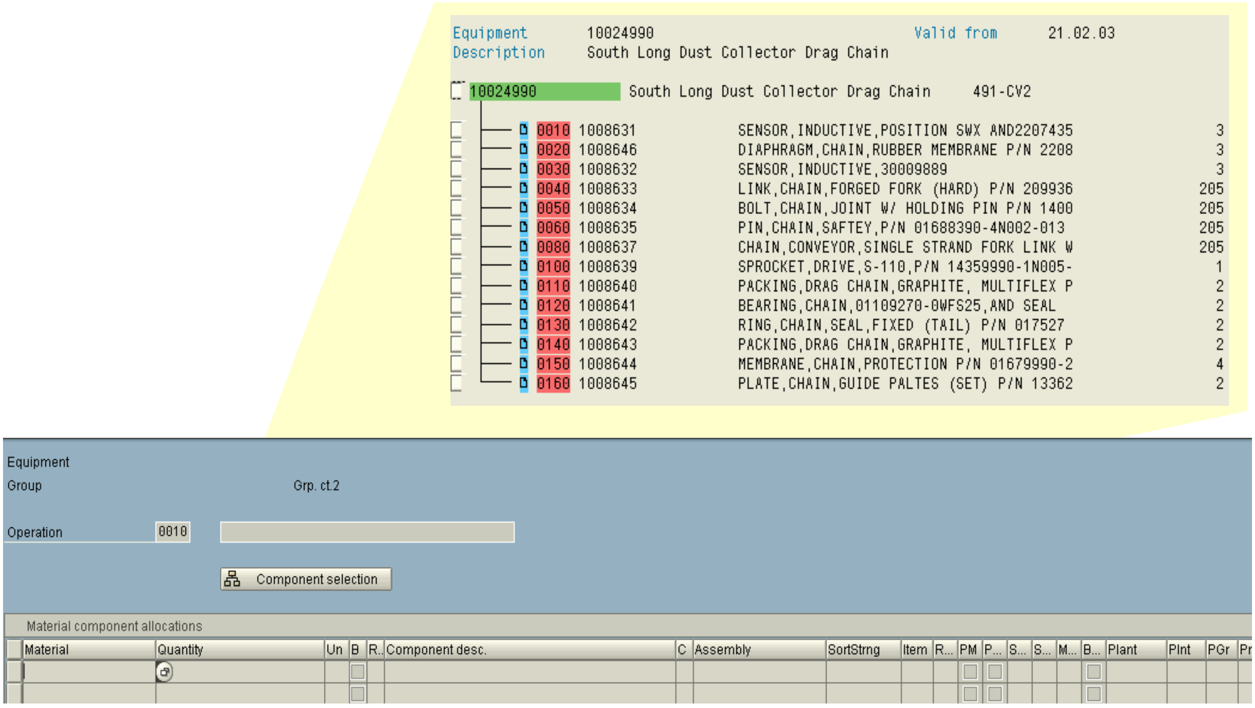
- The instructions and specifications for the PMR are updated in the extended text. Now the recommendation is to define the specification of the PMR in excel or word document and attached them to each operation using DMS functionalities. A specific function part of the MAC SAP standard enhancement (or specific SAP development) allows to automatically print the attached document allows the print them with the work order.



- The conveyor should be locked out while making this inspection!!!
- Check for any damage to the belt or splice (Rubber belt damage should be repaired using the hot vulcanized repair method or the cold repair method These repairs are critical to prevent moisture from penetrating the belt and breaking down the cover adhesions
- Check all components
- Tail pulley check for damage and free from build-up and trapped material
- Skirting in the loading area
- Impact bed or impact idler damage
- Slider bed clean and smooth
- Carrying side idler damage
- Carrying side self trainers –operational and not tied off
- Head pulley and/or drive pulley : clean, check for worn lagging, re-lag drive pulley if rubber is old, worn, smooth and hard
- Head pulley cleaner or scraper –operational
- Head pulley snub –clean
- Return idlers –clean and turning freely
- Bend pulleys –clean
- Take-up –clean, aligned and operational
- Return side self trainers –operational and not tied off
- Damage to return side frame due to poor tracking
- Scraper in front of tail pulley -operational

Figure 38 Long text of operation

- Components can also be assigned to each operation.



Equipment 10024990 Valid from 21.02.03
Description South Long Dust Collector Drag Chain

10024990 South Long Dust Collector Drag Chain 491-CV2

0010	1008631	SENSOR,INDUCTIVE,POSITION SWX AND2207435	3
0020	1008646	DIAPHRAGM,CHAIN,RUBBER MEMBRANE P/N 2208	3
0030	1008632	SENSOR,INDUCTIVE,30009889	3
0040	1008633	LINK,CHAIN,FORGED FORK (HARD) P/N 209936	205
0050	1008634	BOLT,CHAIN,JOINT W/ HOLDING PIN P/N 1400	205
0060	1008635	PIN,CHAIN,SAFTEY,P/N 01688390-4N002-013	205
0080	1008637	CHAIN,CONVEYOR,SINGLE STRAND FORK LINK W	205
0100	1008639	SPROCKET,DRIVE,S-110,P/N 14359990-1N005-	1
0110	1008640	PACKING,DRAG CHAIN,GRAPHITE, MULTIFLEX P	2
0120	1008641	BEARING,CHAIN,01109270-0WFS25,AND SEAL	2
0130	1008642	RING,CHAIN,SEAL,FIXED (TAIL) P/N 017527	2
0140	1008643	PACKING,DRAG CHAIN,GRAPHITE, MULTIFLEX P	2
0150	1008644	MEMBRANE,CHAIN,PROTECTION P/N 01679990-2	4
0160	1008645	PLATE,CHAIN,GUIDE PALTES (SET) P/N 13362	2

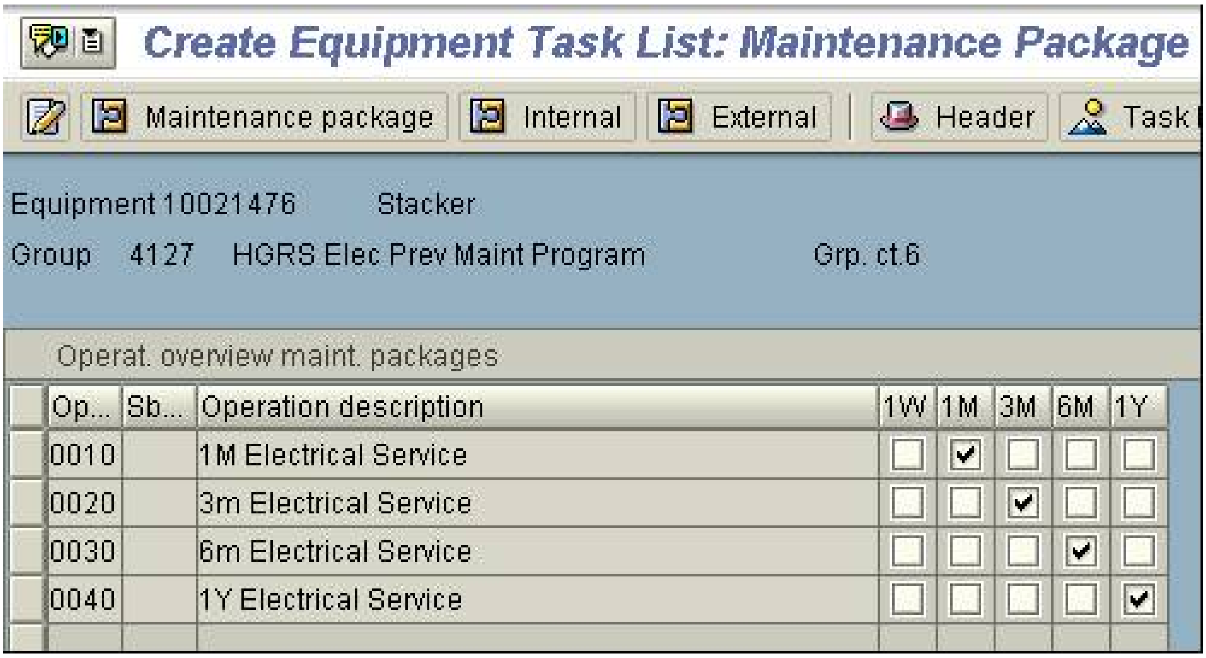
Equipment
Group Grp. ct.2
Operation 0010
Component selection

Material component allocations

Material	Quantity	Un	B	R.	Component desc.	C	Assembly	SortStrng	Item	R...	PM	P...	S...	S...	M...	B...	Plant	Plnt	PGr	Pr

Figure 39 Material assignment (*BOM only visible for Equipment Task List*)

- Each operation is assigned a Frequency (maintenance package). According with the strategy and linked to each operation of the task list
- If the design of the task list has several operations you must consider the hierarchy of the maintenance packages of each operation to avoid blocking operations unnecessary.



Create Equipment Task List: Maintenance Package

Maintenance package | Internal | External | Header | Task l

Equipment 10021476 Stacker

Group 4127 HGRS Elec Prev Maint Program Grp. ct.6

Operat. overview maint. packages

Op...	Sb...	Operation description	1W	1M	3M	6M	1Y
0010		1M Electrical Service	☐	☑	☐	☐	☐
0020		3m Electrical Service	☐	☐	☑	☐	☐
0030		6m Electrical Service	☐	☐	☐	☑	☐
0040		1Y Electrical Service	☐	☐	☐	☐	☑

Figure 40 Assignment of package to operation

7.4 Maintenance Item

The maintenance item describes which preventive maintenance operations have to be performed on the equipment. One or more maintenance items can be assigned to a maintenance plan but a maintenance item only can be assigned to one maintenance plan.

A maintenance plan always automatically contains at least one maintenance item.

You can assign maintenance items to a maintenance plan in the following ways:

- You create a maintenance plan and create a maintenance item directly in the maintenance plan by entering the required data in the tab strip Item.
- You create additional maintenance items in a maintenance plan.
- You create a maintenance item without assignment and subsequently assign it to a maintenance plan.
-

The easiest way is to create maintenance items directly in the maintenance plan

You must have created the maintenance item you want to assign to a single cycle plan or multiple counter plan without reference to a maintenance strategy. The maintenance item you assign to a strategy plan must have the same maintenance strategy as the maintenance plan. The maintenance item you assign to a strategy plan must have the same maintenance plan category as the maintenance plan.

The main purpose of the Maintenance Item is to combine and link the object with the task list, it also provides the 'header' information for the PM02 work order, this includes:

- The Equipment, planning data etc.
- The maintenance item also links the task list (operations) to the order.
- The Maintenance Item also references the strategy

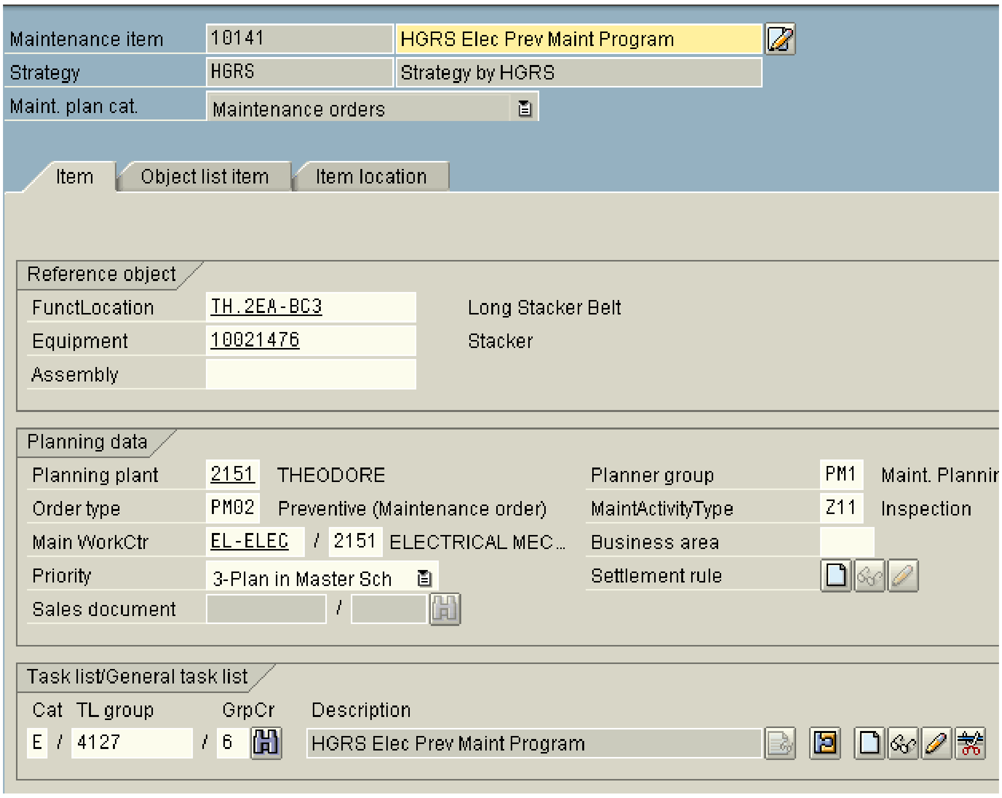


Figure 41 Maintenance Item screen

7.5 Maintenance Plans

The maintenance plans specify the scheduling data for the maintenance Item, regarding the strategy employed.

- **Single cycle plan**
  You can also define a maintenance cycle directly in the maintenance plan. This maintenance plan corresponds to a strategy-based maintenance plan with exactly one time-based or counter-based package. In this case, you do not need to create a strategy or assign operations in the task list to this specific package. The total work contained in the specified task list is called up.
- **Strategy-based maintenance plans**
  Maintenance strategy defines the number of packages and their frequency.

The following types of maintenance plan are available in SAP:

Type of Maintenance Plan	Type of maintenance strategy
Single cycle plan	Not required
Time basis maintenance plan (days)	Based on frequency (time)
Performance basis maintenance plan (Wear control, elongation, tons produced, etc.)	Based on activity (counters are required)
Multiple plan (oil sampling, wear control, etc)	Maintenance strategy not required, (multiple counters are required)

The selection of the maintenance plan is based on the type of maintenance strategy and always according to the equipment needs as shown in Figure below

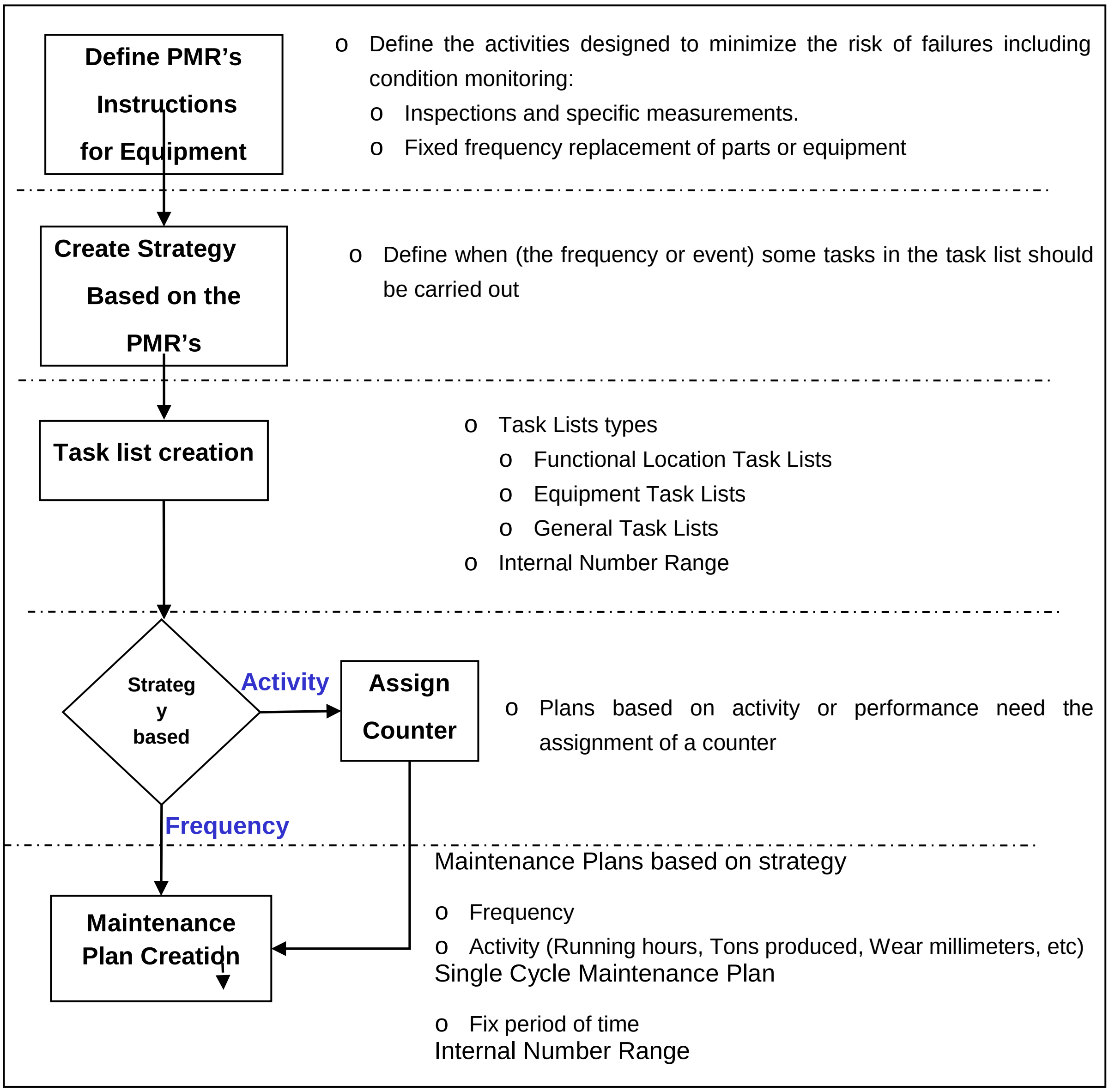


Figure 42 **Definition of Maintenance Plan type**

A maintenance plan can contain one or more maintenance items (for example, maintenance of a pump - a maintenance item for the pump gears with accompanying task list, and a maintenance item for the pump motor with accompanying task list).

The maintenance plan contains:

- Scheduling Data
  - The Maintenance Strategy
  - Cycle / maintenance intervals
  - Scheduling parameters for fine-tuning scheduling
  - List of planned dates and call date
- Maintenance Item
  - Planning data (e.g., maintenance plant, planner group, and order type)
  - Reference object
- Task list
  - Planning data (e.g. maintenance plant, planner group, and order type)
  - Reference object

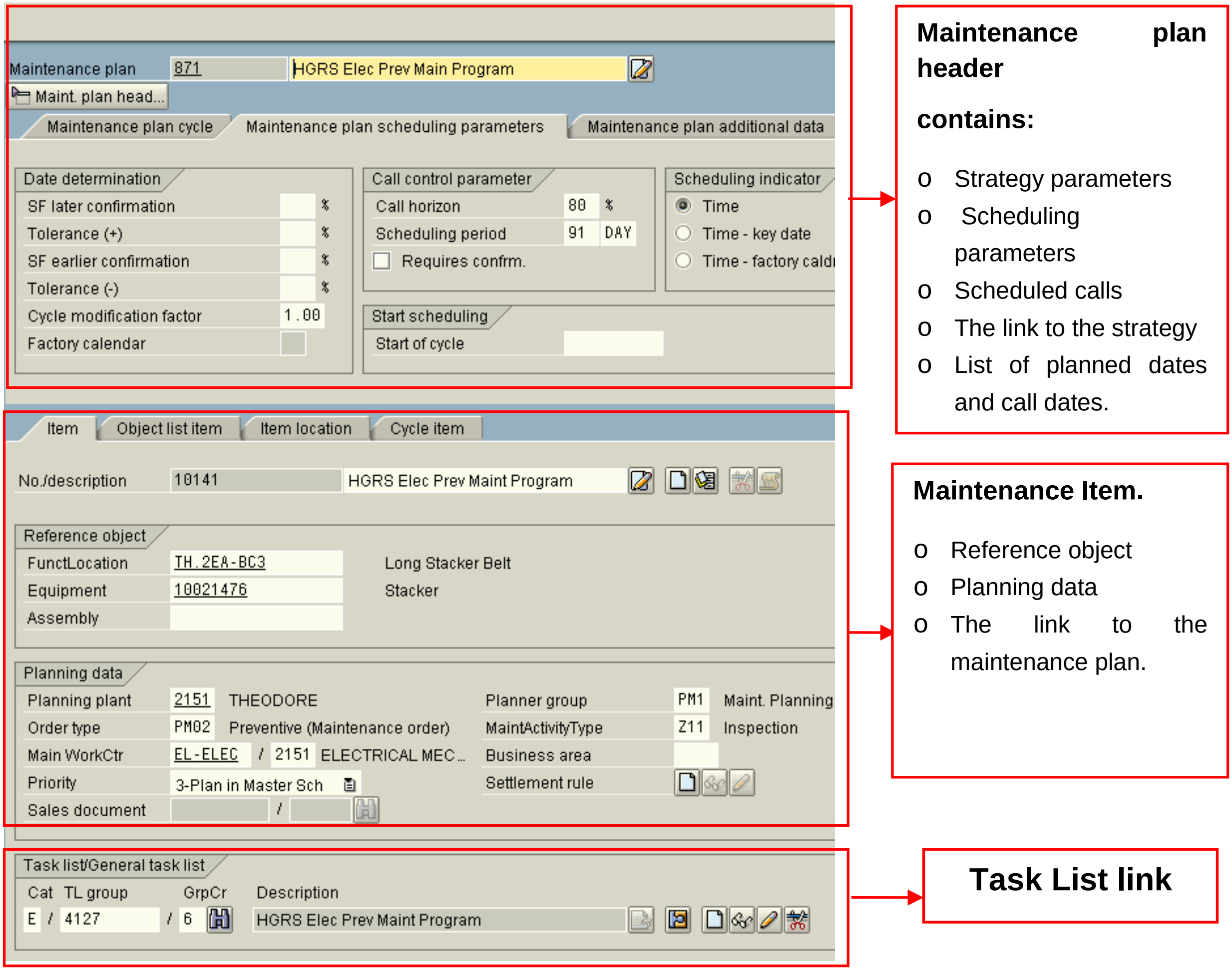


Figure 43 Structure of a maintenance plan

7.6 Scheduling a Maintenance Plan

The process of scheduling a maintenance plan can be resumed in the following steps:

- **New start**: Function normally used to start a maintenance plan for an object, which has just been put into operation, or for which preventive maintenance work is required.
- **Schedule**: Function used to call up the next maintenance order after the last maintenance order has been completed. It is not usually performed manually, but triggered by the technical completion of the previous order and the deadline monitoring program.
- **Start in current cycle**: You can restart scheduling for your strategy plan in the current cycle. This function is useful if you have previously been using a different EDP system to SAP, or no EDP system at all, to manage your maintenance work. For example, you may have a maintenance strategy with three packages - monthly, every four months, and every six months, which you have assigned to your maintenance plan. Instead of starting the schedule with the package "monthly", you can start with the six-month package and enter the date when the last preventive maintenance work was executed.
- **Manual call**: If you also want to schedule a maintenance call for a particular date, you can schedule this date manually. You use a manual call to insert additional dates, without affecting normal scheduling. To do this, you enter:
  Call date and due maintenance packages.

7.6.1 *Scheduling parameters*

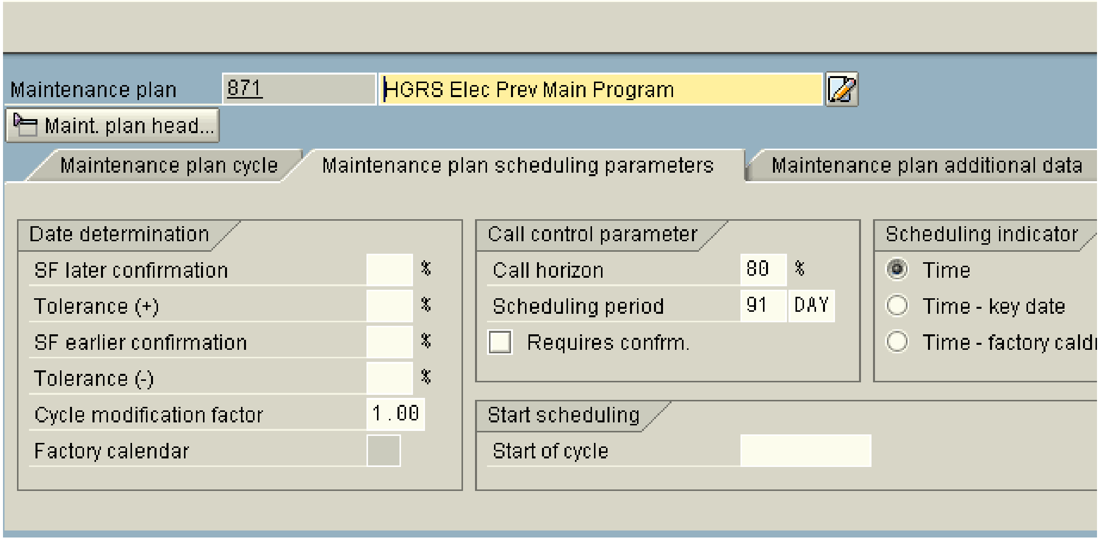


Figure 44 Scheduling parameter screen of maintenance plan

The scheduling parameters are:

- **Cycle start**: Start date for calculating planned and call dates.
- **Call horizon**: Is entered as a percentage and refers to the cycle length. It specifies when an order should be generated with reference to a calculated maintenance date.
  - The call horizon is specified as a percentage of the cycle:
    - 100% means that the order is generated exactly on the planned date.
    - 0% would mean that the order is generated when the maintenance plan is started
  - For a call horizon of 80% and a cycle of 3 months (= 91 days), the call - the generation of the order - would therefore occur after 72 days (= 80% of 91 days).
- **Scheduling period**: Specifies the period for which planned dates should be calculated in advance. *Scheduling period is established in 91 days in order to fulfill the master schedule*
- If **confirmation requirement** is activated, the system only generates the next call object once the previous call object has been confirmed.
  It is not recommended to use this field because it would disorganize your balancing preventive maintenance plan.
- The following parameter are only activated if **confirmation requirement** is set
  - **Shift factors**: The shift factors for early/delayed confirmation of a maintenance task define what percentage of the shift should be considered for the next date.
  - **Tolerances for shift factors**: The tolerances for early/delayed confirmation define the time period, for which positive or negative differences between actual and planned dates do not affect subsequent scheduling.
- **Scheduling indicator:** Specifies the type of time-based scheduling involved: - Time (= based on calendar): The dates are calculated in **calendar days,** - Time - key-based, the dates are calculated from the cycle start always **for the respective key date**, - Time - factory calendar: The dates are calculated in **workdays**.
  Always used **Time.** Time Key date can be use for some specific task like electrical counter reading beginning of the month. Never assigned a specific key date afater the 28 of the month (February!)

7.6.2 Scheduling the maintenance plan

On all information and scheduling parameter enter in your Maintenance plan you need to set it in process => “Scheduling”

For after start the maintenance plan in the cycle you need to select the package in which you start.

You can use **deadline monitoring** to monitor maintenance plans regularly. Two functions can be executed here:

- Rescheduling: For example, if the scheduling parameters have changed since the last scheduling, deadline monitoring can execute a complete rescheduling. All the existing planned dates are deleted and recalculated.
- Calling up orders: In addition to rescheduling, waiting planned dates can be converted into orders. Here, a time period is specified in days. All planned dates and call dates, which lie within this period of time, are converted into orders.

Warning: Without deadline monitoring (or manual scheduling), the planned dates will not be recalculated and orders will not be generated. The maintenance plan created is therefore not active in itself.

Deadline monitoring is used in close conjunction with the **call horizon** (for example, executing deadline monitoring daily and no entry in the "Orders" field for the next n days, combined with a call horizon of 80% > results in a preliminary run that corresponds exactly to the call horizon).

If no scheduling period is defined in the maintenance plan, a new planned date is added automatically when the current waiting call is converted into an order.

Deadline monitoring can be executed either in dialog or automatically by a system job.

8. Message

Preventive Maintenance is a key component of the overall Maintenance strategy; proper resources have to be allocated and dedicated to it.

The clear goal of Preventive Maintenance within LafargeHolcim is to focus on Condition Monitoring activities, as long as it is economically feasible. Time based replacement activities must be limited to well justified cases, where their benefits outweigh performing Condition Monitoring.

Be aware: Problems are solved fighting root causes and not just by creating new PMR’s!.

Preventive Maintenance is responsible for all time-based activities (inspection, lubrication, condition monitoring) and must make sure that the deviations detected in the equipment condition are timely addressed and corrected (supporting the responsible for Mechanical and Electrical Corrective Maintenance) and verifying the effectiveness of the corrective activities on the equipment.

Preventive Maintenance must harmonize the content of the different PMR’s throughout the plant and make sure that no duplication or repetition of tasks is taking place.

The more time invested in the creation and proper set up of PMR’s in SAP-PM (or other CMMS), the less administrative time will have to be spent on scheduling and manual handling of the generated Work Orders.

PMR’s are not only good wishes; they are activities that must be performed in order to maintain the good condition of equipments, for prevention and early detection of failures. Work load balancing is a key issue for the successful implementation and optimization of a preventive maintenance database because in some way is also part of the design of the preventive maintenance strategy and is the planning phase of the preventive maintenance activities. Build a practical and safe sequence of activities; remember that you are planning maintenance operations that will be executed by people in the field!. In addition; the result of this work is a key input for the master maintenance plan. So take your time to build the template with precision and remember, always work as a team!

Preventive maintenance function in SAP is not an easy process. That is the reason you need to prepare your task and frequency in a excel file first before starting to implement in the system. Be aware of the usage of strategy to avoid multiple creation of work order and try always to have work orders that fit with your available time during the shift. SAP system will call all data as were loaded and scheduled, so this step must be developed carefully, it is also important the care and precision dedicated to the prior design and work load balance of PMR's because the effectiveness and practicality of the preventive maintenance management system will be reflected on the availability and reliability of the equipments and plant results, through KPI's performance.

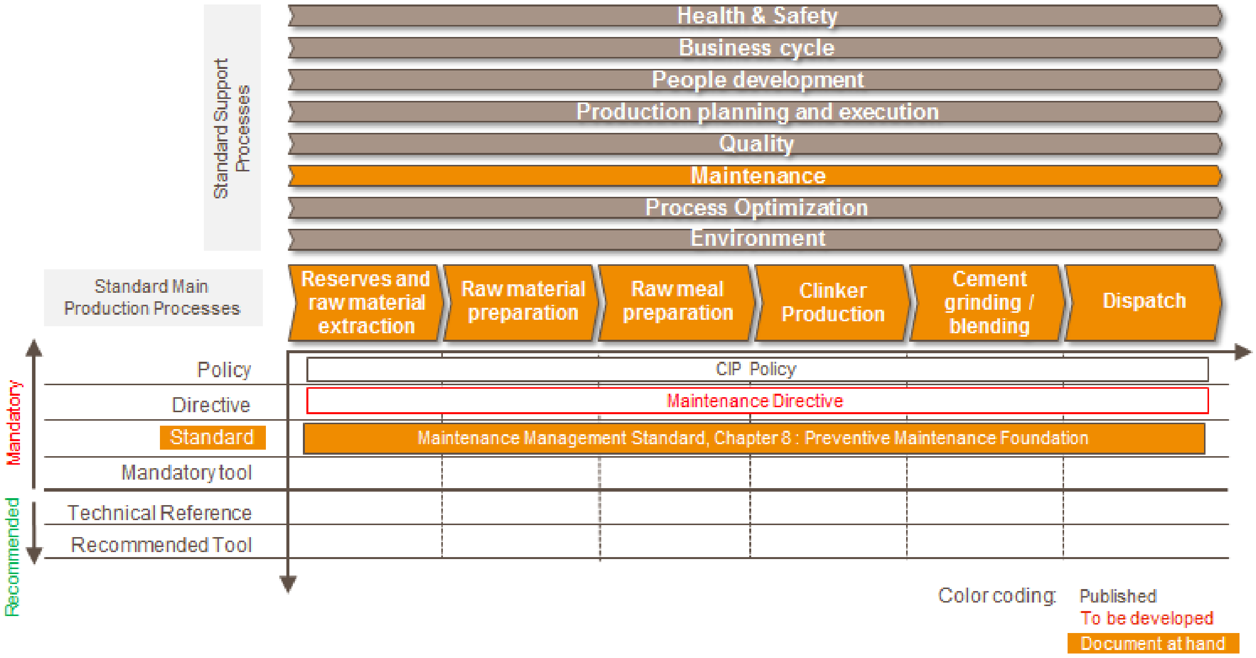
Lubrication and walk-by inspection are relatively simple techniques but should be considered as the core activities of the Preventive Maintenance which demand nevertheless a systematic and disciplined approach to provide the desired benefits. Once these cornerstones are in place, the Preventive Maintenance can be enriched with other more advanced techniques.

The main outcomes of the walk-by inspections are the notifications and any values to trend, i.e. actionable items. Try to eliminate as much paper(work) from the walk-by inspections as possible!

Lubrication management demands a change in mindset to achieve the challenging targets of cleanliness and a reliable, trouble-free equipment operation.

9. Document management

9.1 Cement Industrial Framework



9.2 Document information & revisions

Content owner	Jorge Gamarra, Head of Maintenance & Equipment		
Author(s)	Rodolfo Tiglao, Bruno Callais		
Reviewed by	Jorge Gamarra, Jean-Yves Marrel, Alino Bertolo, Michael Schmid		
Validated by	CIP Standards and Tools		
Revisions	**Version**	**Date**	**Main changes**
	1.0	09 Jan 2017	First version

9.3 Related Document

	Type	Name
I	Policy	CIP policy
II	Directive	Maintenance Directive
III	Standard	Maintenance management standard, chapter 1 to 13
IV	Mandatory Tool	
VI	Technical Reference	
VI	Recommended Tool	

This document replaces:

Type	Name
Legacy Holcim	MER1MM_08v0 - Preventive Maintenance Management.doc
Legacy Lafarge	

10. Annexes: Lubrication

10.1 Norms

A.P.I. Norm (American Petroleum Institute)

API performance standards are indicated with the abbreviation API SJ or API CE :

- the first letter designates the type of engine (S = gasoline and C = diesel),
- the second letter designates the performance level (for gasoline engines, etc.).
- Lubricants must successfully complete four tests to achieve API performance levels; these tests take into account :
- the rise in the temperature of engine oils in service ;
- the lengthening of the period between oil changes recommended by manufacturers ;
- efforts to achieve engine performance ;
- increasingly stringent environmental protection standards ;
- and, for some oils :
- lower fuel consumption due to low viscosity (energy-conserving category).
- Three types of classification :
- API transmission Classification
- API Gasoline Engine Classification
- API Diesel Engine Classification

API-GL-1

For axle transmissions with spiral gears and worm screw and certain manual transmissions. May contain additives: antirust, antioxidant, antifoam and an agent which lowers the point of solidification.

API-GL-2

For worm-screw transmissions in which a GL-1 oil is insufficient.

API-GL-3

For axle transmissions with spiral gears that function at moderate speeds and medium service for which a GL-1 oil is insufficient.

API-GL-4

For spiral-gear transmissions and special hypoid transmissions for vehicles which operate in high speed conditions at low torque or at low speed at high torque. Anti-wear and extreme pressure additives are often integrated.

API-GL-5

Same as previous case but under high-speed conditions generating extremely low torque and low speed at high torque. Anti-wear and high pressure additives are often used.

ACEA Norm

ACEA standards are divided into three categories :

- A for gasoline engines
- B for diesel car engines
- E for diesel engines for commercial vehicles and trucks

Each specification category comprises several performance levels, indicated by a number (1, 2, 3, etc.), followed by the last two digits of the year the most recent version was introduced.

The following standards are applied for gasoline engines:

- A1-96 : energy-conserving oils
- A2-96 : oils for normal use
- A3-96 : oil for use under severe conditions.

S.A.E. Norm

The SAE J 300 norm defines what is called a "Grade of viscosity" for each lubricant. Ex : S.A.E. 40 (summer viscosity grade). The higher the number, the more the oil will preserve viscosity when subjected to heat.

In the case of city or sport driving, or when ambient temperatures are high, the engine is subjected to high temperatures. It is important to use an oil that remains sufficiently viscous under heat to protect the engine.

When the engine is cold, on the contrary, oil has a tendency to thicken. It is important then that it remain fluid, even at low temperatures in order to flow throughout the engine and protect mechanical parts and to aid in starting. Cold viscosity is signalled in S.A.E. norms by a "winter viscosity grade". Ex : S.A.E.10W The number which signals the winter viscosity grade is always followed by a "W" (for "winter")

The smaller the number, the more the oil will remain fluid in cold weather or at vehicle start.

Monograde oils are generally used when the running temperatures do not vary greatly (or for specific uses).

Multigrade oils offer a winter and summer grade simultaneously.

Ex : S.A.E. 10W 40

Where : 10W = Winter grade

40 = Summer grade

A multigrade oil is less sensitive to temperature.

10.2 References (Resource Library) for chapter “Lubrication management concept”

Jim Fitch, "Defining and Executing Excellence in Lubrication". *Practicing Oil Analysis* Magazine. January 2000.

Keith Stanbury, Preventive Maintenance of Centralized Lubrication Systems - *KE-LUBE, Inc publication (1984) (American Society of Lubrication Engineers).*

Bill Jacobyansky, Paul Thorngren and Wes Ehlers, Guardian Industries, "Changing Greasing Habits with Predictive Maintenance". *Machinery Lubrication* Magazine. November 2004

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SKF bearing maintenance handbook.

Anne Spano; “Increasing Accuracy in Lubrication Testing”, Industrial technology.

http://www.internormen.com

http://www.wearcheck.com

http://www.rdc.uscg.gov

Drew D. Troyer, "Monitor Particles On-Site with Low-Cost Patch Microscopy". *Practicing Oil Analysis* Magazine. July 2001