reganosa		**Specific Procedure RD**

MAINTENANCE MANAGEMENT

REGANOSA DEUTSCHLAND

MAINTENANCE MANAGEMENT

RD M P 001

Rev.	Date	Details of revision	Prepared	Reviewed	Approved
0	dd/mm/yyyy	Creation	X	Maintenance /Operation/ HSEQ Managers	Plant Manager

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0. MODIFICATIONS

SECTION	MODIFICATION

1. PURPOSE

The present procedure is aimed to describe the system for the maintenance of the facilities and each piece of equipment of Reganosa Deutschland (hereinafter referred as Reganosa), to ensure their safe and reliable operation, guaranteeing the fulfilment of the established safety, quality and environmental requirements.

2. SCOPE

This procedure applies to the facilities and equipment of the Elbehafen LNG FSRU Terminal (hereinafter referred as terminal), in particular to the following:

- Jetty Facilities.
- High pressure natural gas pipeline.
- Facility Control Room.

However, maintenance of those pieces of equipment installed onboard the FSRU are not covered by this procedure.

3. DEFINITIONS

- **CMMS:** It stands for Computerized Maintenance Management System. The system used is the SAP, which provides a holistic management of maintenance activities in the Terminal, including PTW creation and approval.
- **DMS:** It stands for Document Management System
- **Facility:** Set of systems working together and contributing to perform a common function or activity.
- **Failure:** Event leading to the non-ability of an Item (functional unit) to perform a required function.
- **Fault:** Condition of an Item defined by the inability of that Item to perform the required function, excluding the inability associated to a preventive maintenance or other planned activity, or due to lack of external resources. A *Failure* is an event, which is different from the *Fault*, which is a condition.
- **Fault Notification:** Notification of a failure or fault made generally by the Shift Supervisor, requiring the intervention of the Maintenance Department.

- **FSRU:** It stands for Floating Storage and Regasification Unit.
- **KPI:** It stands for Key Performance Indicator.
- **LACD:** It stands for Last Allowable Completion Date. Last date in which a maintenance job can be completed.
- **Isolation:** Physical barrier or equipment disconnection which guarantees maintenance inspections or repairs are done without risk for the people, the environment and the rest of the systems and facilities.
- **Item:** Any part, component, device, subsystem, functional unit, equipment or system that can be individually considered.
- **Maintenance:** Combination of all technical and administrative activities carried out throughout the life cycle of an Item, and which are aimed to retain and/or restore such Item to a set of conditions in which it can perform its required function.
- **Maintenance Contractor:** External company hired to perform or execute any maintenance inspection or activity, either preventive maintenance or corrective maintenance.
- **Maintenance Task List:** Detailed breakdown of all the tasks and activities to be performed as part of a maintenance repair or inspection. This breakdown should include the frequency of the task as well as safety conditions.
- **OEM:** It stands for Original Equipment Manufacturer.
- **Performance Standard:** Standard of the performance required of a system, Item or equipment, person or procedure.
- **System:** Set of Items which perform a specific function.
- **Work Order:** Document in which the information necessary for the correct execution of a job is summarized.

4. RESPONSABILITIES

Plant Manager

- Approve the present procedure and its modifications.
- Allocate funds and manpower as required to implement and sustain the provisions and requirements specified in this procedure.
- Promote the correct application of this procedure.

Maintenance Manager

- Prepare this procedure and its updates.
- Monitor and ensure the compliance with maintenance planning and modify it as per the necessities of the Terminal, guaranteeing technical integrity and optimizing costs.

- Ensure correct implementation of maintenance plans and its management through the CMMS tool.
- Promote and guarantee maintenance checklists, Work Orders and Technical Instructions are kept updated and they reflect the real nature of the works and activities to be done.
- Ensure this procedure is applied and followed by maintenance personnel.
- Guarantee the Terminal complies with all statutory inspections and technical integrity requirements.
- Manage the Work Orders, ensuring quality and technical standards are fulfilled. Maintenance Manager shall be responsible for the closure of the Work Orders, verifying correct execution of each activity.

Operations Manager

- Review this procedure and its updates.
- Ensure this procedure is applied and followed by operations personnel.
- Promote the correct application of this procedure.

Maintenance Engineers

- Elaborate and execute the maintenance plans, combining the time-based, condition-based and statutory inspections with corrective maintenance repairs, ensuring compliance with the standards, optimizing costs and fulfilling maintenance windows.
- Analyse the priority of Fault Notifications and prepare the works orders accordingly.
- Execute the required troubleshooting to identify the root cause of a failure.
- Generate technical instructions when required, defining all the steps required to perform a job.
- Ensure all the inspections and repairs are duly documented and registered.
- Directly supervise the Maintenance Contractors, ensuring a diligent and efficient performance.
- Analyse the hazards of a specific maintenance activity and implement them in the job hazard analysis form.

Shift Supervisor

- Monitor the performance of the facilities and notify any deviation from the required performance standards through a Fault Notification.
- Collaborate with Maintenance Engineers on the required troubleshooting.
- Collaborate in the execution of those maintenance activities that might be assigned to them from time to time.
- Test an equipment or system after a maintenance activity, ensuring its correct performance.

- Prepare the facilities for maintenance works.
- Check that the operation conditions of the facilities are fulfilled according to the conditions included in the permit to work prior the beginning of the works.
- Coordinate the management of work permits and the associated interlocks (if applicable), as per the procedure *RD HS P 005 Permit to Work*.

Field Operator

- To perform a monitoring, punctual or continuous, of operation and safety conditions which are defined in the Permit to Work during its validity time.
- To carry out the routine maintenance.

HSEQ Department

- Review this procedure and its updates.
- Promote the correct application of this procedure.
- Advise the maintenance department on the prevention of occupational and environmental risks, in order to minimise the risks associated with the execution of work at the terminal.
- Report any deviations detected during safety inspections through a Fault Notification.

5. DEVELOPMENT

5.1. Action principles

The performance and control of the maintenance activities is based on the principles of prevention, quick detection of non-conformities and correction and continuous improvement.

The maintenance system has been established considering the following criteria and principles:

- Quick detection of faults in equipment and control of operational performance, by means of:
    - Surveillance rounds carried out by the operations staff twice per shift.
    - Evaluation of results obtained from condition-based maintenance.
- Time-based maintenance which will be applied to equipment under warranty from OEM, safety critical equipment or to those equipment or systems which shall follow statutory requirements.
- Corrective maintenance actions when a failure occurs.
- Scheduling of the activities to improve the efficiency of the inspections and repairs, optimising material, and human resources.
- Availability of resources and tools necessary for the performance of the maintenance operations, as well as the measuring, inspection and testing equipment, maintaining

them in optimal operational conditions, as described in the procedure *RD M P 002 Measuring Equipment Management*.

5.2. Maintenance strategies

5.2.1. Introduction

At the beginning of the Terminal life and until completion of the warranty period, the maintenance scheme will be based on a preventive maintenance approach which will follow a fixed calendar, also called “time based” or TBM with pre-defined inspection and/or maintenance intervals, in line with the recommendations of the manufacturer.

Upon completion of the warranty period, maintenance and inspection intervals for some equipment will be gradually adapted, using well proven “Condition Based Maintenance” (CBM) instead of the “time-based” maintenance philosophy.

Initially CBM will mainly rest on expert interpretations of the results obtained during the inspections, but at a later stage part of these routines may be automated and interpretation algorithms introduced leading to a predictive maintenance approach.

5.2.2. Corrective Maintenance

The corrective maintenance is based on the Run to Failure (RTF) strategy where no action is taken to maintain the equipment until the onset of failure becomes self-evident. While it can be viewed as saving money because no maintenance costs are being incurred, because the nature of the failure will be unknown, additional capital may be spent in replacing parts which have failed because of the primary failure.

This maintenance might be applied to equipment with a low impact or low maintenance costs.

5.2.3. Risk Base Maintenance

Maintenance periods can be defined based on the Risk Based Inspection. RBI is a decision-making methodology for optimizing inspection plans. The RBI process is based on the failure probability and consequence. This process is used to optimize inspection intervals based on site-acceptable risk levels and operating limits.

5.2.4. Time Based Approach

Also called "clock-based" maintenance, or "condition- independent" maintenance or "calendar-based" maintenance. This is a form of maintenance of an asset according to a strict timetable, with the following general attributes:

- **Fixed Intervals:** There is a fixed period of time (i.e., fixed intervals) between scheduled maintenance activities.
- **Routine Tasks:** This approach is typically applied to highly routine maintenance tasks that occur on a regular basis. Typically, a form of preventive maintenance (PM).
- **Contracted Services:** Often performed by contractors under the terms of a service agreement and it is therefore a form of planned maintenance.

Time-based maintenance is best suited and appropriate for the following assets and circumstances:

- **Bounded assets**, which are those assets that are highly regulated for safety, environmental protection or other reasons in the public interest.
- **Critical assets** (and critical components).
- **Assets under warranty period.**

TBM approach provides consistency and predictability in the administration of the maintenance program; however, it may result in over-maintenance of some assets, and it does not recognize the changing condition of assets over time and may not be the optimal risk management strategy.

5.2.5. Condition Based Approach

Condition-based maintenance is a maintenance strategy where various elements of an operating asset are observed and measured over time to identify and prevent deterioration and possible failure at the earliest possible moment. Under CBM, maintenance only occurs when data indicates a decline in performance or the early warning signs of failure.

The goal of condition-based maintenance is to uncover equipment failure before it happens, so maintenance can be done exactly when needed.

Although condition-based maintenance can be used on most assets, equipment must meet certain requirements for CBM to be used effectively.

First, as the name suggests, there must be a condition that can be monitored. If performance cannot be measured, it will not be possible to know if there is a change in performance, which indicates the need for maintenance.

It is also crucial to be able to observe these changes in performance far enough in advance of failure so maintenance can be completed before the asset fails or deterioration affects production.

The measurements that form the basis for monitoring and equipment's operating conditions are obtained by non-invasive data collection activities. These condition measurements may be collected in a non-destructive manner continuously or at intervals using transducers, sensors, and different condition monitoring tools (portable instruments).

For condition-based monitoring to be effective it is essential that the monitoring interval is shorter than the "P-F Interval", which is time from when a defect can first be detected to the time when the component fails (or can be replaced / repaired).

The following are the usual condition monitoring techniques being applied:

- **Vibration analysis:** Vibration analysis is the most commonly used monitoring technique for rotating equipment (e.g. centrifugal pumps, motors). Installed vibration sensors monitor axial, vertical, or horizontal movement and send notifications when it becomes excessive.
- **Lubricant and transformer oil analysis:** Lubricant (oil analysis) is another non-invasive technique that can reveal the internal condition of a machine. It works by

analysing the number and size of particles (debris) such as iron, silicon, aluminium silicate, etc. in collected oil samples to determine asset wear. For transformers the critical parameters are those such as dissolved water, neutralisation number, dielectric breakdown voltage, interfacial surface tension, type and quantity of furans, dissolved gases, etc.

- **Infrared thermography:** The amount of radiation emitted by an object increases with temperature. This is invisible to the human eye but is easily and quickly detected by infrared cameras. These cameras constantly watch for temperature irregularities in energized equipment.
- **Ultrasound testing:** Malfunctioning equipment generates a sound that ultrasonic sensors can detect. This technique is applicable for a very wide range of machinery, from both high-speed and slow-speed equipment to high-pressure fluid situations. It quickly alerts operators about issues like deep subsurface defects (e.g. welding defects or extensive corrosion), leaking gases, and over/under lubricated bearings. It is also ideal for specific electrical inspections especially closed gears (for safety reasons).
- **Run time monitoring / analysis:** The run time or cut-in interval of intermittent equipment during steady-state operation or during standstill (e.g. pumps, etc.) gives a simple indication of leaks or similar losses.

5.2.6. Predictive Maintenance Approach

Predictive maintenance combines condition-based diagnostics (measuring vibrations, temperature, and other variables that have a predictable pattern) with complex predictive algorithms to predict when a piece of equipment might fail.

CBM relies on set intervals and lacks those predictive formulas that are used to interpret different trends.

So, in a way, predictive maintenance is a more accurate version of condition-based maintenance which can be implemented once a solid and robust CBM is in place.

5.3. Management planning

Maintenance plans for the different equipment of the Terminal will be elaborated in line with the OEM recommended frequencies and adapted to the necessities of the Terminal.

Those plans shall include the controls, tests, checks and maintenance actions to be carried out in each case, and they will be based on the OEM's manuals and recommendations as well as statutory inspections to be performed. Maintenance plans can be adjusted over the time as experience is being acquired in the operation and maintenance of the Terminal and taking in mind the results coming from the condition-based inspections. Modification of maintenance plans (either content or frequency) shall be assessed and documented following the procedure *RD G P 003 Management of Change*.

The frequency of the time-based and condition-based maintenance shall be set by time cycle or as per the running hours of each equipment based on OEM's recommendations and experience in similar equipment or systems. For repetitive maintenance activities, LACD will be established as per the criteria defined at Table 1 below.

Table 1. LACD for time-based and condition-based maintenance

Preventive Maintenance	LACD
Weekly	Same week
Monthly	+1 week after planned date
2-Monthly	+1 week after planned date
3-Monthly	+1 week after planned date
4-Monthly	+2 weeks after planned date
6-Monthly	+2 weeks after planned date
Yearly	+1 month after planned date
2-Years	+1 month after planned date
3-Years	+1 month after planned date
4-Years	+1 month after planned date
5-Years	+1 month after planned date
10-Years	+1 month after planned date
200 Hours Initial	Same week
2000 Hours	+1 week after planned date
4000 Hours	+2 weeks after planned date
6000 Hours	+2 weeks after planned date
8000 Hours	+1 month after planned date
16000 Hours	+1 month after planned date
18000 Hours	+1 month after planned date
24000 Hours	+1 month after planned date
32000 Hours	+1 month after planned date
48000 Hours	+1 month after planned date

Corrective maintenance works will be planned according to different criteria as explained below:

- Criticality of the equipment in which the malfunction is detected. Each equipment in the Terminal has an associated criticality, ranging from 1 to 4 (being 1 the highest criticality and 4 the lowest) as defined in the procedure *RD M P 003 Critical Equipment Management*.
- The availability of personnel, including internal, contractors and OEM service engineers.
- The availability of materials, spares and consumables.
- Production restrictions and preventive maintenance plans that might be already scheduled.
- Meteorological restrictions.

- Force majeure restrictions such as pandemic, earthquake, tsunami, volcanic eruption, war or similar.

As defined for the time-based and condition-based maintenance, a LACD shall be established, in this case following the criteria of Table 2.

Table 2. LACD for corrective maintenance

Corrective Maintenance	LACD
Priority 1	+24 hours after notification
Priority 2	+1 week after notification
Priority 3	+1 month after notification
Priority 4	+3 months after notification

5.4. Maintenance management

5.4.1. Development of works

5.4.1.1. Work Order creation and approval

The Work Order shall describe the works that are to be performed and should include the correspondent permit to work to be used, if applicable.

As minimum, the Work Order should include the following information:

- Maintenance Item, for preventive and predictive inspections and activities.
- List of materials or consumables which are expected to be used.
- Technical Instruction of the works to be performed.
- Job Hazard Analysis for the specific job.

Once the Work Order is created and all the personnel, tools, spares and consumables for the execution of the works are available, the Maintenance Manager shall approve such Work Order.

5.4.1.2. Schedule and execution of Work Orders

Once the Work Order has been approved, it shall be introduced in the correspondent maintenance schedule in order to execute the job.

5.4.1.3. Closure of Work Orders

For the case of time-based or condition-based maintenance, the following shall be performed upon completion of the maintenance job:

- Return to the storage place/warehouse the tools and the remaining materials and consumables that have not being used.
- Log and register all the man-hours, materials and consumables used for the execution of the works.

- Report to the Maintenance Manager any abnormality observed during the execution of the Work Order and inform of those to the Shift Supervisor in case such abnormalities are relevant for the operation of the Terminal.
- Create the Work Orders required for the resolution of those abnormalities detected during the execution of the inspection.
- Create the activity report for the inspection performed and upload it in the document management system. The activity report should include the number of the Work Order performed, to ensure the traceability of the activity carried out.

In case of corrective maintenance, the person who had created the maintenance request (normally Field Operators) shall be notified about the execution and completion of the maintenance inspection. This person (or a delegate) shall inspect the equipment and ensure the fault which prompted the maintenance request has been solved. If the repair cannot be verified due to operational circumstances, the Fault Notification shall be closed and a new one will be open if the fault is repeated.

Closure of Fault Notifications after completion of the job shall be done as per the following criteria:

- **Priority 1:** To be closed immediately after the completion of the work.
- **Priority 2:** To be closed no later than 1 day from the completion of the work.
- **Priority 3-4:** To be closed no later than 1 week from the completion of the work.

5.4.2. Request for Corrective Maintenance

5.4.2.1. Non-urgent corrective maintenance

When a fault or malfunction of a facility or equipment is detected, a Fault Notification shall be generated using the CMMS or equivalent provided tool.

Once the Fault Notification is created, it is received by Maintenance Department which will have the following options:

- Accept the Fault Notification as it is.
- Modify the priority of the Fault Notification. This shall be notified to and accepted by the Operations Manager.
- Close the notification, if it is considered inappropriate, informing the author of the notification as well as the Operations Manager.

Each Fault Notification will have a priority. The priority shall be assigned based on the criticality associated to each equipment and explained at *RD M P 003 Critical Equipment Management*. Although this is a valid reference, person responsible for creating the Fault Notification shall evaluate each malfunction individually and assign the correct priority depending on the impact of the failure.

Once priority has been agreed by Maintenance Department, the Work Order shall be created, and all the steps included in Section 5.4.1 followed.

5.4.2.2. Urgent corrective maintenance

As an exception and only when an immediate intervention is required, the malfunction can be verbally communicated to the Maintenance Department. In a later stage, the Fault Notification shall be generated in order to keep a record of the failure.

Verbal notifications for immediate intervention shall be communicated to the Maintenance Engineers and Maintenance Manager. Outside of normal working hours (i.e. from 8 AM to 5 PM) on-call maintenance shall be notified and requested to attend to the Terminal.

In these cases, in which immediate intervention is required, the work can be executed without the creation and approval of the correspondent Work Order provided this is authorized by the Shift Supervisor and the correspondent permit to work is in place. This process shall be done as soon as possible after or during the intervention to ensure traceability of the failures and a proper record of the maintenance hours.

5.4.3. Management of maintenance documentation

The planning and performance of the maintenance activities are supported by technical documents which can be elaborated by own personnel or external companies. All the documentation should be archived in the Document Management System (DMS) or in CMMS.

a) Documentation generated by own personnel.

Maintenance activities should be supported by the following documents:

- Maintenance Checklist.
- Where possible and for works with a more-than-normal complexity, technical instruction describing in detail the scope of the works to be done, including the isolations required to perform the jobs safely.
- Job Hazard Analysis.
- Technical reports documenting the maintenance interventions.

b) Documentation generated by external companies

This refers to all the documentation that has been provided by manufacturers and suppliers of different equipment of the facilities, such as manuals, detailed drawings, as well as any other document which provides technical information about the systems, etc.

Works carried out by external companies will be documented by means of activity reports, which shall contain, as minimum, the description of the works done, all relevant findings and resources consumed (time and materials).

5.4.4. Maintenance control and reporting

Control, monitoring and reporting of maintenance activities shall be performed in accordance with the following KPIs:

- **Limitation of backlog:** Defined as the man-hours of planned maintenance exceeding the LACD.

- **Speed for Fault Notification management:** Average time to convert a Fault Notification of priority 2 or 3 in an approved Work Order.
- Fulfilment of **planning ratio**, defined as:

$$Planning\ ratio = \frac{Actual\ manhours\ of\ WO\ Closed}{Planned\ manhours\ of\ WO\ Closed} \cdot 100$$

- **Fulfilment of LACD** for the different jobs scheduled.
- **Liquidation of maintenance Work Orders**, defined as:

$$Liquidation\ of\ WO = \frac{Estimated\ manhours\ of\ WO\ Closed}{Estimated\ manhours\ of\ WO\ Planned} \cdot 100$$

At the beginning of each year, following the provisions of the procedure, the management of the Terminal shall define the required performance levels for each of the KPIs which shall be followed in a monthly basis. The definition of this required performance levels shall have in consideration the criteria of continuous improvement and shall be done also in accordance with the procedure *RD G P 004 Process monitoring*.

5.4.5. Maintenance Management through the SAP

The complete maintenance management lifecycle will be done through the SAP, the selected CMMS for the Terminal.

6. REGISTER AND ARCHIVE

REGISTERS	FORMS	FILE	PERIOD
Fault Notification	Free	CMMS	5 Years
Work Order	Free	CMMS	5 Years
Report Activity	Free	Document Management System (DMS)	5 Years
KPI Monitoring Sheet	Free	Document Management System (DMS)	5 Years

7. REFERENCES

- **RD G P 003** – Management of Change
- **RD G P 004** – Process monitoring

- **RD M P 002** – Measuring Equipment Management
- **RD M P 003** – Critical Equipment Management
- **RD HS P 005** – Permit to Work

8. ANNEXES AND FORMS

8.1. Annexes

- Not applicable.

8.2. Forms

- Not applicable.