Inspection and maintenance of jacking systems
FOREWORD

DNV GL recommended practices contain sound engineering practice and guidance.
CHANGES – CURRENT

General
This is a new document.

Acknowledgement
DNV GL wants to thank its partners Paragon Drilling, Rowan Drilling, Seadrill, Prospector Drilling, Noble Drilling and the UAE’s National Drilling Company; recently merged service suppliers Energy Service International and WillTeco; and vendor Cameron Le Tourneau for their engagement, input and cooperation throughout the Joint Industry Project (JIP) Jacking Systems resulting in this Recommended Practice (RP).
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SECTION 1  INTRODUCTION

1.1 Background
Correct maintenance and inspection of the jacking systems have proven to be challenging due to the high turnover of people with specific knowledge on board, the evolving nature of the systems and the intermittent use of the systems. This document intends to address this challenge.

1.2 Objective
The objective of this RP is to ensure the correct and safe functioning of an electric rack and pinion style jacking system during operations (jacking and holding) throughout the asset’s life time.

1.3 Scope
This RP covers the recommended practices for the inspection and maintenance of electric rack and pinion type jacking systems. It includes:

— establishing competencies level of different roles involved in jacking system maintenance and inspection
— highlighting critical components and areas where experience indicates lack of attention
— giving guidance to OEM/yards/system designers on what information to provide (in order to be able to assess system conditions concerning wear limitations)
— giving guidance on inspections and maintenance follow-up to ensure proper conditions/functioning of the system
— providing information for better understanding of observations
— recommendations to ensure the right awareness and follow-up in extraordinary operations close to design limitations and thereby significantly increasing fatigue and wear.

This RP does not include:

— actual wear limits
— details with regard to the overhaul of components.

1.4 Application
The document should be regarded as a supplement to the original equipment manufacturer’s instructions and maintenance requirements and not as a replacement for these.

This document is not meant to replace or overrule any existing rules, regulations or technical standards.

1.5 Structure
This document discusses and defines in Sec. 2 the levels of competence in jacking systems and inspections used in the subsequent sections. Sec. 3 provides an overview of inspections, divided into operational inspections done by the crew on board, detailed inspections normally done by specialists and inspections to be done after extraordinary operations. Sec. 4 subsequently discusses maintenance with a specific focus on spares. Sec. 5 thereafter lists the system documentation required for the robust maintenance of the jacking system, including the operational records expected to be kept by the crew. Sec. 6 discusses inspection and maintenance with a specific focus on the main components. Sec. 7 conclusively completes the recommendations, with an approach to further improvements beyond the general recommendations given in the rest of the document.
1.6 References

Table 1-1 References

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>/1/</td>
<td>BS-EN 13460, Maintenance. Documentation for maintenance</td>
</tr>
<tr>
<td>/2/</td>
<td>ISO 60300, Dependability management - Part 3-11: Application guide - Reliability centred maintenance</td>
</tr>
</tbody>
</table>

1.7 Definitions and abbreviations

1.7.1 Definitions

The application of characteristic jacking system elements follows from a number of system design choices made. To reflect these design choices, the definitions below are grouped into the complementary design alternatives where applicable.

— Different types of legs:
   — Tubular leg
     A tubular steel structure usually with internal structural stiffening, with racks usually welded to the outside of the tubes;
   — Truss
     Leg consisting of at least three main structural chords that run straight up and down the length of the leg. These chords are typically placed symmetrically at the corners or extreme positions in a plan view of the leg. If using three chords, the leg forms a triangular truss with the chords on the corners of the triangle. If using four chords, the leg is generally given a square form and the chords are placed on the corners of the square. The use of more than four chords is uncommon.

— Different types of jacking systems:
   — Floating jacking system
     A jacking system where the gears are connected to the jack house suspended by soft pads intended to distribute pinion loads per chord;
   — Fixed jacking system
     A jacking system where the gears are connected directly to the jack house.

— Different types of rack systems
   On a truss design leg, the racks are always attached to or part of the chords. This is done in one of two ways; either single or double sided:
   — Single sided rack
     A system that uses a rack with teeth on only one side. The jacking gear thrust loads are typically transferred into the leg guides;
   — Double sided rack or opposed rack system
     In this alternative, the racks are placed such that the thrust loads are perpendicular to a line drawn from the centreline of the chord to the centreline of the leg. These racks are generally made by torch cutting one plate with a rack on either side of it from large plates. Typically these plates are cut such that both sides of the torch cut may be used with a minimal waste of material.
Figure 1-1  Single sided (left) vs. an opposed jacking rack (right)

— Leg fixation system
On some rig designs, a stronger, stiffer connection between the rack and jack-case - called a rack fixation device - is used to support the rig while it is not being elevated (or lowered). These are made in the form of reversed racks that are clamped into position after the rig is elevated and removed when the rig is ready to be moved. Because the load transfer takes place directly between the rack chock and leg chords, the legs can be built with a slender design, thus decreasing the resistance to currents, sand and waves.
1.7.2 General definitions

Table 1-2 Definitions

| Extraordinary operations | Operations close to or beyond the documented design limitations. |

1.7.3 Abbreviations

Table 1-3 Abbreviations

<table>
<thead>
<tr>
<th>Class</th>
<th>Classification Societies</th>
</tr>
</thead>
<tbody>
<tr>
<td>OEM</td>
<td>Original Equipment Manufacturer</td>
</tr>
<tr>
<td>FMECA</td>
<td>Failure Mode, Effects and Criticality Analysis</td>
</tr>
<tr>
<td>MCC</td>
<td>Motor Control Center</td>
</tr>
<tr>
<td>RAM</td>
<td>Reliability, Availability and Maintainability</td>
</tr>
<tr>
<td>RCM</td>
<td>Reliability Centered Maintenance</td>
</tr>
<tr>
<td>RPD</td>
<td>Rack Phase Difference</td>
</tr>
</tbody>
</table>
SECTION 2  COMPETENCE LEVELS

2.1  General
This section describes the different levels of competence for the personnel engaged in the operation, inspection and maintenance of jacking systems.

Higher level personnel are encouraged to engage lower level personnel during their inspections and as such increase the average level of knowledge and awareness on board.

Notwithstanding the descriptions, each company is expected to define its own organisation, including definitions of roles and responsibilities taking into account the knowledge and experience of its human resources, available training arrangements and the availability and utilisation of second and third parties.

Conclusively, App.A provides a detailed overview of knowledge, competencies, experience and training requirements as expected for the different levels.

2.2  Competence level descriptions

2.2.1  Level 1
Personnel on board with a basic knowledge of the function of a jacking system and the sequence of events during a rig move or jacking operation.

Such personnel can generally assess, through visual observations, whether the jacking system is operating normally. Their knowledge covers the lubrication requirements of jacking systems and they can generally discern the normal jacking sounds when the system is being operated.

These individuals will typically be rig staff assigned to supervise normal jacking operations at each leg and include drillers, crane operators, assistant drillers, etc.

2.2.2  Level 2
Personnel on board with adequate experience and knowledge of jacking systems and their components.

These individuals are able to do first-line inspection and maintenance, including pre- and post-jacking checks and component replacements, and keep records of maintenance and rig moves and they have technical knowledge of and competence in mechanical/electrical/control systems (depending on their field of expertise).

They are aware when a Level 1 inspection is not good enough. The expected basic knowledge in addition to Level 1 relates to system loads, system components and the function of the components.

Guidance note:
Level 2 personnel are encouraged to transfer their knowledge to Level 1 personnel. This not only allows more distribution of tasks during e.g. a pre-rig move inspection but also increases awareness during jacking operations.

These individuals will typically be experienced rig mechanics, rig electricians and other technicians.

2.2.3  Level 3
Personnel on board with sufficient experience and training to oversee all relevant preparations for jacking operations and to assess the overall impact on the rig if the jacking system is damaged.

These individuals have system-specific training and the ability to review maintenance records and inspection results and assess the rig’s capability/limitations with respect to the jacking system (encompassing both the maintenance condition and the operational readiness). In addition, Level 3 personnel are able to plan and coordinate major system repairs and overhauls and have the authority to call in Level 4 specialists or Level 5 design experts.

These persons will typically be barge engineers, rig engineers or technical section leaders or have other supervisory roles.
2.2.4 Level 4
Personnel with relevant experience, knowledge and training to perform detailed inspections and repairs of the specific jacking system in use, including structural weld inspections, structural welding repairs and machinery component replacements or electrical diagnostics and repairs (power and control systems).

In general, the Level 4 person is capable of assessing the general condition of the (examined/overhauled) components and system as is typical during 5-yearly inspections and extraordinary events, either by concluding on their suitability for continued use or by identifying the need for further analysis.

These individuals will typically be specially trained rig mechanics and electricians or OEM or specialised service supplier technicians. These individuals include those approved by Class to inspect a jacking system in connection with 5-year periodical Class surveys.

2.2.5 Level 5
Personnel uniquely qualified in the area of jacking systems, with a formal education in engineering and expert-level experience, capable of performing evaluations and analyses to assess system reliability, residual component/system life and strength, and with the ability to apply expert judgement, typically during overhauls or end-of-life evaluations and following extraordinary events as discussed in [3.4].

Level 5 personnel typically consist of Original Equipment Manufacturer (OEM) engineers or employees of engineering firms specialising in jacking systems that are recognised by Class.

2.3 Hand-over between different roles
The safety and reliability objectives are only maintained when the different roles involved are aware of their limitations and know when to call in support from others. Table 2-1 provides a basic overview of these handovers.

Table 2-1  Table with operational observations implying hand-over and expectations for follow up actions for the different levels in the case of abnormal observations, completed with expected maintenance activities

<table>
<thead>
<tr>
<th>Operational observations</th>
<th>Actions</th>
<th>Expected maintenance activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>From Level 1</td>
<td>Indicates that the system is working strangely/not normal/possible problem/abnormal observation</td>
<td>Stop jacking</td>
</tr>
<tr>
<td>From Level 2</td>
<td>Concludes that the indicated problem needs a closer look/expert attention</td>
<td>Continue or discontinue jacking operations</td>
</tr>
<tr>
<td>From Level 3</td>
<td>Concludes that the system needs an overhaul</td>
<td>Intervene with/provide input for asset planning</td>
</tr>
<tr>
<td>From Level 4</td>
<td>Complete inspection to assess the reliability and safety of the unit for the subsequent 5-year period/after an extraordinary event.</td>
<td>Identify the need for further advanced engineering analysis</td>
</tr>
<tr>
<td>Level 5</td>
<td>Determine the residual strength and remaining life time based on advanced analysis</td>
<td>Engineering analysis</td>
</tr>
</tbody>
</table>
SECTION 3 INSPECTION

3.1 Introduction

3.1.1 Structure

This section provides guidance on jacking system inspections. This guidance is divided into three themes:

1) Operational inspections as executed by the onboard crew, both in relation to jacking operations/rig moves and as part of periodical inspections ([3.2])
2) Detailed inspections as executed by Level 4 and 5 personnel ([3.3])
3) Extraordinary inspections as done after extraordinary operations ([3.4]).

3.2 Operational inspections

3.2.1 General

Operational inspections are executed by the onboard crew, i.e. by Level 1 to Level 3 personnel. These are required during rig moves and periodically as discussed in the following sub-sections.

3.2.2 Rig moves

As is self-explanatory, the rig move is an important phase for the inspection and maintenance of the jacking system. Not only has the availability and functioning of the system to be assured, but the use of the system during the rig move also provides important information on the status of the system that is not available during periodical inspections.

Table 3-1 Overview of operational inspections

<table>
<thead>
<tr>
<th></th>
<th>Why</th>
<th>What</th>
<th>How</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-jacking</td>
<td>To ensure that the system is ready and fit to operate</td>
<td>The entire system should be assessed on a basic level</td>
<td>To ensure that no elements are overlooked or forgotten, a pre-jacking checklist should be available on the rig¹)</td>
</tr>
<tr>
<td>During jacking</td>
<td>To ensure that the system operates within its limits and that failures and anomalies/unforeseen situations receive effective follow-up</td>
<td>A set of system-specific observations (both visual and audible) and measurements. In addition, all the applicable components of the system should receive sufficient lubrication</td>
<td>— System-specific issues + required lubrication should be known and briefed to all involved — Teamwork: to ensure that the entire system is covered continuously, a sufficient number of personnel is expected to be engaged/involved, including proper communication (i.e. a sufficient number of channels + agreement on reporting formats and a clear understanding of orders)²)</td>
</tr>
<tr>
<td>Post-jacking</td>
<td>To ensure that the platform/legs and systems are brought into a fixed and safe position + system is weather protected and properly conserved for future use³)</td>
<td>In accordance with system-specific instructions and checklist</td>
<td>In accordance with system-specific instructions and checklist³)</td>
</tr>
</tbody>
</table>

1) The checklist enclosed in App.B can be used as a guideline for establishing this (rig/system-specific) standard checklist.
2) An example of the reporting formats is that everybody involved should be aware when a system should be stopped and how to report any anomaly/critical failure...
3) It is underlined that the weather protection includes watertightness, e.g., during wet-towed rig moves, sandblasting around jacking systems, etc.

3.2.3 Periodical inspections

Apart from the rig moves, onboard periodical inspections should be scheduled to ensure confirmation of system availability and the right level of awareness of the system condition.

The schedule should be based on experience, the manufacturer’s recommendations and one or more of the
following factors listed in Table 3-2.

**Table 3-2 Factors affecting periodical inspection schemes**

<table>
<thead>
<tr>
<th>Factor</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environment</td>
<td>Corrosive environments, extreme environmental temperatures, thermal damage due to the close proximity of burner booms, etc.</td>
</tr>
<tr>
<td>System utilisation</td>
<td>Jacking more frequently or with higher loads than per the original jacking system design will impact the expected life and inspection frequency.</td>
</tr>
<tr>
<td>Regulatory requirements</td>
<td>Class and/or other regulatory bodies.</td>
</tr>
<tr>
<td>Operating time and loads</td>
<td>Ideally, an overview of loads vs duration/length should be available as is discussed in more detail in [5.3].</td>
</tr>
<tr>
<td>Extraordinary operations</td>
<td>As a 'secondary follow-up' of extraordinary operations (primary follow-up discussed in [3.4])</td>
</tr>
</tbody>
</table>

Notwithstanding the above-listed factors, it is recommended to define a scheme including quarterly and yearly inspections.

— **Quarterly**
   A quarterly inspection is to detect above-average wear and tear. The inspection is to be performed by onboard Level 2 competency staff under instruction from Level 3 staff.

— **Yearly**
   Besides the detection of above-average wear and tear, the yearly inspection aims to establish an (early) overview for maintenance priorities/areas/scope (for example identifying areas close to burner booms or in upwind directions needing more attention). Such inspections are to be performed by Level 3 competency staff.

The overview in Table 3-3 includes inspection items connected to these periodical surveys.

**Guidance note:**
In the case of relatively infrequent jacking cycles, the Quarterly inspection content can be incorporated into the Yearly one. As an alternative, a schedule based on run hours instead of calendar time can be established.

For 5-yearly inspections meeting Class requirements, see [3.3].

Yearly inspections may be utilised to comply with 5-yearly renewal/special Class surveys on a continuous basis. In such case, the inspection should be executed by Level 4 competency staff as further detailed in [3.3].

---end---of---Guidance---note---

### 3.3 Detailed inspections

#### 3.3.1 General approach

Detailed inspections aim to a) re-assess the calculated durability confirming that this meets expectations with respect to operational availability and b) assess the need and plan for overhaul activities. The scope and frequency of these detailed inspections should be based on the jacking system fatigue life as specified by the OEM and the operational use of the system.

**Guidance note:**
Both the information subsequently needed from the OEM and the records of operational use are further discussed in Sec.5.

---end---of---Guidance---note---

The detailed inspection is normally expected to be performed by Level 3 or Level 4 competency staff (except where such an inspection is part of a Class special/renewal survey where Level 4 staff should perform the inspection). Notwithstanding, the involvement of onboard Level 1 and Level 2 inspectors is advised; not only do they need to be aware of the system status and any operational limitations, but the detailed inspections also give them valuable feedback on the correct operation of their unit and the effectiveness of the applied maintenance.

Furthermore, to even out the inspection load over Class's renewal/special survey 5-year interval, it is recommended to inspect 20% of the overall system each year (ensuring at the same time that subsequent inspections of any particular element are never in excess of the 5-year interval).

The following subsections discuss the approach of detailed inspections in more detail concerning:
— wear vs. fatigue life as limiting factor for the system’s durability
— inspection focus areas.

### 3.3.2 Wear vs. fatigue life

Each machinery component in the load path will generally be limited by a combination of material loss (i.e. wear) and fatigue. It is important to know what components are limited primarily by material loss and what components are limited primarily by fatigue. The condition of components that are limited by material loss can be determined by standard inspection methods and a subsequent estimation of the remaining life. However, the condition or remaining life of components that are limited primarily by fatigue cannot usually be determined by inspection as this is a calculated value based on internal material properties.

Although each system is unique, component wear is often characterised by the following three periods:

1) “Break-in” period where components wear off mating high spots
2) Normal wear, which is the majority of the component’s life
3) Accelerated wear leading up to failure.

For components limited primarily by material loss, after the initial break-in period, the life of the jacking system is typically consumed approximately uniformly throughout its utilisation period. Components limited primarily by fatigue may not exhibit appreciable material loss until failure is imminent and hence, as stated above, the extent of wear can be difficult to determine.

To reduce the potential for unplanned downtime, it is recommended that the jacking system is inspected by a Level 4 inspector at frequency intervals not exceeding 5 years or when 20% of the rated Jacking System Life is consumed, whichever occurs earlier. The extent of this 5-yearly inspection may be dictated by the available records of “life usage”. For a detailed discussion on these records, see [5.4].

When operating beyond 80% of the rated life of the jacking system, the jacking records should be forwarded to the OEM or a Level 5 individual, who may then recommend the scope of the inspection/replacement taking into consideration the rig’s operating parameters.

### 3.3.3 Focus areas

During the periodical inspections, careful attention should be paid to determining whether components have been overloaded or improper maintenance has degraded components. High loads on jacking system components can be caused by both high external loads being applied to the system and by improper maintenance conditions causing increased internal loading. Poor lubrication, worn-out components and other detrimental maintenance conditions also increase the loads on components even when the external loads on the system are within the “rated” values. If the actual loads are higher than the rated loads, the life of the components can be dramatically reduced.

**Guidance note:** Although not recommended, should an emergency situation arise and the unit is jacked even once with weights exceeding the maximum rated jacking loads, the unit owners should contact the OEM or a Level 5 individual to determine the residual life and/or the scope of the inspection. For a further discussion on emergency situations, see [3.4].

---end of Guidance note---

The detailed inspections are expected to include the status of the control system as well. This is especially required to ensure a periodical review of obsolescence issues which may act as a major driver in life cycle cost and negatively affect the reliability of the system.

The results of the inspection are expected to be taken further in the owner’s/operator’s obsolescence strategy and monitoring as further discussed in [4.4.3].

For a more detailed discussion on the ageing and availability of (software-based) control components, see [6.8].
Table 3-3 provides an overview of inspection items connected to periodical surveys. **Table 3-3 Recommended interval and inspections. Yearly/5-yearly inspections include quarterly or yearly inspections unless stated otherwise**

<table>
<thead>
<tr>
<th>Component</th>
<th>Sub-component</th>
<th>Quarterly</th>
<th>Yearly</th>
<th>5-yearly</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leg guides</td>
<td>Leg guides</td>
<td>Visual inspection and measurement according to upper/lower limits</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Structure</td>
<td>Shock pads</td>
<td>Visual</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Leg fixation system structural components</td>
<td>Visual</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Leg fixation engagement system</td>
<td>Operational function test</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Jack-house structure</td>
<td>Visual inspection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gearing system</td>
<td>Primary gear box</td>
<td>Oil seals (check for leaks) Drain moisture</td>
<td>Visual inspection</td>
<td>Oil/grease samples annually unless dictated otherwise by manufacturer</td>
</tr>
<tr>
<td>Secondary gear box/Reduction gear</td>
<td>Drain moisture</td>
<td>Visual inspection</td>
<td>Oil/grease samples annually unless dictated otherwise by manufacturer</td>
<td></td>
</tr>
<tr>
<td>Climbing pinion</td>
<td></td>
<td>Visual inspection and measurement according to upper/lower limit</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Keyways &amp; fasteners</td>
<td></td>
<td></td>
<td></td>
<td>Visual</td>
</tr>
<tr>
<td>Braking system (holding system)</td>
<td>General</td>
<td>Check brake holding torque and ensure discs are not stuck. Inspect heater operation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motor shafts</td>
<td></td>
<td></td>
<td>Visual &amp; NDT inspection</td>
<td></td>
</tr>
<tr>
<td>Brake discs/bands</td>
<td>Visual inspection and test every 2nd quarter</td>
<td></td>
<td>NDT inspection</td>
<td></td>
</tr>
<tr>
<td>Brake solenoids</td>
<td>Check air gaps for solenoids annually Visual checks on cabling</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Braking resistors</td>
<td>Injection tests, schedule test but with some gaps</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power/motor system</td>
<td>Electric</td>
<td>Visual inspection</td>
<td>Megger test</td>
<td></td>
</tr>
<tr>
<td>Cabling</td>
<td></td>
<td></td>
<td>Visual</td>
<td></td>
</tr>
<tr>
<td>MCC units</td>
<td>Check for cleanliness</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contactors</td>
<td>Check for pitting/damaged contactors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Controls</td>
<td>Jacking consoles</td>
<td>Function check</td>
<td>Motor temperature (RTD) alarms should be calibrated Meters (kW, amps, volts, frequency) should be calibrated annually.</td>
<td></td>
</tr>
<tr>
<td>RPD systems</td>
<td></td>
<td></td>
<td>Check alarms</td>
<td></td>
</tr>
<tr>
<td>PLC software</td>
<td></td>
<td>PLC spare battery (if applicable) changed every 2 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cables/ connectors</td>
<td></td>
<td>Construction methods must be checked to ensure the integrity of the system (IP integrity, cable supports, identification, etc). Inspect wire termination to ensure all is tidy and no controls are by-passed.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3.4 Extraordinary inspections

The operational and detailed inspections described in the previous subsections should be further extended if incidents involving extraordinary operations as defined in [1.7.2], are experienced. The objective of these inspections is to ensure that:

— The possibly affected systems are still available;
— No structural damage/deformation has been induced;

and (in the case of affected systems and/or structural damage):

— the rig is safe to continue operating within (assessed) operational limitations.

Notwithstanding the initial positive assurance these inspections may offer, it is underlined that the system has, by definition, operated outside its normal operational profile and that the related loads will have an effect on the remaining design/calculated life time. As such, it is strongly recommended to take the extraordinary operations into account in the planning and scope of subsequent periodical inspections (see also [3.2.1] and [3.3]).

Extraordinary inspections are performed by onboard Level 2 or 3 personnel immediately following an extraordinary incident/operation. Based on their findings, a more detailed inspection by a Level 4 or 5 specialist may be initiated.

Table 3-4  Overview of extraordinary operations with expected follow-up

<table>
<thead>
<tr>
<th>Event</th>
<th>Effect on the system</th>
<th>Affected components</th>
<th>What to inspect</th>
<th>What parameters to log</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of leg shimming during holding</td>
<td>High horizontal loads</td>
<td>Design dependent: bottom pinions, leg fixation system</td>
<td>1) Basic visual inspection of the affected systems 2) NDT of stressed areas of jack houses 3) Tanks/compartment spaces behind the guides</td>
<td>Leg position as was located at the upper guide</td>
</tr>
<tr>
<td>Extreme weather conditions during dry tow</td>
<td>As above</td>
<td>Legs, chords, braces, pinions, guides</td>
<td>As above</td>
<td>Leg elevation</td>
</tr>
<tr>
<td>Overload due to high deck loads</td>
<td>Rack/pinion damage Fixation system damage</td>
<td>Pinions, racks</td>
<td>Stability programmes Racks/pinions</td>
<td>Actual leg load on each leg and corresponding environment/weather criteria</td>
</tr>
<tr>
<td>Going on/off location</td>
<td>Hard bottom Shock loads</td>
<td>Spud can, leg joint, rack, pinion interface</td>
<td>1) Rack and pinions 2) Shock pads (especially if previously decomposed)</td>
<td>Maximum roll/pitch angle Period of roll/pitch Sea state (wave height) and vessel vertical motion</td>
</tr>
<tr>
<td>Use of extraordinary jacking force to pull legs from seabed</td>
<td>Overload when trying to take out the legs. Damage to legs</td>
<td>Entire gear train on the affected leg, leg itself</td>
<td>Visual inspection of gears and rack section on the particular legs</td>
<td>Leg depth under water, operational time, loads and hull draft beyond the normal floating depth on the particular rack section, kilowatt readings</td>
</tr>
<tr>
<td>Lowering the legs on location while the rig is moving</td>
<td>Bending of the legs. In the fixed system, the top and bottom pinion will experience excessive loads</td>
<td>Top pinion in sailing direction and bottom pinion in opposite direction Rack-phase difference Leg straightness</td>
<td>Top pinion in sailing direction and bottom pinion in opposite direction</td>
<td>Log the incident</td>
</tr>
<tr>
<td>Flaring</td>
<td>Excessive ambient temperatures</td>
<td>Gearbox/electric motors</td>
<td>Oil sample and megger test</td>
<td>Log the incident</td>
</tr>
</tbody>
</table>
### Table 3-4 Overview of extraordinary operations with expected follow-up (Continued)

<table>
<thead>
<tr>
<th>Event</th>
<th>Effect on the system</th>
<th>Affected components</th>
<th>What to inspect</th>
<th>What parameters to log</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performing drilling operations with cantilever beyond the working limits</td>
<td>Overload on aft legs Low fixity/sliding of forward leg</td>
<td>Jacking system Load path bulkheads</td>
<td>Load path bulkheads Jacking systems/pinions Spud cans (aft legs)</td>
<td>Maximum loads leg by leg Distance exceeded by cantilever Hookload Weather (wind/waves/current)</td>
</tr>
<tr>
<td>Punch through</td>
<td>Damage to legs Well damage Hull tanks Damage</td>
<td>Legs Hull structures Guides Jacking systems</td>
<td>Load path bulkheads Jacking systems/pinions Spud cans (aft legs) Shock pads All tanks around the legs Cranes (if moved during PT) Deck cargoes &amp; lashings</td>
<td>Maximum distance of leg drop Hull loads Centre of gravity when leg punched through Air gap/hull drafts before/after Any anomalies observed during visual inspection Motor torque in case of large angles of heel</td>
</tr>
<tr>
<td>Bottom scour</td>
<td>Erosion of footing Unbalanced loading on leg chords Leg/spudcan connection damage Leg damage Damage to jacking system</td>
<td>Spud can leg braces Rack/ pinion interface</td>
<td>Spud can (divers survey) Rack phase difference</td>
<td>Area of support under spudcans Maximum list Maximum heel Total loads on hull</td>
</tr>
<tr>
<td>Increasing RPD values Ignoring RPD values</td>
<td>Leg damage. Jacking system overload</td>
<td>Legs, Jacking system</td>
<td>Leg bracing/joints. Rack and climbing pinion</td>
<td>RPD extent</td>
</tr>
<tr>
<td>Miscalculation of weight during preloading (difficult to detect)</td>
<td>Rack/pinion damage Fixation system damage</td>
<td>Pinions, racks</td>
<td>Stability programs racks/pinions</td>
<td>Actual leg load on each leg and corresponding environment/weather criteria</td>
</tr>
<tr>
<td>Mechanical failure (brake and gearbox)</td>
<td>Overload on the remaining sets</td>
<td></td>
<td>As above</td>
<td></td>
</tr>
<tr>
<td>Failure to lubricate properly</td>
<td>Higher than expected loading on components and accelerated wear</td>
<td>Gearbox/electric motors Oil samples, backlash or visual examination; megger test of motor windings</td>
<td>Contaminant count, type, and rate of increase; wear amount; veracity of windings and motor performance</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Climbing pinion Teeth, shaft</td>
<td>Wear amount and type (even/uneven; scoring/smooth; deformation, etc)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Leg rack Teeth</td>
<td>Wear amount and type (even/uneven; scoring/smooth; deformation, etc)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bearings (plain or roller) Wear</td>
<td>Wear amount</td>
<td></td>
</tr>
<tr>
<td>Event</td>
<td>Effect on the system</td>
<td>Affected components</td>
<td>What to inspect</td>
<td>What parameters to log</td>
</tr>
<tr>
<td>--------------------------------------------</td>
<td>----------------------</td>
<td>---------------------</td>
<td>-----------------</td>
<td>------------------------</td>
</tr>
<tr>
<td>Jarring (shallow drilling)</td>
<td>For rigs that have engaged leg fixation systems, there should be no expected impact. For rigs without fixation systems, there could be a potential for unbalanced loading and chafing</td>
<td>Pinions, gears &amp; rack teeth</td>
<td>Rack &amp; pinions</td>
<td>Wear amount and type (even/uneven; scoring/smooth; deformation, etc)</td>
</tr>
<tr>
<td>Flooded member/submerged system</td>
<td>Corrosion on part Excessive use of anodes</td>
<td>Jacking gearbox or motor</td>
<td>Drain the gear with fresh water, clean up, dry and refill with oil. Check condition of anodes</td>
<td>NA</td>
</tr>
<tr>
<td>Excentric loading</td>
<td>Leg Rack Climbing pinion</td>
<td>Leg bracing/joints Rack teeth Climbing pinion teeth</td>
<td>Damage or unusual deformation</td>
<td>Extent of excentric load</td>
</tr>
<tr>
<td>Shock pad failures (floating system functions as a fixed system)</td>
<td>Uneven load on pinions, which cannot be readjusted any more</td>
<td>Pinions and complete jacking gearboxes</td>
<td>Shock pad clearance</td>
<td>Clearance shock pads jacked up and afloat.</td>
</tr>
<tr>
<td>Uncontrolled descent</td>
<td>Assuming brakes are ineffective, then impact is catastrophic on the rig. The jacking system damage would depend on the circumstances</td>
<td>Control system, brakes &amp; motors</td>
<td>Test sensors &amp; check brakes &amp; software controls</td>
<td>Brake air gap, test sensors &amp; software controls</td>
</tr>
<tr>
<td>Speed difference of electric motors</td>
<td>Higher than expected loading on components</td>
<td>Gearbox/electric motors</td>
<td>Oil samples, backlash or visual examination; megger test of motor windings</td>
<td>Contaminant count and type; wear amount; veracity of windings and motor performance</td>
</tr>
<tr>
<td>Extremely low ambient temperatures</td>
<td>Higher than expected loading on components (cold lube and/or tight tolerances)</td>
<td>As above</td>
<td>Wear amount and type (even/uneven; scoring/smooth; deformation, etc)</td>
<td>As above</td>
</tr>
<tr>
<td>Components break due to brittle transition</td>
<td>Case structure/housing All</td>
<td>Inspect for cracking</td>
<td>Wear amount</td>
<td>Wear amount</td>
</tr>
<tr>
<td></td>
<td>Exposed machinery Machinery/structure</td>
<td>Inspect for cracking</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fasteners</td>
<td>Inspect for cracking</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Jack pads Pads</td>
<td>Brittle failure</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Leg rack Teeth (under load)</td>
<td>Inspect for cracking</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Leg fixation structural components Exposed machinery/structure</td>
<td>Inspect for cracking</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sandblasting of legs and protection Loss of protective coating</td>
<td>All exposed component/structures</td>
<td>Corrosion</td>
<td>Corrosion extent/depth</td>
</tr>
</tbody>
</table>
Table 3-4  Overview of extraordinary operations with expected follow-up (Continued)

<table>
<thead>
<tr>
<th>Event</th>
<th>Effect on the system</th>
<th>Affected components</th>
<th>What to inspect</th>
<th>What parameters to log</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slipping in old footprints</td>
<td>Splaying of legs&lt;br/&gt;Binding of legs&lt;br/&gt;Damage to braces&lt;br/&gt;Damage to leg guides&lt;br/&gt;Rack phase damage&lt;br/&gt;Collision between the rig &amp; wellhead platform</td>
<td>Legs &amp; spudcans&lt;br/&gt;Hull structures&lt;br/&gt;Guides&lt;br/&gt;Jacking systems&lt;br/&gt;Deck cranes</td>
<td>Legs&lt;br/&gt;Legwells&lt;br/&gt;Upper guides&lt;br/&gt;Jacking systems&lt;br/&gt;.(In the case of contact damage)&lt;br/&gt;Tanks and compartments in way of the damaged hull&lt;br/&gt;Crane booms</td>
<td>Maximum inclination of hull&lt;br/&gt;Total load on jacking system&lt;br/&gt;Load on each leg&lt;br/&gt;Hull drafts on hull&lt;br/&gt;stabilisation&lt;br/&gt;Leg settlement distance/time&lt;br/&gt;Distance from wellhead tower (if applicable)</td>
</tr>
<tr>
<td>Commissioning</td>
<td>None</td>
<td>All</td>
<td>Entire system as per OEM design</td>
<td>If needed a test procedure could be provided.</td>
</tr>
<tr>
<td>Unbalanced motor torque</td>
<td>As for “Speed difference of electric motors”</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spraying of cooling water</td>
<td>As for “Sandblasting of legs and protection”</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1) The table excludes incidents such as boat collisions, seismic activities, fires and extreme wind and water-loads leading to the platform moving in a fixed position. These require a case-by-case analysis of the damage inflicted to the system, remaining integrity and inspections required to regain confidence.

2) In the case of large settlements due to legs slipping into old holes, if this occurs after the hull is elevated out of the water (this has the same effect as a punch through), a surface NDT inspection such as MT of the legs must be carried out for the portion of the legs contained between the guides in addition to a divers examination of the legs/spudcan connections.
SECTION 4 MAINTENANCE

4.1 Introduction
This section describes the maintenance on board with regard to general considerations, the replacement of jacking system elements and spares.

Component-specific instructions are given in Sec.6.

The maintenance of the jacking system discussed here includes adjustments, cleaning, lubrication and (preventive/corrective) repairs and the replacement of expendable parts. It does not include the overhaul of components.

4.2 General considerations
The jacking system should be covered by the Planned Maintenance System on board, the activities depending on factors given earlier in Table 3-2.

The manufacturer should define any special tools, materials, measuring and inspection equipment and, where necessary, personnel qualifications necessary to perform the maintenance.

The cleaning and lubrication is expected to be done by the crew on board. For repairs and the replacement of parts, an owner/operator can select either crew on board, a dedicated company maintenance team or OEM/independent service suppliers. The selection depends on many factors, such as:

— the complexity of the maintenance activities,
— the need for specific tools,
— the acceptable downtime,
— the lead time when ordering spares and/or maintenance personnel,
— the availability of spares in a central depot/warehouse,
— the availability of resources and/or training capacities,
— the consequences of specific component failures concerning non-availability/downtime.

Since the final selection is a trade-off between cost and availability, it is recommended to utilise a structured approach as further discussed in Sec.7.

4.3 Replacement of jacking system elements
Jacking system repairs sometimes require the replacement of one or more elements of the jacking system. These replacements should ideally be planned during a shipyard stay while the rig is undergoing maintenance/inspections. However, in reality such replacements are often undertaken with the rig jacked up on location and in operation. Because the jacking unit in such cases is generally supporting the hull loads, extreme care must be taken before commencing such replacement work (and, after completion, before loading/energising the system).

The following should be considered before any replacements are attempted:

— The Class society must be informed of all proposed jacking system element replacements before commencement and upon completion of the same (typically Class surveyors will require to assure material traceability and the use of approved material).
— The number of jacking gear trains to be taken offload simultaneously depends on the system design. Unless an evaluation is conducted by a competent engineer, not more than a single gear train should be taken offload at any given point in time.
— All procedures to isolate energy and restore electrical and mechanical systems must be strictly adhered to.

Other considerations depend on the availability of a leg fixation system:

— **Rigs with leg fixation systems**: leg fixation systems typically allow the jacking pinions to be taken offload. Therefore, jacking system element replacements on rigs fitted with fixation systems can
normally be carried out at any time without any special considerations except ensuring that OEM procedures are properly adhered to and the adjustments are carried out accordingly.

**Guidance note:**
Not all chock systems require pinions to be unloaded when chocks are engaged. If there is any doubt, the OEM/designer must be consulted with regards to the conditions in which pinions can/must be unloaded.

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— **Rigs without leg fixation systems:** jackups that do not have leg fixation systems will have the climbing pinions supporting the full weight of the hull. For these systems, releasing the brake torque on any element of the jacking system is a high-risk activity and must be done carefully. The following must be considered before trying to release the brake torque in preparation for replacing the jacking system elements:

— Permission must be sought from controlling authorities (in some places, regulatory authorities must be informed of this activity before starting);
— The loads on jacking systems must be recalculated and minimised to the extent possible. Redistribution of the weights must be carried out to the extent possible to ensure equal loading of the remaining pinions;
— Leg load limits may be set by authorised and competent personnel and monitored by crew;
— Weather report monitoring must be carried out throughout the replacement process.

Upon completion of the replacement process, the jacking system element in question must be retorqued to the average load of the other elements of the system on that leg so that it supports similar loads. Other precautions like ensuring the correct direction of motor rotation, etc, must be taken.

### 4.4 Spares

#### 4.4.1 General
For the availability of spares on board/in a central depot, an identical trade-off as for the maintenance activities is to be made. It is noted that the outcome of the trade-off can be different, e.g. capability on board but spares located in a central depot.

#### 4.4.2 Critical spares
Notwithstanding the above, critical items/spares are expected to be identified. These are spares which can correct single point failures preventing jacking. The OEM should identify these/these should follow from a failure mode, effects and criticality analysis (FMECA) analysis.

**Guidance note:**
Older designs often do not have FMECA analyses. As an alternative, the OEM/designer may have built up a large design service history providing alternative input.

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#### 4.4.3 Obsolescence
Obsolescence of parts is a major contributor to the life cycle cost and unavailability in jacking systems. This applies to the jacking system in general and the electronic components of modern control systems in particular (see [6.8] for a more detailed discussion on these).

Owners/operators are therefore recommended to monitor major components as they advance through production decline, phase out and discontinuance. The life cycle of the major component or part provides a basis for forecasting plans for system redesigns or periodic upgrades to ensure the reliability and longevity of a safe operating jacking system.

The above-mentioned monitoring can be part of a life cycle parts management system as incorporated into an owner’s/ operator’s maintenance management system. A vital input to this life cycle management system are the results of the periodical detailed inspection by Level 4 inspectors as discussed in [3.3.3] and life cycle information from the OEM as discussed in [5.2.5].

In conclusion, for parts identified as (close to) obsolete, compensating measures are required. These
measures range from an increase in the available inventory to a selection of alternatives fulfilling design requirements or a search for alternative suppliers.

**Guidance note:**
Where alternate parts/suppliers are chosen, these must be approved by Class.

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### 4.4.4 Baseline

Table 4-1 provides a recommended baseline for spares to be available on board/in the central depot, in case the recommended FMECA analysis not has been performed. This baseline is based on an expert assessment, taking into account experienced delivery times and the cost of spares. The replacement of these is expected to be handled by competence Level 2 or 3 crew on board (with the exemption of the replacing of the rack section as noted in the table).

**Table 4-1 Recommended spare part list**

<table>
<thead>
<tr>
<th>Component</th>
<th>Recommended amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric motor (complete with brake)</td>
<td>5% of total number</td>
</tr>
<tr>
<td>El. motor bearings</td>
<td>5% of total</td>
</tr>
<tr>
<td>Complete brake assy.</td>
<td>10% of total number</td>
</tr>
<tr>
<td>Gearbox</td>
<td>1 (of each type if applicable)</td>
</tr>
<tr>
<td>Fuses for control and motor systems</td>
<td>10%</td>
</tr>
<tr>
<td>Control lights, breakers and PCBs for jacking panel</td>
<td>10%</td>
</tr>
<tr>
<td>Weight indication system</td>
<td>5%</td>
</tr>
<tr>
<td>Climbing pinion + bearings</td>
<td>1</td>
</tr>
<tr>
<td>Rack section</td>
<td>5 teeth¹</td>
</tr>
<tr>
<td>PLC software/hardware on board</td>
<td>Depending on life cycle phase²</td>
</tr>
</tbody>
</table>

1) Replacing a section of rack is a major job and requires special planning, leg stabilisation, etc.
2) For example, it may be efficient to increase the number of components close to the end of their life cycle due to non-availability on the open market.
SECTION 5 INFORMATION REQUIREMENTS

5.1 Introduction
This section discusses the information expected to be supplied during the construction/building of the platform and the user and maintenance records to be maintained during operation. Both elements are prerequisites for a complete system assessment and maintenance.

5.2 Design information

5.2.1 General
Besides the information listed in the operation manual (as is governed by class and flag regulations) additional details will support further assessments of the system during its life time, supporting inspection, maintenance and repair objectives. These should be available on board as supplied by the OEM, system integrator and/or newbuilding yard.

The following sub-sections specifically discuss the following:
— information to assess the remaining system life time
— material specifications and welding parameters/specifications
— replacement criteria
— life cycle status
— user/maintenance material.

Table 5-1 provides a general overview of the expected data (based on BS EN 13460:2002).

<table>
<thead>
<tr>
<th>Document</th>
<th>Description</th>
<th>Contents</th>
<th>Typically supplied by</th>
</tr>
</thead>
</table>
| Technical data      | Manufacturer’s specification of the jacking system as a whole (and sub-elements thereof). | Manufacturer  
Model/type/serial number  
Size  
Capacity  
Power and service requirements  
Other: (Assembly details and operation data) | OEM |
| Operation manual    | Technical instructions to reach proper item function performance according to the item's technical specifications and safety conditions | Model/type  
Manual date (edition)  
Technical details of the item(s)  
Functional description of the item(s)  
Procedures for:  
— installation/commissioning/starting-up;  
— warming-up;  
— normal operation;  
— emergency/abnormal operation;  
— controlled shutdown  
— operation limitations/precautions.  
Regulations and standards applicable to the system and abided to | OEM |
### Table 5-1 A general overview of the information expected from the OEM, newbuilding yard and/or system integrator (Continued)

<table>
<thead>
<tr>
<th>Document</th>
<th>Description</th>
<th>Contents</th>
<th>Typically supplied by</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintenance manual</td>
<td>Technical instructions intended to preserve the jacking system in, or restore it to, a state in which it can perform safe jacking functions in normal and identified emergency situations. NOTE: Emergency situations to be defined by the manufacturer/designer.</td>
<td>Model/type&lt;br&gt;Manual date (edition)&lt;br&gt;Technical details of the item&lt;br&gt;Preventive maintenance operations/actions:  &lt;br&gt;— inspections  &lt;br&gt;— calibration/adjustment  &lt;br&gt;— parts replacements  &lt;br&gt;— lubrication.  &lt;br&gt;Procedures for:  &lt;br&gt;— troubleshooting  &lt;br&gt;— dismantling/assembly  &lt;br&gt;— repair  &lt;br&gt;— adjustment.  &lt;br&gt;Cause and effect diagrams  &lt;br&gt;Special tools required  &lt;br&gt;Spare parts recommendations  &lt;br&gt;Safety requirements (if any)</td>
<td>OEM</td>
</tr>
<tr>
<td>Components list</td>
<td>Comprehensive list of user serviceable items which constitute part of the jacking system, including, where applicable, components outsourced from other manufacturers. Details of original P/N and manufacturer details to be provided, including, where applicable, the jacking system supplier P/N if such items are customised/modified by the OEM. Components subject to fatigue failure prior to external, inspectable wear are to be listed along with the recommended replacement timeline.</td>
<td>Upper level item (heading)&lt;br&gt;(Model/type/serial number)&lt;br&gt;Item number&lt;br&gt;Item description&lt;br&gt;Item quantity.</td>
<td>OEM</td>
</tr>
<tr>
<td>Arrangements</td>
<td>Drawing showing replacement component layout for all items.</td>
<td>Drawing code and identification&lt;br&gt;Date (issue/revision)&lt;br&gt;Dimensions&lt;br&gt;Equipment components location and identification&lt;br&gt;Necessary space for disassembly and maintenance&lt;br&gt;Relevant information about connection details&lt;br&gt;Lifting arrangements, lugs, inspection ports, etc</td>
<td>OEM/ yard</td>
</tr>
</tbody>
</table>
### Table 5-1 A general overview of the information expected from the OEM, newbuilding yard and/or system integrator (Continued)

<table>
<thead>
<tr>
<th>Document</th>
<th>Description</th>
<th>Contents</th>
<th>Typically supplied by</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detail drawing</td>
<td>Drawing with part list to ensure dismantling, repair and assembly of items.</td>
<td>Code identifying the item which is detailed Assembly drawing showing parts positions Identification of each part of the drawing: — part number — description — number of units — approximate weight of each component (for safe handling). Any other relevant information for assembly and disassembly of the jacking system elements as specialty tools and handling equipment</td>
<td>OEM</td>
</tr>
<tr>
<td>Lubrication map</td>
<td>Drawing showing position of each item lubrication point, with lubrication data and specifications.</td>
<td>Map code and identification Date (issue/revision) Item identification (code and name) Lubrication point position (drawing), identification and description Lubricant specifications Routing of lubrication pipes where applicable</td>
<td>OEM</td>
</tr>
<tr>
<td>Single line diagram</td>
<td>Overall power distribution diagram: — electrical — pneumatic — hydraulic. including switchboard circuits.</td>
<td>Diagram code and identification Date (issue/revision) Power distribution units (motor control centres, switch gears, etc.) Power regeneration units. Hydraulic power rooms, motors, pumps, etc</td>
<td>OEM/system integrator</td>
</tr>
<tr>
<td>Logic diagram</td>
<td>System control diagram to clarify the overall jacking system logic.</td>
<td>Diagram code and identification Date (issue/revision) Logic functions (symbols, internet-working and control flow) Modes of operation (e.g. starting, shutdown, alarm, trip functions)</td>
<td>OEM/system integrator</td>
</tr>
<tr>
<td>Circuit diagram</td>
<td>Overall feeder and control circuits diagram.</td>
<td>Diagram code and identification Date (issue/revision) All internal connections for control, alarms, protection, interlocks, trip functions, monitoring, etc. Settings of timers, thermal overload and protection relays Wire and cable numbers Terminal numbers Component list for in-line, control and protection systems Switch gear/board location code Termination details and type of external signal (overload trip signal, brake set signal) Power and current rating Reference drawings</td>
<td>System integrator/yard</td>
</tr>
</tbody>
</table>
5.2.2 Life time expectation

The (design) life time expectation of the jacking system is an important input to an assessment of the reliability of the system and is a baseline for more detailed re-assessment of the remaining life time after an operational period (see also [3.3]).

As such, the rated life of the jacking system should be available on board the rig including specifications of the applied/assumed loads and duty cycles used in the underlying calculations. With the applied loads related to the (defined) operational restrictions for the unit, the following three ratings are typically expected:

1) Rated life time for leg jacking
2) Rated life time for normal jacking and
3) Rated life time for preload jacking or emergency jacking.

**Guidance note:**
The ratings available for a particular model of jacking system may not include all three jacking loads. Often the leg jacking loads are ignored if they are considered so small that they contribute very little to component fatigue. This should be confirmed with the OEM or system integrator if leg jacking ratings are not available.

For normal jacking, the defined operational restrictions (and hence applied loads) may either be based on "maximum pinion loads for normal operating", or on "rig elevating load capacity", depending on the design.

---end-of-guidance-note---

5.2.3 Material and welding specifications

For the correct execution of repair and maintenance work, material specifications of the following components should be available:

- Rack
- Leg members (chords, braces, gussets, etc.)
- Guides
- Jack house structures.

The material specifications should include approved welding parameters/specifications.

**Guidance note:**
Normally this information is provided on the as-built drawings and in the construction portfolio. Note that welding codes and Class require welding procedures to be qualified by the company doing the welding. E.g. it is not permissible for a company to use a welding procedure developed by another company. The first company must qualify its own procedure.

---end-of-guidance-note---

5.2.4 Replacement criteria

The designer is to provide acceptance/rejection criteria for all owner-serviceable components. This is to include, but not be limited to, the elements listed in Table 5-2.

The criteria could include wear, corrosion, dimensional or hardness limits; the required compliance with a published standard; test values; or defect size or extent. Original design or manufacturing tolerances are not expected unless they correspond with the maximum allowable component limits.

**Table 5-2 Listing of components on which (wear) acceptance criteria is expected, with guidance on expected information**

<table>
<thead>
<tr>
<th>Component</th>
<th>Typical expected information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leg/rack guide</td>
<td>Provide the minimum and maximum dimensions for the clearance between the rack/leg and guide.</td>
</tr>
<tr>
<td>Rack</td>
<td>Wear limits, possibly supported by a drawing of four of the rack teeth so that the rig owner can make a template to gauge the rack during inspections</td>
</tr>
<tr>
<td>Rack to climbing pinion interface</td>
<td>Provide a tooth profile with minimum and maximum wear limits</td>
</tr>
<tr>
<td>Gearbox</td>
<td>Wear limits</td>
</tr>
<tr>
<td>Bearings</td>
<td>Lifting clearances as applicable and method of carrying out this task</td>
</tr>
<tr>
<td>Brake</td>
<td>Wear limits for consumable items</td>
</tr>
</tbody>
</table>

5.2.5 Life cycle status

As discussed in section [4.4], the obsolescence of components is a major contributor to the life cycle cost and availability of jacking systems and as such the parties involved are advised to have a specific focus.

In this focus, is the OEM expected to provide information to assess and control obsolescence issues throughout the (contractually agreed) life time of the system, including (approaching) unavailability of components and spare parts.

5.2.6 User/maintenance manual

The user/maintenance manual providing system-specific guidance and instructions is an important element...
in ensuring correct maintenance and inspections.

The completeness of the manual should be balanced against the manual's readability, providing a clear focus on the most critical operating and maintenance issues.

In addition, the instructions are expected to be on a reasonable technical level, taking into account operational time and knowledge constraints.

The topics discussed in the manual should include, but not be limited to, the following elements:

- Pictures/diagrams
- Operation manual
- Troubleshooting manual (this may be incorporated in the maintenance manual)
- Maintenance manual, including:
  - routine maintenance - mechanical and electrical
  - general inspection
  - periodic inspection
  - maintenance after a fault condition
  - troubleshooting
  - the setting of adjustable components
  - inspection criteria
  - guidance and diagrams to show and explain normal wear and tear on the system and include dimensional information at key points to inspect gears to determine the extent of wear.

- Electrical and control schematic drawing
- Layout and structure drawing
- Spare parts list with part number, quantity installed and recommendation
- Special tools list with detailed part number
- Specification of 5-yearly inspection criteria.

5.3 User and maintenance records

5.3.1 General

As discussed in [3.3], enable operational records a more accurate assessment of the remaining life time of the components (compared to the information available during the design phase). Presented to a Level 5 individual, this data can be used to create a customised and more fit-for-purpose inspection scope during the periodical inspection/overhaul by the Level 4 personnel.

Guidance note:
Beyond the advantages for a single system, the availability of (statistical) data provides feedback for further design and maintenance improvements.

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5.3.2 User records

It is recommended that the following operational data related to utilisation of the jacking system is to be recorded and stored for later analysis:

- Torque settings (i.e. pinion or jacking load) prior to jacking (on each gear)
- Jacking hours/metres (or feet):
  - Hull up/down
  - Leg up/down.
- Load conditions during jacking:
  - Normal/preload/emergency jacking
— Availability of units per leg
— Individual leg loads.
— Weather conditions during jacking
— Extraordinary operations:
  — see the overview in Table 3-4
  — including information required to completely assess the situation, i.e.:
    — pinion loads
    — rack height on lower and upper guides
    — length travelled.

The above data is typically recorded in a jacking log-book. It is recommended that records are kept both for the single jacking operation and in a cumulative file. The last provides a direct awareness of the remaining (calculated) life time.

5.3.3 Maintenance records

Besides the operational records, the following maintenance should be recorded:
— Inspection results
— Maintenance, overhaul and replacements
— Software updates/changes/revisions.

Guidance note:
It is the owner's responsibility to maintain the available drawings on board (e.g. the structural, electrical and system drawings). Software updates/changes/revisions are to be approved by the OEM and/or Class.

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5.4 Calculation of jacking system fatigue life

5.4.1 Introduction

Sub-section [3.3] discussed the approach for detailed inspection with recommended intervals at 20% of rated jacking system life consumed and a more in depth analyse at 80%. This section describes a basic approach to determine these percentages of life usage.

It is directly underlined that the basic approach leads to a (safe case) approximation only and as such does not imply a direct need for replacement of the components.

Jacking system life ratings are usually given as the load on the climbing pinion (in tons, kN or thousands of pounds) for a given period, either in "operating hours" or rack travel (feet or metres). These ratings are an output of the fatigue utilisation analysis carried out by the jacking system designer assuming certain operating parameters and maintenance conditions and hence are expected as a part of the design information (as specified in [5.2.2]).

5.4.2 Approach

Any estimate of the consumption of the jacking system rated life may, unless otherwise stated by the OEM, be based on the three components as were specified in [5.2]:

— **Jacking hours with leg jacking loads**: These refer to the time when the unit's legs are being lowered to the seabed/raised from the seabed and while the hull is afloat in the water.
— **Jacking hours with normal jacking loads**: These refer to the time spent on any operations in which the hull is being raised or lowered; i.e., when the legs are on the bottom and start supporting the elevated loads on the seabed. Although it is recognised that there might be some minor variations in the jacking loads due to the existing variable load on the unit at the time of this operation, for the purpose of this operation it is recommended that the assumed load shall be taken at the defined operational restriction for normal elevating weight.
Guidance note:
The operational restrictions may be defined as "rig elevating load capacity" alternatively "maximum pinion loads for normal operating" (see also guidance note at [5.2.2]).

Some unit designs incorporate a higher number of pinions available for preload jacking than required for normal jacking. When such units are elevated with preload, the jacking would be considered "normal jacking loads" so long as the load per pinion remains below the "maximum allowable pinion elevating load for normal operations".

It is also recognised that a transition stage exists when the hull is partially afloat; this should be regarded as normal jacking.

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— Jacking hours with preload jacking (or emergency jacking) loads: These refer to the time spent on all jacking operations where the unit is raised or lowered with supporting loads beyond the normal jacking load.

The remaining jacking life for each load condition may be approximated as the rated jacking life for each load condition minus the cumulative jacking duration with that load. For the three load conditions presented above, the remaining life would be calculated as follows:

— Leg jacking life remaining = the rated life leg jacking – cumulative leg jacking duration
— Normal jacking life remaining = rated life normal jacking – cumulative normal jacking duration
— Preload jacking life remaining = rated preload jacking life – cumulative preload jacking duration

Different/ more load cases for rated life times may have been specified than the three explained above. For a better estimate these can be utilized as well. Notwithstanding, to ensure a safe case, the next higher load case should be used in case of deviations of operational conditions from the specified load cases.

Guidance note:
The expected follow up of a resulting remaining life at 80% of the rated life is typically a more detailed analyse as discussed in [3.3].

The choice of maximum permissible jacking loads ensures that the discussed basic approach (when operating below these limits) will logically include a margin with the actual life consumed. Subsequently, it can be expected that the follow up analyse based upon the actual loads (see [5.3] on user records) will show a larger share of the life remains and hence an update of the rated life.

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SECTION 6  SPECIFIC COMPONENTS

6.1  Introduction
This section provides specific guidance for the inspection and first line maintenance of specific components. For the intervals of the described inspections, refer to section Sec.3, while for a complete overview of the records to be taken, refer to [5.3].

6.2  Guides, jack house and racks
The leg guides limit the horizontal movement of the leg in the jack house and as such ensure that the loads are distributed properly. Hence, too much wear on the guides will cause uneven wear and tear on the jacking system.

For floating systems, extra guides are normally provided on the jacking cassettes to ensure alignment of the pinion and rack; i.e. rack guides.

The wear of the top leg guides and rack guides can normally be measured directly - the lower leg guides need special (temporary) access.

The wear on the racks can be assessed using a template; samples are to be taken every 15ft in the region of normal operations and 30ft elsewhere.

*Guidance note:*

Note the need for inspection of cracks in every tooth in high-wear areas.

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Some self-elevating units are designed with a leg fixation arrangement. Their satisfactory operation is to be verified by testing. It must be noted that these systems require very good mating between their components and the leg rack. Special attention should be paid to cracks, plastic deformations and contact patterns.

The jack house and brace beams should be examined for cracks and corrosion.

**Table 6-1  Typical observations on guides, jack houses and racks**

<table>
<thead>
<tr>
<th>Guides</th>
<th>Typical observations (pos/neg)</th>
<th>Might be caused by</th>
<th>Expected follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excessive wear (depending on system design)</td>
<td>Tilting of legs by uneven sea bed</td>
<td>Replace</td>
<td></td>
</tr>
<tr>
<td>Cracks</td>
<td></td>
<td>Repair/replace</td>
<td></td>
</tr>
<tr>
<td>Jack house</td>
<td>Cracks</td>
<td>Poor chocking during dry tows</td>
<td>Repair. Improve chocking procedures</td>
</tr>
<tr>
<td></td>
<td>Excessive wear on guides</td>
<td>Repair</td>
<td></td>
</tr>
<tr>
<td>Corrosion</td>
<td>Inadequately maintained coating</td>
<td>Renew</td>
<td></td>
</tr>
<tr>
<td>Racks</td>
<td>Deformed teeth</td>
<td>Excessive tooth loads, e.g. due to legs stuck in the bottom</td>
<td>Rack repair</td>
</tr>
<tr>
<td>Uneven wear</td>
<td>Poor lubrication</td>
<td>Improve instructions</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Play in pinion bearings</td>
<td>Replace</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Excessive wear on guides</td>
<td>Replace</td>
<td></td>
</tr>
<tr>
<td>Missing teeth</td>
<td>Unreported event</td>
<td>Investigate possible event. Examine section of leg above and below. Replace section of rack as per inspection and Class recommendation</td>
<td></td>
</tr>
</tbody>
</table>
6.3 Shock pads

Shock pads, as used on floating systems only, are to transfer and balance vertical loads.

Pads are expected to have a useful lifetime of 5 – 10 years depending on the environment and operational conditions. The lifetime of the upper pads is shorter than that of the lower pads.

Corrosion is normally the factor that limits the pads’ life time. It is therefore recommended to clean and paint the steel plates regularly, coating the pads with protectant sealant to avoid moisture entry/rust. Heavy corrosion of intermediate shims may cause “swollen” pads which can damage the jacking system. A certain air gap should normally be evident in way of unloaded shock pads.

Shock pads should always be bolted together and not welded due to the inability to remove corrosion between plates. During assembly, the plates should be blasted (taking care to protect the rubber components), dime coated, primed and painted. Assemble with proper bolts and then apply a rubberised coating to the entire unit using a brush.

When replacing, care should be taken to select the right hardness of rubber following the OEM’s specifications. Shock pads should always be changed in pairs, with the allowable height differences within the tolerances given.

**Table 6-2 Typical observations on shock pads**

<table>
<thead>
<tr>
<th>Typical observations (pos/ neg)</th>
<th>Might be caused by</th>
<th>Expected follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deterioration of the steel parts</td>
<td>Poor coating/maintenance</td>
<td>Replace</td>
</tr>
<tr>
<td>Hardening of rubber. This can be observed when</td>
<td>UV light</td>
<td>Replace</td>
</tr>
<tr>
<td>going afloat, the pads are being unloaded and</td>
<td></td>
<td></td>
</tr>
<tr>
<td>recovered</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lamination of steel parts/rubber</td>
<td>Corrosion/ fatigue</td>
<td>Replace</td>
</tr>
<tr>
<td>Cracks in rubber layers</td>
<td>Too much clearance of leg guide</td>
<td>Replace, Measurement of leg guide clearances</td>
</tr>
<tr>
<td></td>
<td>Aging of pads</td>
<td></td>
</tr>
<tr>
<td>Uneven height</td>
<td>Progressed deterioration and</td>
<td>Replace</td>
</tr>
<tr>
<td></td>
<td>subsequent loss of rubber layers</td>
<td></td>
</tr>
<tr>
<td>Swollen such that the air gap is eliminated</td>
<td>Corrosion</td>
<td>Replace</td>
</tr>
</tbody>
</table>
6.4 Enclosed gearing

The reliability and availability of the jacking system are directly dependent on the functioning of the gear systems.

Oil sampling will most likely give a first indication of wear in either the gears or bearing. This oil sampling can be accomplished in a variety of ways, including magnetic plug inspection (for particulates), visual oil examination for water, filter paper oil exam, oil circulating system filter exam and/or laboratory oil analysis. For the last-mentioned, the evaluation is generally long-term trending. In addition the oil samples should be taken directly after a jacking operation, otherwise contaminants settle down and the sample is not truly representative of the condition. For the other methods, samples should be taken from the gearbox’s lowest access point and from each separate gearbox cavity.

**Guidance note:**
The different methods presented here will all have different values and reliability and that should be noted. E.g. a visual oil examination is not nearly as valuable or accurate as a laboratory oil analysis.

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If oil sample results indicate issues, a detailed visual inspection (e.g. by boroscope) will subsequently provide further information before further action has to be taken; typically dismantling for precise measurements and/or replacement.

**Table 6-3 Typical observations on enclosed gearing and gearboxes**

<table>
<thead>
<tr>
<th>Typical observations</th>
<th>Pictures</th>
<th>Might be caused by</th>
<th>Expected follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deterioration of the gearbox exterior</td>
<td>Poor coating/maintenance</td>
<td>Renewishment or renew</td>
<td></td>
</tr>
<tr>
<td>Cracking on flanges</td>
<td></td>
<td>Corrosion/poor maintenance, aging/deterioration of fasteners and gaskets</td>
<td>Renew</td>
</tr>
<tr>
<td>Leaking</td>
<td>Figure 6-3, Figure 6-4</td>
<td>Deteriorated shaft seals, Loose bearings on speed shaft</td>
<td>Renew shaft seals, Replace bearings</td>
</tr>
<tr>
<td>Water entrainment in oil</td>
<td>Figure 6-3, Figure 6-4</td>
<td>Deterioration of gaskets, corroded air breathers</td>
<td>Renewishment or renew</td>
</tr>
<tr>
<td>Particulates in oil</td>
<td></td>
<td>Wear of gears and bearings, damage to gears and bearings</td>
<td>Monitor oil condition (for minor indications), refurbishment (for serious indications)</td>
</tr>
<tr>
<td>Deteriorated output shaft</td>
<td></td>
<td>Possible damaged bearings and seals</td>
<td>Replace output shaft and inspect gearbox</td>
</tr>
<tr>
<td>Damaged</td>
<td>Figure 6-5</td>
<td>Fatigue</td>
<td>Replace</td>
</tr>
</tbody>
</table>

---e-n-d---o-f---G-u-i-d-a-n-c-e---n-o-t-e---
6.5 Climbing pinion including bearings and other non-enclosed gearing

The observations and causes described in the previous subsection also apply to the climbing pinion and its bearings (being part of the gearing system). In addition, the wear on the pinion system could reveal excessive wear on the racks, guides and shock pads as leading to undue forces throughout the drive train. One of these areas is the keyed section of the bull gear and climbing pinion shaft.

The key ways and splines should be measured and replaced or repaired if out of specification. The inspection should subsequently focus on specific wear patterns (as further detailed in the table below). In addition, the total wear should be checked. The bearings should also be checked for sufficient greasing and allowable tolerances following OEM specifications.

### Table 6-4

<table>
<thead>
<tr>
<th>Typical observations</th>
<th>Might be caused by</th>
<th>Expected follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Worn pinion teeth</td>
<td>Worn out pinion bearings</td>
<td>Check and renew</td>
</tr>
<tr>
<td>Uneven wear pattern</td>
<td>Excessive wear on leg guides</td>
<td></td>
</tr>
<tr>
<td>Pinion out of line</td>
<td>Worn out pinion bearings</td>
<td>Renew</td>
</tr>
<tr>
<td>Bearing surface significantly scored/gouged</td>
<td>Inadequate lubrication</td>
<td>Renew</td>
</tr>
<tr>
<td>Pinion-bearing journals significantly scored/gouged</td>
<td>Inadequate lubrication, worn out pinion bearings</td>
<td>Renew</td>
</tr>
</tbody>
</table>

![Figure 6-5 Damaged gear teeth (enclosed gearing)](image1)

![Figure 6-6 Worn bushing](image2)

![Figure 6-7 Worn pinion teeth (exposed gearing)](image3)

---

**Figure 6-5** Damaged gear teeth (enclosed gearing)

**Figure 6-6** Worn bushing

**Figure 6-7** Worn pinion teeth (exposed gearing)
6.6 Braking system

The braking system holds the hull on the required elevation either temporarily until the fixation system is engaged or at all times under all conditions for designs without a fixation system. The braking system is typically either in a parallel path with the jacking motor or mounted as a motor brake (braking torque transmitted through the motor shaft). Brakes are always of fail-safe design (automatic set, activated release).

The unplanned/unexpected release of a single brake will result in uneven pinion loads. If multiple brakes on one leg malfunction, the residual holding power may become too low, resulting in the rig slipping or, in the worst case, collapsing/tipping over.

On the other hand, a brake may also fail to disengage or unintentionally engage, resulting in major damage to the gears and/or rack. It is common to perform a brake function test of each brake prior to jacking operations, especially if the jacking system has not been operated for an extended period. During jacking, brakes should be monitored for failure to release and dragging (the latter evidenced by excessive motor torque, brake heating and/or smoke coming from the brake). Further, most modern jacking control systems monitor and sound an alarm for failure to release during jacking and excessive motor torque.

Guidance note:
The root cause of brake malfunctions may be a control system failure (see [6.8]).

Brake inspections should include examination of the entire brake load path and, when necessary, the strip down and visual inspection of the brake band/discs and measurement of the solenoid gaps. The brake disc lining thickness should be recorded.

On some braking systems, a brake slip test is required to ensure that the brake holding power is a) equally shared between the individual brakes, b) sufficient to hold the (maximum) storm pinion load and c) that the brake slippage is not adjusted higher than the admissible loads indicated in the operational manual.

Normally, the brake slip test should be done annually and when an electric motor is overhauled.

Guidance note:
The maximum pinion load is higher than the maximum pre-load pinion holding load.

6.7 Power/motor system

The non-availability of a motor when jacking will limit the lifting capacity of the jacking system and create unbalanced loads. Failure of the motor during jacking could cause major damage to the motor, gears and rack.

The integrity of the motor is to be checked visually and by performing electrical checks (a megger test for example). Items of interest are the cable glands, cables and motor bearing lubrication. These items should be checked in advance of jacking, particularly if the jacking system has not been operated for an extended period of time.

An area of concern during installation of the motor system is the correct rotation direction; serious damage occurs to both the gears and/or rack if one of the motors is running in the opposite direction. The damage may in this case also affect adjacent gear systems. A clear and simple procedural description is recommended in order to prevent this.

During jacking operations, motors should be monitored for unusual sounds (with a focus on high-frequency sounds), an unusual rise in the motor temperature and smoke. Additionally, some systems are provided
with load indicators which may indicate possible problems.

**Table 6-5**

<table>
<thead>
<tr>
<th>Typical observations</th>
<th>Might be caused by</th>
<th>Expected follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reverse power</td>
<td>Insufficient load or insufficient load on engines</td>
<td>Ensure enough house load is present and correct number of engines on line</td>
</tr>
<tr>
<td>Grounded motor/circuit</td>
<td>Loss of insulation or dielectric strength</td>
<td>Megger check motor circuits. Monitor ground fault indication system</td>
</tr>
<tr>
<td>Main breaker will not close</td>
<td>Faulty breaker (trip unit, UV/shunt)</td>
<td>Change breaker with spare. Should be drawout type frame/breaker. Current inject breakers at least every 5 years</td>
</tr>
<tr>
<td>Main drive or contactor not closing</td>
<td>Current overload, short circuit</td>
<td>Check circuit for activated ESD, short circuit or failed component</td>
</tr>
</tbody>
</table>

**6.8 Control systems**

**6.8.1 General**

The control system with its functions and alarms allow remote operation of the jacking system, including remote emergency shutdown capabilities in the event of an unexpected failure or condition. Independent from the control system, emergency stops should be fitted on each leg. The controls should be constructed with sufficient redundancies in the system to provide safe operation in the event of a major component failure. If redundancies are not built into the system, these components should be considered critical spares and kept in good condition as backup on board the vessel.

A visual and audible alarm is to be provided at the jacking control station to give an indication of any jacking motor overload condition. In addition, the following alarms should be available for the operator at the central control station:

- Audible and visual alarms for:
  - Unit out-of-level (elevated condition)
  - Significant differences in the currents or torque in the motors on one rack
  - Rack phase differential, where applicable to the design
  - Leg upper and lower limits reached
  - Brake release status/alarm.

- Indication of:
  - Availability of power
  - Power consumed (during raising and lowering operations)
  - Inclination of the unit, in two horizontal, perpendicular axes (elevated condition).

Two major types of control systems are commonly used: 1) relay control logic hardwired and 2) CPUs, PLCs, servers with LAN or fibre communication. Both control the power contactors that run motors and release brakes, show system status and/or activate alarms. The following are typical problems and checks that
apply to either or both systems:

### 6.8.2 Software

The control functionality of the latest-generation systems is to a large degree based on Programmable Logic Circuits (PLCs), so malfunction of the software may have the same consequences as the previously discussed component failure. In this respect, ensuring the correct status of software deserves an equivalent level of attention.

Software-specific maintenance consists of the following:

1) Keeping control of revisions/updates
2) Ensuring the availability of a backup

The following Guidance note provides a best practice for keeping backups of system software.

**Guidance note:**

1. System backups should be controlled by the rig management.
2. Make 3 copies (e.g. original + external/local + external/remote).
3. Have them geographically distributed (on rig, to local office and corporate office).
4. Data backup options:
   a) Disk
   b) Hard drive (examples: via Vista backup, Mac Timeline, UNIX rsync)
   c) Server
   d) Cloud storage
5. Secure your software/data.
   a) The rig manager should provide storage in a locked safe or filing cabinet.
   b) Unencrypted is ideal for storing your data because it will be most easily read by the crew and others in the future. But if you do need to encrypt data because of its sensitivity:
   c) Keep passwords and keys on paper (2 copies) and in a PGP (pretty good privacy) encrypted digital file.
   d) Uncompressed is also ideal for storage, but if you need to compress to conserve space, limit compression to your 3rd backup copy.
6. Test your backup system

In order to make sure that your backup system is working properly, try to retrieve your data files and make sure that you can read them. You should do this upon initial setup of the system and on a regular schedule thereafter.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

### 6.8.3 Ageing and availability

(PLC-based) Control systems are not prone to traditional wear and tear as software does not age. Notwithstanding, their hardware, software and firmware do age; capacitors age, hard drives seize, CMOS batteries die and data on magnetic strips must be refreshed. Scheduled inspections should be performed to determine where software and supporting hardware are in their life cycle.
The above should especially be taken into consideration with regard to obsolescence issues as discussed in [4.4.3]. A main reason for this is the relatively short life cycle of electronic components compared to the self-elevating unit, i.e. typically around 5 years compared to the 30-year life time of the unit.

This short life cycle also applies to major PC software which in turn may affect the usability of backup and diagnostic applications. Later software versions become unsupported after a time and anti-virus software becomes no longer available, creating a risk for the PC running the aforementioned applications.
SECTION 7  FURTHER IMPROVEMENTS

7.1  Introduction

Some risk-based analyses can be performed to optimise and improve an asset’s performance. Below, two approaches are presented: a) a Reliability, Availability and Maintainability (RAM) study and b) Reliability Centered Maintenance (RCM).

— A RAM study is recommended to be performed in order to optimise the spare part regime, pinpoint weak links/focus areas and assess future performance based on historical failure events.
— RCM is a method to identify and select failure management policies to efficiently and effectively achieve the required safety and economy of operation.

7.2  RAM approach

7.2.1  Objective

The previous sections described a best practice concerning the inspection and maintenance of the jacking system. It is underlined that the actual follow-up and opportunity to make further improvements depend on a large number of rig-specific factors and choices made:

— Availability and cost of spare parts
— Availability and level of resources, both in-house and at service suppliers
— Storage space on board
— (Contractual) uptime requirements
— Possibilities to perform the maintenance task on board given the need for specific conditions and tools
— System-specific redundancy and failure risks
— Preventive replacement of failure-prone parts
— Etc.

Since balancing the above comes down to a trade-off between cost and the desired availability, it is up to the owner/operator to conduct the required analysis. A standard approach to such an analysis is a Reliability, Availability and Maintainability (RAM) study.

— Reliability denotes a product’s or system’s ability to perform a specific function and may be given as design reliability or operational reliability.
— Availability denotes the ability of a system to be kept in a functioning state. The availability of a system depends on the system’s design reliability, maintainability and maintenance support.
— Maintainability is a design property of a product or system and is determined by the ease with which the product or system can be repaired or maintained. The maintainability of a system depends, among other things, on the system’s accessibility, standardisation and modularisation.

Within the scope of this document, there are various benefits of carrying out a RAM study:

— Forecast sub-system availability, system availability, production availability etc.
— Identify and improve; identify the main downtime contributors and highlight improvement measures.
— Optimise the maintenance regime; compare maintenance alternatives with respect to availability and cost aspects, e.g. on board maintenance vs. shore maintenance.
— Input to other activities such as risk analyses or maintenance and spare-parts planning.

7.2.2  Case study

To ensure the validity of the outcome, a RAM study is normally performed on a specific design with a specific component failure. Notwithstanding, a generic case study based on a simplified, generic jack-up design, expert judgement and/or limited actual historical failure data will highlight industry trends and improvement areas.
Appendix B shows such a generic case with two different scenarios simulated; a base case and a spare case.

— The base case assumes that no spares are available on site and that it takes 7 – 10 days to mobilise a spare, with the exception of shock pads and jack house structure parts. This implies that the spares are available from an onshore storage site and do not have to be ordered from the manufacturer. Shock pads and jack house structure parts take 15 – 30 days and 30 – 45 days respectively to arrive.
— The spare case assumes that all spares are readily available on site and can be fitted whenever a failure occurs.

The outcome shows an average lifetime availability that is ca. 4% higher in the spare case than in the base case. In other words, saving capital costs by eliminating spares on site may introduce substantial lost-production costs.

It is recommend further optimisation of the spare part regime, pinpointing weak links/focus areas and assessing future performance based on historical failure through a system-specific RAM study.

7.3 RCM approach

Reliability centred maintenance (RCM) is a structured, logical process for developing or optimising the maintenance requirements of a physical resource in its operating environment in order to realise its potential performance. The potential performance is the level of performance that can be achieved with an effective maintenance programme. RCM is based on the assumption that efficient preventive maintenance will reduce the cost and improve asset availability.

The objective of an RCM study is to:

— Establish optimal maintenance tasks for an item
— Identify opportunities for design improvements
— Evaluate where the current maintenance tasks are ineffective, inefficient or inappropriate
— Identify the dependability improvements

A typical RCM process touches upon the following questions:

— What is the equipment there to do?
— How does it fail to do it?
— What are the effects and are these important?
— What preventative actions can be taken to reduce the consequence of a failure?
— If no suitable preventable action is applicable; what steps must the operator take?
— What spares, personnel, tools, etc. are required to support the action decided upon?

An RCM exercise can result, among other things, in:

— Maintenance plans; detailed task packages/lists of detailed routines
— Task bundling; grouping tasks together for improved efficiency
— Surveillance aids; field displayed instructions
— Organisational development; adjusted staffing and resourcing

Guidance note:
For further details with regards to the RCM study and its objective, see ISO 60300.
APPENDIX A  TRAINING, COMPETENCE AND KNOWLEDGE GUIDANCE

A.1  Level 1

A.1.1  Knowledge
— Maintenance organisation and responsibilities
— Comprehension of:
— Principles related to the working and function of the jacking system
— Sequence of events during a rig move/jacking operation
— Basic system-specific introduction
— All grease points/grease type
— Basic knowledge of wear observations for the rack and pinion
— Typical system observations/identify abnormalities
— Need to know the dangers relating to the jacking system/operation.

A.1.2  Competencies
— Ability to grease
— Ability to assist technicians in carrying out torque checks
— Ability to call for stop (that is after being briefed on the topic).

A.1.3  Experience
— No one but a leg supervisor needs to be familiar with jacking operations on the unit.

A.1.4  Training requirements
— No formal training required
— Extended briefing possibly supplemented by e-learning.

A.2  Level 2

A.2.1  Knowledge
— Maintenance organisation and responsibilities
— The complete jacking system + components
— First-line maintenance procedures
— Company + system-specific maintenance procedures
— System loads and system redundancy (basic knowledge only).

A.2.2  Competencies
— Ability to identify component replacements
— Ability to troubleshoot the system.

A.2.3  Experience
— 2-3 years
— Familiarity with jacking operations.
A.2.4 Training requirements

— System-specific inside a person’s technical discipline, incl.
— (for new systems) an overview of the network topography and control system logic
— software and parameter revision control
— Typical 1-2 days of theoretical training followed by 1-2 days of practical instructions.

A.3 Level 3

A.3.1 Knowledge

— Maintenance organisation and responsibilities
— The complete jacking system + components
— Overview of pre-jacking checklists and documentation (company-specific)
— System-specific load criteria.

A.3.2 Competencies

— Ability to conduct a risk assessment based on findings and decide whether a jacking operation can be carried out safely
— Ability to review maintenance and inspection results
— Ability to prepare a yearly maintenance plan
— Ability to support and instruct personnel carrying out maintenance and repair tasks.

A.3.3 Experience

— 2-3 years of close involvement in at least 5 rig moves
— Covering both operational and maintenance functions.

A.3.4 Training requirements

— System- and rig-specific
— Typical duration 4-5 days.

A.4 Level 4

A.4.1 Knowledge

— Insight into the complete system and failure causes
— Maximum wear on components
— Material grades/welding procedures.

A.4.2 Competencies

— Knowledge of system-specific acceptance criteria
— Ability to review NDT reports
— Knowledge of structurally critical components and critical inspection areas.

A.4.3 Qualification requirements

— ISO certified as approved by Class
A.4.4 Training

- To be completed in future revisions.
APPENDIX B  GENERAL CHECKLIST

B.1 Pre-jacking inspections and activities

Table B-1  Pre-jacking inspection and activities

<table>
<thead>
<tr>
<th>Component</th>
<th>Check/actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>General</td>
<td>Brief personnel on the details of their duties and activities</td>
</tr>
<tr>
<td></td>
<td>- instructed to observe motors for unusual sounds or excess heating</td>
</tr>
<tr>
<td>Guides, jack house and racks and other grease-lubricated components</td>
<td>Put grease and brush on each driven corner for rack on top of jack houses. For jacking-down operations, grease at the bottom.</td>
</tr>
<tr>
<td>Shock pads</td>
<td>Check if all is clear and clean under the bottom of shock pads</td>
</tr>
<tr>
<td></td>
<td>Check the condition of top shock pads and report</td>
</tr>
<tr>
<td>Enclosed gearing</td>
<td>Check oil levels in all jacking gearboxes</td>
</tr>
<tr>
<td></td>
<td>Check all jacking gearboxes for leakage and report</td>
</tr>
<tr>
<td></td>
<td>Check main flanges/bolts and all fasteners visually</td>
</tr>
<tr>
<td>Climbing pinion (and other grease-lubricated components)</td>
<td>Apply grease to all grease-lubricated bearings</td>
</tr>
<tr>
<td>Braking system</td>
<td>Check brake release and brake alarms</td>
</tr>
<tr>
<td></td>
<td>Check brake gap and holding capacity if applicable</td>
</tr>
<tr>
<td>Power/motor system</td>
<td>Check all torques of electric motors and re-adjust if needed (see operational manual) and report¹</td>
</tr>
<tr>
<td></td>
<td>Ensure enough motors are online prior to commencing jacking operations (follow operation manual instructions)</td>
</tr>
<tr>
<td></td>
<td>— Perform power system electrical checks</td>
</tr>
<tr>
<td></td>
<td>— megger test</td>
</tr>
<tr>
<td></td>
<td>— reverse power check</td>
</tr>
<tr>
<td></td>
<td>— breaker trip settings (ST, LT and INST)</td>
</tr>
<tr>
<td></td>
<td>— Check motor contactors for signs of heating or damage</td>
</tr>
<tr>
<td></td>
<td>— Check motor overload settings (if applicable)</td>
</tr>
<tr>
<td></td>
<td>— Check motor plug connections (if applicable)</td>
</tr>
<tr>
<td>Control</td>
<td>Function test directional contactor controls – main breaker open</td>
</tr>
<tr>
<td></td>
<td>Leg fixation system - ensure leg fixation system is disengaged</td>
</tr>
<tr>
<td></td>
<td>Check key switch functionality</td>
</tr>
<tr>
<td></td>
<td>Upper and lower limit switches must be function tested</td>
</tr>
<tr>
<td></td>
<td>Manual control must be in place to stop jacking system. Personnel strategically placed at power isolation for emergency shutdown (e.g. main power breakers, ESD at legs)</td>
</tr>
<tr>
<td></td>
<td>E-stop must be checked at all locations (e.g. legs/control panel).</td>
</tr>
<tr>
<td></td>
<td>Check emergency override function (if applicable)</td>
</tr>
<tr>
<td></td>
<td>RPD calibration (control interface)</td>
</tr>
<tr>
<td></td>
<td>Leg depth indicators must be calibrated</td>
</tr>
<tr>
<td>Communication</td>
<td>Check operation of phone/headsets at each jacking leg to confirm communication with control room</td>
</tr>
<tr>
<td></td>
<td>If radios are used, ensure their function and access to spare battery</td>
</tr>
</tbody>
</table>

¹ Some systems do not require torque checks

B.2 During-jacking inspections and activities

- Grease climbing pinions and racks
- Listen for sounds not consistent with normal operations
- Monitor for jacking motor overheat and particularly for smoke and sparks
- Monitor the readings and indications at the jacking control console (kW, amps, volts, frequency). Meter values should be recorded while performing jacking operations at several intervals.
B.3 Post-jacking inspections and activities

— Check torque equalisation ¹)
— Check brake release
— Check for oil leaks, loosened fasteners, freshly cracked or chipped paint and obvious deformation
— Visual inspection of brake discs/ bands.

¹) Some systems do not require a check on the torque
APPENDIX C  RAM CASE STUDY

C.1 Disclaimer
Although a Reliability, Availability and Maintainability (RAM) study is typically based on a specific design, this particular case study is not. The following results are based on a simplified, generic jack-up design with input data based on expert judgement and/or limited actual historical failure data. Thus, the results and the input data are not applicable to any specific jack-up rig. The results should be used to focus discussion on general problem areas and to underline the importance and advantages of performing a thorough project-specific RAM analysis.

C.2 Cases
Two different scenarios were simulated; the base case and spare case.

1) The base case assumes that no spares are available on site and that it takes 7 – 10 days to mobilise a spare with the exception of shock pads and jack house structure parts. This implies that the spares are available from an onshore storage site and do not have to be ordered from the manufacturer. Shock pads and jack house structure parts take 15 – 30 days and 30 – 45 days respectively to arrive.

2) The spare case assumes that all spares are readily available on site and can be fitted whenever a failure occurs.

C.3 System overview
Figure C-1 shows a Reliability Block Diagram (RBD) of the simulated system. The rig consists of three legs, a control system and the jack house structure. Each leg contains three chords and shock pads. The chords can be divided into rack teeth, guides and a climbing system. The climbing system contains a climbing pinion, brake, primary gear box, secondary gear box, keyways and a drive.

Due to the lack of data, the guides, rack teeth and shock pads are not simulated individually but as one component on an aggregate level.

Total components modelled:
- 36 of each: climbing pinions, brakes, primary gear box, secondary gear box, keyways and drive.
- 9 of each: guides and rack teeth – aggregated for each chord.
- 3 sets of shock pads – aggregated for each leg.
- 1 of each: control system and jack house structure.
Figure C-1  RBD of the modelled jack-up rig. Each coloured box represents a (sub)system and contains the equipment and subsystems below it. The white boxes represent the components.

C.4 Input data

Table C-1 shows the input data used in the simulations. The total downtime due to a failure is the sum of the active repair time and any time required to mobilise spares. It is important to emphasise that all failure rates, either expert judgement or historical failure data, already include some kind of preventive maintenance regime. It is very difficult to determine failure rates that are not influenced by preventive
maintenance. Thus, it is assumed that our jack-up rig has an industry-average maintenance regime in place.

Between 2007 and 2012, a total of 11 assets were lost 1). The reason for the losses may be externalities like the weather/storms and accidents, or internal failures such as operational errors and jacking gear component failures. The latter, jacking gear component failures, are part of our scope. Since a jack-up rig has some in-built redundancy, a common cause failure usually has to occur in order for there to be a catastrophic outcome like the total loss of the asset (and multiple fatalities, but that is not discussed here). By comparison, in the past decade, at least four of the total losses have been due to multiple brake failures.

To capture this phenomenon that may have varying root causes but will have a major impact on the average availability, an event (dummy component) called a "common cause failure" has been introduced. Due to the high number of total losses of jack-up rigs, it is important to include such a failure that can have a significant impact, even though it may be difficult to pinpoint the actual component to blame.

Out of the 11 failures within a period of five years, it is assumed that around 4 of them (∼4/11) are due to jacking gear failure, presumably a common cause failure. During this period, approximately 300-350 jack-up rigs were in operation around the globe, giving a mean time to failure (MTTF) of ∼400 years. Assuming an average rig lifetime of 40 years, one rig out of a fleet of ten will be lost due to jacking gear failure 2).

Table C-1  Input data used in the simulation cases

<table>
<thead>
<tr>
<th>Component 3)</th>
<th>MTTF (y)</th>
<th>Active repair time (d)</th>
<th>Source for MTTF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climbing pinion</td>
<td>35</td>
<td>0.25 – 1</td>
<td>Expert judgement</td>
</tr>
<tr>
<td>Brake</td>
<td>35</td>
<td>0.25 – 1</td>
<td>Expert judgement</td>
</tr>
<tr>
<td>Common cause failure</td>
<td>400</td>
<td>Loss of asset</td>
<td>Historical data from Jack et. al.</td>
</tr>
<tr>
<td>Primary gearbox</td>
<td>100</td>
<td>1 – 7</td>
<td>Historical data from one company</td>
</tr>
<tr>
<td>Secondary gearbox</td>
<td>100</td>
<td>1 – 7</td>
<td>Historical data from one company</td>
</tr>
<tr>
<td>Keyways</td>
<td>350</td>
<td>1 – 7</td>
<td>Expert judgement</td>
</tr>
<tr>
<td>Drive</td>
<td>500</td>
<td>1 – 7</td>
<td>Historical data from one company</td>
</tr>
<tr>
<td>Rack teeth</td>
<td>10</td>
<td>11 – 7</td>
<td>Expert judgement</td>
</tr>
<tr>
<td>Guides</td>
<td>50</td>
<td>15 – 30</td>
<td>Expert judgement</td>
</tr>
<tr>
<td>Shock pads</td>
<td>5</td>
<td>15 – 30</td>
<td>Expert judgement</td>
</tr>
<tr>
<td>Control system</td>
<td>16.4</td>
<td>1 – 7</td>
<td>Historical data from one company</td>
</tr>
<tr>
<td>Jack house structure</td>
<td>15</td>
<td>15 – 30</td>
<td>Historical data from one company</td>
</tr>
</tbody>
</table>

2)  Similar calculations, independent of failure cause, would result in 3-4 losses in a fleet of ten.
3)  The lower failure rate of rack teeth, guides and shock pads reflects that they are simulated at aggregate level.
C.5 Assumptions

— Only critical failures have been modelled, i.e. degraded failures are not included. It is assumed that, due to their critical nature, all failures will require a replacement.

— A constant failure rate is assumed, i.e. modelled exponential time to failure.

— 40 years of system life time and 250 iterations are simulated.

— It is assumed that failures of components in the climbing system (pinion, keyway, drive, gear boxes and brake) and rack teeth will give up to 6 hours of downtime while the component is being bypassed, after which production will continue as normal. The component will then be repaired at the next available opportunity.

— On each leg, only one failed climbing system is tolerated. I.e. a maximum of three climbing systems can fail, one on each leg, without impacting production. However, production will stop if two fail on the same leg.

— Only downtime caused by a jacking system failure has been considered in this report. Downtime caused by external factors or inadequate operations is not covered.

C.6 Results

Figure C-2 and Table C-2 show that the average lifetime availability is around ≈4% higher in the spare case compared to the base case. The two cases are extremes at each end, no spares on site vs all spares on site; but this shows that saving costs by reducing the total number of spares in a fleet due to not having them on site may lead to a substantial cost increase in the form of lost production. Spare part optimisations should be based on a RAM analysis which includes historical failure data and all cost considerations. The analysis should be performed in close collaboration with key crew members to reflect a company’s operations.

![Figure C-2](image-url)

Figure C-2 Cumulative probability for the two cases. The markers show the respective average availability.

Not surprisingly, if the common cause failure (loss of asset) occurs, the availability will be very low. This is the reason for the long “tails” in Figure C-2, and also why the average availabilities are so low (Table C-2). Please note that the model excludes external and/or operational impact and human errors. These factors are known to cause many incidents for a typical jack-up rig and may result in even lower actual availability.
Figure C-3 shows the downtime contribution from each component in both cases. The downtime difference for redundant components (climbing system) is minimal. This is because the system can continue to operate normally after a small stop while waiting for the spare part. However, as with shock pads, there is much to gain by having non-redundant spares on board.

Since the two cases only differ in spare part availability, the number of failures, and subsequently the usage of spares, is the same (Figure C-4).

### Table C-2 Availability value for the two simulation cases

<table>
<thead>
<tr>
<th></th>
<th>Base case [%]</th>
<th>Spare case [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>P10 1)</td>
<td>85.22</td>
<td>90.88</td>
</tr>
<tr>
<td>Average 2)</td>
<td>86.2</td>
<td>89.99</td>
</tr>
<tr>
<td>P90 3)</td>
<td>92.44</td>
<td>95.11</td>
</tr>
</tbody>
</table>

1) The 10th percentile or P10 is the value below which 10 per cent of the observations are found. E.g. there is a 10% chance that the availability will be below this figure.
2) Arithmetic mean, not necessarily similar to the 50th percentile (P50).
3) The 90th percentile or P90 is the value below which 90 per cent of the observations are found. E.g. there is a 90% chance that the availability will be below this figure.
C.7 Recommendations

The above results show that, on average, the industry expects close to one rig loss due to jacking gear failure every year. Based on the experience of those participating in the JIP, an alarming amount of rigs are lost due to the unexpected release on multiple brakes. The root cause of each rig loss may be different, but the general consensus is that more emphasis must be given to preventive maintenance of the brakes to reduce the number of lost rigs.

Another consensus is that spare part optimisation is too often done without a substantial focus on the broader picture – savings in the spare part stock may be outweighed by losses in production stops. E.g. assuming a USD 100k loss each day a rig experiences unintentional downtime, the ≈4% difference in the cases translates to ≈USD 58 million over a 40-year lifetime. It is therefore recommended to perform a RAM analysis so that the decisions take the different factors into account. The RAM analysis can be used in spare part optimisation, to pinpoint weak links/focus areas and to assess future performance based on actual historical failure events.

However, a RAM analysis is not suitable for mapping the current level of the maintenance regime and how these specific activities can be improved. In order to ensure that a safe minimum level of maintenance is in place, a complementary exercise may be used instead; a Reliability Centred Maintenance (RCM) analysis. RCM is a method to identify and select failure management policies in order to efficiently and effectively achieve the required safety, availability and economy of operation. For more information on the application of RCM analyses, IEC 60300-3-11 is referred to.
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