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ABSTRACT

The offshore industry is seeing the advent of new technologies and complex systems as it ventures into harsher and more remote locations. Integrity and reliability are the keys to such systems. It is critical to technically evaluate these complex systems thoroughly and modify them to meet the harsh challenges they have to withstand.

The already existing mobile assets also have to be studied and recertified to meet the higher load conditions of rougher seas.

The module handling system (MHS) is a complex system which could handle up to 60Te of subsea modules at 4.5Hs making it versatile system in the North Sea subsea market. The MHS has various structural, electrical, mechanical, hydraulic, control subsystems which have to be upgraded and properly interfaced to meet the requirements.

The main objective of this thesis is to evaluate the system by studying all the subsystems in detail and providing with solutions / recommendations for improving the reliability. Various areas of improvement have been identified. Recommendations provided for the improvements of the systems are generic and could be used in the asset management in the offshore industry.

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Abbreviations

ACOP	Approved Code of Practice
AHC	Active heave compensation
AMC	Aker marine consultants
DNV	Det Norske Veritas
FMEA	Failure Modes & Effects Analysis
GWW	Guide wire winch
HPU	Hydraulic power unit
Hs	Significant wave height
HSE	Health safety and environmental
IMCA	International marine contractors association
IMR	Inspection maintenance and repair
IO	Integrated operations
IOC	Integrated operations center
IP	Integrated planning
LCI	Life cycle information
LOLER	Lifting Operations and Lifting Equipment Regulations 1998
MHS	Module handling system
NDE	Non-Destructive Examination

O&M	Operation and maintenance
OCV	Offshore construction vessel
OSHA	Occupational safety and health administration
PPE	Personal protective equipment
PPU	Push pull unit
PUWER	Provision and Use of Work Equipment Regulations
QMS	Quality management system
ROV	Remotely operated vehicle
SCM	Subsea control module
SWL	Safe working load
TCIG	Tower crane inspection group

1. Introduction

The state of the art complex systems of the offshore industry provides some of the most demanding yet exciting project management and engineering challenges. It is the perfect example for a globalised market where equipments and labor are bought from different parts of the world to be assembled and used in some of the remotest and demanding areas. Reliability is the key and quality assurance in each step from the design drawing board to fabrication followed up by proper maintenance program till the end of the life cycle is important. In a complex system, where different subsystem are designed and fabricated by different sub supplier, assuring quality and proper integration of the components is a herculean task for the clients. Quality assurance and quality control should be managed by the parent company, not by a contractor or other third party (Doucet, 2007) stretching the already limited labor resource availability of the clients. When the subcontractors are spread globally, constant quality surveillance is difficult. There is need for more resident quality surveyors who can witness the critical operations at the subcontractor site. Fit up tests before / during decisive component delivery and installation are usually not performed due to schedule pressure. Proper training for the fabricator about the codes and regulations of the country where it is going to be used has to be provided. Companies have lost millions of dollars, when equipments fabricated outside Norway could not be used for the job as they do not meet the Norwegian standards. This is very obvious in case of construction vessel, in the inspection maintenance and repair (IMR) market, when they are bought from other geographical location, fails to meet the requirement during Norwegian standard fitness audits.

With the advent of the integrated operation (IO) where assets and complex operations are integrated for economical benefits (OLF,2005) , the complex offshore system has taken a giant leap in using the modern advancement is science but have added an extra degree to associated complexities. In the long run it would be beneficial especially in having expertise from the onshore facilities available for operations. While planning an offshore system extra focus is now made on the onshore communication scope as it’s a critical element in the IO system. The industry has witnessed its advantages through Integrated Operations Center of Conoco Philips in

Stavanger through which they were able to control majority of offshore operations through the onshore base.

A complex offshore system is usually a unique state of the art facility based on the rules and regulations of the operating area. Proper integration of the various high tech subsystems is vital for a reliable scheme. The uniqueness of each system makes it difficult to develop a generic design/ solution forcing the engineers to make a tailor made solution each time every time. It's usually the nitty gritty details that matters most in case of such interfaces and the project team have to be prepared with backup solutions. As seen in the industry most of the complexities emerge during the testing phase of the project offshore making the teething problems really strenuous. As a thumb rule an operation offshore will cost 5 times that of onshore, meaning each small modification need to the system while offshore could potentially blow up the total life cycle cost. This kind of surprises occur in the subsea industry when its next to impossible to accurately check and measure the dimensions till a diver or an ROV is in site for the purpose, which could be too late and expensive. Statfjord C riser replacement welding campaign is a good example as the design was based on welding a smooth machined bore pipe but during the actual operation when the divers where on site it was seen to be a rough bore pipe, resulting in substantial work scope change in the offshore operation.

Offshore facilities have limited accommodation facilities and the transportation could be an area of high risk concern. From 1976 up to year-end 2002, there have been 7 fatal accidents related to helicopter transport in the UK offshore sector claiming lives of 88 offshore workers and flight crew (HSE UK 2004), further highlighting the need for reliable integrated system . During 2002/03 in the UK sector offshore 64 serious injuries have been reported of which 21 (32%) have been related to maintenance / construction , making it the most vulnerable working area in the whole offshore operation phase (HSR,2006)

In an industry that seems forever changing, one visible constant is the drive towards lower cost. With the associated breakdown maintenance cost being too high, reliable offshore equipment is primary requirement. The integration of the various subsystems has to be tested for the worst case loading that the equipment could see during its operation. Compared to the onshore structures which are typically larger and seeing much less dynamic loading the design

and fabrication along with the material properties gains importance as the offshore structure have to resist the fatigue loadings as well as corrosion and colder temperature. The situation calls for not only stronger material with superior qualities but also state of the art welding equipments, procedures to minimize the associated welding problems such as cracking.

The experts may not be available on time offshore, making even more difficult to get the equipment up and running. This could also result in getting system experts flying in from far of locations resulting in more downtime and higher costs.

The complex systems used offshore are a beautiful yet challenging symphony of various intricate subsystems. Understanding about the working and maintenance of each of these components are critical for a successful operation. A single elemental failure could lead to disastrous results. The prime example is an offshore crane – where the crane wire is a single critical element and its failure could lead to fateful operations. The inbuilt redundancies of the system starts at the design phase but maintenance of the components are critical during the life of the system. For doing proper maintenance comprehensive and regular training need to provided to the technicians. They also need to be updated with the latest condition monitoring as well as asset management procedures.

Inspection maintenance and repair operations are characterized by quick mobilisation with short notification period. A pool of equipments, with long lead times needs to be pooled and kept ready for operation at the earliest. The operation critical items have to be identified and pooled at required amount and the management of the pool with regular inspection and emergency responses trials have to be checked. The development of the system is a part of the integrated planning process. Integrated planning (IP) can be described as a planning process aimed at integrating all dispersive plans across different disciplined, enabling the alignment of key operational planning processes to provide a common perspective across work plans (Kayacan and Celik, 2003) and while developing an ac complex offshore system along with its associated infrastructure onshore the long term planning , reflection of the organizations business development that involves specific investment strategies and business actions which are fundamental components of business eyesight and the long term future (Bai and Liyanage, 2012) is important.

Designing a QMS system for a complex system is another challenging task faced by the project team A composite and comprehensive management system ensure competitive performance in the global economy (Karapetrovic and Willborn , 1998) .and to develop this comprehensive system each and every subsystem need to be studied in detail and practical system developed. The uniqueness of each of the complex systems adds to the task Personnel's role, involvement, competence, skills and development feature in a total QMS system.

1.1 Aim of this thesis

This report is a detailed study of a complex offshore system. Through this report I intend to study /evaluate general challenges of a complex system in the offshore subsea industry taking Module handling system (MHS), an asset owned by Technip Stavanger, as a case study. MHS is installed over the moon pool of construction vessels and is designed to handle 60 Te subsea equipments at harsh environmental states of 4.5 Hs, making operational at the bad sea states in remote location.

MHS system installed on the Fugro symphony in the summer of 2011 was not able to perform to its promised potential. In this report I try to study the system and analyze the various components in detail and modify the various components so as to improve the reliability and performance. The technical evaluation has brought to light various issues with the MHS and the report here elaborates on the study that was undertaken and includes the recommendation for re-commissioning and suggestions for improvements in future operation. These recommendations could be used in any similar offshore applications.

There were various structural, mechanical, control systems that had to be studied and upgraded. There are also corrosion issues to be addressed. The main challenge is to identify the root cause of the various errors and then proposing a solution for it. The report carries a description and evaluation of each of the main subsystems and the recommendation for modifications are mentioned in each section for easy reference and practical use.

The issues with the MHS includes a wide array of issues – with most of them related to

- fabrication intolerances,
- design irregularities,

- material selection
- wrong manufacturing techniques
- unpractical designs
- ergonomics

The technical recommendations given in this report could be applied to any of the offshore facility during its fabrication, testing, installation or maintenance. Through this study I have tried to extend my area of knowledge into the various segments of an asset and bring to notice what would be the areas of concern of typical offshore complex system.

Also through this report I also plan to develop a spare part list and put in place a maintenance strategy in order to develop the basis for the maintenance system which is to be implemented in the long run for the asset.

1.2 Methodology

This is real time industrial project and for the evaluation, all the documents were comprehensively reviewed and all the technical data were collected. To check the integrity of the components, they were physically assessed offshore onboard Fugro symphony and AMC hinna base. The physical assessment includes the check for the intolerance, physical damages and possible issues that could arise during the offshore operations. The physical measurements were done to millimeter accuracy at all the relevant location. I also had detailed discussion and interviews with many industry pioneers.

The report is divided into the technical evaluation of the various subsystems with each carrying the relevant recommendations. Some of the modifications are particularly relevant to the MHS (design, fabrications, intolerances etc) while some of them are more generic and are relevant to the all of offshore industry.

1.3 Limitations of the thesis

In this report structural, both global and local, strength and serviceability criterions are not verified (the initial designers are responsible for ensuring this).The recommendation given in this report are to be evaluated along with the designers to develop a reliable system. The same goes for the mechanical and hydraulic subsystem systems evaluated here.

2. Literature survey

The MHS is classified as an "offshore lifting appliance" which has been tested and certified in accordance with the **Det Norske Veritas** "Rules for Certification of Lifting Appliances" (DNV, 2008) which gives the criteria and guidance for certification and verification of the design, materials, fabrication, installation, testing and commissioning of lifting appliances. MHS falls into the category of Shipboard cranes -onboard vessels intended for cargo handling within and outside the vessel, as here we are using to handle subsea modules in and out of the vessel. The components designed and certified based on DNV on MHS are

- All load-carrying structural members
- Sheaves, shackles, lifting beams, swivels and ropes
- rope drums (winch drum)
- power systems (for hoisting, derricking, slewing and travelling)
- brakes and braking systems
- safety equipment
- seating and fasteners for prime movers, winches and for bearings of power transmitting components
- control and monitoring (DNV, 2008)

The structural components are checked with the drawing supplemented with calculations supporting the basis of design. For the MHS this includes the dynamic forces occurring during the launching and recovery of the modules critical through the splash zone. Code also mentions about the horizontal forces that need to be considered during operations.

Functionality movement requirements

- safety brakes on all movements
- overload protection
- load indicator or load moment indicator
- safety valves on all main circuits of the hydraulic system

- emergency stop system
- end stoppers
- audible warning alarm
- slack wire rope detection
- means for emergency lowering of load (DNV, 2008)

IMCA Guidelines

The international marine contractors **IMCA guidelines M171** discusses the general aspects of lifting applications design. Even though the guidelines are generic to the crane systems, it has elements which are relevant to the MHS (IMCA M171, 2003). The guideline briefs about:

- Mechanical requirement - including the functional purposes, arrangement, sea states for operations, lifting capacity and radius, working height, maximum depths of operation, requirements of constant tension / active heave compensations and wire construction
- Supply requirements – drive mechanism, voltage supply requirements, Start up mechanism, power requirements
- Control/instrumentation system requirements –specifying about Operator's Cabin location and ergonomics , Cabin Controls and Instruments , Remote Control , Safety & Emergency Devices
- Maintenance and repair requirements -Recommended Spares, Maintenance Program applicable for all the subsystem, Maintenance Access and Aids
- Testing, installation, trials and training –Testing, FMEA (Failure Modes & Effects Analysis), Installation & Commissioning, Trials, Training
- Certification and documentation – classification society rules and approval, Documentation

The wire ropes for the lifting winches are the single most critical item in the whole lifting arrangement. The IMCA guidelines **IMCA SEL 022/IMCA M 194** discuss the integrity management of the wire ropes used for lifting. It includes guidance on selection of wire ropes, storage, transport, maintenance, description of the causes of wire rope deterioration, thorough examination, inspection, testing, discard criteria and documentation for wire ropes used by

vessels in the marine industry (IMCA SEL022, 2008). It also advises about documentation of all the elements of this guidance, such as selection, certification, storage, thorough examination and inspection, history of use, records of damage or wear and final discard. **IMCA SEL 023, IMCA M 197 guidelines** discuss about Non-Destructive Examination (NDE) of Magnetic Rope Testing which would be used for testing in the future (IMCA SEL023, 2009).

Provision and Use of Work Equipment Regulations (PUWER)

Provision and Use of Work Equipment Regulations (PUWER), UK, place responsibility on the companies to provide quality equipments to user. They regulate the quality of equipments and maintenance of the system. It also stresses on the complete training for the equipment in use. The equipment should come with sufficient safety features and controls, with adequate emergency stops. The access to the dangerous parts needs to be barriered in a proper manner (PUWER 1998). The puwer also discusses about the drop object protection systems in place in the system. The general isolation of the equipment from power source is also covered in detail.

Lifting Operations and Lifting Equipment Regulations 1998 (LOLER)

Lifting Operations and Lifting Equipment Regulations 1998 (LOLER) are the regulations regarding the lifting equipments. The LOLER is supported by Safe use of lifting equipment: Approved Code of Practice (ACOP). LOLER discusses about importance and standards of marking the safe working loads SWL on the equipment. Planning and supervision of the lifting operations are referenced in the regulations. The regulation also covers inspection and certification of the lifting equipments. (LOLER ,1998)

Working at heights regulation 2005 is based on the UK laws and is seen as an industry standard in the North Sea oil and gas industry. The rule is for everyone involved in working in height. In the case of the MHS all the maintenance activities needs to be done at a height and also during operation when the moon pool doors are opened it involves working at heights and over board. The rules discuss the use of safety equipment needed to aid in doing the work. There are details about the planning needed prior to operation and the limiting weather criteria before performing the work safely. Other items are about hierarchy of organization, selection and inspection of lifting equipments.

NORSOK Standards

The MHS is painted according NORSOK M501 specifications. NORSOK M 501 – surface preparation and protective coating specifies the requirements for the selection of coating materials, surface preparation, application procedures and inspection for protective coatings to be applied during the construction and installation of offshore installations and associated facilities. (NORSOK M501, 2004). The codes gives specification about the various types of coating that could be used for offshore application and the testing that need to be done for each of the different type of coating system along with the operation and maintenance philosophy.

Norsok standard C -002 states the minimum functional requirements for design and construction of architectural components and equipment to be installed and used on offshore installations (NORSOK C-002, 2004). The MHS system and documentation is evaluated , in relevant areas , to meet the Norsok standards. Norsok C-002 are the standard for the architectural components used in the design . They are used especially in the hand rails and stairs design.

Occupational safety and health administration (OSHA)

Occupational safety and health administration (OSHA) in 'Occupational Safety and Health Standards'- The control of hazardous energy (lockout/tagout)' specifies about the lockout regulations to prevent the unexpected start up of machines and also release of unexpected energy (OSHA 2012). It discusses about disconnection of the hydraulic systems and testing after hooking up before pressurizing it.

OSHA also has standards while using electrical equipments and connections. 'Occupational Safety and Health Standards-electrical' states about the inspection, approval and use of electrical appliances. It also stated further about the insulation integrity and deteriorating agents including the environmental agents which would influence the life of the equipment. There are sections dealing with equipments stored outdoors which are relevant to equipments stored on deck.' Wiring design and protection' discusses about the color coding, branching and multi wire branch circuits and is relevant not only for the MHS system alone but also for the interface with the electrical connections on the vessel. 'Use of equipment ' specifications states

the handling, visual inspection, grounding requirements and over current protection methodology which would be critical when the MHS gives back the power to the vessel through active heave compensation system is activated.

Offshore lifting has always been a focus area and seen a lot rules and regulations getting into place to assure the safety of the operations. The main HSE focus of statoil for the year 2012 is the prevention of dropped objects accidents. Statoil is giving special emphasis on 'sweeping the equipments' to make sure that there are no small items kept unstrapped on the bigger equipments that are lifted.

Offshore industry forum/ standards

'International Regulators' Forum on offshore lifting and mechanical handling issues has identified. The top ten priority/serious issues identified are :

1. Competence of crane operator
2. Competence of banksmen / slingers
3. Man riding using winches
4. Planning of lifting operations
5. Analysis of lifting accidents
6. Static and dynamic crane rating
7. Hook snagging on the supply boat
8. Competence of maintenance staff
9. Supervision of lifting operations
10. Inadequate maintenance

Maintenance features twice in the list, showing the concern of the industry about the maintenance of the subsystems in the overall performance and safety of operations (IRF, 2005). There have been various proposals and regulations to capture the maintenance activities of the lifting operations. Some of the regulatory initiatives are featured in the report are :

- Inspection reports (pre-use, monthly, quarterly, and Annual) to be checked thoroughly by management. Visual inspection of the rigging conditions and implementation of wire

rope inspection program. Annual Third party inspections are also highly recommended for the lifting appliances now

- New Norwegian regulations and standards are highly focused on maintenance
- HSE key program KP3 on Installation Integrity includes in depth inspection of the effectiveness of maintenance. Safety Notices published following recent crane boom collapses on older cranes. Emphasize the importance of reviewing the adequacy of maintenance arrangements to reflect age of crane.

During the life time of the MHS, the maximizing the assets could mean more stringent checking of the systems and developing more ways of increasing the life time . 'Beyond lifetime criteria for offshore cranes' by HSE, Which contains information on the present standards and UK could be reference document for industry practices and regulation for extended life (OTO, 2001)

The other main challenge is the structural integrity of the MHS and there has to be checks in the long run of the equipment for deteriorations and structural damages. Some of the mechanisms which could potentially limit the life of the system structure includes :

1. Fatigue (loading)
2. Creep (when crane operating over high temperature zones, GT exhausts, flare booms, etc.)
3. Corrosion
4. Erosion
5. Brinelling
6. Impact damage
7. Ageing
8. Leakage (ingress of water/condensation effects)
9. Vibration
10. Loose fittings (electrical, mechanical, hydraulic and pneumatic systems)
11. Buckling
12. Brittle fracture (OTO,2001)

3. Introduction to a complex offshore system– Module handling system (MHS)

The Module handling system (MHS) is a significant asset for Technip norge, having substantial influence on the inspection, maintenance and repair (IMR) market in the north sea sector. It's a system designed to handle 60Te subsea equipments at harsh environmental states of 4.5 Hs, which makes it operational almost all year around in the Norwegian sector. It could be used for installation and decommissioning of most of subsea infrastructure and aid in transporting it onshore to the quay side facilities.

The MHS was designed and delivered to Technip by TEKMAR and it's the sixth module handling system fabricated by them. This time the scope includes the supply of main lift winch, guide wire winches, hydraulic power units and remote control cabin integrally mounted on the structure of the MHS. As well as the MHS, within Tekmar Subsea's scope of work includes all the deck skidding systems, pallets, rotary turntables and hydraulic push / pull units required for safe and controlled handling of subsea tools and equipment. (Tekmar, 2010). The winches, the sheave and wires arrangement were provided by Lebus international engineers, UK. The control systems and the HPUs were delivered by MJR controls, UK

The system is designed for 'easy' mobilisation onto vessels and has a 35Te Integrated Main Winch. It is designed for use of vessel crane trough tower as supplement to winch. The main winch is delivered with non rotating wire for operations to 1500m depth and is dimensioned for a 35Te submerged load at 1500m (Wire weight 23Te) FOS 5:1 on 35 Te lifted load. The tower is dimensioned to operate in Hs up to 4.7m @ better than 95% efficiency.

Control system / cabin integrated in tower structure for good visibility. There is direct access from the vessel deck and has all the major control systems. There are also high Capacity Guide wires System, 3 off winches (8 Te in CT operation) which can operate in POD mode. One of the guide wire winch has AHC capacity of 5Te @1500m and 95% efficiency. The cursor winch, 15Te capacity operates cursor carriage located to the side of main winch.

The MHS is installed on the moon pool of the vessel and has the main wire and guide wire system which is used guide and lower the modules over the xmas trees or manifolds and commission them with ROVs or divers. The complete MHS system is 241 Te and the main winch is presently rated for 35 Te and could be upgraded to 60Te. The guide wire winch wires lock themselves to the subsea manifold and guides the modules to and from the seabed to the vessel deck.

The modules could be stored on the deck of the vessel and could be transported into the MHS from the deck in the special skidding system. Once the modules are inside the MHS it could be hooked on the main winch and the moon pool doors could be opened and then deploy the modules though the hull of the ship. Position of the guide wire and the main wire winch could be modified based on its manifold structure and the nature of the job. The system has unique features to be operated with ROV backup from vessel.

The system was first installed on the Technip's third party vessel Fugro symphony during October 2011 in Teeside, in UK.. The first planned project for the MHS was balder project, of Exxon mobile, in changing out the SCM in the balder field. Testing of the MHS was done on the vessel during the vessel transit from UK to Norway and on the quay side in haugasund.

The commissioning of the control system of the MHS was not completed and during the testing there was an accident when guide wire winch lost control the socket of the wire collided with the sheave. The commissioning of the control system was not finished but the balder project was successfully completed using the MHS along with additional deck winches.

Further testing and inspection of the system revealed many errors which resulted in the decommissioning of the system from the Fugro symphony and getting to fix the system in the quay side AMC base in hinna, Stavanger. The decommissioning was done in December and detailed survey of the system was performed during the initial months of 2012. An extensive modification, repair and recommissioning program was scheduled and implemented. The testing arrangement for the MHS has to simulate the motions of the vessels in the sea. Various signals are imposed on the system to simulate the sea state. The plan is to finish the commissioning of the tower on the quayside in AMC and then install it on the vessel with subsequent deep water

trials on the vessel. It's important to test the system each time it's on a new vessel and fine tune it to meet the vessel requirement.

The system has high potential and could be a market leader of especially in the IMR segment and installation of smaller subsea modules because of the various unique features of the system. To attain this, rigorous testing and commissioning plans have to be implemented. Reliability of the system has to be proven to the industry. Also the various maintenance programs have to be implemented thoroughly to meet the high performance requirements of an offshore system, which would be the key to successful utilization of the MHS with minimum downtime.

Figure 1: MHS frame (with no subsystems)

4. Technical assessment and integrity evaluation, Results and Recommendations

4.1. General description

The MHS is used to launch modules from the rear deck of the vessel down through the moonpool to the seabed. The MHS is located directly over the moonpool of the vessel and is mounted on a subframe that has been specifically designed to interface with the moonpool on the Fugro Symphony. The subframe need to be designed for specific offshore construction vessel (OCV) based on the moonpool details.

The MHS consists of various modules and proper integration of the various modules is the key to a successful offshore operation. The system has a safe working load (SWL) of 35 Te, with the scope to be upgraded to 60Te. 3guide wire winches are on the unit, a maximum of four guide wire winches can be fitted onto the MHS. The MHS is classified as an "offshore lifting appliance" which has been tested and certified in accordance with the Det Norske Veritas "Rules for Certification of Lifting Appliances 2008".

The assembly comprises of the following modules :

Each of these subsystem are described and evaluated later in the report	
a.	Main Sheave positional system assembly
b.	Guide wire sheave positional system assembly
c.	Sheaves for guide wire winches
d.	Main winch wire sheave
e.	Wire ropes
f.	Main winch
g.	Hydraulic Cursor Winch
h.	Mid level Platform
i.	Skidding system
j.	Pallets
k.	Moonpool door system
l.	HPU system
m.	Structuaral and general layout

When the system is mobilized on the vessel total associated weight is around 300 tones with around 7 heavy non standard lifts. There are hydraulics that need to be fitted up and tested .Also the interface with the vessel have to be modified to meet the power requirements and the active heave compensation system have to be tested and fine tuned based on the new vessel dynamics. The mobilisation on the new vessel is approximately 5 days. The hydraulics needs to be also pressure tested prior to mobilization and the proper connections need to be coupled to the HPU and the main systems on the tower. There are seafastening that has to be done to the main tower on the moon pool and the skidding rail and the HPUs on the deck.

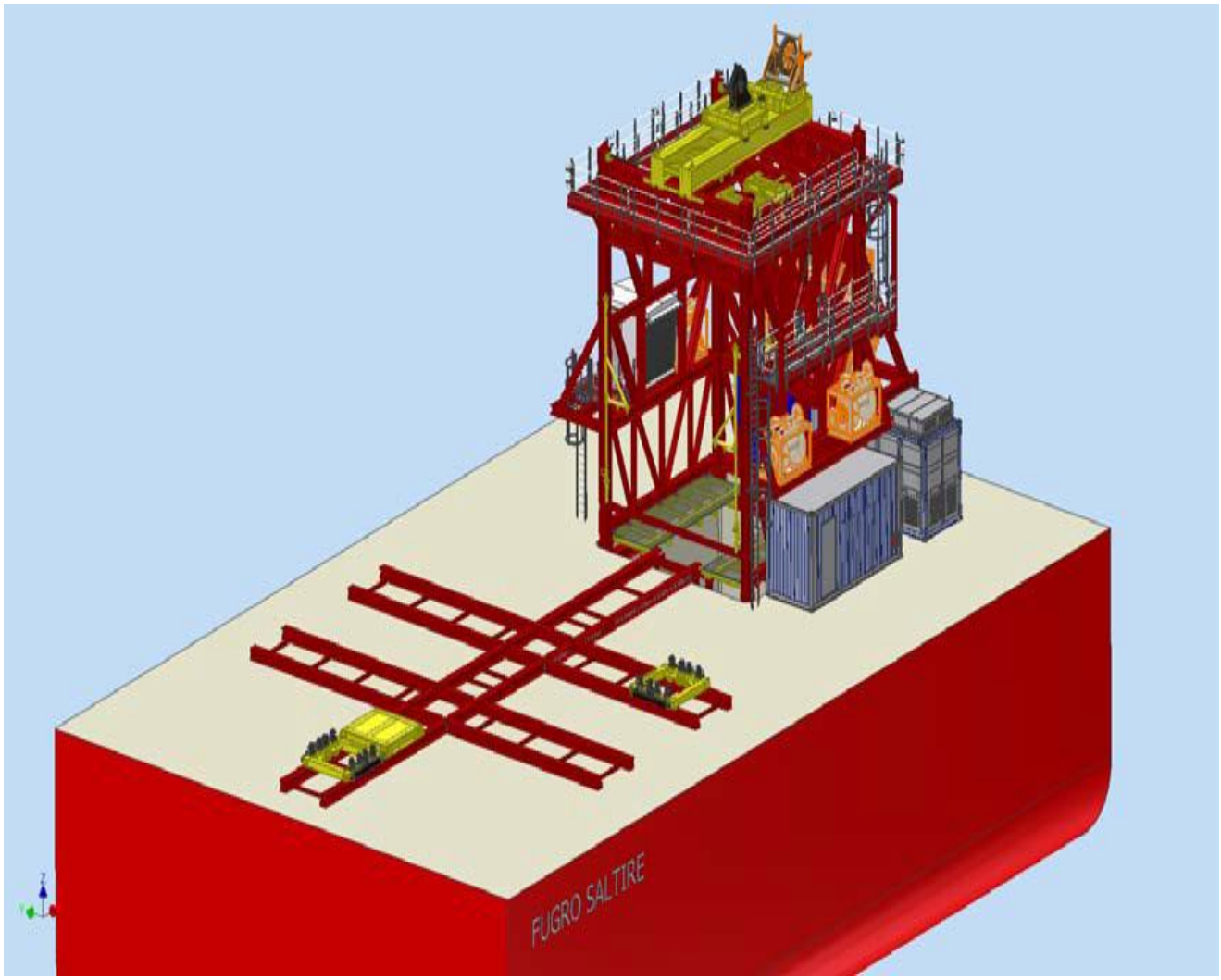


Figure 2: Complete MHS system

Description	Specification
Safe Working Load dimension	6.0 x 6.0 x 8.0 m
Moonpool dimensions	7.2 x 7.2 m
Module dimensions	60Te capacity / 1-off
Operating Depth	Depth 1500 msw
Guide Wires	3-off 8 Te SWL
AHC Main winch	35 Te SWL
Tool Slot	4-off in a cross over design
Cursor system	Constant tension winch
Cursor Length	Deck elevation + 10.0 m, - 8.5 m
Tower Weight	250,000 kgs (estimated)
Push / pull units	60Te capacity / 2-off
Skidding pallets	60Te capacity / 2-off
Rotating pallet	60Te capacity / 1-off

Table 1 Description

The MHS is a four storey structure with its main operational components segregated from each other by the particular working level.

The deck level is directly accessed onto the back deck of the ship. The auxiliary hydraulic controls and basic electrical panel are mounted on this level. Internal to the MHS are three platforms which cover the moonpool. The central moonpool door is an extension of the skidrails and hinges down into the moonpool itself in the open position. The two side platforms are man riding and hinge upwards in the open position. All platforms are independently controlled.

Other modules located at deck level are:

1. Main winch HPU
2. Guide wire winch HPU
3. Deck skidding system
4. Auxiliary hydraulic controls
5. Interfacing panel controls

6. Emergency stop and clear coms control point
7. Moonpool flood lighting (3 off)

The Main Winch HPU is used to power up the main winch of the tower as is stored in a standard 20ft offshore container for easy storage and mobilization. It has two modes of operation which are Local Control (using paddle controller) Basic winch control only and Remote Control (using the Cabin Controls). The main winch HPU powers only the main winch component while the guide wire HPUs runs the skidding system as well.

The Guide Winch HPU is place in a different 20ft HPU and is used to operate all the three guide wire winches and has two modes of operation with local Control (using paddle controller) Basic winch control only and remote Control (using the Cabin Controls).It is also included in the Towers Emergency Stop system (3 in total for level 1)

Figure 3: MHS level 1

The skid system is used to transfer modules from the deck to inside the tower and then back to deck. It is a manually operated hydraulic load transfer system which shares no control features with the rest of the MHS. The skid system operator needs to be aware that he will have complete handling control of the load and will require specific instruction on this.

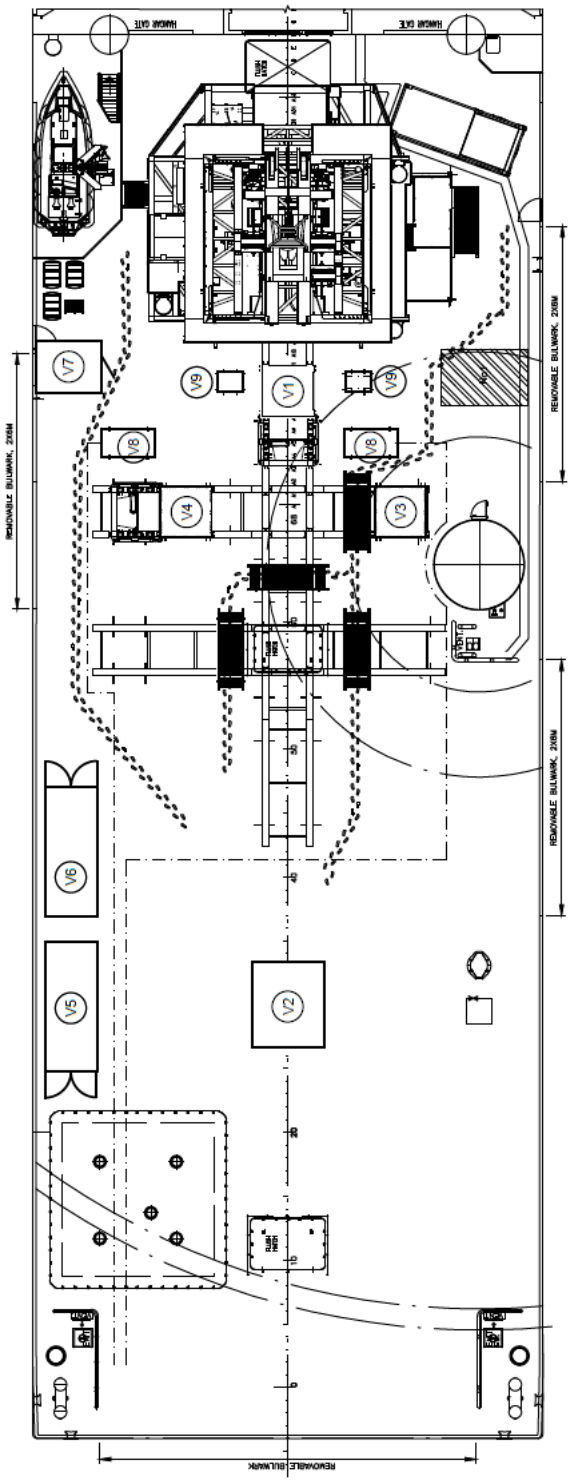


Figure 4: Deck layout on Fugro symphony

Figure 5: Skidding system level 1

The system has auxiliary hydraulic controls unit on the side of the MHS.These controls under normal conditions should not be used manually. The controls are mounted just off the port side rear leg next to the Lower Electrical Panel. Removal of the Stainless Steel cover gives access to the manual operation handles.

The Auxiliary controls are used for:

- Main Winch Position X/Y
- Guide Winch 1 Position X/Y
- Guide Winch 2 Position X/Y
- Guide Winch 3 Position X/Y
- Cursor Winch operation
- Moon Pool Doors
- Upper Tower Door

All of the above are controlled within the cabin under normal conditions

The deck level has interface control panel for the MHS lighting and subsea camera reel control. The Panel is used for the following functions:

- Operate the Tower Floodlights
- Operate the Tower Strip lighting
- Operate the Subsea Cable Reel 1 & 2
- Remote I/O & Integration Marshalling (Cabin Control)
- Power Distribution (Tower & Cabin)

The communication point for clear coms and emergency stop point is situated to the left of the Interface panel and easily accessible from the deck.

The first floor can be accessed from the deck level from both port and starboard side of the vessel. The following modules are present on the first floor:

1. Operator control cabin
2. 1-off 35t SWL active heave compensated (AHC) main lift winch
3. 3-off 8t SWL guide wire winches (1-off with AHC
4. 1-off 10t SWL constant tension cursor carriage winch
5. CCTV cameras

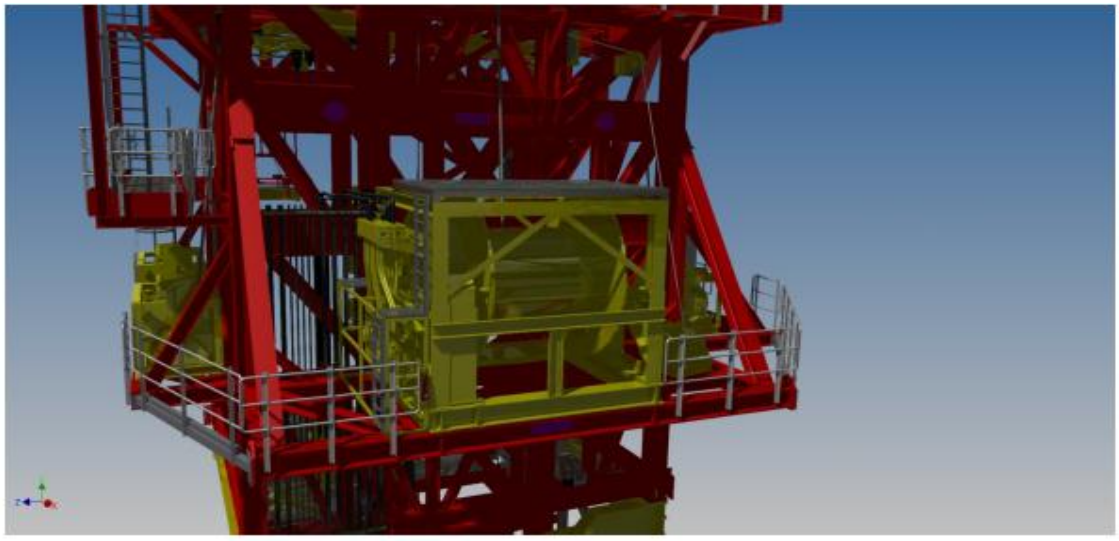


Figure 6: Main winch

There is full access to all winches for maintenance purposes. Stairways have been supplied to access the space between the two starboard winches and control cabin and portside winch. The operator control cabin is the main control centre for the MHS and serves as the hub for all the other Modules of the system. The cabin is environmentally controlled and ergonomically designed to keep the operator in readiness for system use over extended time frames. The Control Cabin is the only point that has “Clear Coms” and Emergency Stop Controls.

The main winch is the largest winch on the system and has its own hydraulic power unit (HPU). The winch is fitted with Active Heave Compensation as is rated to 35t SWL. This has an option to be upgraded to 60t SWL in the future. The three guide wire winches are all powered from a separate HPU. One of the guide wire winches (starboard side nearest the main lift winch) also has the capability of active heave compensation.

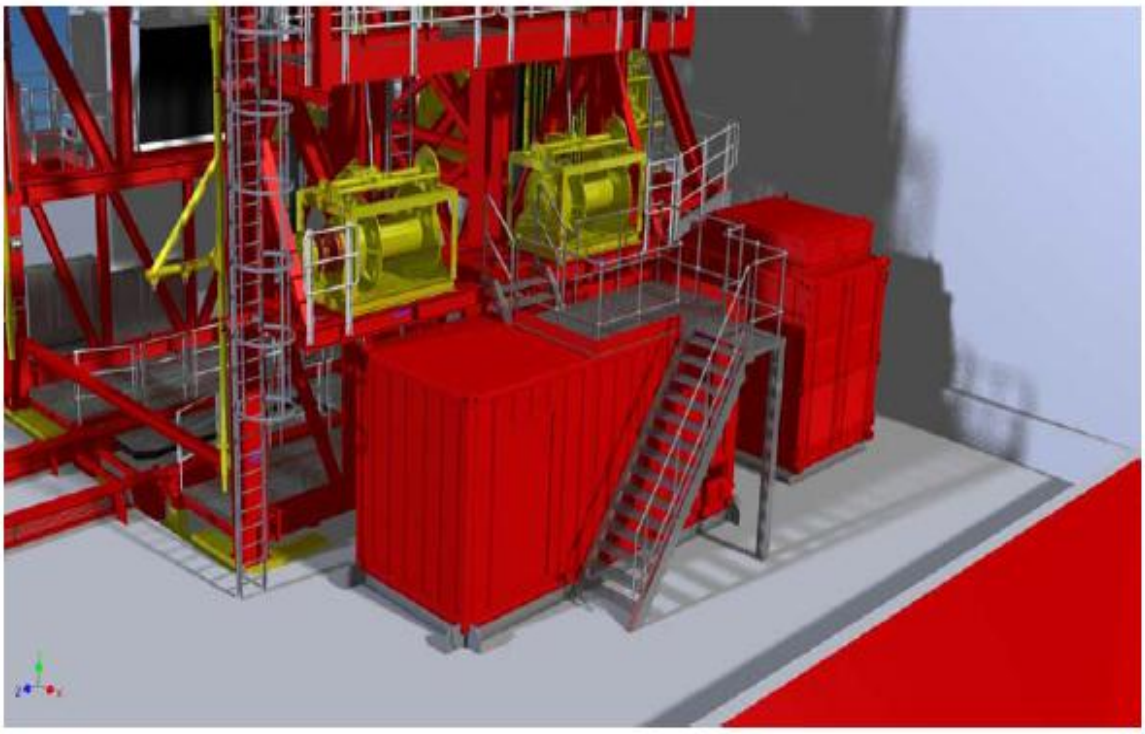


Figure 7: Guide wire winches

The third level is limited basically to the walkway between deck level and the top of the MHS. Halfway along the walkway is a hinged platform that can be used for maintenance purposes above tools to be deployed. The platform is raised and lowered via a hydraulic cylinder controlled from the operator cabin. This level also incorporates Emergency Stop and Clear Coms Control Point.

The top level is fitted with the main hang-off points for all winches. This incorporates all wire rope sheaves and positional assemblies. All hang-off points are adjustable in the X and Y axis from the operator control cabin. There is a walkway going all around the sheave assembly.

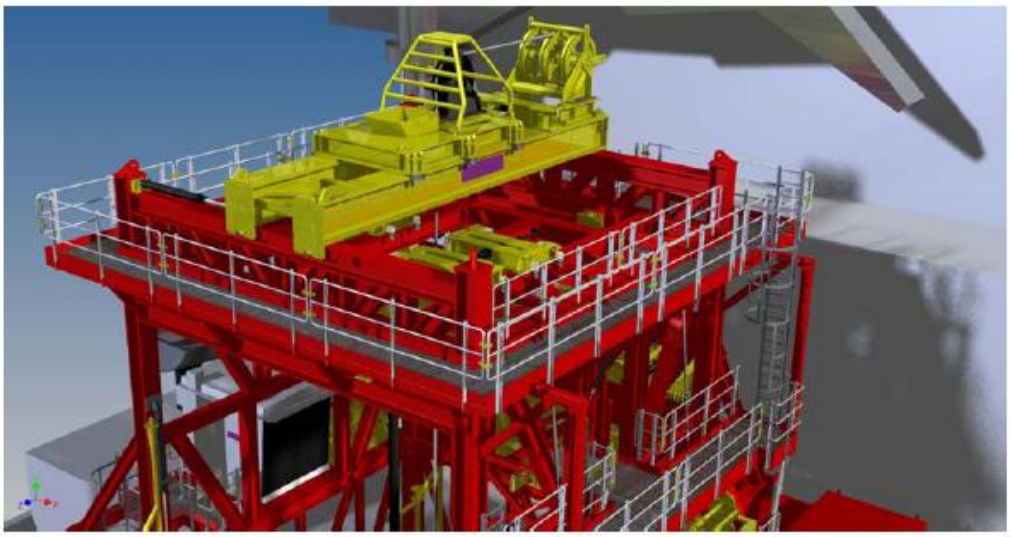


Figure 8: Top level

Figure 9: Overall view of the tower

There are lot of unique features of the MHS , which makes it state of art in the industry, are mentioned below

- Twin Beam incl. sheaves
- Wire fleet system / Floating sheave arrangement
- 60 Te overall structural capacity
- Modue size: 6x6x8.5m
- Main winch
- 35Te Capacity (prepared for upgrade to 60Te). This require two additional motors & a main HPU upgrade.
- Active Heave Compensated – 4,7m Hs@ 95% efficiency
- 1500m of Low Rotation Wire Ø56mm
- Spooling device on winch
- Floating sheave arrangement on top of tower for main wire control
- Modular winch location, May be moved to deck level

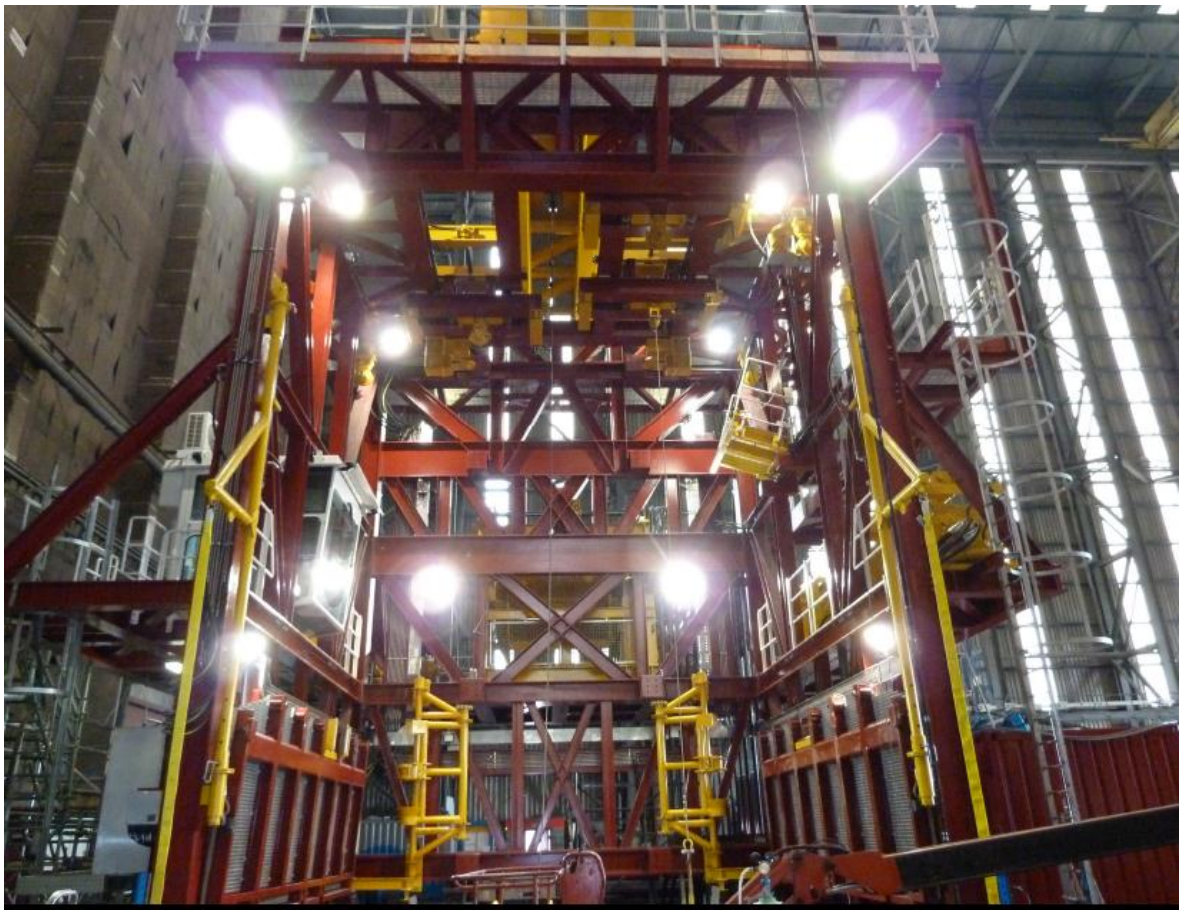


Figure 10: Tower seen from Front with side doors folded up

Some of unique operation features that help the system during offshore operation are :

- Guide post rests / storage locations 2 off
- Sheaves /hang off arms 2 off, 2.5Te capacity
- Hydraulically operated Monkey Platform
- Control cabin
- 10 point lighting into tower and to back deck
- Cameras overlooking top of tower twin beams, back deck & tower internals

4.2.Major subsystems – Description and evaluation:

4.2.a Main Sheave positional system assembly

Description and evaluation

The main sheave assembly is mounted on the top the tower and is the primary load point on the structure from which the load is hanging. There are two sheave wheels which are routing the main winch wire into the moon pool and to the subsea modules. Based on the location where it needs be the center position could be adjusted 0.5m.

The position is adjusted using hydraulic jacks which could push or pull the system in the direction. There are bearing pads and roller guide to to help and guide the relative motion of the sheave assembly with respect to the main tower. It also has conic receptacles for receiving the crane wires (the crane could be used instead of the main winch).

The MHS main sheave system enables the main winch wire to be offset from the centre position inside the tower ± 0.5m in both the X & Y plane.

The MHS main sheave system can be operated by 2 methods, the first method is via the control panel in the control cabin and the second method is via the hydraulic panel at deck level. The operating of the main sheave positional system via the hydraulically can be done by the hydraulic control panel situated at the front of the tower. The unit has 16 functions in the top draw with each function highlighted on the panel door below.

To operate the main sheave in the X axis (port to starboard) you would operate lever 7, up moves this towards starboard (-) moving the lever down will move the sheave toward the port side (+). To operate the main sheave in the Y axis (forward to aft) you would operate lever 6, up moves this forward (+) moving the lever down will move the sheave toward the aft of vessel (-).

The main sheave assembly is a very practical design which gives very good flexibility during the offshore operations. The features related to positioning are useful in accurate positioning of the

wires ropes and avoids unwanted stresses on the subsea assets that's getting lifted. The Teflon friction reduction pads are good designs but would need constant monitoring and maintenance.

The main sheave has seen severe rust issues during it short operation period and this highlights the use of proper maintenance techniques for the shaft. The shaft as it stands now is not fit for purpose. Also closer inspection revealed that the rollers for guiding the assembly are stuck at some locations which could be due to lack of lubrication. The rigidity of the roller are also questionable and have to be confirmed by the initial designers.

Figure 11: Main sheave assembly

General Recommendations for modification of the sheave positional system :
1. The O&M document for MHS (D-955-TEC-06) refers "For information on maintenance of the main sheave please refer to D-955-TEC-13 (main winch operator & maintenance manual)". D-955-TEC-13 is missing from Technip document system and need to be updated
2. Check the play for the guiding rollers. To be checked and maintained weekly
3. Modify the guiding arrangement for the vessel crane hook on the beams for more offshore friendly operations
4. It is recommended to move the sheave assembly before the load is being suspended, moving the sheave after the load is suspended could result in heavy unbalanced loading and could potentially damage the sheave, wire or the hydraulic movement system.
5. **Weekly maintenance-** check and reporting of the sliding area. Any irregularities/misalignment/debris/roughness could mean additional torque on the sliding block.
6. **Weekly maintenance**: The sheave shaft needs to be properly greased and checked weekly.
7. **Monthly maintenance-** check of Teflon pads in between the sliding surface for ingress of metal debris and about the general condition.

Stuck roller

Figure 12: Roller stuck

Description	• Roller stuck (No play relative to the beam flange) The roller are designed to move relative to the beam flanges as shown by the arrows in the pictures
Reason	• Lack of lubrication
Consequence	• Getting locked in place • Inability to take the uplift as planned for (integrity issues) • Damage to the beam and rollers
Solution (Recommendation)	• Lubricating the roller • Regular inspection

4.2.b Guide wire sheave positional system assembly

Description and evaluation

There are three guide wire trolley which carry the sheaves through which the guide wires are routed .There are three guide wire trolleys present on the tower with an option for adding an extra in the future . These guide wire trolleys could be moved on both X and Y plane making it possible to place them exactly in line with the guide posts in the subsea infrastructure. In case of a subsea module change out using the MHS the trolley could be adjusted exactly based on the subsea guide post. The ROVs could stab the guide wires in the guide post of the subsea trees. By placing the guide wire sheaves exactly over the subsea geometry, the recovery of the modules to the vessel becomes safer and easier as it would avoid the unwanted twist and stresses on the guide wire which otherwise could occur.

Figure 13: Guide wire sheave positional system

The guide wire sheave system enables the winch wires to be offset from the central location of the guide wire trolley to ± 0.5m in both the X & Y plane. A hydraulic jack screw arrangement is used to move the guide wire trolleys. One end of the jack screw is attached to a fixed reaction point on the MHS tower and the other end is connected to the movable trolley. As the screw is

operated the movable part slides relative to the fixed reaction point, There are Teflon pads placed between the sliding part and the tower main part. There are also side rollers placed to provide guidance and to take up the uplift forces. These rollers are design to have to have s light vertical play to avoid jamming of the systems. There are two separate screw system –one for each direction of the sheave movement.

The MHS guide wire sheave systems can be operated by 2 methods, the first method is via the control panel in the control cabin and the second method is via the hydraulic panel at deck level.

The operating of the guide wire sheave positional system hydraulically can be done by the hydraulic control panel situated at the front of the tower. The unit has 16 functions in the top draw with each function highlighted on the panel door below. To operate the guide wire sheaves it is as the main winch sheave but using different levers.

The operations of the guide wire positional system has revealed substantial design related problems which has resulted in the closer examination of the design and various modification. There are accessibility problems to check and modify the lower rollers in case the trolleys get stuck offshore. The system depends too much on close tolerance and could be doubtful to perform in the offshore dynamic environment. The tolerance needed is not available in the mill beams available in the market and have to be specially machined guiding beams. Also a differential friction on the beams could mean high torsion on the assembly. Constant monitoring for debris is needed. The sheave should not be operated with load hanging.

Recommendation:
1. The O&M document for MHS (D-955-TEC-06) refers " For information on maintenance of the main sheave please refer to D-955-TEC-09 (guide wire winch operator & maintenance manual)" . D-955-TEC-09 is missing from Technip document system and need to be updated
2. **Weekly Maintenance**: Weekly detailed inspection of the rollers during offshore operations- to be checked for play, lubrications , bending

3. **Weekly Maintenance**: The movement of the assembly is controlled by screw shaft. weekly lubrication and inspection of the shaft is advisable
4. **Weekly Maintenance**: The assembly is moving on the primary beams with nylon pads in between. Inspect the surface for irregularities before operating. Differential friction, on the primary beams will cause twisting of the assembly and subsequent jamming. It could also damage the nylon pads
5. **Monthly Maintenance**: of the nylon friction reduction pads , for damages and other mechanical inclusions
6. It's noted that the inspection of the inner rollers is difficult. Make proper inspection plans as this location is potentially a high maintenance area with very limited access. Take a manlift offshore in case of emergency
7. Make permanent lift plans for the guide wire trolley – to be used in case of emergency offshore
8. Disable the control for moving the beams when loaded to prevent accidental moving of the sheaves with load

Concern - Too much clearance on the rollers

Figure 14: Too much clearance on the rollers

Description	• Too much clearance between the roller and the beam
Reason	• Fabrication error • Tolerance of the roller beams • Lack of restrains • Due to misalignment / bending of the roller shaft on the opposite side support
Consequence	• Getting locked in place • Inability to take the uplift as planned for (integrity issues) • Torsion on the system
Solution (Recommendation)	• Machining the roller block for decreasing the tolerance • **Weekly inspection:** Need to monitor closely the tolerance s of the rolled beam used for guiding and run extensive fit up / operation test in the shop floor and then install the system on the MHS • Increasing the rigidity of the system

Concern - Twisting of the roller box

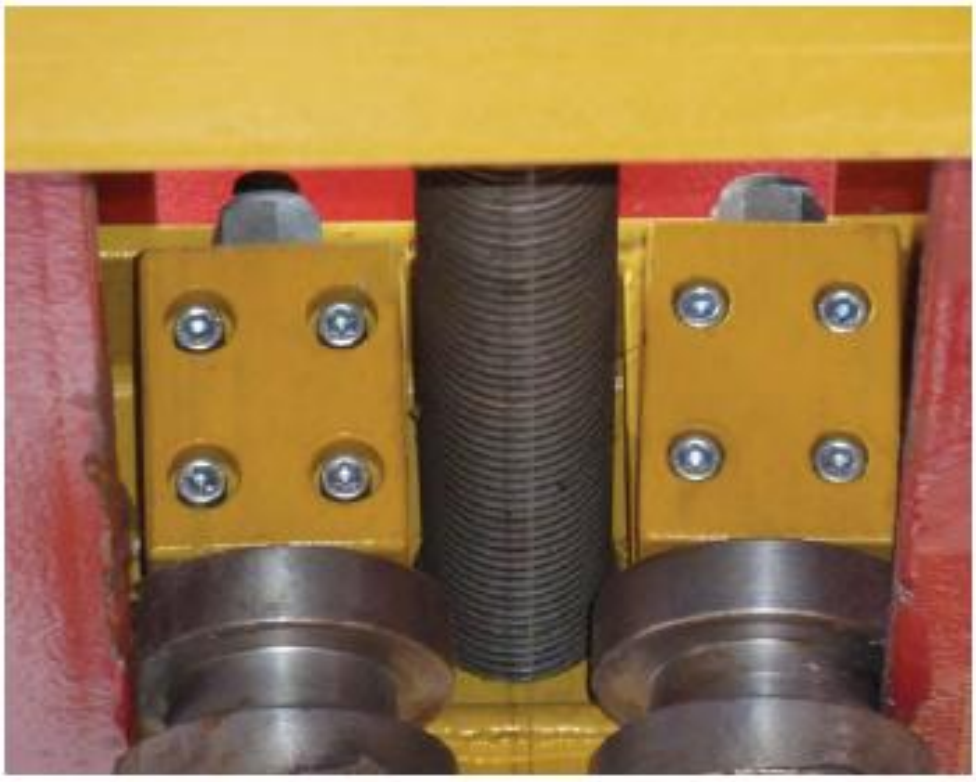


Figure 15: Twisting of the roller box

Description	• Twisting of the roller box
Reason	• Fabrication error • Tolerance of the roller beams • Lack of restrains • High horizontal force on the sheaves
Consequence	• Getting locked in place • Inability to take the uplift as planned for • Torsion on the system
Solution (Recommendation)	• Machining the roller block for decreasing /increasing the tolerance • Increasing the rigidity of the system

Concern -Different sets of rollers

Figure 16: Different sets of rollers

Description	• Different sets of rollers used on the same beam
Reason	• Fabrication error
Consequence	• Getting different plays on each block • Possible errors during maintenance
Solution (Recommendation)	• Changing out the roller box and using the standard set of roller boxes • Mark and record them carefully – making sure of individual maintenance plan for each of the rollers

4.2.c Sheaves for guide wire winches

The sheaves for the guide wires are the critical components in transferring the loads from the wired to the MHS primary members. The sheaves are designed based on the wire diameter and the minimum bending radius of the wires. Also sheaves are certified and with each permanent modification they have to be tested and recertified. The sheaves also have to be checked and maintained during its life time. The following section is the technical evaluation of the sheaves used in the MHS and the various maintenance schedules for the sheaves are proposed.

Description and evaluation

The sheaves are manufactured from machined steel and are grooved to accept 24mm SWR, the sheave runs on a stationary shaft supported by two spherical roller bearings. Lubrication to the sheave bearings is provided by a Greasomatic lubricator mounted in the end of the sheave shaft. The sheave shaft is supported by fabricated frame which is designed to allow mounting of the sheave to the MHS frame. The frame includes a retention bar which prevents the SWR from being able to leave the sheave groove.

The performance specification is as follows:

Rated Line Load: 10 Tonnes x 1.8 - 18 Tonnes (180 KN)

Sheave Groove: To suit 24mm SWR

Approximate Weight: 150 KGS

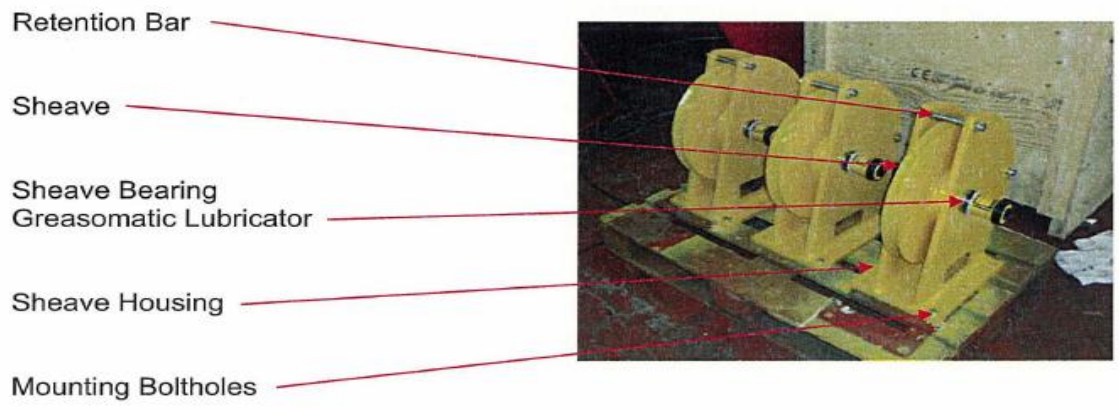


Figure 17: Sheaves

The sheaves are designed to be mounted on the MHS platform via a set of bolt holes drilled into the frames. The sheave should be installed to the MHS with bolts of grade 8.8 (or A4 Grade 70 if Stainless Steel). All bolts should be installed and correctly torque prior to any operation. The sheaves are suited for the purpose but a proper maintenance procedure is no in place. I recommend the flowing maintenance system

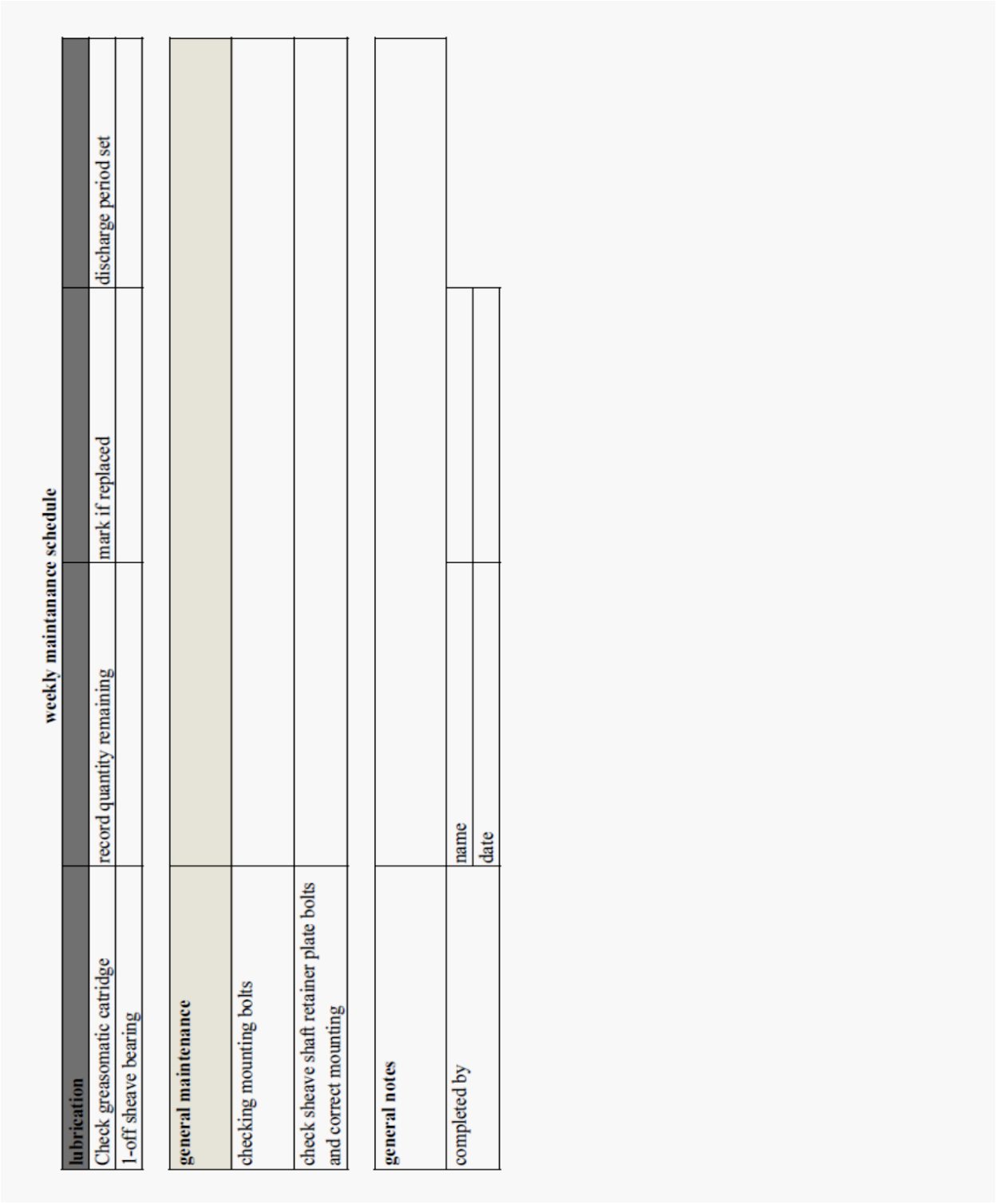
Recommended Maintenance procedure

No maintenance should be carried out on a sheave when the winch is operational, at all times when maintenance is being carried out the electrical supply to the hydraulic power unit must be isolated and locked off. When in operation the sheaves have rotating and moving parts, no attempt should be made to carry out work on a sheave when it is in operation.

The sheaves are designed to require minimal maintenance in order to maintain optimum operating performance. The bearings in the sheaves are lubricated using Greasomatic cartridge lubricators which provide a constant pressurized grease supply to the bearings.

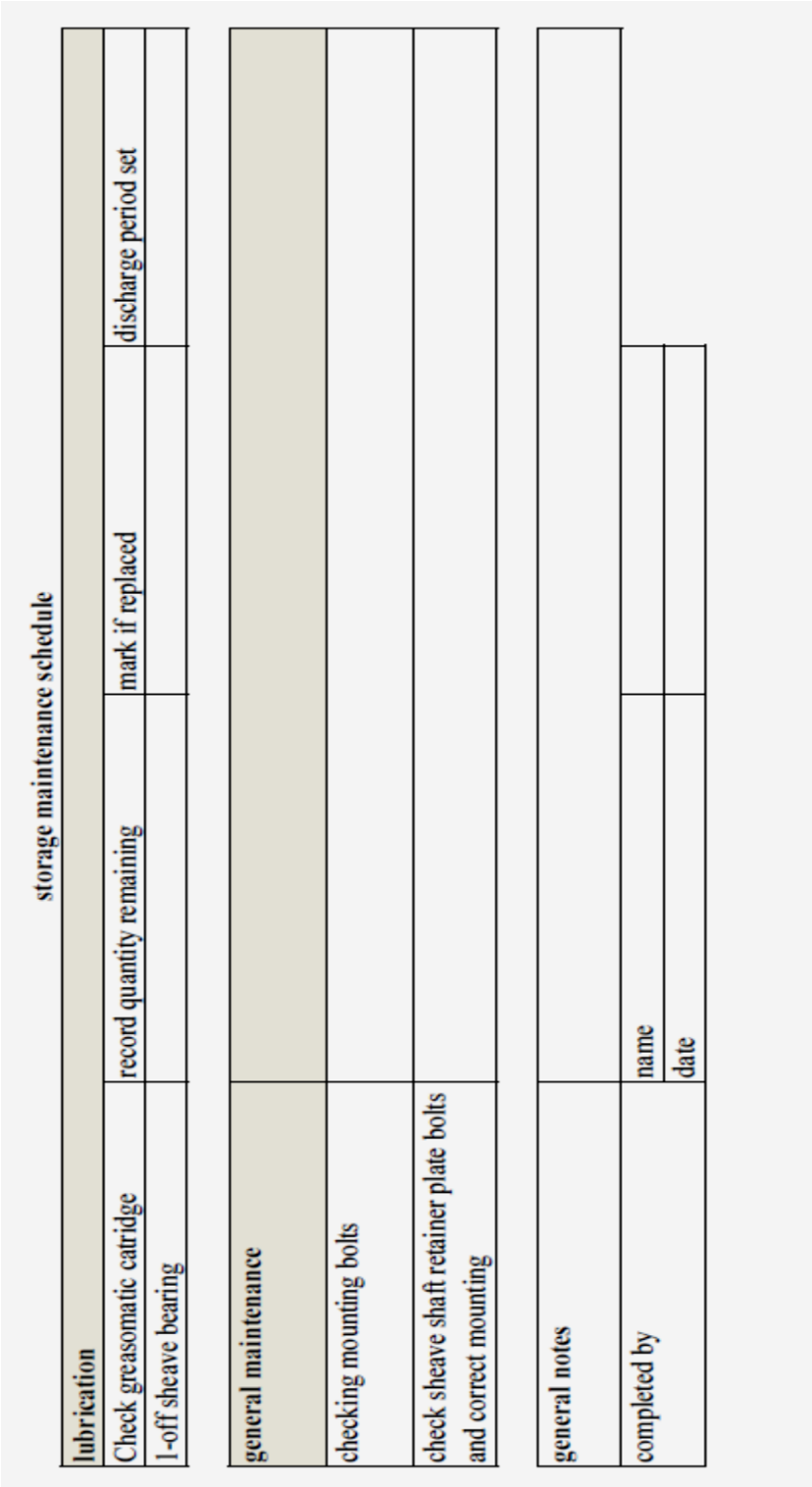
Maintenance Schedules : I recommend three maintenance schedules; the first is a weekly schedule which should be carried out routinely when the sheave is mobilized. The second schedule is to be used when putting the sheave into long term storage for a period of more than 3 months.

The third schedule is a five year overhaul schedule which must be carried out every five years from the date of manufacture irrelevant of usage. When the sheave is in storage after undergoing the storage schedule, no further maintenance is necessary; up on return to service a full monthly service should be carried out in order to prepare the sheave for operation. If the sheave has passed the due date for a five year overhaul then this should be carried out in place of the monthly maintenance upon return to service.



weekly maintanance schedule			
lubrication			
Check greasomatic catridge	record quantity remaining	mark if replaced	discharge period set
1-off sheave bearing			
general maintenance			
checking mounting bolts			
check sheave shaft retainer plate bolts and correct mounting			
general notes			
completed by	name		
	date		

Table 2 Recommended weekly maintenance schedule for sheaves



storage maintenance schedule			
lubrication			
Check greasomatic catridge	record quantity remaining	mark if replaced	discharge period set
1-off sheave bearing			
general maintenance			
checking mounting bolts			
check sheave shaft retainer plate bolts and correct mounting			
general notes			
completed by	name		
	date		

Table 3 Recommended storage maintenance schedule for sheaaves

5 year overhaul schedule

OVERHAUL MAINTENANCE			
disassemble sheave assembly			
inpect all components for signs for signs of wear and damage			

lubrication		
Check greasomatic catridge	record quantity remaining	mark if replaced	discharge period set
1-off sheave bearing			
general maintenance checking mounting bolts check sheave shaft retainer plate bolts and correct mounting			

general notes		
completed by	name	
	date	

Table 4 Recommended 5 year overhaul schedule for sheaves

The Greasomatic cartridges incorporate a gauge into the side of the cartridge which can be used to determine the quantity of oil remaining in the cartridge. The cartridge should be replaced when empty with a new cartridge of the correct grease type. The type of grease used on the sheave is EPM which is designed for bearings and bushes. See appendix 1 for details

The following torque settings should be used for the fasteners on the sheaves. The torque setting should be used for the standard M20 Grade 8.8bolts which are recommended. In the event of using stainless steel fasteners

Please revert to the manufacturers recommended torque settings

Description	Thread	Bolt Grade	Torque Nm
Mounting Bolts	M20	8.8	387

The following chart details the recommended lubricants for each sheave along with approximate quantities.

Location	Lubricant	Quantity
Sheave Bearings	Greasomatic Cartridge – Grease EPM	1

Concern -Damage to the sheave

Figure 18: Damage to the sheaves

Figure 19: On closer inspection

Description	• Damage to the sheave and wire run out protection pin (can be seen bend in the picture above
Reason	• GW running to the sheave during the trials
Consequence	• Need to inspect the sheave closely for the extent of damage • Bearing of the sheaves need to be checked
Solution (recommendation)	• Closer inspection –possible replacement

4.2.d Main winch wire sheave

Technical Description and evaluation

The sheave consists of a fabricated frame comprising of two end frames welded to a base plate. The main sheave is fabricated in steel and is machined to incorporate a groove for 56mm wire rope. The sheave is mounted on a load cell shaft and runs on two spherical roller bearings.

The sheave is locked in position with substantial end plates which bolt to both the end frames and locate the bearings supporting the sheave. The shaft is located by a locking collar at each end which locks the shaft in position and prevents rotation; the locking collars are bolted to the end frames.

The sheave is fitted with a chain drive, an encoder assembly is bolted to the side frame and is fitted with a pinion which is turned by the chain as the sheave rotates. The pinion is fitted to a shaft supported by two bearing inserts which take any side loading, the encoder plugs directly into the other end of the shaft.

There are two retention rollers fitted to the sheave assembly to prevent the SWR from leaving the groove of the sheave, in addition there are two alignment rollers positioned at the point where the SWR meets the sheave, these rollers are mounted on shafts supported by spherical roller bearings.

The main sheave is fitted with a Greasomatic lubricator which provides pressurized grease to the main sheave bearings. Each of the alignment rollers also fitted with a Greasomatic lubricator which lubricates the bearings.

The performance specification is as follows:
Rated Line Load: 60 Tonnes x 1.8 = 108 Tonnes (1060 KN)
Sheave Groove: To suit 56mm SWR
Approximate Weight: 1500 KGS
Load Cell Readout: 0-1500
Encoder Drive Ratio: 5:1

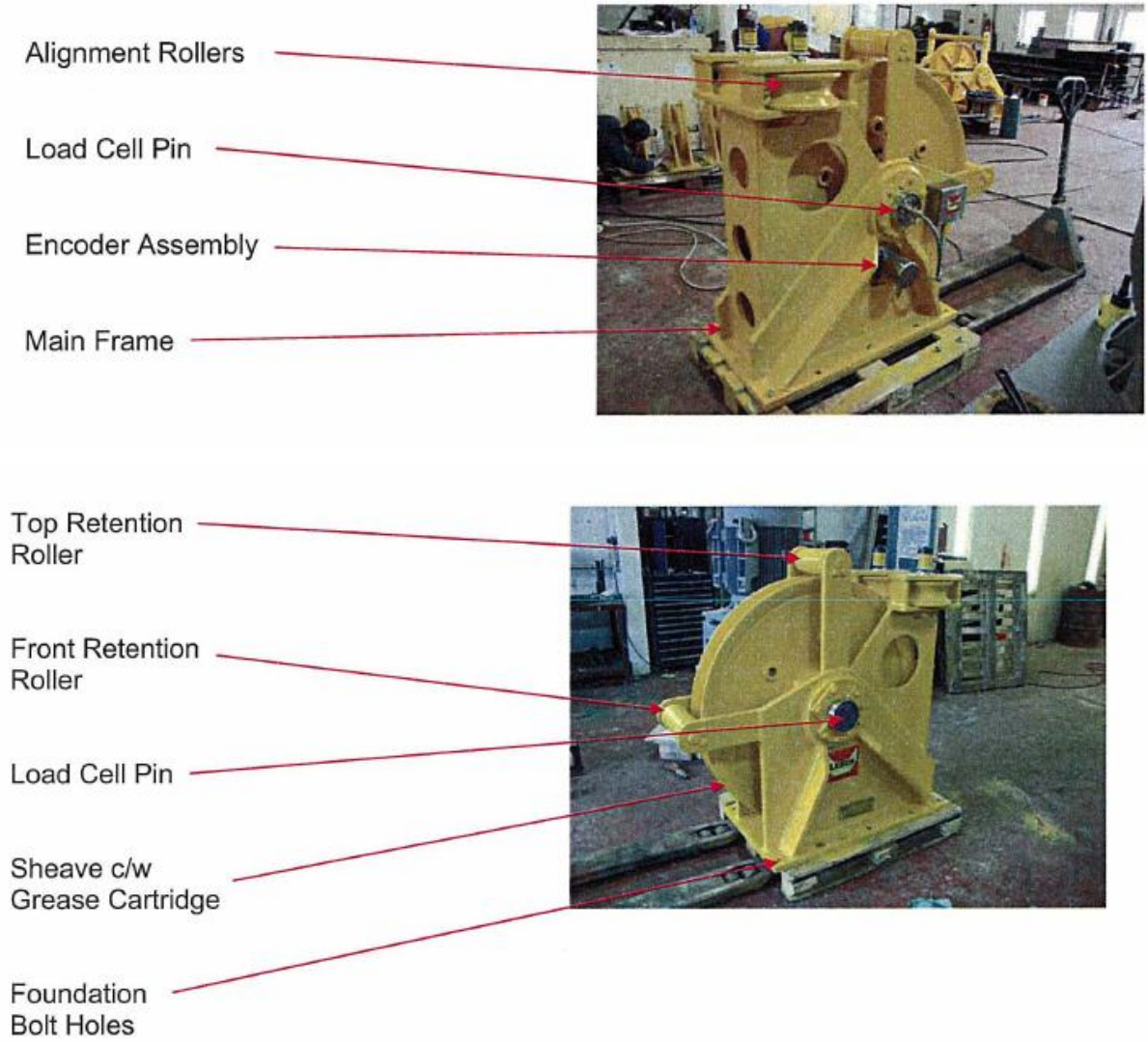


Figure 20: Main winch wire sheave

The sheave is designed to be mounted on the MHS platform via a set of bolt holes drilled into the base frame. It is important that the platform onto which the sheave is to be mounted is flat, preferably the mounting positions should be machined to ensure a level mounting surface across all of the pads.

The sheave should be installed to the MHS with bolts of grade 8.8 (or A4 Grade70 if Stainless Steel). All bolts should be installed and correctly torque prior to any operation of the winch. In

addition to the bolt holes a pair of collision chocks is supplied with the sheave and should be welded to the tower in the direction of the line load to prevent any movement on the foundation under line load.

Both the encoder and load cell need to be wired into the control system. Once the wiring aspects are completed it is then recommended that a full load test is carried out in order to verify the sheave connections and installation integrity. The load cell measures the resultant load at the pin, the load cell has been designed based on this resultant force and was calibrated at the factory to read 0 -1500 KN line load over its full range.

This range is field adjustable and we recommend that the load cell is calibrated against know weights ranging from 1 to 63 Tonnes which is the brake holding load of the main lift winch. The following torque settings should be used for the fasteners on the sheave. The base frame torque setting should be used for the standard M24 Grade 8.8 bolts which are recommended. In the event of using stainless steel fasteners please revert to the manufacturers recommended torque settings

Description	Thread	Bolt Grade	Torque Nm
Base Frame	M24	8.8	666
Shaft Locking Plates	M16	A4	162
Shaft Retainer Plates	M12	A4	66

The following chart details the recommended lubricants for the sheave along with approximate quantities.

Location	Lubricant	Quantity
Sheave Bearings	Greasomatic Cartridge – Grease EPM	1
Alingnment Roller Bearings	Greasomatic Cartridge – Grease EPM	2

Travelling sheave consists of a fabricated frame comprising of two end frames supported by a number of tie bars. Each end frame has a machined pad on the base for bolting of the sheave assembly to the tower. The main sheave is fabricated in steel and is machined to incorporate a groove for 56mm wire rope. The sheave is fitted with a Phosphor Bronze bush and slides on a steel shaft.

The shaft is installed between the two end frames and locked in position with substantial end plates which bolt to both the shaft and the end frame; this prevents any rotation of the shaft itself and increases the rigidity of the entire assembly. The sheave assembly also features 2-off retractable retention bars, these bars prevent the wire rope from leaving the groove in the sheave. The bars position can be adjusted to allow removal of the wire rope from the sheave for maintenance; this is achieved by slackening the locking bolts at each end of the bar and sliding it along the slot in the frame. The sheave is designed to travel along the shaft in order to accommodate the fleeting angle between the moon pool sheave and the spooling gear on the winch, the movement occurs automatically as a result of the line tension.

The performance specification is as follows:

Rated Line Load: 60 Tonnes x 1.8 = 108 Tonnes (1060 KN)

Sheave Groove: To suit 56mm SWR

Sheave Travel: 1080 mm

Approximate Weight: 1750 Kgs

The sheaves are found suitable for use. Travelling sheaves provides flexibility to operate at different locations

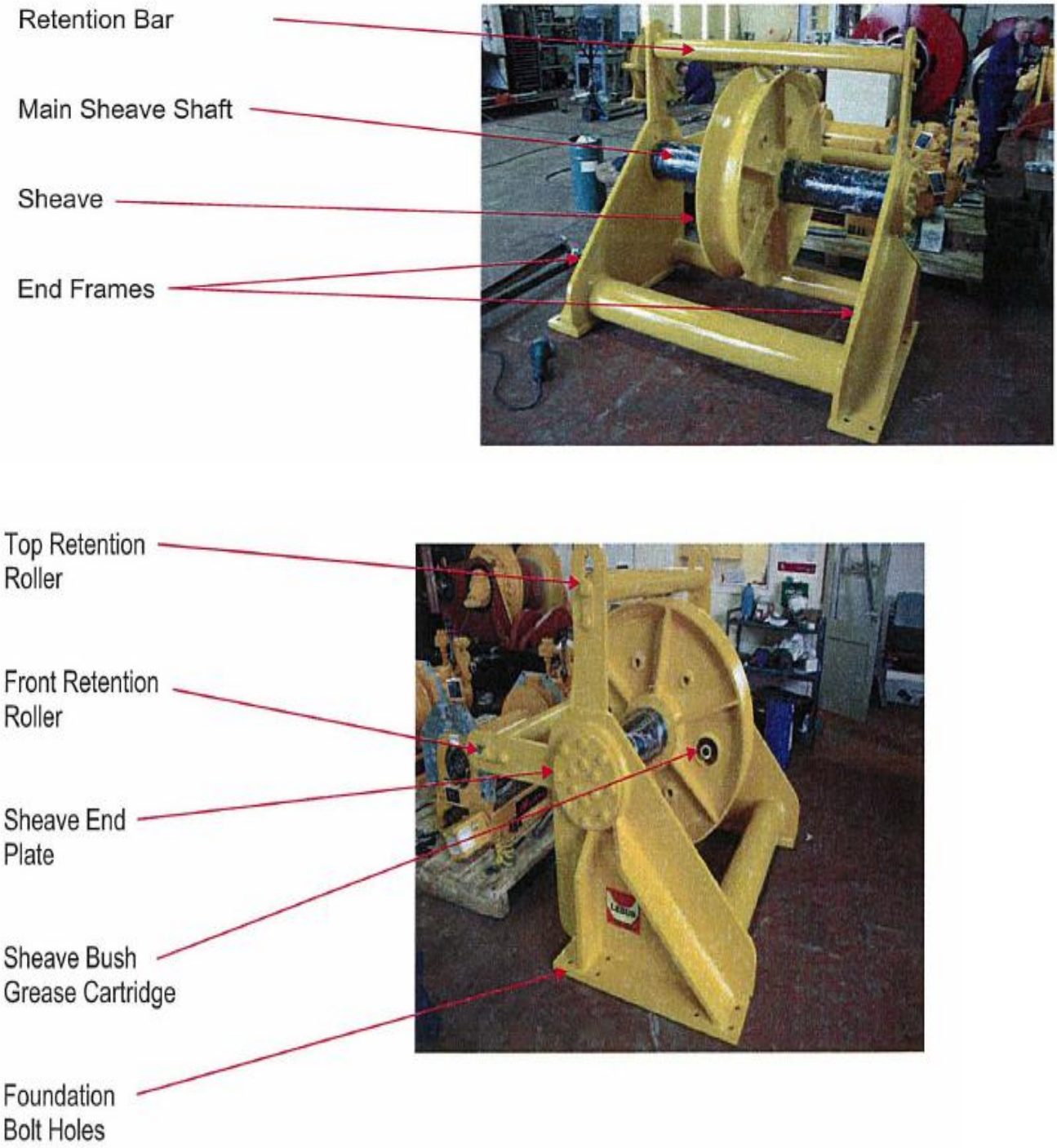


Figure 21: Travelling sheave

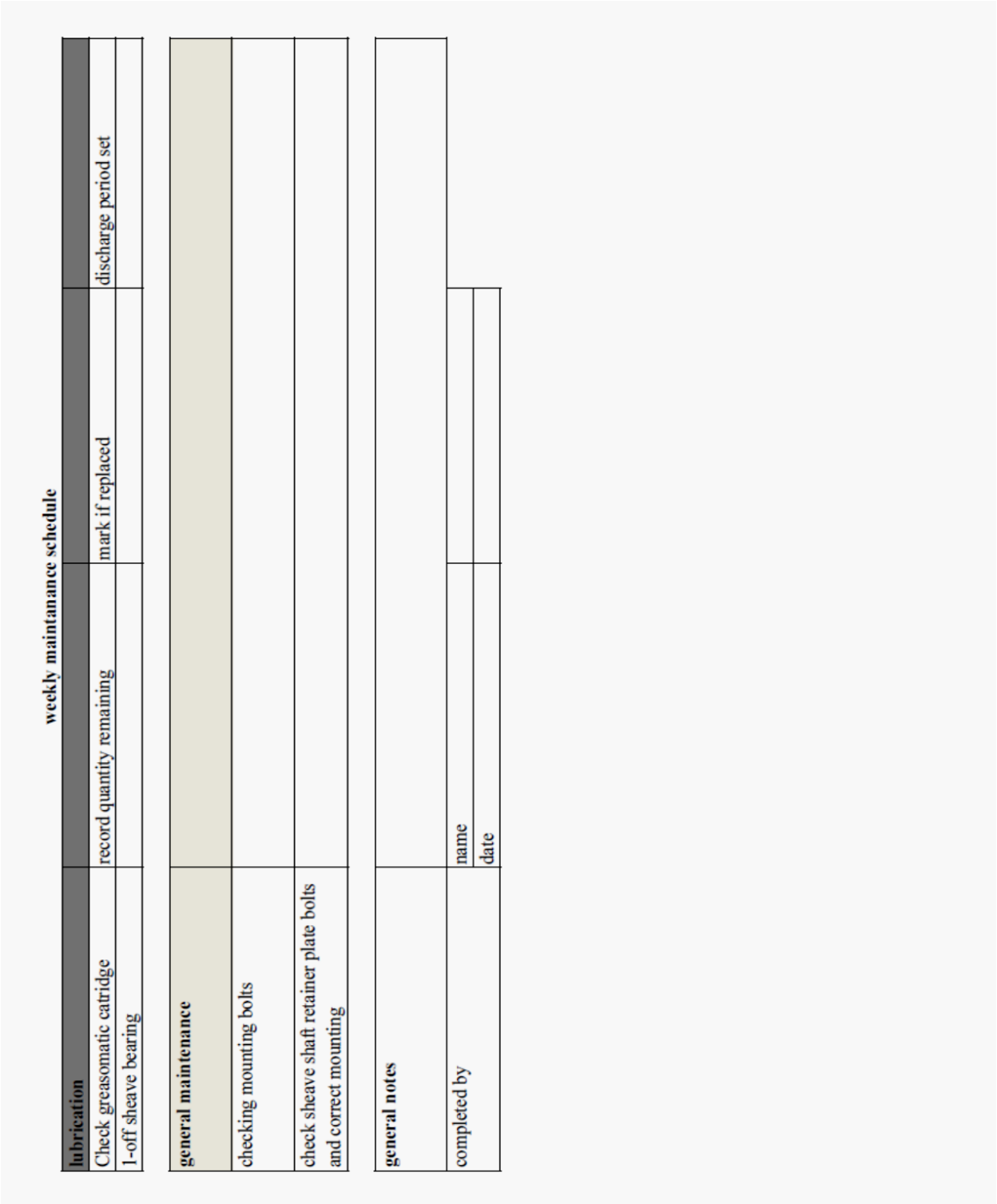
A pair of collision chocks is supplied with the sheave and should be welded to the tower in the direction of the line load to prevent any movement on the foundation under line load

Recommended Maintenance Procedure

We have provided three maintenance schedules, the first is a weekly schedule which should be carried out routinely when the sheave is mobilized where the lubrication and bolting is checked.

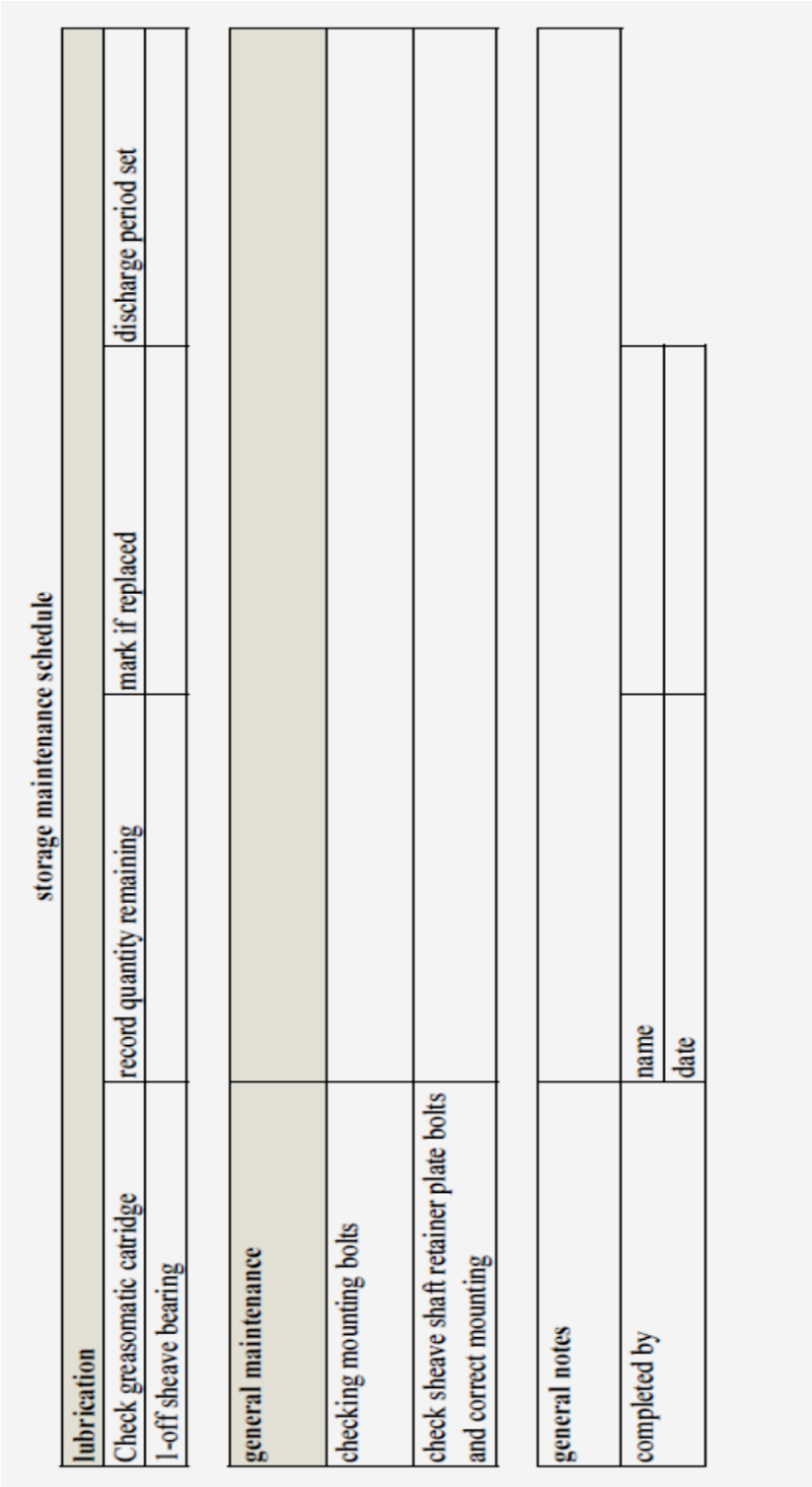
The second schedule is to be used when putting the sheave into long term storage for a period of more than 3 months where the lubrication is checked with the bolts and also wrap sheave shaft in protective film after greasing to prevent grease loss and contamination.

The third schedule is a five year overhaul schedule which must be carried out every five years from the date of manufacture where remove end plates and withdraw Sheave shaft - inspect for signs of wear Or damage and replace sheave bush.



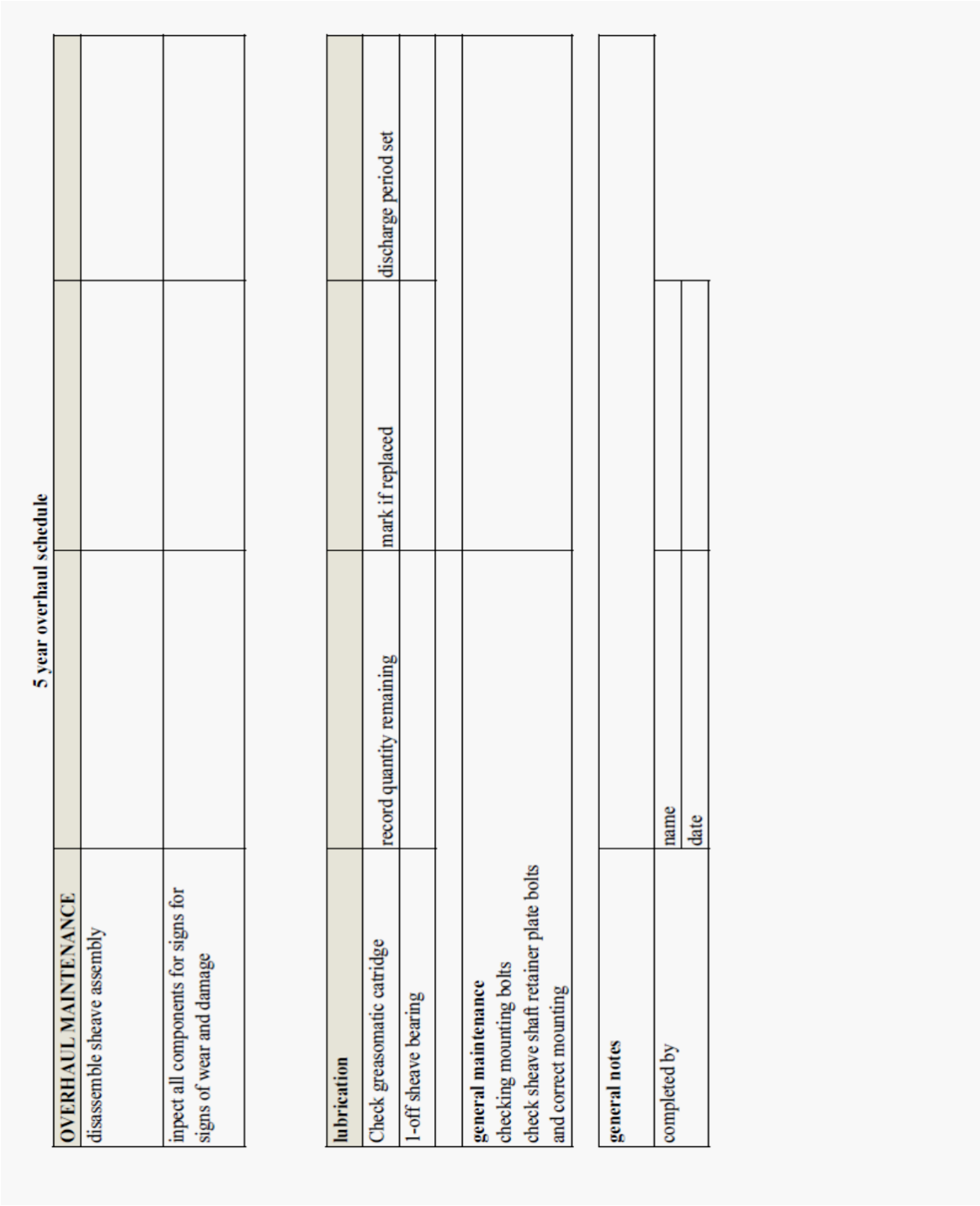
weekly maintanance schedule			
lubrication			
Check greasomatic catridge	record quantity remaining	mark if replaced	discharge period set
1-off sheave bearing			
general maintenance			
checking mounting bolts			
check sheave shaft retainer plate bolts and correct mounting			
general notes			
completed by	name		
	date		

Table 5 Recommended weekly maintenance schedule for sheaves



storage maintenance schedule			
lubrication			
Check greasomatic catridge	record quantity remaining	mark if replaced	discharge period set
1-off sheave bearing			
general maintenance			
checking mounting bolts			
check sheave shaft retainer plate bolts and correct mounting			
general notes			
completed by	name		
	date		

Table 6 Recommended monthly maintenance schedule for sheaves



5 year overhaul schedule

OVERHAUL MAINTENANCE			
disassemble sheave assembly			
inpect all components for signs for signs of wear and damage			

lubrication		
Check greasomatic catridge	record quantity remaining	mark if replaced	discharge period set
1-off sheave bearing			
general maintenance checking mounting bolts check sheave shaft retainer plate bolts and correct mounting			

general notes		
completed by	name	
	date	

Table 7 Recommended 5 yearly overhaul maintenance schedule for sheaves

Corrosion on the travelling sheave shaft

Figure 22: Corrosion of shaft

Description	• Corrosion on the travelling sheave shaft
Possible Reasons	• Lack of maintenance of the system • Wrong material used in the fabrication
Consequence	• High risk to damage the sheave /shaft /wire
Solution (recommendation)	• Modify the shaft in the workshop and machining • Proper greasing and maintenance of the shaft • Replace the shaft

4.2.e Wire ropes

Description and Evaluation

Wire ropes are the most vital component for the safe offshore operation as it's the main and only link carrying the loads. The offshore industry has recognized the importance of integrity management of the wires and for the MHS which relies heavily on the winch wires the management of the wires becomes significant.

Wire rope forms an important part of many machines and structures. It is comprised of continuous wire strands wound around a central core. There are many kinds of wire rope designed for different applications. Most of them are steel wires made into strands wound with each other. The core can be made of steel, rope or even plastics. ire ropes (cables) are identified by several parameters including size, grade of steel used, whether or not it is preformed, by its lay, the number of strands and the number of wires in each strand. A typical strand and wire designation is 6x19. This denotes a rope made up of six strands with 19 wires in each strand. Different strand sizes and arrangements allow for varying degrees of rope flexibility and resistance to crushing and abrasion. Small wires are better suited to being bent sharply over small sheaves (pulleys). Large outer wires are preferred when the cable will be rubbed or dragged through abrasives. (Turner and Barne, 2012)

The International Marine Contractors Association (IMCA) in its Guidance on Wire Rope Integrity Management for Vessels in the Offshore Industry (IMCA SEL 022, 2008) provides guidance on the necessary elements of an integrity management system required to achieve an acceptable level of ongoing safety for the use of wire ropes in a marine environment.

The wires are sources of potential high residual energy and could lead to 'whipping 'effect of the wires and the personnel working on it need to take extra protection and barrier of the area from unwanted personnel. Also specific risk assessment could be done based on the history of operations

The documented management of a wire rope includes selection, certification, storage, thorough examination and inspection, history of use, records of damage or wear and final discard should

be recorded. Wire management systems need to be developed and put in place in Technip as it MHS doesn't fall under TMOS scope which usually does the asset management of Technip fleets assets.

Tools specified by IMCA for the management for wire ropes

- automatic discard (replacement) after a set period, e.g. twelve months;
- thorough examination and inspection;
- non-destructive examination;
- destructive tensile testing; and
- range of post-retirement activities which will provide feed-back into the integrity management system.

The maintenance of winch machinery, control systems, sheaves, swivels, rollers or any other mechanical equipment also forms a large part of the maintenance activity . but special attention needs to be given to wires as they are the main components going subsea . Wire rope lubrication should be carried out periodically under a vessel's wire rope integrity management procedures, which should be part of a vessel's PMS (IMCA SEL 022, 2008). For the MHS , as its not the integral part of the vessel, the wire management, along with other system , need to be addressed by technips internal procedures

IMCA ask to ensure that the wire rope is, as appropriate, lubricated and covered with a service dressing, particularly on those lengths which pass through and around sheaves and/or are used subsea.

Any lubrication and service dressing should be compatible with the original lubricant used by the wire rope manufacturer. Manufacturers should advise whether pressure lubrication is suitable for a specific wire or, if not, what method of lubrication and lubricant is recommended (IMCA SEL 022, 2008),

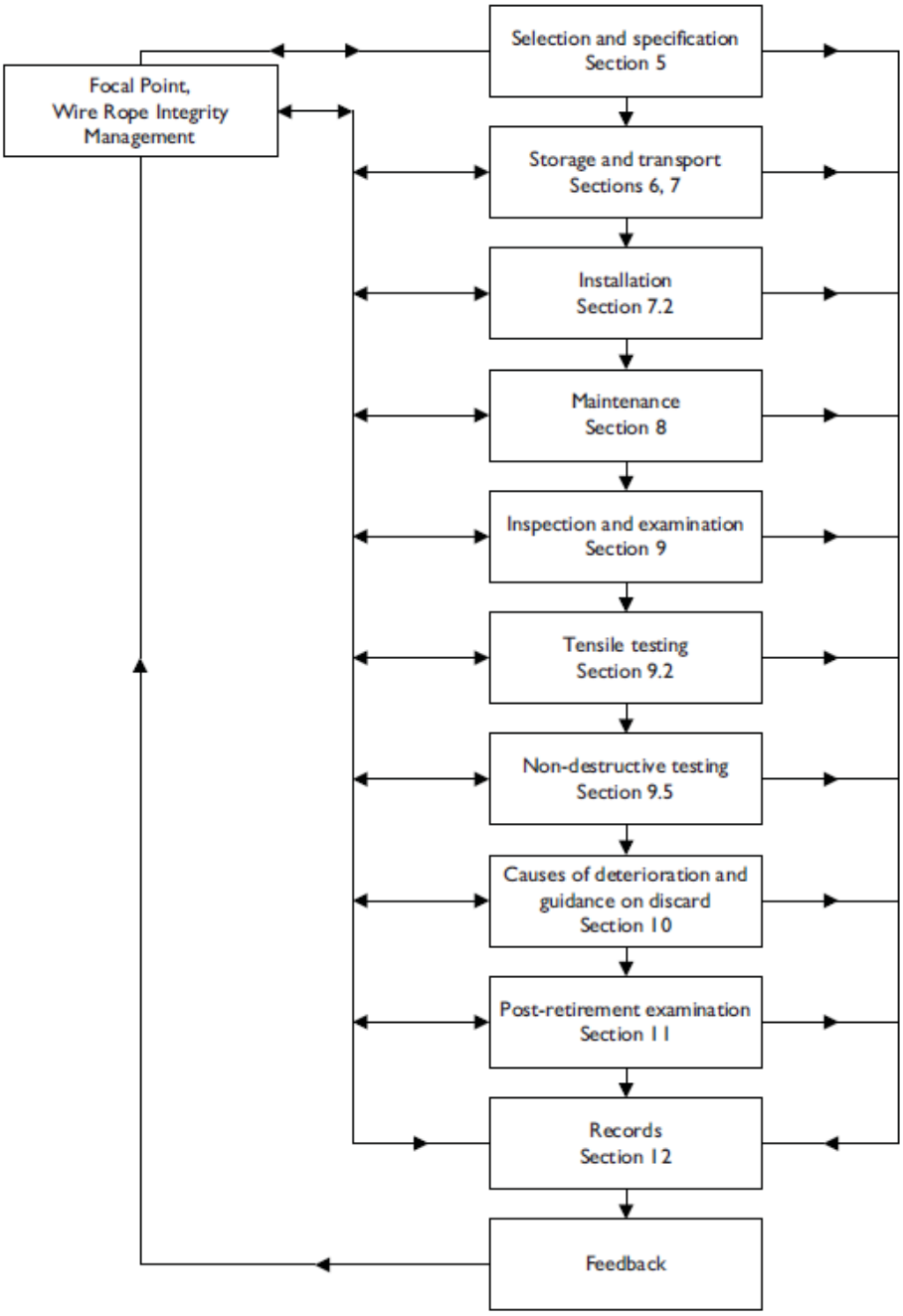


Figure 23: Overview of wire integrity management (IMCA SEL 022, 2008)

Tools	Advantages	Disadvantages
Automatic periodic discard	• Cost-effective compared to other tools for low-value wire ropes • Scheduling advantage	• Discarding wire rope which remains fit for further service
Thorough examination and inspection	• Primary integrity tool • Principal means of locating mechanical damage/degradation • Statutory requirement	• Difficult for examiner to retain focus on long length of wire rope • Lack of 360° view or multiple examination runs required • Visual examination is restricted to the outside of the wire rope • Access to all parts of the wire rope not always possible • Spooling requirements
NDE	• A screening tool to supplement visual inspection that identifies areas of the wire rope which require more detailed examination • Indication of internal condition • Permanent record • Comparability of records	• Availability of experienced personnel • Spooling requirements • Not always logistically practicable • Reliability depends on: – competency and experience of operator and analyst – suitability or performance limitations of equipment – access to all of the wire rope
Tensile testing	• Indication of residual strength • Demonstrates maintenance of FoS • Comparability of test bed results, year on year	• Accuracy/range of results • Location of cutback not necessarily the weakest part of the wire rope • Test sample preparation: – handling – serving – cutting – transportation – test bed availability and location
Post-retirement dismantling and condition checking	• Positive evidence of strength/ condition when retired • Scientific/repeatable/controlled conditions • Numerous processes available • May provide useful information for the selection of the most suitable wire ropes • Builds up empirical evidence of effectiveness of integrity management system	• None

The integrity assurance toolbox (IMCA SEL022,2008)

The lay of a wire rope is the direction that the wire strands and the strands in the cable twist. There are four common lays: right lay, left lay, regular lay and lang lay. In a right lay rope the strands twist to the right as it winds away from the observer. A left lay twists to the left. A regular lay rope has the wires in the strands twisted in the opposite direction from the strands of the cable. In a lang lay rope, the twist of the strands and the wires in the strands are both twisted the same way. Lang lay ropes are said to have better fatigue resistance due to the flatter exposure of the wires. (Turner and Barnes, 2012). With reference to the during the maintenance its important to connect wires in the future with the same kind of wires as in the winch which would otherwise could lead to the opening up of wires . The use of swivels for connecting the wires should be addressed after careful risk analysis .

There are two types of wire rope lubricants, penetrating and coating. Penetrating lubricants contain a petroleum solvent that carries the lubricant into the core of the wire rope then evaporates, leaving behind a heavy lubricating film to protect and lubricate each strand. Coating lubricants penetrate slightly, sealing the outside of the cable from moisture and reducing wear and fretting corrosion from contact with external bodies. For the winch wires, the first methods seems suitable as it would ensure that the cores are well lubricated. This could be followed with subsequent coating on the outside which would waterproof (critical as the wires goes subsea) and protect the surface. The selection of the lubricants needs to be based on the wire specifications

Recommendations:
1. The state of lubrication of the wire seems poor. Need to re lubricate the wires.
2. Any lubrication and service dressing should be compatible with the original lubricant used by the wire rope manufacturer. Manufacturers should advise whether pressure lubrication is suitable for a specific wire or, if not, what method of lubrication and lubricant is recommended. Pressure lubrication needs to be carried out, with care, by operators trained in using the equipment. (IMCA SEL 022,2008)

3. During the testing phase where additional smaller wires need to be attached to the bigger wire few points need to be noted • Lay of the wire used • Connection type used – careful use of Chinese fingers • Minimum rounds around the winch drum – calculated from the winch property and the maximum loads
4. As the wire ropes are removed and shortened from drums for maintenance and testing purposes, it is important to re-spool them correctly.
5. Also alarms, cut-outs and other control equipment will require to be preset and checked.(IMCA SEL 022, 2008))

Figure 24: Lubricating the wires (on construction vessel Skandi arctic)

4.2.f Main winch

The main winch is the main machinery of the MHS which is used to deploy and recover the modules into the subsea infrastructure. The winches which are the core elements for the crane are in focus in terms of maintenance and safety.

Description and evaluation

The winch comprises of a fabricated steel base frame onto which are mounted machined end frames. The drive end frame is fitted with three pinion drive assemblies and is pre machined to accept two additional pinion drives in the future in order to increase the duty capacity of the winch. Each pinion shaft is fully supported in spherical roller bearings and is driven by a Hagglunds Drives Compact series hydraulic motor complete with a multi plate hydraulic release failsafe disk brake. The pinions drive a spur gear bolted directly to the drive end of the drum, the non drive end is supported in a bearing housing mounted onto the non drive end frame.

The drum is fitted with a Lebus Grooved sleeve. An upper frame is mounted to the end frames which carry an automatic spooling device, the spooling device is driven via chains from the main drum. The upper frame also supports a hydraulic distribution manifold which is installed above the drive motors, the manifold accepts 8-off 2" pipes from the incoming supply and provides 12-off 1 1/4" outlet pipes to drive the motors. The brake supplies, flushing supplies and case drains are also distributed by the manifold. The main winch can be operated from 2 areas within the MHS.

- HPU via scan-reco system
- Control cabin via joysticks

The MHS main winch has been designed and manufacture to run in active heave compensated mode, constant tension and standard mode. The AHC mode enables the unit to run in sea states of up 4.5m with a 95% accuracy.

The performance specification as supplied with three motors fitted is as follows:

Pull (1 st Layer): 55 Tonnes @ 0-45 m/min

Pull (8th Layer): 35 Tonnes @ 0-60 m/min

AHC Mode (1 st Layer): 0-126 m/min

Brake Holding Load: 180% Duty

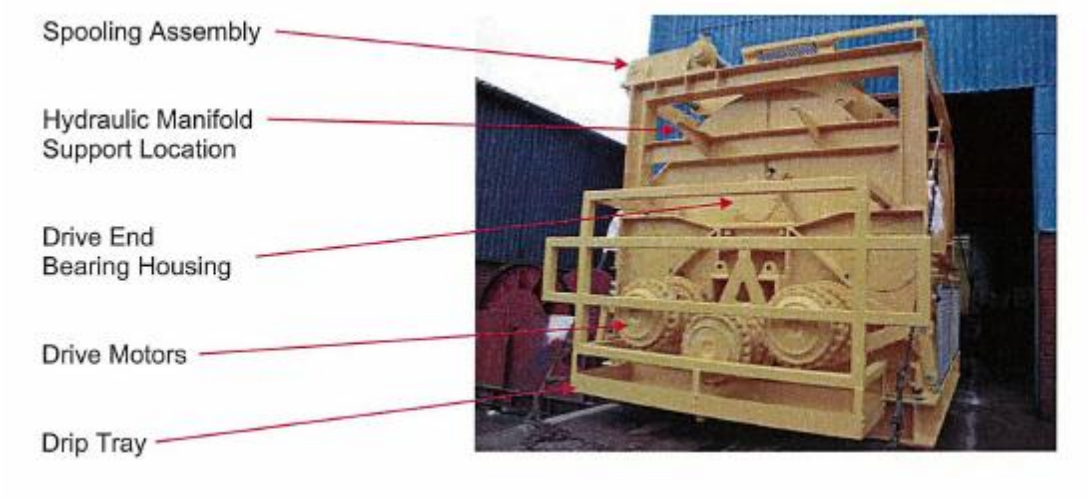
Drum Capacity: 1500 M of 56 Dia SWR in 8 Layers

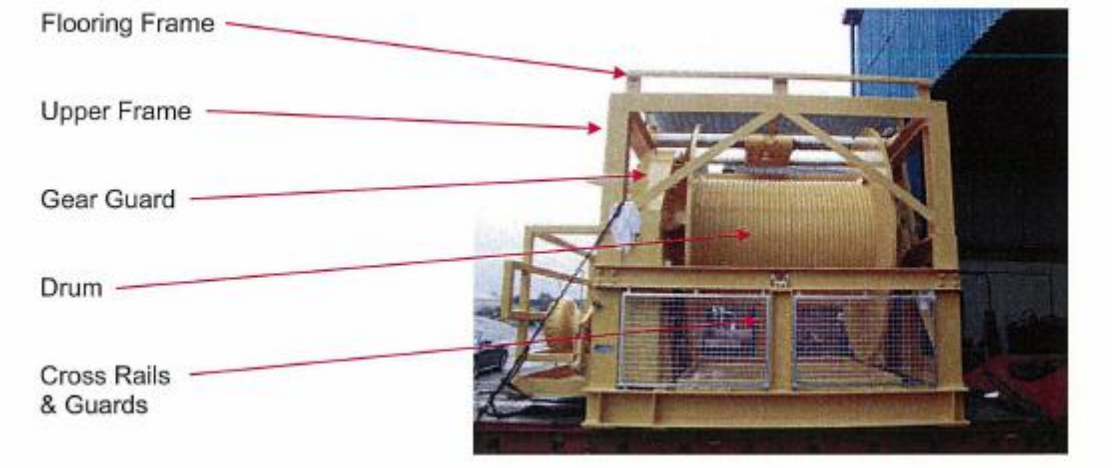
Max Drum Capacity: 2000 M of 56 Dia SWR in 10 Layers

Power Required (Duty): Approx. 450 KW

Power Required (AHC): Up to 1600 KW

Approximate Weight: 24000 KGS (Excl. Wire Rope)





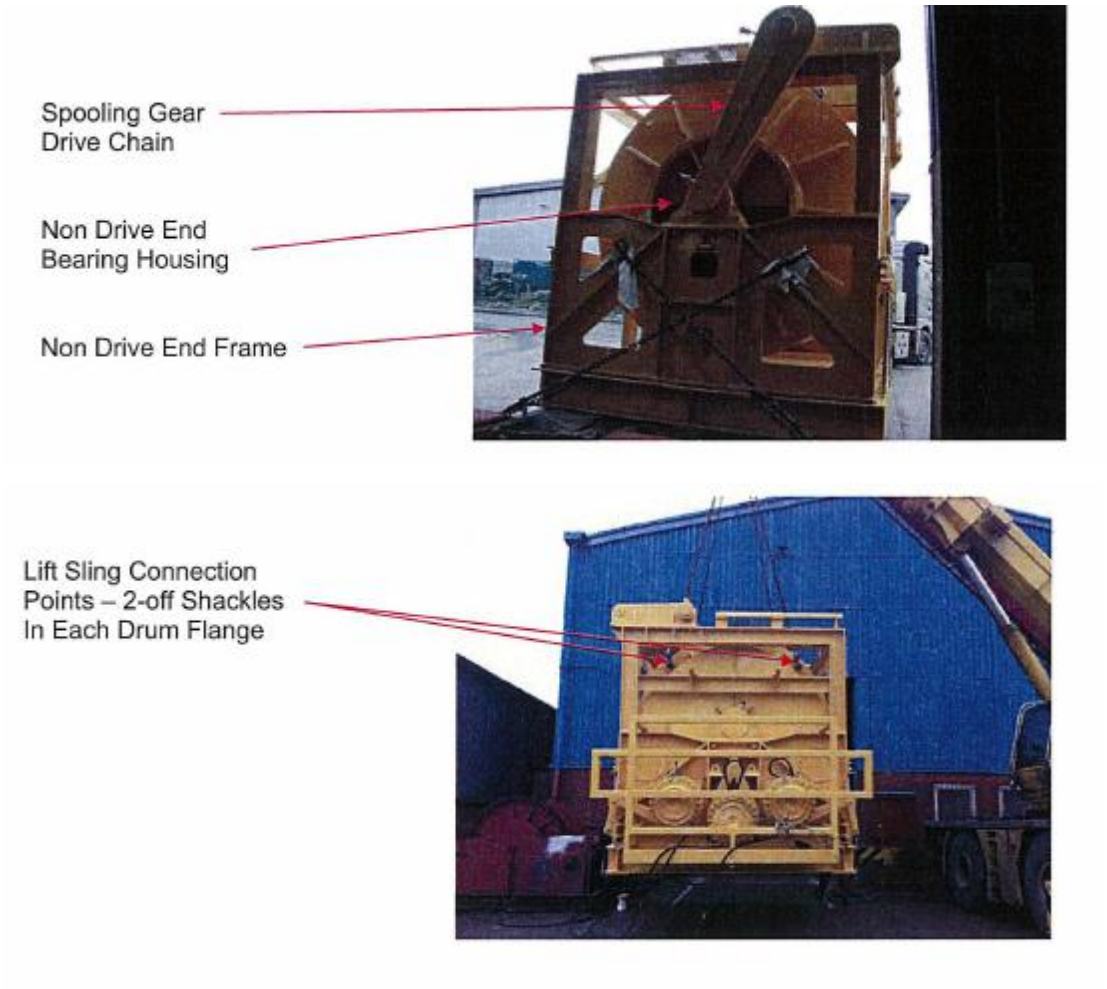


Figure 25: Main winch

The winch is designed to be mounted on the MHS platform via a set of bolt holes drilled into the base frame. It is important that the platform onto which the winch is to be mounted is flat, preferably the mounting positions should be machined to ensure a level mounting surface across all of the pads.

The winch should be installed to the MHS with bolts of grade B.B (or A4 Grade 70 if Stainless Steel). All bolts should be installed and correctly torque prior to any operation of the winch.

Once the winch is installed the gear alignment should be checked to ensure correct alignment and backlash. If necessary the main frame should be shimmed in order to achieve the correct settings. The hydraulic connections should be carried out in accordance with Hagglunds schematic. The winch is supplied ready for operation however the spooling shafts are covered during transportation and installation to prevent damage. The spooling drive shafts should be

uncovered, cleaned and covered with the correct grease as detailed in the maintenance section. The winch should initially be run at low load to ensure all controls and systems are functioning correctly. It is then recommended that a full load test is carried out in order to verify the winch connections and installation integrity.

The drum is fitted with a Lebus grooved sleeve to aid correct spooling of the wire rope, the wire rope termination transfers through the flange of the drum, there are two cable anchors which need to be installed to fasten the cable to the drum. The wire rope should be installed onto the winch using a back tension rig. It is important that the tension applied is in accordance with the wire rope manufacturer's specification. Note: The drum termination is not load bearing, a minimum of 5 wraps must remain

The winch is operated using a hydraulic power unit supplied by Hagglunds Drives (Bosch Rexroth Ud). The hydraulic power unit provides control of all winch functions including the brakes.

This winch is designed for operation in a safe zone, it is not intended for use in an Atex classified zone. No maintenance should be carried out on the winch when the drum is turning, at all times when maintenance is being carried out the electrical supply to the hydraulic power unit must be isolated and locked off.

When in operation the winch has numerous rotating and moving parts, where possible these items are guarded but certain areas such as the spooling gear and rope exit area are unguarded, no attempt should be made to enter these areas when the winch is in operation.

The winch is designed to require minimal maintenance in order to maintain optimum operating performance.Where possible all bearings and bushes are lubricated using Greasomatic cartridge lubricators which provide constant pressurized grease supply to the bearings.In addition to the bearings and bushes the spur gears and spooling shafts require a manual application of grease in order to ensure correct lubrication and corrosion protection.

Looking at the accident related to winch maintenance, the Priettman Sea Lion 60D diesel hydraulic pedestal crane incident is focus on the maintenance of the braking system . The boom was placed directly above the boom rest at an angle of approximately 45 degrees. The crane operator switched off the diesel engine when the crane the boom lowered in an uncontrolled

manner, resulting in considerable damage to the boom when it made contact with the rest. The boom luffing winch unit, situated above the crane cab, was torn from its mounting pedestal, debris from the winch unit fell onto the deck which had the potential to inflict fatal injuries . Even thought the MHS doesn't have the boom system ,the incident highlights the need for a regular inspecton of the raking system s on the winches.

Recommendations maintenance schedule

I recommend for four maintenance schedules, two of the schedules are weekly and monthly schedules which should be carried out routinely when the winch is mobilized. The third schedule is to be used when putting the winch into long term storage for a period of more than 3 months.

The fourth schedule is a five year overhaul schedule which must be carried out every five years from the date of manufacture irrelevant of usage. When the winch is in storage after undergoing the storage schedule, no further maintenance is necessary; up on return to service a full monthly service should be carried out in order to prepare the winch for operation. If the winch has passed the due date for a five year overhaul then this should be carried out in place of the monthly maintenance upon return to service. The schedules are on the following pages and are also provided as individual documents for printing in quantity.

weekly maintanance schedule

lubrication			
Check greasomatic catridge	record quantity remaining	mark if replaced	discharge period set
6-off Pinion bearings			
1 off drive end bearing			
1-off non drive end drum bearing			
5-off spooling gear carriage bushes			
4-off spoooling gear end frames			
1-off spooling chain drive			

general maintenance
checking hydraulics for leaks
check foundation bolts
check spooling shafts are greased and free form debris

general notes		
completed by	name	
	date	

Table 8 Recommended Weekly maintenance of winches

monthly maintanance schedule

lubrication			
Check greasomatic catridge	record quantity remaining	mark if replaced	discharge period set
6-off Pinion bearings			
1 off drive end bearing			
1-off non drive end drum bearing			
5-off spooling gear carriage bushes			
4-off spoooling gear end frames			
1-off spooling chain drive			

manual grease application	record quantity applied	manufacture	grease type
spooling shaft			
spur gear and pinions			

general maintenance	
checking hydraulics for leaks	
check foundation bolts	
check frame bolts	
visual inspection of spur gear and pinions	
visual inspection of spooling drive chain	
visual inspection of spooling shafts clean prior to greasing if necessary	
check operation of spooling spooling gear rollers	
check hydraulic motor mountings and torque arm connections	

general notes		
completed by	name	
	date	

Table 9 Recommended monthly maintenance of winches

storage maintanance schedule

lubrication			
Check greasomatic catridge	record quantity remaining	mark if replaced	discharge period set
6-off Pinion bearings			
1 off drive end bearing			
1-off non drive end drum bearing			
5-off spooling gear carriage bushes			
4-off spoooling gear end frames			
1-off spooling chain drive			

manual grease application	record quantity applied	manufacture	grease type
spooling shaft			
spur gear and pinions			

general maintenance		
remove and plug hydraulic connections from inlet of manufold-fill manifold full of oil to keep motors		
Wrap spooling shaft with protective film after grewasing to prevent grease loss and contamination		
check frame bolts if remaining on platform		
visual inspection of spur gear and pinions		
visual inspection of spooling drive chain		
check bearing housing bolts		
visual inpection of spur and pinions		
visual inspection of the spooling drive chain		
Check hydraulic motor mountings and torque coneections		
general notes		
completed by	name	
	date	

Table 10 Recommended storage maintenance of winches

5 year overhaul schedule	
overhaul of winch	
Remove and dissamble spooling assembly replace catridges bushes replace follower replace end frames and seals replace roller bearing replace spooling drive chain	
Support drum and remove main bearings inspect drum shaft cononditions and replace bearing	
remove hydraulics motors and hoses	
replace hydraulic hoses inspect hydraulic motor	
Remove pinion shafts and pinions	
replace pinion shaft and bearing inspect pinion	
remove gear gaurds	
inspect spur gear	
check hydraulic motor mountings and torque and connections -replace bushes in torque arem if necessary	

lubrication			
Check greasomatic catridge	record quantity remaining	mark if replaced	discharge period set
6-off Pinion bearings			
1 off drive end bearing			
1-off non drive end drum bearing			
5-off spooling gear carriage bushes			
4-off spoooling gear end frames			
1-off spooling chain drive			

manual grease application	record quantity applied	manufacture	grease type
spooling shaft			

general maintenance	
checking hydraulics for leaks	
check foundation bolts	
check frame bolts	
check bearing housing bolts	

general notes		
completed by	name	
	date	

Table 11 Recommended 5 year overhaul schedule of winches

The spooling gear shafts should be inspected weekly and lubricated as required. The shafts should be coated with a thin layer of grease at all times, the movement of the spooling carriage will spread the grease over the shaft and may cause an accumulation of grease at the ends of travel. This accumulation should be removed at the time of maintenance to prevent trapping solid debris. It is also important that the shafts are lubricated along their entire length not just the operational section, this will protect the shaft and prevents any corrosion.

The following torque settings should be used for the fasteners on the winch. The base frame torque setting should be used for the standard M24 Grade 8.8 bolts which are recommended. In the event of using stainless steel fasteners please revert to the manufacturers recommended torque settings.

Description	Thread	Bolt Grade	Torque Nm
Bearing Housings	M36	8.8	2481
Main Frames, Tie Beams & Base Frame	M24	8.8	666
Spooling Assembly	M20	8.8	387
Pinion Housing (Nordlock Washers)	M18	8.8	260
Drip Tray, Flooring Frame, Guard Frame	M16	8.8	193

Table 12 Bolt torques

Main Wire spooler contact

Figure 26: Spooler damaged by wires

Description	• Main wire in contact with the spooler
Possible Reasons	• Wrong geometry • Error during spooling
Consequence	• High risk to damage the wire • (the wire could be approx 1 million NOK)
Solution	• Investigate the cause • Check the geometry while spooling • Check the wire for possible damage

Crack on the bearing of the winch

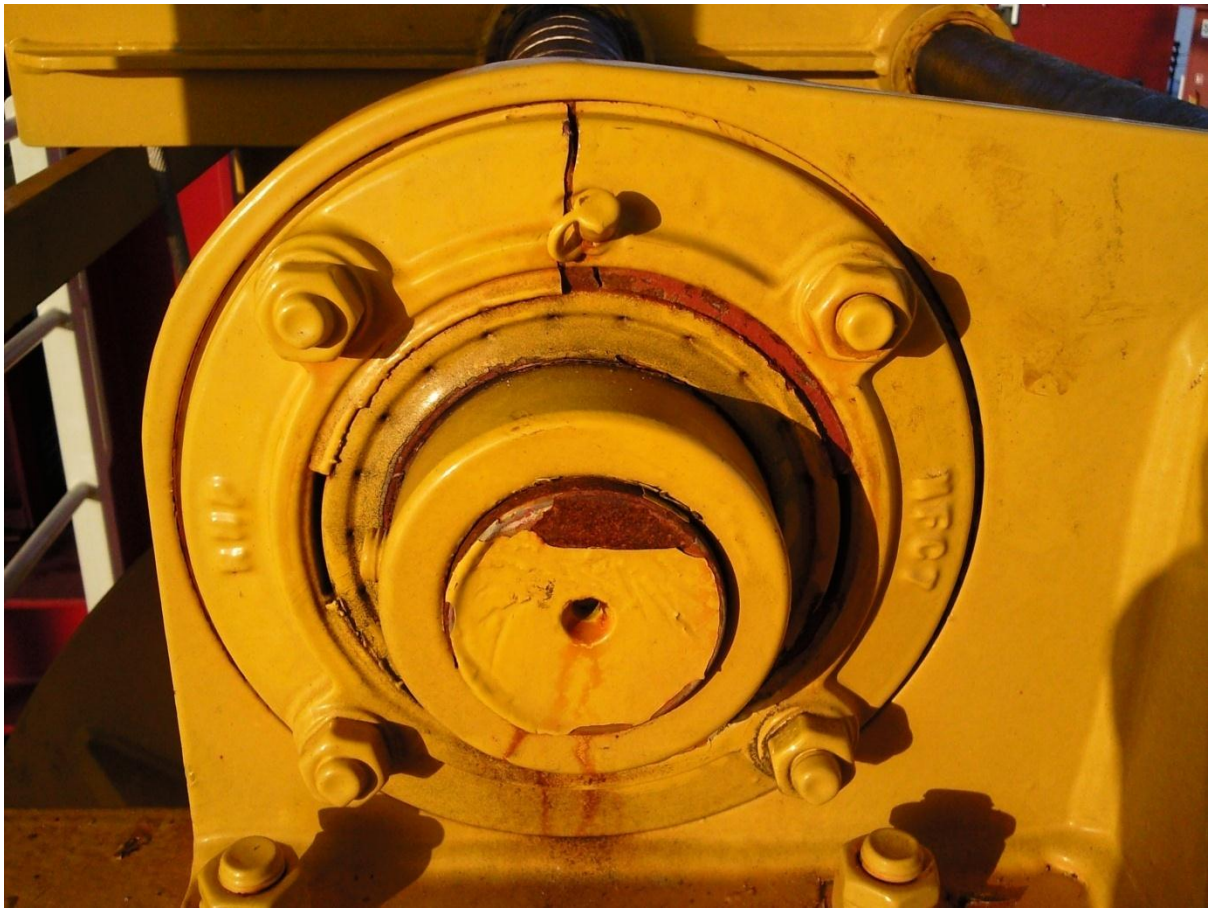


Figure 27 : Crack in the winch bearing

Description	• Crack in the winch bearing
Possible Reasons	• Exceesive loading • Lack of lubrication • Wrong spooling- leading to extensive force s on the winches
Consequence	• Damage to the winch
Solution	• Open up the bearing identifying the cause • Replacing the bearing – analyse the bearing used

Extra padeyes for the winches

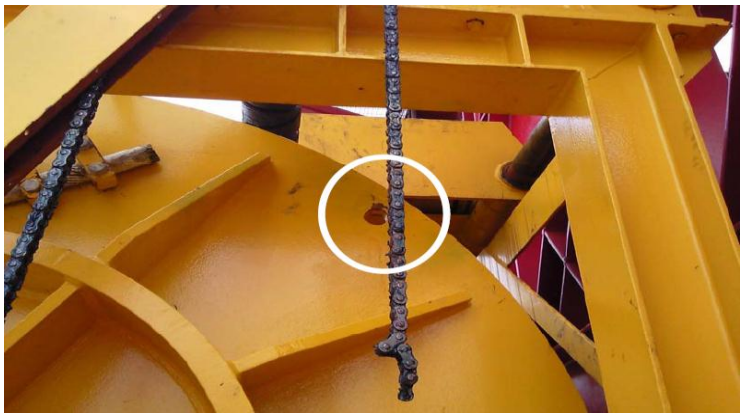


Figure 28: The hole on the drum used for lifting the main winch

Description	• Lack of padeyes for the main winch
Possible Reasons	
Consequence	• Inability to lift of the winch of the tower in case the winch stop at an unfavourable postion (lifting hole in the bottom part of the winch
Solution	• New padeyes for lifting in all possible situations

The winch foundation – possible unplanned modificaitioms

Description	• Winch foundation could have been modified
Possible Reasons	• Fabrication error
Consequence	• Could lead to failure of winch foundation
Solution	• Inspection of the foundation • Evaluate the possible modification

4.2.g Hydraulic Cursor Winch

Description and Evaluation

The winch comprises of a fabricated steel base frame onto which are mounted machined end frames. The drive end frame is machined to accept a hydraulic motor and incorporates a spherical roller bearing to support the drive end of the drum. The drum is machined externally with a Lebus groove and is machined internally to accept a planetary gearbox. The input of the gearbox is driven by a shaft from the hydraulic motor, the output of the gearbox is a splined shaft which is retained in a spline billet welded into the non drive end frame.

The gearbox takes all of the side loading for the non drive end of the drum, the drive end is supported by a spherical roller bearing mounted in the drive end frame. A spring loaded pressure roller assembly is fitted to the winch at the point of cable exit to prevent slack wire at the drum to ensure correct spooling. The tension on the springs is adjustable via threaded adjusters. The lifting points for the winch are located on the top of each end frame

The performance specification is as follows:

Pull (1st Layer): 10.75 Tonnes @ 0-9 m/min

Pull (2nd Layer): 10 Tonnes @ 0-10 m/min

Constant Tension: 0-10 Tonnes Adjustable

Brake Holding Load: 180% Duty

Drum Capacity: 40 M of 24 Dia SWR in 2 Layers

Hydraulic Requirements: 55 LPM @ 200 Bar

Approximate Weight: 1250 KGS (Excl. Wire Rope)

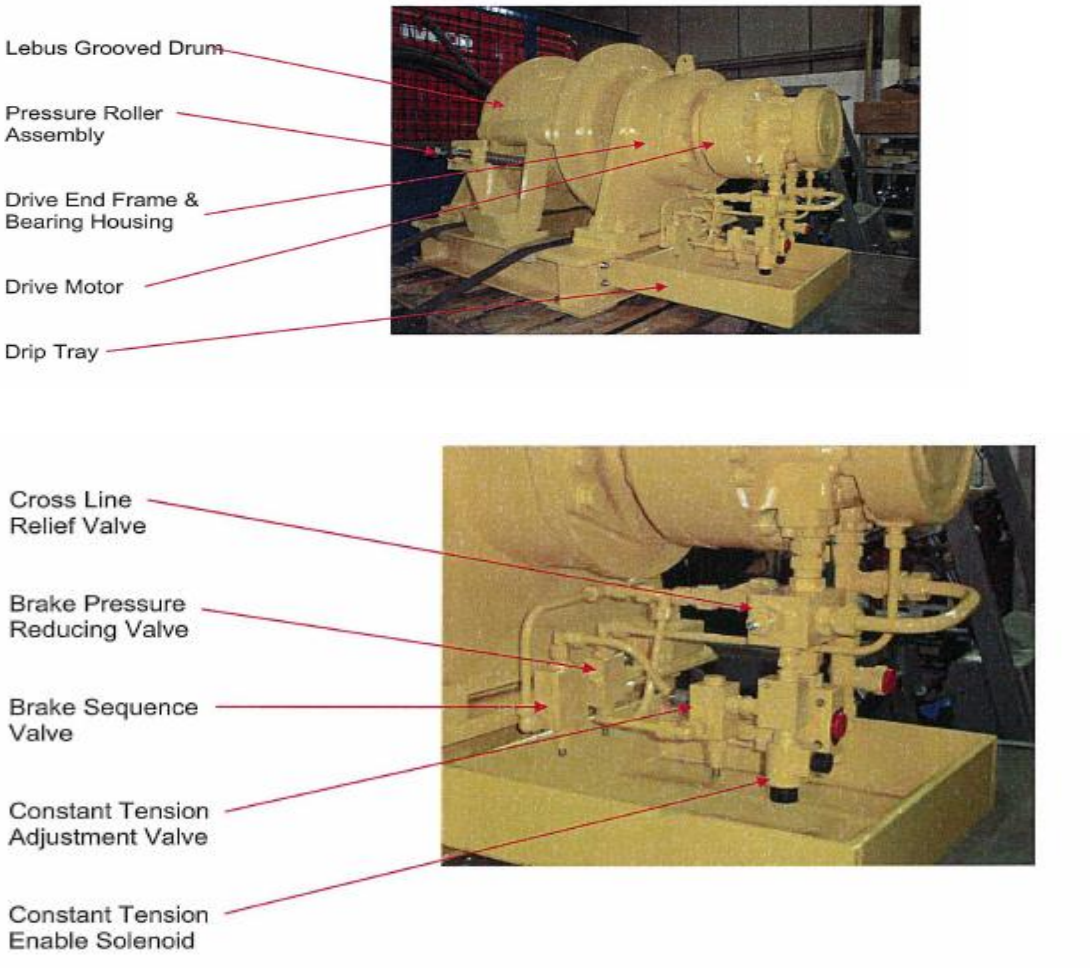


Figure 29: Cursor wire winch

Winch Operation

The winch is operated using a Danfoss PVG32 directional control valve which is mounted at the base of the tower along with all of the auxiliary tower functions. The control valve incorporates a proportional spool providing control of direction and speed of the cursor winch. The directional control valve can be operated manually at the control valve or via a joystick mounted in the control cabin. An electrical solenoid valve which is controlled by the MJR control system provides the constant tension function, when the solenoid is energized a pilot relief valve sets the tensions which will be maintained by the winch. The tension can be controlled by manually adjusting the setting of the pilot relief valve at the winch. For further information regarding the

operation of the winch via the control system please refer to MJR Controls documentation .The maintenance to be in line with the main winch Maintenance procedures.

The international regulatory forum, IRF , has developed a system for the maintenance of lifting equipment . The National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA) is a Commonwealth Statutory Agency regulating the health and safety structural integrity and environmental management of all offshore petroleum facilities in Commonwealth waters in Australia. NOPSEMA has a checklist for lifting equipments .The following is the my evaluation of present status of MHS based on NOPSEMA:

LIFTING OPERATIONS
LIFTING EQUIPMENT MANAGEMENT

IRF (International Regulators Forum) – Maintenance of lifting equipment
(Template MAINT 5 only. Templates MAINT1 to 4 included in CRANE MAINTENANCE SYSTEM PROMPT SHEET)

OPERATOR:
FACILITY / LOCATION:
INSPECTION DATE:

No	Prompt	Remarks	Comments /Status
1	**Procedure**		● ● ● ○ **Tick one (√)**
1.1	Is there a lifting equipment management (use and maintenance) procedure?	Lifting devices (see legend below) often have their own dedicated management system (e.g. cranes)	YES
1.2	Is there a requirement for the creation and maintenance of a lifting/lifted equipment register?	Is the format and content of the lifting equipment register defined?	NO
1.3	Does the procedure define the competencies, authority and responsibility of persons involved in the management of lifting/lifted equipment?	Including maintenance and inspection.	NO
1.4	Does the procedure define which inspection and testing tasks will be performed in-house (using own personnel), which will be conducted using external (independent) inspection and testing agencies?		NO

LIFTING OPERATIONS
LIFTING EQUIPMENT MANAGEMENT

No	Prompt	Remarks	Comments /Status
1.5	How lifting equipment documentation is managed?	What records are kept and where?, E.g. • Design certificates • MDRs (Manufacturer Data Records) • Ins pection/test certificates.	MDRs and inspection certificates
1.6	What provisions apply to contractor and transit lifting gear?		Project specific
1.8	Does the procedure determine what markings are required on each type of lifting equipment?	See lifting equipment register below.	Internal lifting standards
1.9	Does the procedure clearly state "NO MARKINGS NO LIFT" principle?		NO
1.10	Does the procedure define the frequency and extent of inspection and testing for each type of lifting equipment?	See inspection and testing guide below.	YES
1.11	Is there a system for ensuring that each item of lifting gear (including pad eyes) is regularly inspected and tested?	**This is often done under a Colour Code System**	
1.12	Is there a scope and workings of the colour scheme defined?		

LIFTING OPERATIONS
LIFTING EQUIPMENT MANAGEMENT

No	Prompt	Remarks	Comments /Status
1.13	How is defective lifting equipment treated?	Is it clear which equipment - if found to be defective - is removed/destroyed (e.g. wire slings), which is repaired (e.g. chain blocks)? Is this covered by a written instruction setting acceptance/rejection criteria?	YES
1.14	Is lifting equipment management/procedure regularly monitored, audited and reviewed?	Who, what, when?	YES
2	**Personnel**		(red) (yellow) (green) (white) Tick one (√)
2.1	Is there a system for ensuring competency of personnel involved in: • Management • Use, • Inspection and testing of lifting equipment?	This should cover: • company personnel • independent inspection and testing personnel; and • third party (contractor) personnel. • I there a system for ensuring competency of personnel inspecting/testing lifting equipment (are there any provisions for providing personnel with specialist (e.g. inspection) training)? See "Crane driver and dogman competency prompt sheet" for further guidance if necessary	YES

LIFTING OPERATIONS
LIFTING EQUIPMENT MANAGEMENT

No	Prompt	Remarks	Comments /Status
2.2	Are personnel training and assessment (incl. certification) records available?	Are they up to date?	YES
3	**Lifting equipment register**		Tick one (√)
3.1	Is the lifting equipment register kept up to date?		NO
3.2	Check coverage of the register for (see chart below): • Lifting devices (cranes, winches, chain bloks, monorails, padeyes etc.) • Lifted equipement/devices (containers, beams, baskets) • Rigging gear (ropes, slings, chains, shackles, clamps)	Cranes and monorails might be covered by the maintenance system (See crane maintenance checklist)	YES
3.3	Check for the information contined in the register: • Unique ID number • Detail description of equioment (individual items) • SWL or WLL • Serial and batch numbers (wher applicable), • Location on the facility • Cerificate (of initial test or when purchased) • Inspection an subsequent test certificates	SWL- Safe Working Load WLL –Working Load Limit Serial and Batch numbers not unique Identification Number normally used for mass produced items (e.g shackles). Cerificates are often cross referenced in the lifting equipment register to folders where they are kept.	YES

LIFTING OPERATIONS
LIFTING EQUIPMENT MANAGEMENT

No	Prompt	Remarks	Comments /Status
4	**Condition of lifting equipment** **IRF MAINT 5** **(Maintenance of lifting accessories)**		● ● ● ○ Tick one (√) ■ ■ ■ □ Tick one (√)
4.1	Is the lifting equipment inspected as per procedure?	Examine condition of a sample of lifting equipment: • Is it in good condition? • Is it free from obvious visual defects?	IRF MAINT 5 YES
4.2	Is portable lifting gear properly stored, in good condition etc?	• Is lifting gear stored in such a way that would prevent any damage to the equipment? • What arrangements are in place for issuing and returning lifting gear? • Is condition of lifting gear checked prior to issue/use? By whom? • When lifting gear was last thoroughly inspected (check for colour coding)? • Check if there is other lifting gear (e.g. incoming cargo slings) not part of the facility system and how is it controlled.	IRF MAINT 5 YES

No	Prompt	Remarks	Comments /Status
5. Lifting equipment inspection and testing (guide only)			
5.1	Cranes – independent load test	• Initial load test (when installed), • Following major repairs or overhaul (e.g. replacement of brake lining), • Every four years (usual class requirement).	YES
5.2	Cranes – independent survey (visual)	• Visual inspection every 12 months (often includes NDT of some load bearing components – as per manufacturer or company program), • Special NDT requirements may apply (e.g. every 12 months for every load bearing component) if crane used for lifting personnel.	YES
5.3	Cranes – by crane operators	• Daily (before use) and weekly visual inspection and checks by the crane driver as per manufacturer's spec. or company program. These checks should be recorded (crane log book required in WA state jurisdiction)	YES

No	Prompt	Remarks	Comments /Status
5.4	Pad eyes – independent load test	• Initial load test when built (installed), • Following major (structural) repair.	NO
5.5	Pad eyes – independent survey	• Visual every 12 months • NDT as per company program (e.g. every 12 months if frequently used and high reliability required).	YES
5.6	Pad eyes – by users	• Visual check before every use (including check for markings).	YES
5.7	Monorails – load test and independent surveys	Similar to pad eyes	NA
5.8	Winches – independent load tests and surveys.	Similar to cranes.	NO
5.9	Winches – by users	• Visual check before every use (including functional test).	YES
5.10	Manriding winches and associated gear (e.g. sheave shafts, hooks, winch anchor bolts)	In addition to all tests for winches: • Visual inspection and NDT every 12 months of each component (including gears, shafts, shaft keys etc) a failure of which may result in a person being dropped from height.	NA

LIFTING OPERATIONS
LIFTING EQUIPMENT MANAGEMENT

No	Prompt	Remarks	Comments /Status
5.11	Lifted equipment – independent load test	• Initial load test (when new), • Following major structural repairs or alterations. • Every 6 years (at the discretion of the inspection /classification body).	NA
5.12	Lifted equipment - NDT	• Initial when new • Every 3 years thereafter • Following major (structural) repairs	NA
5.13	Lifted equipment – by users	• Visual check before use.	NA
5.14	Personal transfer basket (Billy Pugh etc.) – independent load test	• Yearly (or as per manufacturer's requirements)	NA
5.15	Rigging (slings) - independent load test.	• Wire slings -initial load test, then on request • Chain slings – when new	YES
5.16	Rigging gear – general visual	• By users before every use • Every 3- 6 months (under colour scheme), more thorough inspection by a suitably trained person. Scope of those inspections should be defined.	YES

LIFTING OPERATIONS
LIFTING EQUIPMENT MANAGEMENT

No	Prompt	Remarks	Comments /Status
5.17	Hooks	• Initial load test when new, • Visual inspection; before use and yearly more thorough inspection by a suitably trained person (could be also inspected 3-6 monthly under colour code scheme) • NDT inspection every 2 years	YES
5.18	Shackles, swivels	• Initial load test when new, • Visual inspection; before use and 3-6 monthly under colour code scheme by a suitably trained person. • NDT inspection per company program (depending on application – e.g. yearly if used for personnel lifting, every 3 years if used with containers).	YES
5.19	Containers, skips, lifting beams, spreader beams and frames.	• Initial load test when new • NDT structure 6 years, pad eyes 3 years. • Visual inspection before use and yearly thorough inspection by a suitably trained person.	YES

LIFTING OPERATIONS
LIFTING EQUIPMENT MANAGEMENT

No	Prompt	Remarks	Comments /Status
5.20	Sheave blocks	• Initial load test when new • Visual before use and 3-6 months (under colour scheme) • Additional load test or/and NDT per company program depending on use.	YES

LEGEND:

- non compliance (major failing) - partially complies (incomplete system) - complies - not evaluated

Notes:

1. Scores should be entered in both NOPSA (round) and IRF (square) traffic lights.
2. When allocating traffic light scores for IRF elements only the IRF element marked questions e.g. IRF MAINT 5 should be considered. All questions in each section - including IRF marked - should be considered when allocating NOPSA traffic light scores.
3. In the "Comments/Status" column the following information should be entered, where appropriate:
   - Description of non-compliance(s)
   - Any general or specific comments relating to identified compliance and non-compliance issues
   - Action taken by the OHS inspector
   - Description of identified good practice(s).
4. The Schedule of Specific Requirements as to Offshore Petroleum Exploration and Production 1996 (PSLA Schedule), Part 7- Cranes, applies to Western Australian designated and inland waters (also known as State Waters).

Revision: 0
Revision Date: 27 May 2008
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Reference: N-06200-FM0476
Objective ID: A48713
National Offshore Petroleum Safety Authority

Table 13 Lifting equipment management

4.2.h Mid level Platform

Description and evaluation

The mid level platform has one primary function on the tower, the platform gives raised access to the module/tool. This can be for maintenance, hook up or recovery. It is located at the moonpool location. The system is very useful for rigging up the tools.

The storage position of the platform

Figure 30: The storage position of the platform

Mid level platform operating procedure

When the tower is not in use the platform will be in the upright position. The platform could be operated in two ways

- Via the control cabin
- Via the hydraulic panel

The tower is constructed from individual members, which are mounted together using bolted connections. All bolts are fitted with nyloc nuts, which theoretically require no maintenance, however its recommend that the torque setting on one complete joint be verified before every mobilisation. If 25% (5 out of 20) are loose proceed to check and tighten all bolted joints (100%).

Torque setting: Refer to standard metric bolt torques 8.8, unlubricated.

Description	Thread	Bolt Grade	Torque Nm
Retention Bars, Base Frame	M24	8.8	666
End Plates	M20	8.8	387

Recommendations
1. **Lubrication :**. Use manual grease guns and liberally apply grease to all points.. Where grease nipples are fitted liberally apply as per the maintenance schedule
2. **Paintwork:** Touch up damaged paintwork after every mobilization. The system is painted to NORSOK M-501, system No.1 .
3. **Hydraulic System:** Prior to mobilisation and following long periods of storage it is recommended a thorough inspection of the hydraulic components, pipe work and flexible hoses be performed Bent or damaged pipework should be replaced. Stainless steel 316 tube is used An annual pressure test is recommended to 231 bar (operating pressure x 1.1). Defective or damaged components such as valves, fittings or cylinders should be replaced. This will help to maintain the inegrity of the system in the long run.

4.2.i Skidding system

Description and evaluation

The MHS skidding system enables several tools/modules to be moved around the deck and into the moon pool safely whilst offshore. The skid system is of a double crucifix design and has 2 push-pull units, 2 standard pallets and 1 rotary pallet. The tools/modules are secured to the pallets. The push-pull unit then crawls along the skidrails and are locked to the pallets. The push-pull units are designed to move tools/modules up to 60Te over the skid system and into the moon pool envelope. At the 2 cross overs the rotary pallet is used to rotate the tools into the correct position before and after operation.

The skidding beams are of modular construction each with a 60 Te capacity . The Centre section is 25m long (4 sections). There are 4 off side tracks , each 8m long . they are also connected with Integrated connection points for local hydraulic supply to PPUs. There are typically 6 main storage locations for large modules.

Figure 31: Modular skidding system

The skid system is modular and consists of 2 cross sections, a front latch section, a rear section and 4 side sections. To operate the push-pulls and the rotary pallet the skid system has a ring main hydraulic circuit within the sections. These are fitted with quick release coupling for ease of use.

The skid system gives good coverage over the deck and makes it easy for the vessel crane to pick up the tools, the skid rails could be also covered temporarily and used as deck space which would lead to better utilization of the vessel. The skidding system could witness high stress and deflection in case of intolerances.

Recommendations
1. **Maintenance procedure:** The tower is constructed from individual members, which are mounted together using bolted connections. All bolts are fitted with nyloc nuts, which theoretically require no maintenance; however we recommend that the torque setting on one complete joint be verified before every mobilization. If 25% (5 out of 20) are loose proceed to check and tighten all bolted joints (100%). Torque setting: Refer to standard metric bolt torques 8.8, unlubricated.
2. **Monthly inspection:** The maintenance plan also include checking of the gripper assembly which are gripping the push pull units to the skid rails . A monthly inspection is advisable. Heavy corrosion is noticed on the bottom roller assembly of the skids. Also gripper could be redesigned for a better system performance.
3. **Paintwork:** Touch up damaged paintwork after every mobilisation. The system is painted to NORSOK M-501, system No.1.
4. **Hydraulic System:** Prior to mobilisation and following long periods of storage it is recommended a thorough inspection of the hydraulic components, pipework and flexible hoses be performed Bent or damaged pipework should be replaced. Stainless steel 316 tube is used An annual pressure test is recommended to 231 bar (operating pressure x 1.1). Defective or damaged components such as valves, fittings or cylinders should be replaced as required. (integrity issue)

Push-pull unit

The push pull units are the drivers which move the modules from the open deck to the MHS tower and from tower to the various locations on the deck. There are two units identified as

• Push-pull unit, serial no: SN-955-3904

• Push-pull unit, serial no: SN-955-3905

Both the units have 60 Te push / pull capacity and could be used to move the pallets to nay location on the skidding rail. They attach to the pallets via easy connect disconnect hinge system and are easily mountable on and off the pallets, saving offshore time for operations. They are attached to the skid rails via friction teeth.

The system hydraulic pressure has been tested to 285 bar. The factory set operating pressure has been pre-set on the units to 150 bar.

Figure 32: Technical specification

Figure 33: PPU units attached to the pallets

PPU units attached to the pallets

Push-Pull Unit Technical Specification	
Fluid	Mineral oil
Maximum working pressure	200 bar
Factory set operating pressure	100 bar
Flow rate	Input flow from hydraulic ring main 80 lit/min
Maximum operating temperature	60 °C
Forward speed slow	1.5 m/min
Reverse speed slow	1.5 m/min
Forward speed fast	2.4 m/min
Reverse speed fast	2.4 m/min
Forward thrust (horizontal)	31.0 Te
Reverse pull (horizontal)	21.5 Te
Pallet loading SWL (vertical)	25.0 Te

Table 14 PPU specification

The unit has a 60Te SWL, which allows the operator to push and pull a 60Te tool including the supplied pallets and deck skidding rails. The units are designed based on a set of four mechanically failsafe hardened gripper pads which interface with the deck skidding rails. A separate hydraulic clamp cylinder operates each gripper pad.

Retracting the clamp cylinders using a separate Enerpack type hand pump and unbolting the lower clamps brackets achieve removal off the unit.

The push-pull is transported on a section of the skid system. This allows a quick commissioning time. The system is secured to the skid rails with welded plates front and back.

Procedure;

1. Remove front and back positioning plates
2. Ensure push pull can move forward & backward without obstructions
3. Close both isolation valves
4. Pressurize system up to 210 bar to retract fail safe cylinders
5. Reduce enerpac pump pressure and open both isolations valves

Once the skid has been securely mounted onto the skid rails and the enerpac pump can be removed. The hydraulic power supplied from the main MHS tower HPU and is connected via 2-off 30 meter trailing flexible hoses, this provides a supply and return line. Operation of the push-pull is performed using a hand held valve, which is connected to the push-pull frame via 4-off 3/8" QRC.Prior to mobilisation and following long periods of storage it is recommended a thorough inspection of the hydraulic components, pipe work and flexible hoses be performed.

Bent or damaged pipe work should be replaced. Stainless steel ASTM 249 tube and 316 fittings are used throughout. Defective or damaged components such as valves, fittings or cylinders should be replaced immediately as required. The majority of components is supplied in carbon steel and should be protected with wax oil. An annual pressure test is recommended to 240 bars.

Use manual grease guns and apply liberally to grease nipple points around push-pull cylinder rod ends.

Inspect hardened gripper pads on a regular basis for major structural damage. Damaged gripper pads must be replaced immediately. It is also recommended that the operator to prevent unnecessary down time stock spare gripper pads.

The gripper pad assembly is seen not really suited for very high loads . There have been various local deflection issues that have to be corrected to get a reliable system. Local modifications have been mentioned to Tekmar and they would be fabricated and installed at hinna base. Proper load test need to be performed during the next mobilisation. The skis rails are structurally stable and give considerable coverage over the deck and could be used to store deck items with considerable ease.

Recommendations
1. **Lubrication** : The quality of the lubricant used should be specified by the supplier of the equipment.
2. Look of unusual scratches on the skid rails . debris could be stuck between the pads and skidrails
3. Cover the areas skid rail location when there substantial deck activity. Ex. grinding on the deck causes the debris over the equipments.
4. It's found that the speed of the push pull units are limited. Takes too mush time during offshore operation .Look at the possibility to improve the speed of the units
5. Check the levels above deck – It has to be flat at each mobilizations have to be ensures because of deck irregularity
6. **Paint work :**Touch up all damaged paintwork
7. Gripper pads : to be checked and approved prior to all mobilisations . Integrity should be ensured.

Recommended maintenance schedule

The following table outlines a recommended maintenance schedule:

• Every mobilisation	- inspect hydraulic components - lubricate - touch-up paintwork
• Operational period	- inspect gripper pads - clean skid rail contact areas - lubricate - touch-up paintwork
• Every de-mobilisation	- lubricate - touch-up paintwork
• 12 month interval/after Storage	-pressure test hydraulics

Table 15 Maintenance schedule for PPU

Broken bearing

Figure 34: Trolley on the skidding beams

Figure 35: Rollers and skidding arrangement under the pallet

Figure 36: Broken bearing on deck

Description	Rollers on the underside of the rusted and falling of
Reason	• Corrosion • Lack of lubrication • Material selection
Consequence	• Systems integrity • Getting locked in place • Inability to take the uplift as planned for • Damage to the beam and rollers • Safety compromised
Solution	• Checking the roller specs • Lubricating the roller • Regular inspection • Improved design

4.2.j Pallets

Description and evaluation

Rotary turntable pallet

The pallets are the tables placed on the tops of the skid rails on which the subsea modules are placed. They could be rotated and be taken anywhere to the deck and could be used for sea fastening. Rotary pallets can go 360 degrees making it extremely mobile on the deck.

.

Figure 37: Pallets shown 45 degrees rotation

To hydraulically hook up the pallet there are 3 connections that require lines from the push-pull unit.

• Pressure

• Return

• Drain (motor)

To hook up the pallet there are sets of couplings, these consist of the main knuckle, pins and tab plates. The pallet has been designed with pad eyes on all 4 sides to enable a hook up from a push-pull from any direction. Rotating pallet is hydraulically lockable at any degree of rotation. Hydraulic jumpers from PPU to rotating pallet quick connections. The pallet has integrated sea fastening holes The push pulls also have corresponding pad eyes at the front and back of the push-pull units. Placing the knuckle between the push-pull and the pallet enables a positive connection. Prior to operation the pins and tab plates must be inserted including the tab plates secured with the appropriate fasteners realizing an easy connection change over. The roatary tabkes are the highlights for the deck system allowing for high mobility of the tools on deck

Fixed pallet

Figure 38: Fixed pallets

The fixed pallet is used for placing the tools on prior to connecting to pallet to a push pull unit and moving it in or out of the tower via the skid rail system.

The hooking up of the fixed pallets are done in the same way as the rotary pallets

All bolts are fitted with nyloc nuts, which theoretically require no maintenance; however we recommend that the torque setting on one complete joint be verified before every mobilisation. If 25% (5 out of 20) are loose proceed to check and tighten all bolted joints (100%). Torque setting: Refer to standard metric bolt torques 8.8, unlubricated.

Lubrication that needs to be done for the system consists of two parts

1. Use manual grease guns and liberally apply grease to all points.

2. Where grease nipples are fitted liberally apply as per the maintenance schedule

Touch up damaged paintwork have to be performed after every mobilisation. The system is painted to NORSOK M-501, system No.1.

Prior to mobilisation and following long periods of storage it is recommended a thorough inspection of the hydraulic components, pipework and flexible hoses be performed Bent or damaged pipe work should be replaced. Stainless steel 316 tube is used. An annual pressure test is recommended to 231 bar (operating pressure x 1.1) Defective or damaged components such as valves, fittings or cylinders should be replaced as required.

All the pallets where performing well during the offshore phase of the project and needs to only minor fine tuning.

Recommendations
1. Permanent additional sacrificial plates to be bolted on the pallets. Drill sea fastening holes on all the pallets
2. The speed of travel is limited. (uses lots of time during offshore operation). Look at the options for increasing the speed. Upgrade the HPUs to delivery faster delivery
3. Special warning signals on deck when the pallets are operating to warn the people on deck
4. Barrier off the area when the pallets are moving

4.2.k Moonpool door system

Description and evaluation

The MHS moon pool has 3 doors, 2 side door and 1 central door. To operate the door you can operate these in two ways, via the control system in the cabin or via the hydraulic control cabin. The doors have removable hand railing and roller systems that may require removing prior to operations The MHS moon pool has 3 doors, The 2 side doors lift up to open and move down to close. There are proximity switches located on both doors to confirm the closed position. Prior to operating all safety hand railing must be removed and deck personnel in front of the tower must confirm the doors are safe to operate.

Figure 39: Opening of the moon pool doors

The MHS moon pool central door drops down into the moonpool to open and is raised 5 degrees above true horizontal at deck level to close. Raising the door above true horizontal activates a latch mechanism in located in the front section of the skid system This is a fail safe system to ensure any module/tool up to 60Te can be placed on this if the door hydraulics fail. The central door has a cavity enabling the door to be shut in operation but allowing the main lift wire to still be operation.

Figure 40: Moon pool doors partly opened

The tower is constructed from individual members, which are mounted together using bolted connections. All bolts are fitted with nyloc nuts, which theoretically require no maintenance, however we recommend that the torque setting on one complete joint be verified before every mobilisation. If 25% (5 out of 20) are loose proceed to check and tighten all bolted joints (100%)..Torque setting: Refer to standard metric bolt torques 8.8, unlubricated.

Description	Thread	Bolt Grade	Torque Nm
Retention Bars, Base Frame	M24	8.8	666
End Plates	M20	8.8	387

The systems are seeing quite large forces at the hinge location and lubricating the system over the moonpool is an unique challenge as it involves working at heights and over the water. The personnel involved need to have special PPE including safety harness and life jacket. Working on the system should be preferably be carried on the quay side and the activity over the moonpool during the transit should be strictly restricted. Use manual grease guns and liberally apply grease to all points. Where grease nipples are fitted liberally apply as per the maintenance schedule.

Related to the paintwork Touch up damaged paintwork after every mobilisation. The system is painted to NORSOK M-501 , system No.1. The paintwork at the locations are adequate and over all the required areas.

Prior to mobilisation and following long periods of storage it is recommended a thorough inspection of the hydraulic components, pipework and flexible hoses be performed Bent or damaged pipework should be replaced. Stainless steel 316 tube is used. An annual pressure test is recommended to 231 bar (operating pressure x 1.1). Defective or damaged components such as valves, fittings or cylinders should be replaced as required. The hydraulic system is could lift and operate the moonpool doors at adequate speed and performance.

3 sets of Guide wire rollers installed per side for the guide wires on the moon pool doors to allow for the wires to pass through undamaged. It would allow to pass the guide wires through the moon pool door while performing subsea operations.

The moonpool system as it stands now has a few problems with the corrosion of the rollers. But the operation of the system had revealed that the system is adequate for offshore operation. Placing some more mechanical stops could aid in the safety of the system.

Figure 41: Moon door being tested

Recommendations
1. Safety while operation of the moon pool door
2. The maintenance and proper lubrication of these rollers are essential . Monthly checking is essential for a reliable operation . change out damaged ones
3. Properly barrier of the area when he doors are open
4. Proper PPE for the personnel in the location
5. Proper fit up test of the moon pool door with the skid rails on the deck .(need to match flush)

Interface between the skid system on deck and moonpool

Figure 42: Deck- moon pool interface

Description	Skid rails on the deck and moon pool not meeting flush
Reason	• Fabrication intolerance /vessel interfacing
Consequence	• Stresses on the skidding beam • Damage to the sliding pads and gripper assembly • Possible show stopper during offshore campaign
Solution	• Shimming on the interface points • Checking before loading the moonpool skids with pallets • Modify the skidding system

4.2.l HPU system

Description and evaluation

MHS system is delivered with two separate HPUs in standard 20 feet containers . One HPU is controlling Guide wires & Cursor winch while the second one controls the main winch. GW HPUs is upgradable for the 4th guide wire winch and Main Winch HPU is upgradable to 60Te main winch with AHC capacity. Maximum power consumptions all units running is just below 2MW. Cooling requirement is 900liter / minute (Seawater) . The flow of 4000 liter oil per minute in full capacity and runs in a closed loop system.

Bosch Rexroth Ltd has supplied to Lebus International Engineers Ltd. a containerized hydraulic power unit, for the guide wires, against Lebus ref. TKM/F-4213, who supplied it to TEKMAR for the MHS .

Technical Information (General System Specifications) of guide wire HPUs

Main winch HPU

Power Unit Code:	UKP180100
Serial Numbers:	10-018-093
Project:	UKS002031/02
Manufactured by:	Bosch Rexroth Ltd
Weight complete:	15,500 kg (oil tank empty)
Main voltage:	440V/3ph/60Hz
Tank oil volume:	1600 L (1300L Max Fill Level)

General Settings

Oil level switch (FS1a):	Low Warning 296 mm Level from tank top
Oil level switch (FS1b):	Low Shutdown 533 mm Level from tank top

Filters Contamination switch:

F1	p 2.0 bar for the return filters
F2	p 2.2 bar for the return filters

Oil Heater (H1)

Power:	1 x 1.0 kW
Voltage:	110V ac 3-phase
Oil type, design:	Mineral Oil – ISO VG 68

Guide wire HPU

Power Unit Code:	UKP180100
Serial Numbers:	10-018-093
Project:	UKS002031/02
Manufactured by:	Bosch Rexroth Ltd
Weight complete:	15,500 kg (oil tank empty)
Main voltage:	440V/3ph/60Hz
Tank oil volume:	1600 L (1300L Max Fill Level)

General Settings:

Oil level switch (FS1a):	Low Warning 296 mm Level from tank top
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Filters Contamination switch:

F1	p 2.0 bar for the return filters
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Oil Heater (H1)	
Power:	1 x 1.0 kW
Voltage:	110Vac 3-phase
Oil type, design:	Mineral Oil – ISO VG 68

If subjected to temperatures less than -20 deg C then electrical power must be connected at all times and ensure container space heaters and oil tank immersion heaters are operational.

During mounting of the hydraulic connections the following points must be kept in mind:

The port protections must be kept on until final assembly. It is important that all pipes are mounted to give sufficient working space for maintenance and operation access of the Power Unit. All pipe work inside power unit has been tested and flushed prior to mobilisation. All pipe work external to the HPU must therefore be cleaned prior to fitting and flushed to the filtration levels mentioned earlier and verified by sampling before connection to the power unit. The flow and temperature of the flushing fluid must ensure turbulent flow is achieved to be effective. The required level of cleanliness we would recommend for the equipment incorporated in the HPU is ISO 4406 15/14/12 (equivalent NAS 6) as a minimum.

Description and evaluation

The Hagglunds Drives (HDUK) hydraulic power unit (HPU) is to provide flow and pressure for three Guide Wire Winch drives (GWW1, 2 & 3). The GWW drives are independently sized and piped as separate circuits, with 1x 185kW system and 2x 150kW systems, (all referenced at 60 Hz operation). The system to operate GWW3 is also configured to be able to operate in Active Heave Compensation (AHC) mode. The increased power to facilitate this function is by utilization of an additional 185kW motor/pump referenced GWW4 which is combined hydraulically with that available power from the original GWW3 pump set.

The potential energy from the winch load and cable requires consideration as generated power during all winch lowering operations. This energy recovery will feedback through the HPU to

the ships supply and it is noted that the end user / ship operator is required to handle the energy fed back. Our calculations suggest that the potential feedback is as follows:

GWW #3 In Active Heave Mode = 78 KW per motor i.e. potential 156 KW generated and fed back through the HPU to the ship.

GWW #1 #2 #3 = 63 KW per motor i.e. potential 189 KW generated and fed back through the HPU to the ship.

Maximum simultaneous power generation therefore = 2 x 78KW + 2 x 63KW = 282KW

Guide Wire Winch Drives #1 & #2

Each has a 151kW (60 Hz) electric motor driving a SP355 pump to provide flow and pressure to a Hagglunds Viking 64 series motor/brake connected in a closed loop circuit, where an electro-hydraulic controller is fitted to the pump to provide direction control and proportional flow. The pump compensator port is also connected to an external proportional relief valve to allow adjustable system pressure and therefore adjustable tension control. The control signals are sent via a PLC and HNC100 control unit, which also takes care of pull and line speed. The pump flow and pressure settings are limited within the installed power available, whereby line speed is allowed to increase with lighter loads and vice versa. The power limiting control of each pump unit is designed to produce a flow of up to 600 L/min at a maximum pressure of 124 bar and 298 L/min up to a maximum pressure of 250bar. The following table shows the design criteria considered and calculated performance of Guide Wire Winch motors 1 & 2

Layer No.	Motor Rev/min	Motor Torque KNm
1	21.5	48.7
1	43	32.2
13	22.85	48
13	43.4	25.4

For guide wire winch drive 3 A 185kW (60 Hz) electric motor driving a SP355 pump to provide flow and pressure to a Hagglunds Compact series CA210 motor/brake connected in a closed loop circuit, where an electro-hydraulic controller is fitted to the pump to provide direction control

and proportional flow. The pump compensator port is also connected to an external proportional relief valve to allow adjustable system pressure and therefore adjustable tension control. The control signals are sent via a PLC and HNC100 control unit, which also takes care of pull and line speed. The pump flow and pressure settings are limited within the installed power available, whereby line speed is allowed to increase with lighter loads and vice versa.

An additional 185kW motor driving a SP355 pump is installed to provide provision for options with regards the Active Heave Compensation and the new demands that that would place on the system. The power limiting control of each pump unit is designed to produce a flow of up to 600 L/min at a maximum pressure of 154 bar and 264 L/min up to a maximum pressure of 350bar. As the degree of heave compensation and accuracy of the active heave compensation system is directly related to the installed flow and power, all calculation and simulation data has been

selected to optimize performance commensurate with power limits agreed in the design phase of the project. For reference purposes it is confirmed that the following criteria has been adopted as the basis of such calculation and simulation of active heave compensation:- Lowering Speed = 5 M/min, Simulation of ship movement = Sinus +/- 4.5 meter at frequency 0.083 Hz. Simulated accuracy of static AHC and dynamic AHC (lowering 5M/min) of +/-94.4% is anticipated. It must be noted by all parties that the use of this data remains in context of the development of a prototype system and that no safety critical function endangering equipment or personnel is performed until full & satisfactory commissioning is complete

As can be seen from the pictures below, the power unit is built within a 20ft marine style container where the motor pump sets are table mounted in a line along one wall and balanced off against the hydraulic reservoir mounted along the opposite wall. Not only does this layout allow us to have an even weight distribution within the container but by capping across the end of the table on the floor and by the personnel access door it also creates a full bunded area. For ease of access there is a raised walkway down the middle of the container between the tank and motors which connect the main door opening with the personnel access door to the rear of the container. The walkway ensures that the user is over and above the bunded area of the container and over the

Interconnecting pipe work which then becomes hidden by the mesh

Figure 43: guide wire HPUs

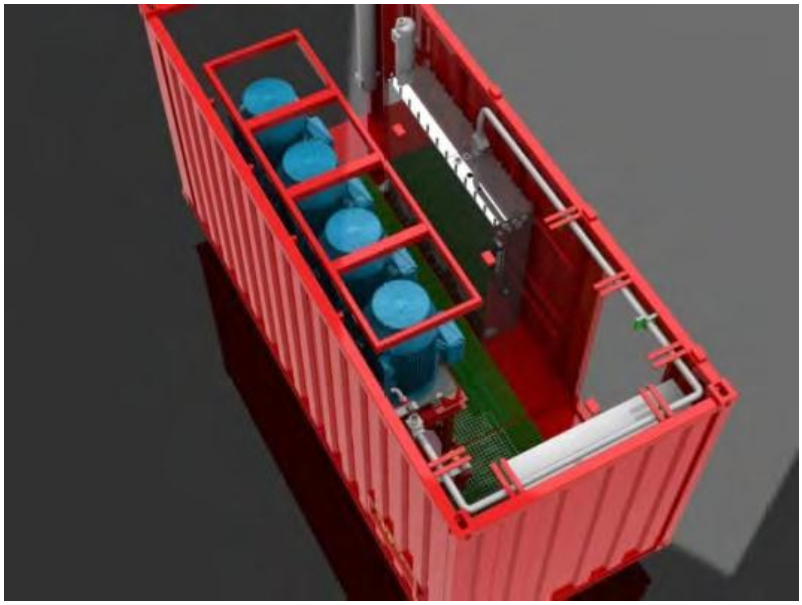


Figure 44: Inside the HPU

As mentioned the container has a personnel door at one end (opposite the main doors) and it is at this end that the control panel is sat on a plinth with high point restraints, ensuring it is above the bundled area but has easy access for incoming/outgoing cables. The walkway terminates at the front of the panel and ensures that the user is at the correct height for all the local controls and the HMI. In order to accommodate the motor pumps sets the container has access doors to allow for installation and removal for maintenance purposes.

The hydraulic service ports interface externally via a Xylan coated mild steel manifold, but the water connections are made via 316 stainless steel sleeved connections manifold to maintain the integrity of that circuit. It is intended that the electrical cables run through Roxtec type cable entry blocks next to the manifold and the frame required for this is built into the container wall.

All circuits are housed within a custom built marine specification container. The container also houses the starter panels and health monitoring systems for all circuits and these will relate back to the customer master control deck via the custom built PLC and the built in ProfiBUS interface. Each component on the HPU will have an address allocated in PLC.

The oil cleanliness levels are maintained by 10μ (micron) rated at Beta ratio 200 ($\beta 10 = 200$) filters and have electrical indication of filter element blocked condition. Careful consideration has been made with regards the cooling circuit of this system and it has been determined to utilize the combined return flow from the circuits as mentioned in the section “common return”. The cooler is a shell and tube type with permanent sea water connection i.e. no temperature control of water on/off.

The power unit control system is based around a Mitsubishi Q-series PLC. The PLC handles the power unit monitoring and interlock functions. This information is provided to the operator via the HMI screen on the front of the panel. In addition all the relevant power unit data is transmitted via Profibus to the MHS Control Cabin.

Recommendations Maintenance schedule

Preventive maintenance

The specific procedures will depend on the nature of the equipment, the environment it is working in and the duty cycle, bearing in mind the consequences of a breakdown.

Daily checks, first week after Commissioning	Pre-start checks (even daily)	Frequent Checks
• Fluid leaks • Fluid level in tank • Operating temperature • System pressure • System performance and general • condition • Unusual noises • Contamination indicators on filters	○ Fluid leaks ○ Fluid level in tank ○ Is the suction valve open ○ Contamination indicator on the filters	• Unusual vibrations • Unusual noises • Fluid leaks • Fluid level in tank • Is the unit relatively clean • Air flow paths unrestricted • Pressure levels normal – stable • Operating temperature • Is the drive running smooth • Contamination indicators on the filters

Table 16 Preventive maintenance schedule for HPU

Scheduled maintenance

Planned maintenance at specific time intervals, including the following checks and actions: Main points to check are :

1. Check all pressure levels
2. Check for stable temperature levels around system
3. Drain water and sludge from the tank at the drain tap

4. Check the electric motor
5. Check the function of monitoring equipment/switches, etc
6. Clean area where dirt is building up
7. Check the cables
8. Check drain line flows and drain line oil condition
9. Check the hoses, couplings and pump with respect to cracks, leakages and condition
10. Check the shaft coupling through the inspection hole.
11. Warning, rotating parts inside the inspection hole.
12. Check the flow of the cooling water
13. Check that the insulation inside the cabinet (especially the roof) is fixed
14. Check that the doors and cover of the Power Unit are not damaged

Lubricate electrical motors larger than 30 kW only. If the type of grease is changed and compatibility is uncertain, lubricate several times at short intervals in order to displace the old grease.

Absolute max intervals for major inspection and replacement				
	Air Inlet	Oil Filters	Air Breather on Tank	Hydraulic fluid
After first 100 hours	N/A	R*		
After 3 months or 500 hours	N/A	R*		
Once every 3 months	N/A		R*	
Once every 6 months	N/A	R*		I
Once every 12 months	N/A			

Table 17 Lubrication check intervals

* If the contamination indicator is tripped out, filter must be changed and oil examined.

I = Inspection

R = Replacement

We recommend that the hydraulic fluid is analyzed once every 6 months. The analysis should cover viscosity, oxidation, water content, additives and fouling

Lubricate electrical motors larger than 30 kW only.

Grease with the right properties are available from all the major lubricant manufacturers. If the type of grease is changed and compatibility is uncertain, lubricate several times at short intervals in order to displace the old grease

CORRECTIVE MAINTENANCE

Before removing any hydraulic/electric components, disconnect the Power Unit. Ensure that no energy is accumulated in the system and the electric motor. Although there are no specific item's requiring maintenance within the electrical system. It is recommended the following checks be carried out at regular intervals to prevent any unwanted problems.

Item/Procedure	Notes	Interval
1. Check condition of all cables. Check for damage to outer sheath and ensure all cables are ok.	Pay special attention to any cables that are exposed or have the potential to be damaged due to their installation position	Monthly (or if impact damage has occurred due to falling tools for example)
2. Check condition of cable transits (Roxtec Blocks) into the container. Ensure all cable entries are tight and secure.	Critically important to ensure IP Rating is maintained.	Monthly
3. Check integrity of cable terminations.	Tighten all terminals to ensure good contact	Every 3 Months or if cable replacement / damage has occurred

Table 18 Corrective maintenance

Modification for sequential start up of motors are recommended for both HPUs to reduce start up Amps requirements

Figure 45: Motors in HPU

Install hard pipe on the MHS for HPU connections to save deck space and avoid congestion on deck. The spaghetti of hoses are not safe practice. Danger of trips and falls is the deck is congested.

Corrosion in the HPUs

Figure 46: Corrosion inside the HPU

Description	Corrosion inside the HPU

Possible Reasons	• Exposed to sea water
	  ○ Water ingress through the vents on the container
	  ○ Sealing on the containers roofs and doors might be inadequate
	• Heating arrangement switched of in fugro symphony while in rough weather
	• Fittings materials may not be up to the standards
	• Acidic oils (wrong specifications) used for coating the fittings
	• Earthing issues in the vessels
	• Cold bends introduced on the pipes after coated with Zinc for protection cracking the uniform zinc coating and forming zinc oxide which is toxic

Consequence	• Health hazard
Solution	• Clearing the HPUs from seawater /salts already inside ○ Options limited as extensive electronics present (looking at the option of taking out the electronic boxes prior to cleaning • Coating the component s with suitable anti corrosion agents • Densel taping the component s • Evaluate the use of cathodic protection • Using stainless piping • Stripping the piping of zinc and recoating with protective layer so that the toxic zinc layer is not exposed anymore • Coating needs to be monthly checked for physical damamges

OIL LEAKS

Figure 47: Oil leak on the valve

Description	Oil leak on the valve
Possible Reasons	Mechanical damage
Consequence	
Solution	Changeout

Corrosion o the fittings

Figure 48: Corrosion in the fittings

Description	Corrosion in the water inlet attachment points of HPUs
Possible Reasons	Wrong material used
Consequence	
Solution	Changeout

4.2.m Structural and general layout /equipments of system

Description and evaluation

The structural integrity of the tower has been approved and accepted ny DNV. The primary structures of the MHS are designed to handle 60Te of load. But the present state they need to carry only 35Te loads. The structure is overall a bolted system with possibility of the bolts to see high dynamic forces during the offshore phase. Most of the issues are directly regarded to the structural integrity of the MHS.

The interface of the MHS with the moon pool of the vessel is a high focus area and the base frame is fabricated to have a perfect connection between the MHS and the vessel . All the loads are transferred to the vessel through the base frame. The base frame has to be designed for each of the vessel as the moon pool design on each of the vessel would be different.

The deck layout around the MHS would also depended on the vessel on which its going on. It depends on the vessel deck space available. And the interfaces points on the deck. The final layout on the vessel will depend on a lot of factors including the safety access routes on the vessel. The deck layout on the fugro symphony looked very crowded and it would be a challenge to make some maintenance work due to accessibility issues.

Structurally one of the issues has been during the mobilisation when extra unplanned bolt holes had to be burned on the mobsite to save time. This has resulted in considerable damage to the beams and as it stands now is not fit for purpose. They have to be repaired using proper material specifications. The bolt holes not matching would be an issue with the most of the ships as getting the holes aligned accurately would be a challenge. The solution would be to use slotted bolt holes with the sizes decided on using the maximum deflection that could be possible based on a range of possible deformations of the base frame.

Also there are areas where there are considerable gaps in the bolt faces. They are not properly matching. This is an error that could be associated with many bolted structures as its an intolerance hard to remove without machining. There is need to ensure that the bolts are torques at regular intervals and the gaps are shimmed at the earliest to ensure structural integrity of the tower.

Recommendations
1. Crowded deck around the tower main structure, with various accessories and hoses in the HPU. Look at the option of using permanent hard pipes or hanging the hoses to the tower
2. Providing with a custom made tool kit of the unit including safety harness to be installed on the port side of the vessel
3. Providing hydraulically controllable system for all the movable parts
4. Heating for the HPU is important. use signal lights outside HPU to confirm power availability to HPU at all times.
5. Add the bridging stairs over the skid rails in the permanent equipment list
6. Cable protection for the wires on deck
7. Color the possible trip hazards for easy visibility
8. Improve the access near the main winch , New portable stairs to be installed by the main winch
9. Look at the possibility of using quick couplings for connecting the winches to the hydraulics
10. Make proper handrails on all possible/ needed areas. Especially during mobilizations when things need to be modified.
11. Barrier the area near the access table on level 3 when not in use
12. The access table on level 3 To be used only by necessary personal during operation
13. The top floor is not properly grated. There is need to design the member to support the gratings and fastening them to the grating .
14. Remodel the funnel near the sheaves , the receptacle for the crane block . It needs to provide better guidance to the crane block

Bolt issues

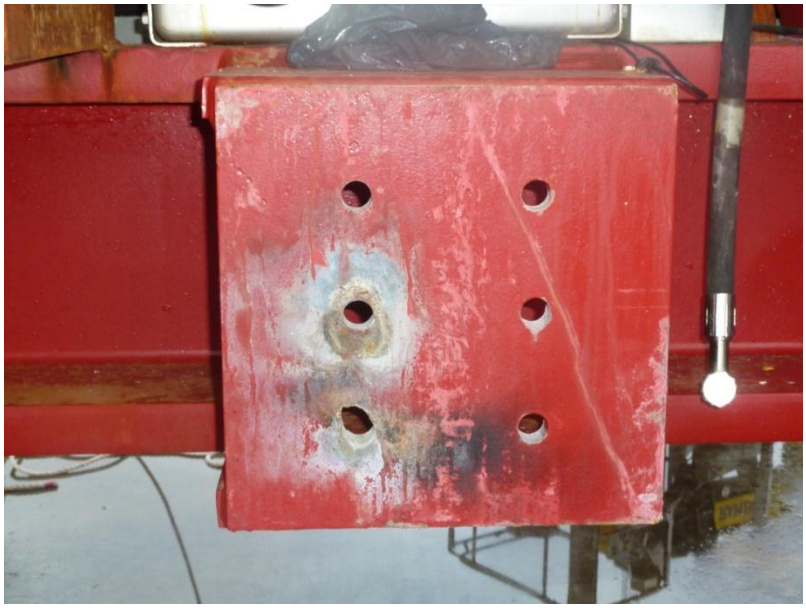


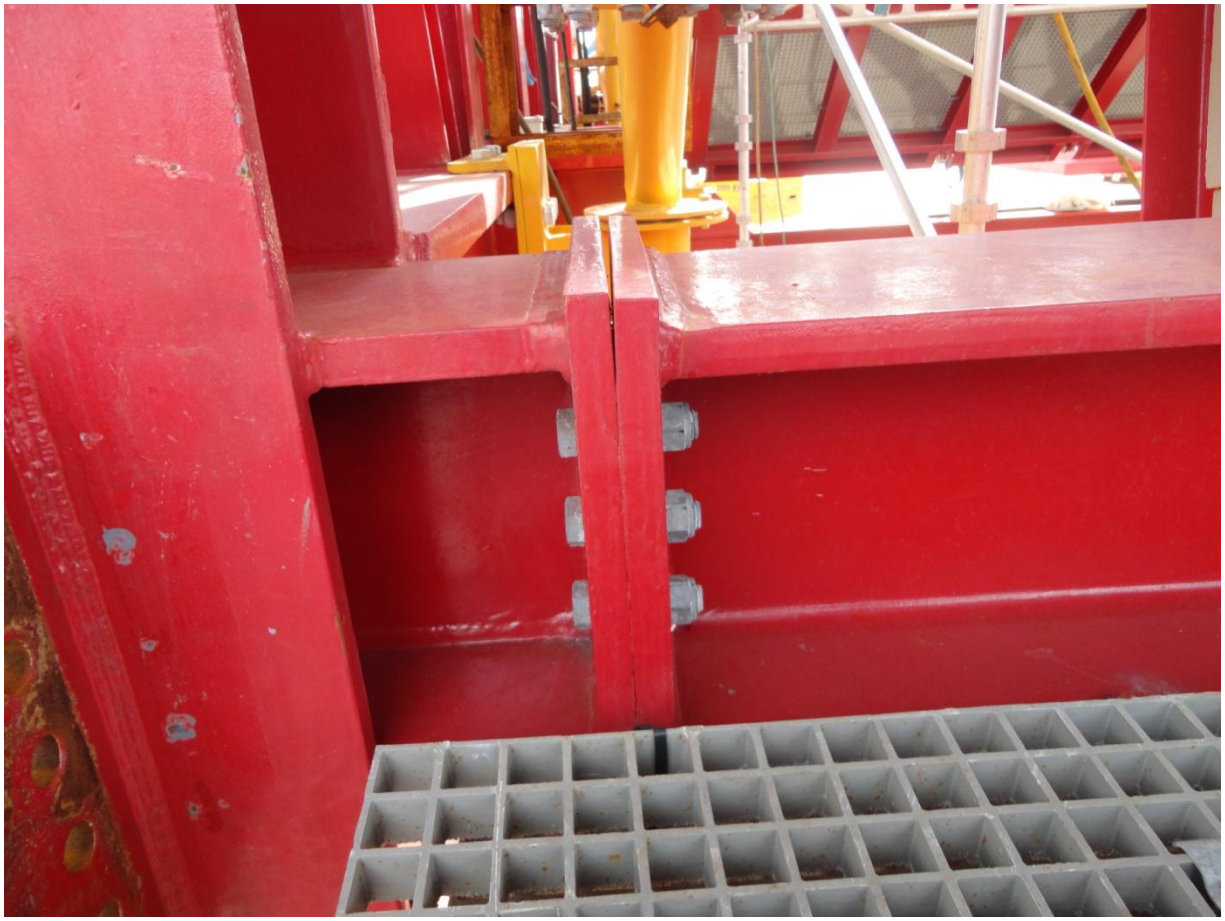
Figure 49: Bolting plate on tower for the cursor rails

Figure 50: Bolting plate on tower for the cursor rails

Figure 51: Burned holes in beams

Description	Holes burned on beams and bolting plates to match patterns (on beams with flanges of more than 70mm)
Reason	• Fabrication intolerance • vessel interfacing • lack of planning
Consequence	• Compromised strength of the beams and plates • Chances of crack development • Increased corrosion on the rough surfaces (integrity issue)
Solution	• Use of slotted holes (cater for mismatches better) and using expansion bolts ,- to be incorporated after careful stress analysis • Holes dimension could be found by analysis the maximizing intolerance possible with the vessel interface • Drilling , instead of burning , if needed • Repair beam o Cut out the piece of the flange and add a new welded piece in place o Fill the unevenly burned holes with weld material and drilling new holes • Replace bolting plates

The gaps in the bolted surface



Description	• Gaps between the bolted faces
Possible Reasons	• Fabrication error • Due to dynamic force form the vessel
Consequence	• Could lead to failure of primary structure (integrity issue) • Bolt Failures could lead to large hazards
Solution	• Tighten the bolts • Shim the gaps • Evaluate the possibility of welding at locations

5. Evaluation of the system for Norsok standard C -002

Norsok standard C -002 states the minimum functional requirements for design and construction of architectural components and equipment to be installed and used on offshore installations. The MHS system and documentation is evaluated for relevant areas, to meet the norsok standards. Items coming under the purview of norsok C-002 are the general requirements for the architectural components, stairs and handrails used for safe access to the levels above the deck.

All materials, components and equipment shall be provided with necessary test reports and certificates from relevant recognized authorities, confirming compliance with project and regulatory requirements. (NORSOK C-002.2006).

The material certificates about the various systems are in the Technip system and has been approved by various regulatory authorities according to requirements

Identification: Each major component, furniture and equipment item shall be provided with a discreetly placed and securely fixed name plate showing the manufacturer's name, equipment type, model, serial number, fire rating, etc.,as appropriate. For doors and windows with a B-rating or stricter, the relevant fire certificate number shall be included on the identification plate (NORSOK C-002.2006).

The Norsok standard C -002 states the requirements for **Life cycle information (LCI) .** LCI shall be developed and transferred to operator/company in accordance with project requirements. The information shall be available for engineering, preparations for operations, start-up, maintenance, repair, modifications and decommissioning of equipment and systems. The LCI shall include both information to be submitted to operator/company, and information to be retained by the supplier on behalf of operator/company. All LCI shall be transferable in digital format. The final LCI shall reflect the as-built status at take-over by the operator/company.(NORSOK C-002.2006).

Norsok rules are applicable to stairs on a field installation except those providing means of access to machinery or equipment skids. On the MHS these are the stairs going to the level 2 (control cabin level) . The other stairs in the MHS system are the ladders that provide access to

machinery or equipment skids shall have to comply with the requirements of EN ISO 14122.Vertical ladders, are used to access the level2 (starboard side) and level 3 .They are areas with little personnel traffic and code allows the use of vertical ladders in such areas

Requirements specified by Norsok , relevant to the MHS tower

Stairs shall be provided in daily frequented areas where there is a height difference between levels of more than 350 mm, and where a ramp cannot maintain the functional requirements. For height differences of less than 350 mm, a ramp solution shall be used.

Stairways in escape routes shall be designed to allow for transportation of injured personnel by use of standard stretchers (length x width = 2 200 mm x 650 mm).

The minimum width of a stairway shall be 1 000 mm measured between the inside of handrails.

Treads shall withstand a foot load of 2 000 N (200 kg) on an area of 100 mm x 100 mm at any position without permanent deflection

For external stairs, treads and landings should be made of open grating. Grating openings shall not allow a 20 mm diameter ball to pass through at any point. This applies above places where personnel are likely to be present. Otherwise 35 mm diameter is acceptable.

Clear headroom (free height) shall be maintained in all stairs, and shall be a minimum of 2300 mm measured vertically above the pitch line of the stair. (NORSOK C-002.2006)

All treads shall have a toe plate of minimum 50 mm height. All landings shall have a toe plate of minimum 100mm height. Openings between toe plate and decks or gratings shall not exceed 10mm.

Extracts from norsok code relevant to the MHS tower :

Handrails should be designed for 1,5 kN/m2, acting horizontally on top of the supports.

The hand- and guardrail system consists typically of a continuous handrail at the top to be grasped by the hand, or just a continuous top-rail when hand support is not required, knee-rails placed parallel with the handrail to prevent accidental passage of a body, vertical stanchions for anchorage of the guardrail system, and a solid toe plate at the bottom to prevent the fall of minor objects.

Decks, gangways and platforms higher than 500 mm shall be equipped with hand- and guardrails. The top of the handrail shall be minimum 1 100 mm above the finished floor or deck

The toe plate shall have a minimum height of 100 mm, and a clearance of maximum 10 mm to the deck. Vertical openings between horizontal knee-rails, handrails and toe plates, shall not exceed 380mm.All connections between elements shall be securely fixed by lock nuts and through bolts, or self-tapping screws Handrails on flights that are 180° to each other shall have a minimum of 100 mm clear distance between rails or between rails and supporting structures, to avoid the possibility of catching hands and fingers.

The handrails meeting the requirements are already in place but any further modifications in the future have to be properly evaluated properly.

Note : The above rule to be applicable for the handrails for the testing arrangement on the quay side .

Recommendations
1. These are not in place for all the major components. Needs to be checked and confirmed. Giving individual part number to the equipments could be beneficial for maintaining the associated documents.
2. The final LCI documentation from TEKMAR , couldn't be found in technip systems . To be obtained from the supplier and used for future maintenance activities.
3. The stairs used for the tower would vary based on the vessel where its installed . but the above mentioned rules needs to be adhered at all times during the fabrication and installation of the stairs during the mobilization on the vessel . The clause about the size of the grating to be used to depend on the deck layout of the ship and smaller grating opening to be used in case the main escape route is bellow the planned stairs.

6. Painting specs used for MHS- NORSOK M501

For the integrity of the structure depends on the types and quality of the paints used . For the MHS following specifications have been used

MHS main structure is painted to Norsok M501, System 7, and colour RAL 3003.
All yellow parts are coated to Norsok M501, System 7, and colour RAL 1004.

These systems are specified by Technip and confirmed used by Tekmar.

NORSOK M 501 –surface preparation and protective coating specifies the requirements for the selection of coating materials, surface preparation, application procedures and inspection for protective coatings to be applied during the construction and installation of offshore installations and associated facilities. This NORSOK standard covers both paints, metallic coatings and application of spray-on passive fire Protective coatings (NORSOK M501, 2004).

Evaluating the main features of the painting system used

The standards specify the coating system no 7 could be used for Submerged carbon steel and carbon steel in the splash zone. Surface preparation is specified by cleanliness - ISO 8501-1 Sa 2½ , roughness- ISO 8503 Grade Medium G (50 µm to 85 µm, Ry5). The minimum dry film thickness (MDFT) is 350µm

Application (if not specified under others)	Surface preparation	Coating system (example)	MDFT µm
Submerged carbon steel and carbon steel in the splash zone.	Cleanliness: ISO 8501-1 Sa 2½ Roughness: ISO 8503 Grade Medium G	Two component epoxy Minimum number of coats: 2	

	(50 μm to 85 μm, Ry5)		350
Submerged stainless steel and stainless steel in the splash zone.	Sweep blasting with non-metallic and chloride free grit to obtain anchor profile of approximately 25 μm to 45 μm.	MDFT of complete coating system:	

The system need to be prequalified and has to be used with a cathodic protection system . the ambient operation temperature is 50 degrees which well above the expected temperatures for the north sea operations. For splash zone additional corrosion allowances. as specified in NORSOK M-0001, to be used . When used in the splash zone the coating system need to be checked for same criteria as coating system 1 . The cursor rails are passing through the splash zones in the moon pool area , which wouldn't see the same effect as an offshore splash zone This could be specifically evaluated and a proper selection criteria to be used .

Prequalification criteria for system 7:

Test	Acceptance criteria
Seawater immersion according to ISO 20340 Testing is required for the following coating systems: • Coating system no. 3B and 7. • Coating system no.	According to ISO 20340.
Ageing resistance according to ISO 20340, procedure A Testing is required for the following coating systems: • Coating system no. 1, 3B, 4, 5A and 5B. • Coating system no. 7 when used in tidal or	According to ISO 20340. Supplementary requirements: 1. Chalking (see ISO 4628-6): Maximum rating 2. Applicable to coating system no. 1 only. 2. Adhesion (see ISO 4624): Minimum 5,0

splash zones.	MPa and maximum 50 % reduction from original value. 3. Overcoatable without mechanical treatment obtaining minimum adhesion of 5,0 MPa. 4. Adhesion (see ISO 4624) for coating system no. 5A and 5B: Maximum 50 % reduction from original value, minimum 2,0 MPa for cement based products and minimum 3,0 MPa for epoxy based products. 5. Water absorption after complete ageing resistance test shall be reported for coating system no. 5A.
Cathodic disbonding according to ISO 20340. Coating system no. 3B and 7. Coating system no. 1 when used in tidal or splash zones.	According to ISO 20340.

Table 19 Prequalification criteria for painting system 7

Recommendations
1. Touch up of the system whenever possible. Thorough checking of the systems every 6 months
2. The prequalification documents were not found in the system. TEKMAR needs to deliver the qualification documents at the earliest.
3. Cathodic protection which need s to be used along with the coating system 7.There are two options that could be looked into in the future
4. Adding new cathodic protection to the system itself. the amount of anodes needed has to be analyzed using proper engineering techniques . the anode will be useful when we have the MHS outside the vessel ,like we have during the recommissioning phase . Also we can have a full control over the corrosion prevention system
5. Connecting the MHS to the ships protection system .even though its a cheaper option , the capacity of ships cathodic protection need to be analyzed and proper connections have to be established . Also the tower would not have any protection system if it on the quay side for extensive modification work. The complete over the protection system could be lacking

7. Spare Parts

Maintenance operations on the offshore systems can only be effective and efficient if the correct spare parts are available at the correct location in a timely manner. For this to happen a robust spare parts management system has to be in place. Ineffective management of spare parts will result in both direct and indirect costs and may well affect the safety of the tower crane. (TCIG, 2008). For an asset on a vessel its all the more challenging as the vessel could be operational in far off distant location and getting the spare parts to the remote location is a challenge as the use of emergency supply boats may be difficult based on the location. In 2011 Technip had operation of nordstream Tie in the Baltic sea and getting offshore certified containers for the spare parts in the Swedish sector was a problem as the offshore infrastructure is not developed there highlighting the importance of having sufficient spareparts.

Out of the two extremes of spare part sourcing - stock every spare part that could ever be required in the MHS stores or to stock nothing, which relies subcontractor stock with courier delivery. A combination of the two has to be used , avoiding a costly inventory whilst ensuring that major items are readily available for use. The items have to listed and stored based on the lead time of delivery and the criticality of damaged components

A list of critical items with long lead times has been identified by consultation with the manufacturer. The items and the place of storage have to be decided based on the criticality evaluation of each item

Ensure that that spares meet the original manufacturer’s specification. Ensuring that this is the case is often a complex process involving a full engineering assessment of the component to be replaced. And could be worth while in investing /preplanning for alternatives for long lead items

Spare parts needs be controlled and monitored using a robust stock control system, helping to allow stock levels to be maintained at economic levels and ensuring that valuable stock is not lost in the pool of equipment. Too much stock will tie up capital unnecessarily and also account

for the storage cost. Stock levels have to be periodically reviewed to guarantee that levels are adjusted in the light of experience from using the system.

Spare parts must be stored in secure dry conditions to minimize deterioration and loss. Some form of racking is essential in order that each part number has a readily identifiable and unique location to ensure that parts can be easily located for issue and stock checks. Spare parts can represent a considerable capital investment and should be treated as tangible business assets (TCIG, 2008).

All spare parts should be permanently marked with at least a part number to ensure that they are readily identifiable in the storage pool with the storage pool manager being aware of the locations. Material specification marking are also important for operations.

Spare Parts –recommendations

Main Winch Trolley System

Item	Qty	Description	Specification	Supplier	Unit Price (GBP)	Total Price (GBP)
1.	1-off	MW trolley roller set	PN-955-01-001	Tekmar	867	867
2.	1-off	MW trolley line encoder	PN-955-01-002	Tekmar	1399	1399
3.	1-off	MW trolley line encoder bracket	PN-955-01-003	Tekmar	79	129
4.	1-off	MW trolley motor & leadscrew kit	PN-955-01-004	Tekmar	8158	8158
5.	1-off	MW trolley motor hose kit	PN-955-01-005	Tekmar	675	675
6.	1-off	MW trolley cylinder	PN-955-01-006	Tekmar	2517	2517
7.	1-off	MW trolley cylinder hose kit	PN-955-01-007	Tekmar	650	650
8.	1-off	MW trolley cylinder seal kit	PN-955-01-008	Tekmar	150	150
9.	1-off	MW trolley cylinder bush & pin set	PN-955-01-009	Tekmar	400	400
10.	4-off	MW Nylon shim set	PN-955-01-010	Tekmar	116	464

Guide Wire Winch Trolley Systems

Item	Qty	Description	Specification	Supplier	Unit Price (GBP)	Total Price (GBP)
1.	1-off	GW trolley roller set	PN-955-02-001	Tekmar	1734	1734
2.	1-off	GW trolley seal kit	PN-955-02-002	Tekmar	150	150
3.	1-off	GW trolley line encoder	PN-955-02-003	Tekmar	1399	1399
4.	1-off	GW trolley line encoder bracket	PN-955-02-004	Tekmar	119	119
5.	1-off	GW trolley motor kit (top)	PN-955-02-005	Tekmar	5625	5625
6.	1-off	GW trolley motor kit (bottom)	PN-955-02-006	Tekmar	5825	5825
7.	1-off	GW trolley motor hose kit (top)	PN-955-02-007	Tekmar	675	675
8.	1-off	GW trolley motor hose kit (bottom)	PN-955-02-008	Tekmar	675	675
9.	4-off	GW shim set	PN-955-02-009	Tekmar	116	464

Mid Level

Item	Qty	Description	Specification	Supplier	Unit Price (GBP)	Total Price (GBP)
1.	1-off	Half height platform cylinder	PN-955-03-001	Tekmar	1650	1650
2.	1-off	Half height platform cylinder seal kit	PN-955-03-002	Tekmar	130	130
3.	1-off	Half height platform cylinder hose kit	PN-955-03-003	Tekmar	350	350
4.	1-off	Wire assembly	PN-955-03-004	Tekmar	333	333
5.	1-off	Hinge pin & bush set	PN-955-03-005	Tekmar	450	450
6.	1-off	Clear com unit	PN-955-03-006	Tekmar	750	750
7.	1-off	Strip light unit	PN-955-03-007	Tekmar	300	300
8.	1-off	Flood light	PN-955-03-008	Tekmar	1150	1150
9.	1-off	Fixed camera	PN-955-03-009	Tekmar	2500	2500
10.	1-off	Pan & tilt camera	PN-955-03-010	Tekmar	3800	3800

Cursor System

Item	Qty	Description	Specification	Supplier	Unit Price (GBP)	Total Price (GBP)
1.	1-off	Latch cylinder	PN-955-04-001	Tekmar	575	575
2.	1-off	Latch cylinder seal kit	PN-955-04-002	Tekmar	170	170
3.	1-off	Latch cylinder hose kit	PN-955-04-003	Tekmar	750	750
4.	1-off	Latch cylinder hydraulic fittings kit	PN-955-04-004	Tekmar	275	275
5.	1-off	Latch cylinder pin & bush kit	PN-955-04-005	Tekmar	260	260
6.	1-off	Latch cylinder grease kit	PN-955-04-006	Tekmar	160	160
7.	2-off	Small split nylon prong	PN-955-04-007	Tekmar	733	1466
8.	2-off	Large split steel prong	PN-955-04-008	Tekmar	834	1668
9.	1-off	Subsea camera	PN-955-04-009	Tekmar	3000	3000
10.	1-off	Proximity switch	PN-955-04-010	Tekmar	208	208
11.	1-off	Cursor carriage roller set	PN-955-04-011	Tekmar	866	866
12.	1-off	Cursor arm cylinder (extend)	PN-955-04-012	Tekmar	1342	1342
13.	1-off	Cursor arm cylinder (open/close)	PN-955-04-013	Tekmar	1142	1142

Hydraulic panel system

Item	Qty	Description	Specification	Supplier	Unit Price (GBP)	Total Price (GBP)
1.	1-off	Danfoss valve bank (8-off)	PN-955-05-001	Tekmar	6273	6273
2.	1-off	Danfoss valve bank (7-off)	PN-955-05-002	Tekmar	5489	5489
3.	2-off	Ball valves	PN-955-05-003	Tekmar	130	260
4.	1-off	Flow divider	PN-955-05-004	Tekmar	1315	1315
5.	1-off	PO check valve	PN-955-05-005	Tekmar	117	117
6.	5-off	Counter balance valve	PN-955-05-006	Tekmar	164	820
7.	1-off	Reducing valve	PN-955-05-007	Tekmar	72	92
8.	1-off	Hydraulic fittings kit	PN-955-05-008	Tekmar	1950	1950

Moonpool Door System

Item	Qty	Description	Specification	Supplier	Unit Price (GBP)	Total Price (GBP)
1.	1-off	Central door cylinder	PN-955-06-001	Tekmar	2792	2792
2.	1-off	Central door cylinder seal kit	PN-955-06-002	Tekmar	150	150
3.	1-off	Central door cylinder hose kit	PN-955-06-003	Tekmar	375	375
4.	1-off	Central door hinge kit	PN-955-06-004	Tekmar	933	933
5.	1-off	Central door roller system	PN-955-06-005	Tekmar	3666	3666
6.	1-off	Central door latch bushes	PN-955-06-006	Tekmar	333	333
7.	1-off	Side door large roller	PN-955-06-007	Tekmar	1416	1416
8.	1-off	Side door small roller	PN-955-06-008	Tekmar	1116	1116
9.	2-off	Side door sheave set	PN-955-06-009	Tekmar	2350	4700
10.	1-off	Side door cylinder	PN-955-06-010	Tekmar	2242	2242
11.	1-off	Side door cylinder seal kit	PN-955-06-011	Tekmar	170	170
12.	1-off	Side door cylinder hose kit	PN-955-06-012	Tekmar	425	425

Push-pull system

Item	Qty	Description	Specification	Supplier	Unit Price (GBP)	Total Price (GBP)
1.	1-off	Push-pull Cylinders	PN-955-07-001	Tekmar	5878	5878
2.	1-off	Push-pull Cylinder pin & bush set	PN-955-07-002	Tekmar	466	466
3.	1-off	Clamp cylinders	PN-955-07-003	Tekmar	2683	2683
4.	1-off	Clamp cylinders top pad	PN-955-07-004	Tekmar	833	833
5.	1-off	Clamp lower clamp assembly	PN-955-07-005	Tekmar	1233	1233
6.	1-off	Rotary pallet motor	PN-955-07-006	Tekmar	858	858
7.	1-off	Push-pull hydraulic fittings	PN-955-07-007	Tekmar	1920	1920
8.	1-off	Rotary pallet hydraulic fittings	PN-955-07-008	Tekmar	650	650
9.	7-off	Counter balance valve	PN-955-07-009	Tekmar	417	2919
10.	1-off	Knuckle & pin set	PN-955-07-010	Tekmar	2050	2050
11.	1-off	Pilot valve	PN-955-07-011	Tekmar	78	78
12.	1-off	Flow divider	PN-955-07-012	Tekmar	1315	1315
13.	2-off	Ball valves	PN-955-07-013	Tekmar	130	260
14.	2-off	Sequence valve	PN-955-07-014	Tekmar	275	550
15.	2-off	DCV	PN-955-07-015	Tekmar	164	328
16.	1-off	Throttle valve	PN-955-07-016	Tekmar	155	155
17.	2-off	Reducing valve	PN-955-07-017	Tekmar	169	388
18.	1-off	Manifold	PN-955-07-018	Tekmar	373	373

Table 20 Spare part recommendations for MHS -general

PROJECT: CONTAINERISED GUIDE WIRE WINCH HPU **CUSTOMER ORDER NO: 11413**

CUSTOMER: LEBUS INTERNATIONAL ENGINEERS LTD **HDUK PROJECT NO: UKS 002031-02**

Recommended Spares List **Date: 11/04/2011**

REF	QTY	HD PART NO.	ITEM PART NUMBER	DESCRIPTION
			HYDRAULIC SYSTEM COMPONENTS	
E1	1	UKS007 000-074	176kW 4P 315SM 440V/3PH/60Hz B5 (IE1 W22) 110v A/C HEATERS	176kW E-MOTOR (160kW AT 50Hz)
E2	1	UKS007 000-073	151kW 4P 315SM 440V/3PH/60Hz B5 (IE1 W22) 110v A/C HEATERS	151kW E-MOTOR (132kW AT 50Hz)
DC1	1	UKS004 002-127	R90.80x125-P500601.95/98sh	DRIVE COUPLING
P1	1	UKS001 001-040	PL A4CSG 355 EPG/30R-VZB85F684N-S1326	CLOSED LOOP PISTON PUMP
P2	1	UKS001 001-045	PL A4CSG 355 EPG/30R-VZB85F684N-S1906	CLOSED LOOP PISTON PUMP
P3	1	UKS001 001-038	A10VO28DFR31RPSC62K01	OPEN LOOP PISTON PUMP
V6	2	UKS002 007-059	KSDER1CB/HN0V	CETOP 3 POPPET DCV
	2	UKS002 012-031	GZ37-4 24VDC 22W	24v DC COIL
V7	1	UKS002 006-018	DBETRE-2X/350G24K31A1M	PROPORTIONAL RELIEF VALVE
V9	2	UKS002 004-078	NFDC-LAN-DBT	FLOW CONTROL VALVE
V10	2	UKS002 002-071	4WE 10 D3X/CG24N9K4	CETOP 5 DCV
V14	2	UKS002 002-053	4WE 6 D6X/OFEG24N9K4	CETOP 3 DCV
V15	1	UKS002 007-055	CDAB-XBN	SHUTTLE VALVE
V17	1	UKS002 001-069	DBDS 20 G1X/315	RELIEF VALVE
V24	2	UKS002 008-011	206010	GAUGE ISOLATOR
A1	2	UKS008 001-013	SB330-02.5A1/112-330A-9	2.5L ACCUMULATOR - 9 BAR PRE-CHARGE
G1	2	UKS005 003-009		0-400 BAR GAUGE
G2	2	UKS005 003-036		0-70 BAR GAUGE
G3	2	UKS005 003-034		0-250 BAR GAUGE
OS1	1	UKS005 002-043	MLG-STD-29-00-16-00	SIGHT GLASS
TS1	1	UKS005 001-049	TA3430	TEMPERATURE SENSOR
FS1	1	UKS005 002-052	SG51.XXSGBCPV	LEVEL SWITCH
H1	1	UKS005 004-001	HBX115/B	1kW IMMERSION HEATER 110v
HE1	1	UKS006 002-012	JK600-3932-8	HEAT EXCHANGER
TP1	4	UKS011 002-024	SMK20-9/16 UNF-VE	TEST POINT
PS1	4	478 2277-759	DS-307/SCH/V2, 5-55 Bar	PRESSURE SWITCH
PT1	2	UKS005 003-052	PN2020	PRESSURE TRANSDUCER / SWITCH
	2	UKS005 007-007	VT-VSPA2-1-2X/V0/T1	AMPLIFIER CARD
EC3	1	UKS014 001-018	E-2031-09	HNC 100 ACTIVE HEAVE CONTROL UNIT
			REPLACEMENT ELEMENTS (12 MONTHS)	
REF	QTY	HD PART NO.	ITEM PART NUMBER	DESCRIPTION
SF1	4	UKS003 007-022	0280 D 010 BN4HC	10µ FILTER ELEMENT
	1		VD 5 D.0/-L24	FILTER SWITCH
SF2	4	UKS003 007-049	2600 R 010 BN4HC	10µ FILTER ELEMENT
	1		VM 2 D.0/-L24	FILTER SWITCH
SF3	20	478 3233-622	400-10	10µ FILTER ELEMENT
	1	478 3233-644	2.2 BAR	FILTER SWITCH
SAB1	4	UKS003 004-016	DC4	AIR BREATHER
			ELECTRICAL SYSTEM COMPONENTS	
	1	**MAIN ENCLOSURE**		
	1	MCCB 1 - 1250A (3VL77122DE)		
	1	Door Interlock Handle for MCCB 1 (3VL9800-3HG-05)		
	1	MCCB 2 & MCCB 3 - 315A (3VL47312DK36)		
	1	MCCB 4 & MCCB 5 - 500A (3VL5702-2DK36		
	1	160kW Soft Starter (3RW4074-6BB34)		
	1	200kW Soft Starter (3RW4075-6BB34)		
	1	C5 - Oil Heater Motor Circuit Breaker (3RV1011-1KA10)		
	1	C5 - Oil Heater Contactor (3RT1017-1AF01)		
	1	C6 - Space Heater Motor Circuit Breaker (3RV1021-4CA10)		
	1	C6 - Space Heater Contactor (3RT1025-1AF00)		
	1	PSU 1 - 24VDC Power Supply 20A (110V-24VDC) WIPOS P1 24-20		
	1	PSU 2 - 24VDC Power Supply 10A (110V-24VDC) WIPOS P1 24-10		
	1	PSU 3 - 32VDC Power Supply 10A (110V-32VDC) PULS QS10		
	1	TX1 - TC 3KVA/3 : Transformer Primary 380-415-440V, Secondary 110V 3KVA		
	1	TX2 - TC 750VA/3 : Transformer Primary 380-415-440V, Secondary 230V 750VA		
	1	MCB 1 Primary Transformer Double Pole - 40A Type C		
	1	MCB 2 Secondary Transformer Double Pole - 32A Type C		
	1	MCB 3 Container Light Circuit Double Pole - 4A Type C		
	1	MCB 4 110V Socket Double Pole - 10A Type C		
	1	MCB 5 PLC Supply (24VDC) Double Pole - 6A Type C		
	1	MCB 6 24VDC Control Circuit Supply Double Pole - 10A Type C		
	1	MCB 7 24VDC Solenoid Circuit Supply Double Pole - 20A Type C		
	1	MCB 8 Primary Transformer 750 VA Double Pole - 6A Type C		
	4	MCB 9 Secondary Transformer 750 VA Double Pole - 4A Type C		
	1	MCB 10-23 Solenoid MCB Single Pole - 2A Type D		

1	MCB 24 Amplifier Card Supply Double Pole - 8A Type C	
1	MCB 25 Water Valve Single Pole - 2A Type D	
4	ESR1 - Pilz Safety Relay PNOZX3 - 24VDC	
1	R0-R14, R16-R23, R25-R29, R40-R43 - Relays 24VDC, 2 pole + Base (G2R2)	
1	R15 - Relay 24VDC (MY4IN)	
1	R24 - Wieland Flare Relay 24VDC (Sckt: 80.063.4021.1 + Relay: 882N-1CH-S)	
1	R32-R35 - Relays 24VDC, 4 Pole + Aux 4 Pole. (3RH1140-1BB40 + 3RH1911-1GA04)	
1	ESR2 - Relay 110VAC, 2 Pole + Base (G2R2)	
1	ESR3 - Relay 24VDC (MY4IN)	
1	EHG060 Heater	
1	ETR 202 (For Regulating Heaters)	
1	NEMO 96HD (MF96001) + Analogue Output Module (IF96004)	
1	Current Transducer - TM3IH30	
1	Current Transformer - TASI (TAS64) 1250/5A	
1	Current Transformer - TABB (TAIBB) 300/5A	
1	Current Transformer - TAIG (TAI400) 500/5A	
	THR1/THR2/THR3/THR4 - Thermistor Relay (TER7)	
	MAIN ENCLOSURE INDICATIONS	
1		
1	White Indicator Light - Contol Voltage On (Lens - 3SB3501-6BA60)	
1	White 24VDC - LED (3SB3400-1PE)	
1	2 Position Switch - Local Control Requested Off/On (3SB3500-2KA11)	
1	2 Position Key Switch - Cabin Control Override Switch (3SB500-4AD11)	
1	2 Position Switch - Container Heating Off/On (3SB3500-2KA11)	
1	Green Pushbutton - Pump Start (3SB3500-0AA41)	
1	Red Pushbutton - Pump Stop (3SB3500-0AA21)	
3	Emergency Stop - 40mm Twist Release (3SB3500-1HA20)	
3	N/O Contact Block (3SB3400-0B)	
	N/C Contact Block (3SB3400-0C)	
	PLC HARDWARE	
1		
1	Q Series - Power Supply - 24VDC PSU 5VDC Out (Q63P)	
1	Q Series - CPU - (Q01CPU)	
1	Q Series - Digital Input Module - 32Pt Input 24VDC Source (QX81)	
1	Q Series - Analogue Input Module 8CH (Q68ADI)	
1	Q Series - Digital Output Module - 16Pt Relay Output (QY10)	
1	Q Series - Profibus Slave (QJ71PB93D)	
1	Q Series - Blanking Module (QG60)	
1	36Pt Terminal Block (A6TBX36E)	
1	1mtr Terminal Block Cable (AC10TBE)	
1	10.4" HMI Touch Screen Including Cable (AGP3500-T1-D24 + CA3-CBLQ-01)	
	4-20mA Signal Splitter Terminals (MCR-SL-UI-2I-NC Ref: 2864176)	
	SCAN RECO	
1		
	Scan Reco Remote Control Unit.	
	OTHER ITEMS	
1		
1	Profibus Redundancy Module (ABB RLM01)	
1	Amplifier Card Holder	
1	Container Space Heater	
	Container Emergency Lighting	

Table 21 Spare part list for winches

Recommendations
1. For the MHS the spare part could be divided into main area- one that stay on board the vessel and the second that would be stored in the base
2. Plan for alternatives for the long lead items
3. Develop a criticality evaluation flowchart could be developed and each item could be evaluated based on this. The main criteria for selection are • Criticality of the equipment- could it potentially stop the ongoing operation • Lead time • Location of manufacture- if the vessel in operation can it picked easily from the current vessel location • Legal requirement of the equipment • Redundancy of the equipment on the vessel- could vessel equipment be used instead (ex. Use of vessel crane instead of main winch) • Size/weight of the equipment • Cost of the spare • Availability in local market- vessel working in the north of Norway need to stock up more spares as the availability of the spare there could very limited • Handling facilities in the base • Use of supply boats in the locations

8. Human Resources - Attributes, Training and Assessment

The supervisors and technicaians for the system are the most important members for the use and maintenance of the system. The industry has identified a few of the generic requirements/Attributes

Maintenance personnel should be:

• Fully conversant with the machinery they are required to maintain and its hazards - hydraulic, mechanical and electrical aspects needs to be covered . • Able to communicate clearly with other personnel on site;

• Properly instructed and trained. Especially the MHS system drivers

• Familiar with safety systems and cultures of Technip.• Aware of their responsibilities under the Health and Safety at Work Act and supporting regulations;

• Trained and competent in the pre use inspection, correct wearing and limitations of their personal protective equipment. (TCIG,2008)

Training

All tower crane maintenance personnel should be trained in a set of skills to enable them to work safely on site and participate effectively in the maintenance process of MHS. There is special requirements for training for the operations of the control systems and the high pressure hydraulic systems on deck. Working at height training and rigging trainings are also needed for the personal involved.

• Understanding basic health and safety requirements, including the risk assessment process especially on the vessel

• Basic crane Slinging and signaling;

• Tool skills are important - including the selection and use of tools Hydraulic and electrical fitting

The MHS should have a supervisor , operator team which is applicable for a mobile asset of this size. When such a huge asset is mobilized on a vessel a dedicated team of technician has to be associated with the asset to perform the offshore operation and perform the maintenance activities. They would work on the maintenance job cards and report back to the base office with a planned shutdown maintenance activity, which will be coordinated by the base team. The lack of supervisors and operators could be the primary reason for the lack of maintenance of the system and the present issues with the MHS..

The MHS system needs supervisor with electro hydraulic background who can take of the system along with doing the maintenance part of the system. The MHS also needs operators for control systems. The control system operator need the similar skills as the offshore crane operator anf the best option would be to have the crane operator of the vessel trained for the MHS as well which could reduce the offshore manning of the vessel.

No personal should use the system without proper training or brief introduction to the system. They have to know the capabilities and limitations of the system along with the knowledge of the possible hidden dangers within the system. Also a psychological approach to the job could be made. There detailed task descriptions are made based on the studies made to job design is developed keeping in mind the physical and psychological limitations of human. Emotional exhaustion correlated negatively with job performance (Wright & Cropanzano 1998).

The management should also develop a [performance evaluation criteria for the supervisory team so as to ensure that they are aware of the benchmarks that’s been set and would like ot achieves those goals as much as possible. This is also regarding the HSE policies and target levels. It is important for objectives, strategies, actions and measures must evolve over time (Dixon, et al ,1990). This stage prepares the ground work for the implementation of the performance system. Manufacturers need a framework to balance all of the elements required for performance management success (Aberdeen group, 2004).

9. Challenges and lesson learnt/ Recommendations

The MHS is a potential market leader in the Inspection maintenance and repair market because the capacity of the system and the features that would make it suitable for application in a wide spectrum of operations. But before it could attain its full potential and to be seen as a reliable tool by the industry it has to be modified and all the systems upgraded to meet the arduous task of offshore operations.

Challenges to the project

The MHS as a system has various stake holders , Technip – the asset owners . Tekmar- the main contractor for the design , fabrication and delivery of systems, MJR- subcontractors for HPU . bosch rextrot- subcontractors for control systems , Leibus- subcontractors for wires and winches and various other smaller subcontractors who have been involved in the fabrications and deliver of the system. To get all the needed information to complete a technical evaluation has been a challenge. The each of the subcontractors had different set of specifications. I went through each of these and compare them with the relevant standards and suggest for modification where it was seen necessary. Having various subcontractors makes it even more challenging to get the information. This highlights the need for having a focal point for each subcontractors and all the information to be available in line with the client/ asset owner document numbers and document control systems. There are also issues regarding the updated revision of the document issued with the equipments. Its seems that in the industry only the hard copies are stored which without the back up of soft copies stored safely could be a dangerous situation (especially coming to tracking the changes.)

The MHS is a complex system with very many different fields of engineering coming along and acting in unison to obtain operational success. The main task was to understand each of these systems and their interfaces with each other in detail. While performing the technical evaluation it was challenging to identify potential issues that could hamper the reliability and safety of operations. The study saw a wide spectrum topics including

Structural engineering –

- Integrity of the primary structural components of tower
- Padeye verification. Detailed design of the Padeyes and verifications of the existing padeyes.
- Bolted joints – use of slotted bolt holes and fit up during mob , modification of the damaged/burned holes. Dimensioning of the bolted holes based on the maximum deflections of the tower.

Electrical engineering

- Power requirement of the individual subsystem for the complete operation of the MHS tower
- Vessel interfaces of the MHS- the MHS used approx 2MW power which on a average ship is very high load. Also when the MHS is working in AHC mode it can give back the power to the ship. The ship must be able to be receive the power or should have facility to burn the extra power received.
- Generator selection for testing and for the future use if the capacity of the vessel seems insufficient

Rigging

- Design for the various lifting operations planned for the testing phase
- Working at heights

Hydraulics

- Modifications for the HPU units and the connections to the operations systems on the tower
- Modification to the piping arrangement
- Modifications to the deck plans in the future

Wire integrity management

- Checking the main and guide wire winches and specifying the maintenance schedule
- Understanding the wire inspection techniques . unspooling lubricating and re spooling of the wire onto the main winch.

Corrosion and material technology

- Modification of the HPU for corrosion prevention
- Corrosion prevention of the tower structures
- Painting
- Evaluation of the use of anodes for the MHS systems and having proper earthing of the components to the vessels.

Maintenance strategy

- Developing a maintenance strategy based on condition monitoring techniques. Keeping in mind the organizational structure and resources of the company

Studying all these various aspects and coming up with solutions has been a very extracting yet rewarding experience where in I got to study the various topics and discuss in detail various subject experts. To come with the recommendations, I had to physically survey most of the part. And had to learn in detail about the offshore operations and interfaces of all the subsystems. It has helped to gain a detailed overview of the various segments in the industry. But it has been challenge to communicate effectively with the various subcontractors and to obtain information about the various subsystems. Also there has been pressure to meet the expectations of the various stakeholders of the system including the owner , fabricator , operator etc.

As an extension of this thesis, I have been asked to take to be a part of the asset management group of Technip where MP8 would be used to monitor the maintenance of all the assets of the Technip Stavanger. The maintenance schedule would be developed in detail and would be updated in the MP8 system that we would be used to monitor the assets of Technip.

There have been issues which have been highlighted during the review of the system during this thesis. From a project management perspective it has been a challenge because of the large scope of work and the amount of subcontractors involved in the project. As it was seen during the evaluation lot of the issues could have been avoided if a better subcontractor follow up was in place. The challenges were magnified due to the geographical distances as the product was fabricated and assembled in the UK where as the management was based in Norway. Also some of the work that seem to have occurred could be a result of schedule pressures on the vessel and the cost involved on the mobilisation of the tower on the vessel.

- The quality control and assurance need to be managed by the clients /parent company . It emphasis on the need for resident quality surveyor when it's a long term project .
- Need for higher quality surveillance in case for fixed cost projects
- Emphasis on the need for resident quality surveyors
- More focus functional test , especially check on the tolerances in the moving parts
- Final acceptance test (FAT) to be more thorough
- Plan for a more efficient mobilisation with proper quality checks

For the technical evaluation, the system was studied in detail along with the documentation. Fabrication intolerance have been the major issue in the system along with lack of timely maintenance. Each of the main items was studied in detail to come with a detailed maintenance plan. The design of the faulty elements have been reviewed and modification proposed where the design seem to have failed. There are have been various recommendation to improve the safety in the system. Also coming up with more ergonomic designs for better efficiency during operation. Some of the items have to be modified to account for faster mobilisation. The mobilization time is critical for the vessel and the asset owner and each day saved could potentially save million during the life time of the MHS

The technical recommendations are:

Functionality of MHS

- Crowded deck around the tower main structure, with various accessories and hoses in the HPU. Look at the option of using permanent hard pipes or hanging the hoses to the tower. –

This quite common in offshore construction vessel that around the secondary items, like the MHS which are installed at a later stage, the deck area is crowded causing substantial tripping hazards. Better planning and used of hard pipe permanently attached to the tower needs fabricated for the future.

- Providing with a dedicated custom made tool kit of the unit including safety harness to be installed on the port side of the vessel – along with the main structure
- Heating for the HPU is important. use signal lights outside HPU to confirm power availability to HPU at all times. HPUs in the North sea sectors need this facilty so as to ensure they are heated to required temperature at all times.
- Cable protection for the wires on deck –Plan to carry spare deck cable protectors onboard
- Color the possible trip hazards for easy visibility- to be implemented in all offshore facilities.
- Remodel the funnel near the sheaves , the receptacle for the crane block . It needs to provide better guidance to the crane block- to be used in all offshore application where the crane blocks have to go in to the structure. Test prior to sailing whether the crane blocks can go into the receptacles in bad weather.

Sheave and positional system for MHS

- All exposed sheave shaft to be greased weekly and covered to prevent grease loss and ingress of dirt and dust
- Weekly checking of the sliding modules for misalignments and debris ingress
- Weekly Checking the Teflon friction pads for general conditions, thickness and debris
- Make permanent lift plans for the guide wire positioning modules with dedicated rigging
- Weekly checking of the exposed jack screws for alignment, lubrication and debris. Needs to be covered when not in used

Use of Rollers offshore

- Weekly check of the roller lubrication –It should not be tight and not lubricated
- Specify the allowable play on the roller itself
- Specify the safe working capacity of the rollers on the itself
- Specify the rigidity of the shaft along with the maximum loading

- Close monitoring of tolerances during assembly –check point for quality surveyors

Wires maintenance offshore

- Weekly checking of the state of lubrication of the wire
- Any lubrication and service dressing should be compatible with the original lubricant used by the wire rope manufacturer. Manufacturers should advise whether pressure lubrication is suitable for a specific wire or, if not, what method of lubrication and lubricant is recommended. Pressure lubrication needs to be carried out, with care, by operators trained in using the equipment.
- During the testing phase where additional smaller wires need to be attached to the bigger wire few points need to be noted
- As the wire ropes are removed and shortened from drums for maintenance and testing purposes, it is important to re-spool them correctly with proper pre tensioning.
- Also alarms, cut-outs and other control equipment will require to be preset and checked, after each spooling.

Gripper pads on skidding system

- Gripper pads modification for better grips with the beams – Proper testing with rated load to find out beam bending.
- Weekly checking of the general status of the gripper pads
- Modifications of the gripper pads for corrosion resistance

Skid Rails on deck and platforms

- Look of unusual scratches on the skid rails . debris could be stuck between the pads and skidrails
- Cover the areas skid rail location when there substantial deck activity. Ex. grinding on the deck cause the debris over the equipments
- It's found that the speed of the push pull units is limited. Takes too much time during offshore operation .Look at the possibility to improve the speed of the units
- Check the levels above deck – It has to be flat at each mobilizations have to be ensures because of deck irregularity

Pallet on deck /offshore facilities

- Permanent additional sacrificial plates to be bolted on the pallets. Drill sea fastening holes on all the pallets
- The speed of travel is limited. uses lots of time during offshore operation
- Special warning signals on deck when the pallets are operating to warn the people on deck
- Barrier off the area when the pallets are moving

Painting specifications

- Touch up of the system whenever possible. Thorough checking of the systems every 6 months
- The prequalification documents need to be followed also for temporary installation.
- Cathodic protections which need s to be used along with the coating system 7.There are two options that could be looked into in the future. More stringent follow up
    - Adding new cathodic protection to the system itself . the amount of anodes needed has to be analyzed using proper engineering techniques . the anode will be useful when we have the MHS outside the vessel ,like we have during the recommissioning phase . Also we can have a full control over the corrosion prevention system
    - Connecting the MHS to the ships protection system .even though its a cheaper option , the capacity of ships cathodic protection need to be analyzed and proper connections have to be established . Also the tower would not have any protection system if it on the quay side for extensive modification work. The complete over the protection system could be lacking

Spare parts

- For the MHS the spare part could be divided into main area- one that stay on board the vessel and the second that would be stored in the base
- Plan for alternatives for the long lead items

HPUs and piping in general

- Use stainless steel pipes especially inside HPUs and area where there are constant human contact
- Avoid using zinc coated pipes. They should not be cold bended after coating and left without proper extra coating. The coating needs to be monthly checked for damages

This thesis report is written to highlight all the details, bringing to light the various aspects of designs along with the various issues that needs to be rectified, making it a reference for the industry in future. This was done taking into considerations the sensitiveness of various stakeholders in the project.

Conclusion

The aim of the thesis was to assess and evaluate a complex system with regards to integrity, reliability and propose modifications which could be used widely in the offshore industry. The MHS highlights the importance of having resident client quality supervisors who can check and ensure the quality of the products received. The technical recommendation given could be used in the asset management of similar systems and in the maintenance of the interfaces of the various subsystems. The integrity issues have been address which would result in a more reliable system operational offshore. Some of the issues where in the basic design, while most of them were related to the interfaces and quality of components used. All these issues have been identified and the various recommendations to solve them have been listed in the thesis. These recommendations have been based on my personal offshore experience and also results of detailed technical discussions with various industry pioneers based on the codes, standards and industry self imposed regulations and various leading company specification.

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APPENDIX -1 *Greasomatic specifications*

WYMARK TECHNICAL INFORMATION

4 August 2000

BRITISH, EUROPEAN & INTERNATIONAL PATENTS

THE GREASOMATIC'96
SELF CONTAINED AUTOMATIC LUBRICATOR

A GREASOMATIC '96
is a self-ejecting canister of lubricant designed to screw into a grease nipple socket or other lubrication point, and discharge its content of 120 ml of lubricant in a controlled continuous flow, for a preselected period of between one month and twelve months. It is driven by gas that is generated by slow galvanic chemical reaction. It is completely self contained and needs no fallible pumps, motors, springs, batteries or electronic circuitry.

HOW IT WORKS
Built into the top of each GREASOMATIC are a zinc/molybdenum galvanic element and a flexible rubber expansion chamber containing a mildly acidic liquid electrolyte. The unit is activated by injecting the galvanic element into the electrolyte. The gas generated gradually expands against a piston, to extrude the lubricant slowly but surely into the bearing to which the GREASOMATIC is fitted. The electrolyte and gas remain hermetically sealed within the expansion chamber to prevent contamination of the lubricant.

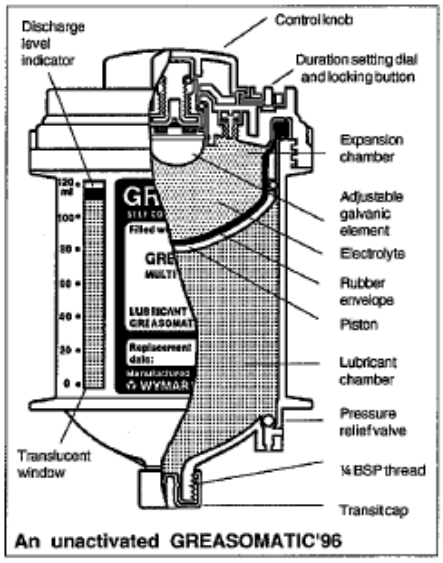
HOW THE DISCHARGE RATE IS CONTROLLED
The discharge duration of a GREASOMATIC '96 is dependant on the rate of gas generation. This is governed by the configuration of the galvanic element. The GREASOMATIC '96 has a unique adjustable galvanic element. Before activation, this is held in the underside of the cap and is connected to the control knob on the exterior of the unit. Rotating the control knob adjusts the protrusion of a rod shaped electrode to provide the appropriate rate of gas generation for the discharge duration set on the dial. Settings of 1, 2, 3, 4, 6, 8 or 12 months duration are available. (These periods apply at an ambient temperature of about +20°C and will be varied by abnormally high or low temperatures - see overleaf).

ACTIVATING A GREASOMATIC '96
After the discharge duration has been set, the red locking button is depressed to secure the setting and disconnect the control knob from the dial. Five further clockwise rotations of the control knob then cause the element to be injected into the electrolyte to start the GREASOMATIC working.

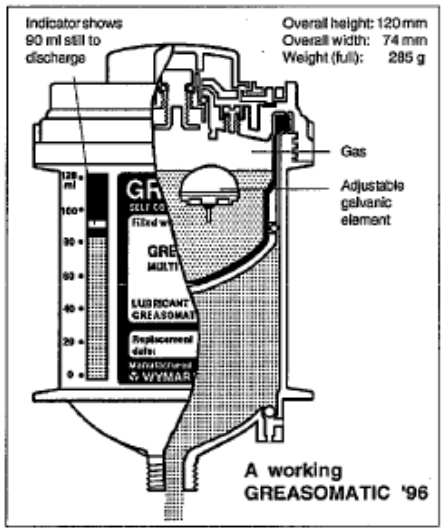
MONITORING THE LUBRICANT DISCHARGE LEVEL
Throughout the working life of a GREASOMATIC'96 an indicating ring on the ejection piston shows through translucent windows in the body to enable its lubricant level to be monitored.

HOW A GREASOMATIC IS INSTALLED
The lubricant outlet in the base of a GREASOMATIC '96 has a ¼ BSP male thread to enable it to be screwed by hand to fit tightly into a standard grease nipple socket. Adaptors are available to enable GREASOMATICs to be fitted into sockets of other sizes. With the aid of extension tubes (of at least 5 mm internal bore and up to 2 metres in length), they can easily be installed at a distance from the lubrication point. This is particularly useful when it is desired to group a number of GREASOMATICs together on a panel for ease of access, or when it is necessary to isolate them from extremes of temperature or from excessive vibration. Two or more units may be coupled together in order to increase the supply of lubricant to a bearing. A GREASOMATIC will work in any position and need not be mounted upright. It can be mounted on its side or upside down. It can be fitted to rotating or moving machine parts, providing the movement is not violent enough to cause the plastic base to break. A GREASOMATIC will work indoors or out of doors - it will even work under water or encased in ice !

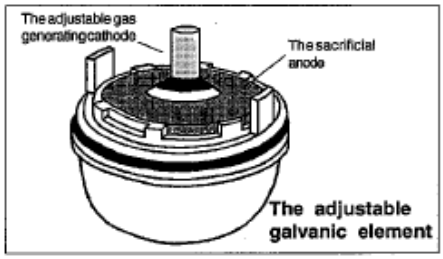
USE IN PRESSURISED SYSTEMS
If a GREASOMATIC is to discharge into a pressurised system (such as a high pressure pump bearing or a compressed air line), it is essential to isolate the GREASOMATIC from the back-pressure by fitting a non-return valve (Accessory GA 17), and the pressure in the system must be relieved periodically to permit the GREASOMATIC to inject lubricant. This can normally be done at the end of the days work. In such circumstances a GREASOMATIC injects lubricant intermittently rather than continuously.



An unactivated GREASOMATIC'96



A working GREASOMATIC '96



The adjustable galvanic element

ACCESSORIES & FITTINGS
A wide range of fittings is available to facilitate the installation of GREASOMATICs. These are normally semi-permanent fixtures that are left in situ when spent GREASOMATICs are replaced. Full details of the current range may be found in the separate information sheet entitled **GREASOMATIC '96 Accessories and Fittings** in which some typical mounting assemblies are also illustrated

CONTINUED OVERLEAF

WYMARK TECHNICAL INFORMATION

4 August 2000

DAILY LUBRICANT INPUTS AND DISCHARGE DURATIONS AT VARIOUS TEMPERATURES

The nominal discharge durations of 1, 2, 3, 4, 6, 8 or 12 months apply at an ambient temperature of +20°C and will vary if the unit operates at abnormally high or low temperatures. Guidance on the approximate discharge durations (and the interrelated daily lubricant inputs) that can be expected at various temperatures is given in the chart below. Values for intermediate temperatures may be obtained by interpolation.

Dial setting	Average ambient temperature at the location of the GREASOMATIC (not that of the bearing)					
	-10°C	0°C	+10°C	+20°C	+30°C	+40°C
1	0.5 ml daily for 8 months	1 ml daily for 4 months	2 ml daily for 2 months	**4 ml daily for 1 month**	8 ml daily for 0.5 months	
2	0.25 ml daily for 16 months	0.5 ml daily for 8 months	1 ml daily for 4 months	**2 ml daily for 2 months**	4 ml daily for 1 month	6 ml daily for 0.7 months
3	0.2 ml daily for 24 months	0.3 ml daily for 12 months	0.7 ml daily for 6 months	**1.3 ml daily for 3 months**	2.7 ml daily for 1.5 months	4 ml daily for 1 month
4		0.25 ml daily for 16 months	0.5 ml daily for 8 months	**1 ml daily for 4 months**	2 ml daily for 2 months	3 ml daily for 1.3 months
6		0.2 ml daily for 24 months	0.3 ml daily for 12 months	**0.7 ml daily for 6 months**	1.3 ml daily for 3 months	2 ml daily for 2 months
8			0.25 ml daily for 16 months	**0.5 ml daily for 8 months**	1 ml daily for 4 months	1.5 ml daily for 2.7 months
12			0.2 ml daily for 24 months	**0.3 ml daily for 12 months**	0.7 ml daily for 6 months	1 ml daily for 4 months
	+14°F	+32°F	+50°F	+68°F	+86°F	+104°F

WORKING PRESSURES

Under normal conditions a GREASOMATIC'96 operates at a low pressure of less than 1 bar, The exact pressure is determined by the resistance to flow of the lubrication channels and the bearing. (The main reason a grease gun is designed to exert very high pressure is to overcome the high resistance of the grease nipple itself - with the nipple removed, the lubricant should flow freely). If old lubricant has stiffened in a neglected bearing, the GREASOMATIC's pressure will build up until the obstruction is cleared and lubrication can begin.

THE PRESSURE RELIEF VALVE

In the event of a complete blockage of the lubrication channels, the GREASOMATIC's internal pressure will build up to about 6 bars at which level the pressure relief valve will operate as a safety measure and release lubricant from the base. This prevents overpressurisation and serves as a warning that no lubrication is taking place.

USE AT EXTREME TEMPERATURES

A GREASOMATIC'96 can be installed at any ambient temperature between -20°C and +60°C. If a GREASOMATIC is required to lubricate a bearing operating at a temperature outside this range, or if it is desired to adjust the discharge rate and lubricant dosage for a bearing operating within that temperature range, the GREASOMATIC should be installed elsewhere in a more moderate temperature and should be connected to the bearing by extension tubing. The lubricant selected must always be suitable for use at the temperature of the relevant **bearing** of course. If a GREASOMATIC'96 is required to work in widely fluctuating temperatures, this will present no problem but the lubricant input rate will fluctuate accordingly.

LUBRICANT FILLINGS

A GREASOMATIC'96 can be filled with almost any type of lubricant. However many widely used **greases** are prone to oil-soap separation when subjected to sustained light pressure in a GREASOMATIC. This can lead to a serious curtailment of the GREASOMATIC's working life. It is therefore essential to use only greases or gels that have been tested and approved for use in GREASOMATICs if the discharge rates and working lives quoted above are to be realised in practice. Such considerations do not apply to **oils**, and GREASOMATICs filled with virtually any type of oil or fluid lubricant will function satisfactorily. For details of approved high performance lubricant fillings, see the separate publications entitled **GREASOMATIC'96 Standard Grease Fillings** and **GREASOMATIC'96 Standard Oil Fillings**.

SPECIAL FACTORS WHEN USING OIL FILLINGS

The handling of GREASOMATICS with oil fillings is not quite as straightforward as in the case of those with grease fillings because liquid will run out of the GREASOMATIC during installation unless simple precautions are taken. One method is to install the GREASOMATIC upside down with the discharge outlet uppermost, using if necessary an **inverted mounting assembly.** Alternatively, an oil filled GREASOMATIC'96 can be installed with its discharge outlet downwards if a **non-return valve** (Accessory GA17B) is fitted. This will only permit the oil to discharge drop by drop as the internal pressure rises above 0.3 bars. If the oil is to be injected into a long rising lubrication channel, the fitting of a non-return valve is essential or the oil will run out of the system whenever a spent GREASOMATIC is replaced. It should be borne in mind when handling an oil filled GREASOMATIC that once the transit cap has been removed, the GREASOMATIC must be held upside down. If it is to be installed with the discharge outlet downwards, the non-return valve must be fitted to it (rather than to the bearing) before inverting the combined GREASOMATIC and valve assembly and fitting it to the bearing. Full details of the non-return valve and an inverted mounting assembly are given in the publication: **GREASOMATIC'96 Accessories & Fittings**.

CAUTIONARY NOTE

GREASOMATICs are made to the highest standards of accuracy and consistency, and the information in this and other GREASOMATIC'96 publications is provided in good faith. However the conditions in which GREASOMATICs are used and the lubrication needs of different bearings can vary so widely, that no responsibility can be accepted for any loss or damage to machinery or equipment as a result of inadequate lubrication provided by a GREASOMATIC. Where continuous lubrication of a bearing is a critical requirement, it is essential for the user to inspect and ensure that lubrication is adequate. This is made easy by the discharge level indicator that shows through the translucent windows in the GREASOMATIC'96.

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WYMARK TECHNICAL INFORMATION

Revised
20 January 2009

THE GREASOMATIC®
SINGLE POINT AUTOMATIC LUBRICATOR

STANDARD GREASE FILLINGS

Grease MP — Multi-purpose grease.

A high quality, multi-application, long life grease with excellent adhesive qualities and water resistance. It is capable of absorbing moderate levels of water without softening or changing consistency.

Greasomatic label marking:	Grease MP
Basis:	Mineral oil with Calcium sulphonate / carbonate complex thickener.
Colour:	Tan.
Consistency:	NLGI 2.
Temperature range:	-25° to +165°C / +13° to +325°F.
Drop point:	+304°C / 579°F.
Worked penetration:	276 at 25°C (IP 50).
Water resistance:	Fully resistant at +90°C (DIN 51807).
Timken OK load:	37 kg/60 lbs minimum.
dN factor:	500.000
Compatibility:	Miscible with other lithium, calcium or lithium/calcium base greases.

Grease FG — For use in processing foodstuffs and pharmaceuticals.

A synthetic grease that has been specially formulated to provide outstanding lubrication in the food processing industry. It is recommended as a multi-purpose lubricant across all food processing applications. NSF Registration No. 135799.

Greasomatic label marking:	Grease FG
Basis:	Synthetic oil with calcium sulphonate complex / carbonate thickener.
Colour:	Tan.
Consistency:	NLGI 2.
Temperature range:	-40° to +200°C / -40° to +392°F.
Drop point:	304°C - 579°F.
Worked penetration:	294 at 25°C (IP 50).
Water washout:	Fully resistant at 90°C (ASTM D1264).
Shell 4 ball weld load:	500 kg (IP 239).
dN factor:	500,000.
Dynamic corrosion resistance:	0:0 (EMCOR) (IP 220).
Copper corrosion:	1A.
Compatibility:	Mixing with other greases not recommended.

Grease HT — For very high temperatures.

A specially formulated grease for maximum lubrication at very high temperatures.

Greasomatic label marking:	Grease HT
Basis:	Mineral oil/synthetic oil mixture : inorganic gel.
Colour:	Green-brown.
Consistency:	NLGI 1.
Temperature range:	-10° to +210°C / +14° to +410°F.
Worked penetration:	310 - 340 at 25°C (IP 50).
Base oil viscosity:	1500 - 2000 cSt at +40°C (DIN 41562).
Water resistance:	Fully resistant at+90°C (DIN 51807).
dN factor:	250,000.
Compatibility:	Mixing with other greases not recommended.

Grease EPM — For extreme pressure conditions.

A high quality, multi-application, long life premium performance, all season, extreme pressure grease, containing 3% molybdenum disulphide for protection against vibration and shock loading.

Greasomatic label marking:	Grease EPM
Basis:	Synthetic oil with synthetic lithium complex thickener plus 3% MoS2.
Colour:	Grey-black
Consistency:	NLGI 1.
Temperature range:	-40° to +170°C / -40° to +338°F.
Drop point:	+305°C / +581°F .
Worked penetration:	324 at 25°C (IP 50).
Water resistance:	Fully resistant at +90°C (DIN 51807).
Timken OK load:	27 kg / 60 lbs minimum.
dN factor:	500,000
Compatibility:	Miscible with other lithium, calcium or lithium-calcium base greases.

andard Greases

Continued overleaf

GREASOMATIC®

STANDARD GREASE FILLINGS (continued)

WYMARK TECHNICAL INFORMATION

Revised
20 January 2009

Grease OG — Open gear grease.

A soft, smooth and extremely adhesive grease for lubrication of open gears. It has excellent water displacing properties and is particulary suitable for gears operating in wet or humid conditions.

Label marking:	Grease OG
Basis:	Solvent refined mineral oil with aluminium soap thickener.
Colour:	Black.
Consistency:	NLGI 0/1.
Working temperature range:	-30° to +70°C / -22° to +158°F.
Worked penetration:	320 - 350 at 25°C (IP 50).
Water spray resistance:	< 0.5% loss (ASTM D404).
Compatibility:	Mixing with other greases not recommended.

Grease CS — For chaindrives and slideways operating in arduous conditions in which Oil SC would be unsuitable.

A semi-fluid grease incorporating extreme pressure additives and anti-oxidants to provide effective lubrication with good corrosion resistance. It provides a water repellent protective film.

Label marking:	Grease CS
Basis:	Mineral hydrocarbons : lithium soap : 2% MoS2.
Colour:	Dark green.
Consistency:	NLGI 00/000.
Working temperature range:	-10° to +100°C / +14° to +212°F.
Worked penetration:	420-450 at 25°C (IP 50).
Base oil viscosity:	900 cSt at +40°C (DIN 41562).
Compatibility:	Mixing with other greases not recommended.

Grease WP — Waterproof grease.

A high performance, strongly adhesive, extremely waterproof grease, containing extreme pressure and anti-wear additives, corrosion inhibitors and anti-oxidants. Specially developed for use in water and sewage treatment plants, marine and off-shore applications and other hostile water environments.

Label marking:	Grease WP
Basis:	Blend of refined mineral hydrocarbons, synthetic polymers & lithium soap.
Colour:	Pale green.
Consistency:	NLGI 2.
Working temperature range:	-20° to +130°C / -4° to +266°F.
Drop point:	+180° C (ISO 2176).
Worked penetration at 25°C:	265-295 (IP 50).
Base oil viscosity:	1000 cSt at +40°C (DIN 41562).
Water resistance:	Fully resistant at +90°C (DIN 51807).
Water washout test:	1% max.
Rust test:	No.1 rating.
Timken OK load:	25 kg / 55 lbs.
Speed rating:	2500 rpm max.
dN factor:	250,000
Compatibility:	Miscible with other lithium base greases.

All the above **standard grease fillings** are produced for Wymark under rigorous quality control by major manufacturers of advanced lubricants. They have been tested in the Wymark Laboratory and found to be free from oil-soap separation (see below) and have therefore been approved for use as GREASOMATIC fillings. The performance figures are provided in good faith for guidance only and are not intended to constitute a guaranteed specification.

Other grease fillings

GREASOMATICs can be filled with other types of grease. However, many widely used greases are prone to oil-soap separation when subjected to sustained light pressure in single point lubricators such as the GREASOMATIC. This can lead to a serious curtailment of the lubricator's working life. It is therefore essential for other greases or to be tested and approved in the Wymark Laboratory if the discharge rates and working lives quoted in the GREASOMATIC Technical Information Sheet are to be realised in practice.

Other packings

All the above greases are available packed in suitable cartridges and cans or kegs, for use when blocked bearings are being purged prior to installing a GREASOMATIC

Wymark Ltd,
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TI Standard Greases

APPENDIX 2 *Checklist for inspectors*

Check list of the inspectors

Lifetime Limiting Mechanisms	Criticality Category	Effect	Mitigation	Current Design Standards	Likely Shortfall	Comments
Structure: Boom						
Fatigue	High	Could lead to a collapse of the boom and a dropped load.	Operational Records, NDE, Inspection, PD6493 Assessment	BS2573: Part 1: 1983: Section 8 and Lloyds Rules		non ductile behaviour, crane likely to be at the end of its fatigue life
Corrosion	High	Could lead to a collapse of the boom and a dropped load.	Protective Coating, Corrosion Allowance, Strengthening of vulnerable areas or de-rating	BS2573: Part 1: 1983: Section 4.2 and Lloyds Rules		Corrosion more likely due to unrectified paint defects
Damage	High	Could lead to a collapse of the boom and a dropped load.	Securing arrangements for boom in stowed position			Unattended minor damage may progress to more serious defects. Procedures should include ensuring that the boom is securely stowed when out of service
Loose Fittings	High	Could lead to the boom becoming detached and may lead to a dropped load.	Type of fitting, maintenance, inspection			
Structure: Whip Hoist Structure						
Fatigue	High	Could lead to a collapse of the whip hoist jib and a dropped load.	Operational Records, NDE, Inspection, PD6493 Assessment	BS2573: Part 1: 1983: Section 8 and Lloyds Rules		non ductile behaviour, crane likely to be at the end of its fatigue life
Corrosion	High	Could lead to a collapse of the whip hoist jib and a dropped load.	Protective Coating, Corrosion Allowance, Strengthening of vulnerable areas or de-rating	BS2573: Part 1: 1983: Section 4.2 and Lloyds Rules		Corrosion more likely due to unrectified paint defects
Damage	High	Could lead to a collapse of the whip hoist jib and a dropped load.	Securing arrangements for jib in stowed position			Unattended minor damage may progress to more serious defects. Procedures should include ensuring that the whip hoist is securely stowed when out of service
Loose Fittings	High	Could lead to the whip hoist jib becoming detached and may lead to a dropped load.	Type of fitting, maintenance, inspection			
Structure: Boom Bearing						
Damage	High	Could lead to a collapse of the boom and a dropped load.	Evaluate risk and strengthen/de-rate if required.			

Lifetime Limiting Mechanisms	Criticality Category	Effect	Mitigation	Current Design Standards	Likely Shortfall	Comments
Structure: Apex/A-Frame						
Fatigue	High	Possible collapse of the apex/A-frame and a dropped load/boom.	Operational Records, NDE, Inspection, PD6493 Assessment	BS2573: Part 1: 1983: Section 8 and Lloyds Rules		non ductile behaviour, crane likely to be at the end of its fatigue life
Corrosion	High	Possible collapse of the apex/A-frame and a dropped load/boom.	Protective Coating, Corrosion Allowance, Strengthening of vulnerable areas or de-rating	BS2573: Part 1: 1983: Section 4.2 and Lloyds Rules		Corrosion more likely due to unrectified paint defects
Damage	High	Could lead to a collapse of the apex/A-frame and a dropped load/boom.	Evaluate risk and strengthen apex if required.			Unattended minor damage may progress to more serious defects.
Loose Fittings	High	Could lead to components on the apex/A-frame becoming detached and may lead to a dropped load.	Type of fitting, maintenance, inspection			
Structure: Superstructure						
Fatigue	High	Could lead to a structural failure collapse or loss of crane.	Operational Records, NDE, Inspection, PD6493 Assessment	BS2573: Part 1: 1983: Section 8 and Lloyds Rules		non ductile behaviour, crane likely to be at the end of its fatigue life
Corrosion	High	Could lead to a structural failure collapse or loss of crane.	Protective Coating, Corrosion Allowance, Strengthening of vulnerable areas or de-rating	BS2573: Part 1: 1983: Section 4.2 and Lloyds Rules		Corrosion more likely due to unrectified paint defects
Damage	High	Could lead to a structural failure collapse or loss of crane.	Evaluate risk and strengthen locally if required.			Unattended minor damage may progress to more serious defects.
Structure: Substructure						
Fatigue	High	Could lead to a structural failure collapse or loss of crane.	Operational Records, NDE, Inspection, PD6493 Assessment	BS2573: Part 1: 1983: Section 8 and Lloyds Rules		non ductile behaviour, crane likely to be at the end of its fatigue life
Corrosion	High	Could lead to a structural failure collapse or loss of crane.	Protective Coating, Corrosion Allowance, Strengthening of vulnerable areas or de-rating	BS2573: Part 1: 1983: Section 4.2 and Lloyds Rules		Corrosion more likely due to unrectified paint defects
Damage	High	Could lead to a structural failure collapse or loss of crane.	Evaluate risk and strengthen locally if required.			Unattended minor damage may progress to more serious defects.

Lifetime Limiting Mechanisms	Criticality Category	Effect	Mitigation	Current Design Standards	Likely Shortfall	Comments
Structure: Base-Plate Connections						
Fatigue	High	Could lead to a structural failure collapse or loss of crane.	Operational Records, NDE, Inspection, PD6493 Assessment	BS2573: Part 1: 1983: Section 8.7 and Lloyds Rules		non ductile behaviour, crane likely to be at the end of its fatigue life
Corrosion	High	Could lead to a structural failure collapse or loss of crane.	Protective Coating, inspection/replacement , Strengthening of vulnerable areas or de-rating	BS2573: Part 1: 1983: Section 8.7 and Lloyds Rules		Corrosion more likely due to unrectified paint defects
Damage	High	Could lead to a structural failure collapse or loss of crane.	Evaluate risk and strengthen locally if required.			Unattended minor damage may progress to more serious defects.
Structure: Pedestal/Pintle						
Fatigue	High	Could lead to a structural failure collapse or loss of crane.	Operational Records, NDE, Inspection, PD6493 Assessment	BS2573: Part 1: 1983: Section 8.7 and Lloyds Rules		non ductile behaviour, crane likely to be at the end of its fatigue life
Corrosion	High	Could lead to a structural failure collapse or loss of crane.	Protective Coating, inspection/replacement , Strengthening of vulnerable areas or de-rating	BS2573: Part 1: 1983: Section 8.7 and Lloyds Rules		Corrosion more likely due to unrectified paint defects
Damage	High	Could lead to a structural failure collapse or loss of crane.	Evaluate risk and strengthen locally if required.			Unattended minor damage may progress to more serious defects.
Hoist/Luffing: Hook						
Fatigue	High	Could lead to dropped load.	Design information, Crane history/records, Replacement, NDE inspection records, End of life assessment	BS2903		
Damage	High	Could lead to dropped load.	Replacement, NDE inspection records	BS2903		

Lifetime Limiting Mechanisms	Criticality Category	Effect	Mitigation	Current Design Standards	Likely Shortfall	Comments
Hoist/Luffing: Hook Block Assembly						
Fatigue	High	Sudden failure which could lead to dropped load	Design information, Crane history/records, NDE inspection records, End of life assessment	BS4534		
Corrosion	High	Sudden failure which could lead to dropped load, or seizure which could lead to a load hang-up	Protective Coating, preservation, inspection and maintenance	BS4534	Corrosion and limited use may cause sheaves to seize	
Damage	High	Sudden failure which could lead to dropped load, or seizure which could lead to a load hang-up	Evaluate risk and provide securing/protection if required, inspection and maintenance	BS4534	Possibility of progressive damage storm due lack of early attention	
Water ingress, condensation	High	Water passing seals could lead to corrosion	Type of seal, maintenance, drainage holes/channels	BS4534		
Hoist/Luffing: Sheaves/Pulleys						
Erosion	High	Could lead to sheave jamming, damage to rope, rope jumping the sheave	Inspection, maintenance, repair/replacement	BS4534	Erosion may cause sheaves to ???	
Damage	High	Could lead to sheave jamming, damage to rope, rope jumping the sheave	Inspection, maintenance, repair/replacement	BS4534	Possibility of progressive damage storm due lack of early attention	
Hoist/Luffing: Sheave Pins						
Corrosion	High	Could lead to sudden failure or seizure and sheave jamming resulting in damage to rope	Material selection, Protective coating/sleeves, inspection, maintenance, repair/replacement	BS4534	Possible pitting due to lack of early attention	Pin should be corrosion resistant material wherever possible
Erosion	High	Could lead to sheave jamming resulting in damage to rope	Inspection, maintenance, repair/replacement	BS4534		

Lifetime Limiting Mechanisms	Criticality Category	Effect	Mitigation	Current Design Standards	Likely Shortfall	Comments
Hoist/Luffing: Rope Compensator						
Fatigue	High	Sudden failure could lead to collapse and dropped load.	Design information, Crane history/records, NDE inspection records, End of life assessment			
Corrosion	High	Sudden failure could lead to collapse and dropped load.	Material selection and preservation, inspection, maintenance, repair/replacement		Late detection of corrosion	
Erosion	High	Sudden failure could lead to collapse and dropped load.	Inspection, maintenance, repair/replacement			
Damage	High	Sudden failure could lead to collapse and dropped load.	Protection, inspection, maintenance, repair/replacement		Progressive storm damage	
Hoist/Luffing: Drums						
Fatigue	High	Sudden failure could lead to collapse and dropped load/jib.	Design information, Crane history/records, NDE inspection records, End of life assessment	BS MA 79 Cl 4.2.2 to 4.2.4		
Erosion	High	Sudden failure could lead to collapse and dropped load/jib.	inspection, maintenance, repair/replacement	BS MA 79 Cl 4.2.2 to 4.2.4		
Damage	High	Sudden failure could lead to collapse and dropped load/jib.	Protection, inspection, maintenance, repair/replacement	BS MA 79 Cl 4.2.2 to 4.2.4		

Lifetime Limiting Mechanisms	Criticality Category	Effect	Mitigation	Current Design Standards	Likely Shortfall	Comments
Hoist/Luffing: Ropes/Pendants						
Fatigue	High	Sudden failure could lead to collapse and dropped load/jib.	inspection, maintenance, repair/replacement	BS302: Part 3, BS464, BS6570		
Creep	High	Sudden failure could lead to collapse and dropped load/jib.	inspection, maintenance, replacement	BS302: Part 3, BS464, BS6570		
Corrosion	High	Sudden failure could lead to collapse and dropped load/jib.	Rope type (zinc coated), inspection, maintenance, replacement	BS302: Part 3, BS464, BS6570	Corrosion due to loss of protective coating, stagnant water due to lack of use	
Erosion	High	Sudden failure could lead to collapse and dropped load/jib.	Inspection, maintenance, replacement	BS302: Part 3, BS464, BS6570		
Damage	High	Sudden failure could lead to collapse and dropped load/jib.	Crane stowing arrangements, local protection, inspection, maintenance, replacement	BS302: Part 3, BS464, BS6570	Progressive damage	
Hoist/Luffing: Rope Anchors						
Fatigue	High	Sudden failure could lead to collapse and dropped load/jib.	inspection, maintenance, repair/replacement			
Creep	High	Sudden failure could lead to collapse and dropped load/jib.	inspection, maintenance, replacement			
Corrosion	High	Sudden failure could lead to collapse and dropped load/jib.	Design, materials, preservation		Corrosion due to loss of protective coating	
Damage	High	Sudden failure could lead to collapse and dropped load/jib.	Crane stowing arrangements, local protection, inspection, maintenance, replacement.			

Lifetime Limiting Mechanisms	Criticality Category	Effect	Mitigation	Current Design Standards	Likely Shortfall	Comments
Hoist/Luffing: Luff Rams (IF)						
Corrosion	High	Sudden failure could lead to collapse and dropped load/jib.	Design, materials, preservation		Corrosion due to loss of protective coating	
Mechanism: Brake Assemblies						
Corrosion	High	Sudden failure could lead to release of load/jib.	inspection, maintenance, repair/replacement	Service brakes to BS MA 79 Cl. 4.4		
Erosion	High	Sudden failure could lead to release of load/jib.	Inspection, maintenance, repair/replacement	Service brakes to BS MA 79 Cl. 4.4		
Mechanism: Gearboxes		* Dependant on position of brake whether cricial or not				
Fatigue	High	Sudden failure could lead to release of load/jib.	inspection, maintenance, repair/replacement, overspeed protection should apply brakes.	Manufactures Instructions		
Mechanism: Couplings						
Fatigue	High	Sudden failure could lead to release of load/jib.	inspection, maintenance, repair/replacement, overspeed protection should apply brakes.	Manufactures Instructions		
Mechanism: Drive Shafts						
Fatigue	High	Sudden failure could lead to release of load/jib.	inspection, maintenance, repair/replacement, overspeed protection should apply brakes.			
Slew Ring Assembly: Slew Ring						
Fatigue	High	Could lead to slew ring failure and loss of structure above slew ring	Inspection, maintenance, repair/replacement, restraining devices	Manufactures Instructions		
Erosion	High	Could lead to slew ring failure and loss of structure above slew ring	Inspection, maintenance, repair/replacement	Manufactures Instructions		

Lifetime Limiting Mechanisms	Criticality Category	Effect	Mitigation	Current Design Standards	Likely Shortfall	Comments
Slew Ring Assembly: Slew Ring Bolts						
Fatigue	High	Could lead to bolt failure and loss of structure above slew ring	Inspection, maintenance, repair/replacement, restraining devices	BS3692, BS4464		
Creep	High	Could lead to bolt failure and loss of structure above slew ring	Condition monitoring, inspection, maintenance, repair/replacement, restraining devices	BS3692, BS4464		
Corrosion	High	Could lead to bolt failure and loss of structure above slew ring	Bolt material, preservation, corrosion allowance, inspection, maintenance, repair/replacement, restraining devices.	BS3692, BS4464	Undetected onset of corrosion	
Slew Ring Assembly: Slew Bearing			- Pintle mounted only			
Corrosion	High	Could lead to bearing failure/collapse and seizure of slew drive system.	Seals, lubricant type, restraining devices.	Manufactures Instructions	Undetected onset of corrosion	
Brinelling	High	Could lead to bearing failure/collapse and seizure of slew drive system.	Condition monitoring, inspection, maintenance, repair/replacement, restraining devices.	Manufactures Instructions	Brinelling due to lack of movement	
Damage	High	Could lead to bearing failure/collapse and seizure of slew drive system.	Condition monitoring, inspection, maintenance, repair/replacement, restraining devices.	Manufactures Instructions		
Water ingress, condensation	High	Bearing failure due to corrosion damage.	Seals, lubricant type, restraining devices, drainage channels.	Manufactures Instructions	Undetected ingress of water	

Lifetime Limiting Mechanisms	Criticality Category	Effect	Mitigation	Current Design Standards	Likely Shortfall	Comments
Slew Ring Assembly: Slew Drive Chain (IF)			- Pintle mounted only			
Corrosion	High	Could lead to drive chain failure and loss of slew drive.	Inspection, maintenance, repair/replacement.	BS 288		
Erosion	High	Could lead to drive chain failure and loss of slew drive.	Inspection, maintenance, repair/replacement.	BS 288		
Damage	High	Could lead to drive chain failure and loss of slew drive.	Inspection, maintenance, repair/replacement.	BS 288		
Slew Ring Assembly: House Roller Assembly			- Pintle mounted only			
Fatigue	High	Could lead to housing failure and loss of structure above slew ring	Inspection, maintenance, repair/replacement, restraining devices	Manufactures Instructions		
Damage	High	Could lead to housing failure and seizure of slew drive system.	Inspection, maintenance, repair/replacement, restraining devices	Manufactures Instructions		
Loose Fittings	High	Could lead to housing failure and loss of structure above slew ring	Inspection, maintenance, repair/replacement, restraining devices	Manufactures Instructions		
Hydraulic: Rams						
Corrosion	High	Damage to seals resulting in loss of control or function	Materials, coatings, protective bellows, inspection, maintenance, repair/replacement.	Manufactures Instructions	Undetected onset of corrosion	
Water ingress, condensation	High	Contamination of oil by condensation	Oil type, seals, maintenance, drainage channels.	Manufactures Instructions	Increased risk of condensation due to infrequent use	

Lifetime Limiting Mechanisms	Criticality Category	Effect	Mitigation	Current Design Standards	Likely Shortfall	Comments
Electrical: Earthing						
Creep	High	Failure of connection, loss of earthing, loss of circuit protection, increased risk of loss of protection against indirect contact.	Material protection, proper prevention of corrosive interaction, inspection.	BS5467, BS6004, BS6007, BS6141, BS7211.	Increased risk of undetected corrosion damage	
Damage	High	Fire or electric shock risk	Sound earth connection/ cable protection, cable routes. Local operating procedures	BS7430	Undetected storm damage	
Electrical: Lightening Protection						
Damage	High	fire, electric shock or explosion	Design, protection arrangements, inspection. Local operating procedures	BS6651	Undetected storm or mechanical damage	
Control & Instrumentation: PLC's/SLI (IF)						
Damage	High	Loss of control or signal errors	Selection of equipment, location, local protection, vibration isolation	BS5490, BS5435	Undetected storm or vibration damage	
Water ingress, condensation	High	Loss of control or signal errors	Enclosure design/sealing, anti condensation heaters	BS5490, BS5435	Increase risk of condensation in unheated spaces	
General Safety Features: Emergency Stops						
Damage	High	Failure to operate or unintended operation	Hardware type, location, inspection, maintenance.	BS5501, BS7535, BS7671	Undetected damage	
Water ingress, condensation	High	Failure to operate or unintended operation	Hardware type, location, inspection, maintenance.	BS5501, BS7535, BS7671	Increase risk of condensation in unheated spaces	
General Safety Features: Overload Alarm						
Water ingress, condensation	High	Failure to operate leading to structural overload	Hardware type, location, anti condensation heaters, inspection, maintenance.	BS5490, BS5435	Increase risk of condensation in unheated spaces	

Lifetime Limiting Mechanisms	Criticality Category	Effect	Mitigation	Current Design Standards	Likely Shortfall	Comments
General Safety Features: Hoist Limit/Stop						
Damage	High	Failure to stop at end of travel resulting in damage and dropped load	Robust hardware, local protection, component duplication, inspection, maintenance.	BS7535, BSEN 60947-5	Undetected damage	
General Safety Features: Luffing Limit/Stop						
Damage	High	Failure to stop at end of travel resulting in damage and dropped load	Robust hardware, local protection, component duplication, inspection, maintenance.	BS7535, BSEN 60947-5	Undetected damage	
General Safety Features: Slew Limit/Stop						
Damage	High	Failure to stop at end of rotation resulting in damage and dropped load	Robust hardware, local protection, component duplication, inspection, maintenance.	BS7535, BSEN 60947-5	Undetected damage	
General Safety Features: Slack Rope Protector						
Damage	High	Failure to operate or unintended operation	Hardware type, location, inspection, maintenance	Lloyds Chapter 7 (cl 6.5.5)		
General Safety Features: Ladders and Walkways						
Corrosion	High	Collapse leading to injury or fatality	Materials selection, preservation system, inspection, maintenance, repair/replacement		Undetected deterioration	
Damage	High	Collapse leading to injury or fatality	Inspection, maintenance, repair/replacement.			
General Safety Features: Safety Harness						
Ageing, Degradation	High	Failure leading to injury or fatality	Material quality, stowage, inspection, maintenance, repair/replacement.			
General Safety Features: Drivers Escape Gear						
Ageing, Degradation	High	Failure leading to injury or fatality	Material quality, stowage, inspection, maintenance, repair/replacement.			

http://www.hse.gov.uk/research/otopdf/2001/oto01088.pdf