QC-FIT EVALUATION OF SHEAVES FAILURES

Office of Offshore Regulatory Programs

QC-FIT Report #005
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BSEE
Bureau of Safety and Environmental Enforcement

EXECUTIVE SUMMARY

On October 7, 2015, while conducting drilling operations in the Gulf of Mexico (GOM) for Freeport-McMoRan Oil & Gas at Grand Canyon Block 643 ("GC 643"), the Noble drilling crew discovered a crack in a sheave on the Sam Croft drilling rig. Freeport-McMoRan Oil & Gas reported the sheave failure to the Bureau of Safety and Environmental Enforcement (BSEE) as a near-miss incident. The failed sheave was a dual web design, 78 inches in diameter, and was in service for five months. The Original Equipment Manufacturer (OEM), National Oilwell Varco (NOV), also informed BSEE about additional cracked sheaves on four rigs operating in the Gulf of Mexico (GOM) and one operating in Colombia between February 7, 2015 and December 6, 2015 (Table 1). All of the affected 78-inch diameter dual web design sheaves were located in the derricks' Crown Mounted Compensators (CMC).

In response to these incidents, the OEM identified ten drilling rigs [1] that needed sheave replacements. Seven rigs were located in the GOM, one was located in Colombia, and two drilling rigs were under construction in Korea. The OEM issued Product Information Bulletins (PIB's) 87819987 (Revisions 0 and 1) (Appendix I) for its 78-inch diameter dual web design sheaves in all positions within the CMC. These PIBs informed product owners about sheave failures which emphasized conducting weekly visual inspections for cracks between the hub-web weld joint. These PIBs also recommended replacement of the affected sheaves with single web design sheaves. There were no reported personnel injuries related to the sheave failures. The OEM ceased procurement of dual web design sheaves from the current manufacturer, and initiated replacement of all the dual web design sheaves with single web design sheaves from a different qualified manufacturer.

Following the discovery on October 8, 2015 of a sheave failure on the Sam Croft drilling rig, BSEE assembled a Quality Control Failure Incident Team (QC-FIT) to conduct a technical evaluation of all equipment involved in this incident and determine if there were global quality assurance/quality control (QA/QC), technology, safety, and/or environmental concerns that required further action by BSEE and/or industry related to the design, materials, manufacture, construction, and use of these sheaves on the Outer Continental Shelf (OCS). The QC-FIT technical evaluation consisted of meetings with the operator, contractors, and OEMs, as well as review of applicable reports, technical documents, and industry standards (see Appendix II – Asset Integrity Management). These activities provided relevant information about the sheaves' design, material properties, and the manufacturing and welding processes used to ensure that the sheaves' design was fit for service. The QC-FIT also verified with the International Regulators Forum (IRF)[2] if there were any additional sheave failures within their areas of jurisdiction. The IRF did not report any additional sheave failures. In BSEE's view, this issue had potential to impact drilling rigs globally but after confirming the lack of failures with the IRF, and noting that the failures were limited to one OEM's product line, it was determined to be a localized issue which could be quickly and effectively addressed by the manufacturer.

[1] As of January 30, 2017, nine of the ten identified drilling rigs replaced all of their 78 inch dual web design sheaves with single web design sheaves.

[2] International Regulators Forum (IRF) is an international forum of twelve regulators dedicated to health and safety in the offshore upstream oil and gas industry.

The QC-FIT team's key concerns during the technical evaluation included the following:

- Design deficiencies that could result in failure which could pose a safety risk to personnel;
- Whether the design and the material mechanical properties (yield and ultimate tensile strengths) were adequate to meet the anticipated operating conditions;
- Whether the welding procedure used to create a hub-web weld joint was adequate for the design.

BSEE's technical evaluation also included the review of third-party submitted data concerning the sheave evaluation. A comprehensive list of recommendations is outlined at the end of this report.

Key findings include the following:

- The OEM PIBs' recommend that sheaves' product owners perform weekly visual inspections for cracks between the hub-web weld joint.
- The OEM's root-cause analysis (RCA) identified the cause of the sheave failure to be the following:
  - The dual web design and hand weld root pass procedures resulted in a gap at the weld joint. This gap prevented weld filler metal from an automated welding technique from penetrating and completely fill the gap on the inside of the hub-web weld joint. An automated welding technique with sufficient heat input should have been used to fill the gap along the backing surface of the hub-web weld joint. This would have allowed the weld to be more resistant to crack initiation.
  - At the time of the RCA, the material test certificate for the hub and web plate from the steel supplier was not available to the test laboratory to verify with the OEM's specified materials specification (alloy composition, mechanical properties, heat treatment) and with the analysis performed by the test laboratory.
- The effects of the design change for the 78-inch dual web design sheave were not fully evaluated by the OEM. The hub dimensions were reduced from 600 mm to 550 mm to decrease the moment of inertia, but the web plates' thickness of 12 mm was not changed. This decrease in the hub's dimensions increased the sheaves' load rating by approximately 11%, where the stress levels on the inside of the web plates exceeded allowable limits for compression by 27%. This design change resulted in cracks initiating at the gap of the root of the weld joint, resulting in fatigue failure.

As a result of these findings, in the interest of safety, BSEE recommends the following:

- The OEM should investigate why multiple sheave failures occurred on one rig.
- Since the sheaves are interchangeable in other locations within the CMC assembly, tracking the sheaves' service life is challenging, therefore, operators and inspectors should conduct daily visual inspections of sheaves for cracks between the hub-web weld joint.
- BSEE agrees with the OEM's recommendation that all CMC dual web design sheaves should be replaced with single web design sheaves. The single web design sheave results in a more robust hub-web weld joint and is not as susceptible to cracking as the dual web design sheave.

- The OEM should conduct a finite element analysis (FEA) on the new single web sheave design to ensure that the operational stress concentrations and load levels remain within the load limits and have a built-in safety factor to assure safe operation.
- The OEM should follow API Recommended Practice (RP), 8B Eighth Edition, 2014, "*Recommended practices for procedures for inspections, maintenance, repair, and remanufacture of hoisting equipment,*" [3] section 5.3.2.2, Category I and request that the operators and/or contractors should conduct daily visual inspections of the CMC 78-inch diameter dual web design sheaves for cracks until they are replaced.
- The OEM should follow appropriate sections of API Specification (Spec) 8C, Fifth Edition, 2012, *"Drilling and Production Hoisting Equipment,"* [4]as follows:
  - Section 3.1.9 'Load Rating' and Section 4.7 'Design Safety Factor' specifies consideration of both the static and the dynamic load conditions; and design safety factors for the design of the sheaves of the CMC assembly.
  - Section 8.4 'Quality Control for Specific Equipment and Components' requires verification that the material test certificates for the sheave bearing hub and the web plates meet the OEM's specified material specifications requirements (alloy chemistry, materials mechanical properties, heat treatment, etc.). The OEM should also define the specific material properties, stress load conditions, manufacturing processes, and related welding procedures for the sheave intended functional purpose.
- In this case of welding the dual web or a single web design sheave, weld cross-sections should be evaluated for weld integrity before engaged in for field service.
- Industry should evaluate API Specification Q1, Ninth Edition, 2013, *"Specification for Quality Management System Requirements for Manufacturing Organizations for the Petroleum and Natural Gas Industry,"* [5] for the following:
  - Industry should ensure that information on equipment failures are reported, analyzed, and reported to the industry via the API Monogram Program and the SAFEOCS Program.
  - Develop and implement improvements to API Spec Q1 Ninth Edition to address OEM's oversight and auditing of subcontracted second-tier, third-tier, and lower-tiered vendors who perform a manufacturing process in the manufacturing chain. This would ensure proper manufacturing at the lowest levels.
  - Develop improved QA/QC practices to verify design and inspection of manufacturing processes at each stage of an OEM's supply chain. QA/QC practices should include controls for producing products and identifying nonconformities to industry standards and specifications.

[3] API RP 8B is not incorporated by reference in BSEE regulations.
[4]API SPEC 8C is not incorporated by reference in BSEE regulations.
[5] API Q1 Eighth Edition is incorporated by reference in BSEE regulations, not API Q1 Ninth Edition.

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BACKGROUND

Sheaves are pulleys that use wire rope to lift loads, apply forces, and transmit power. NOV-affected sheaves are located in the CMC assembly, which is installed on top of the drilling rig derrick (Figure 1) and consists of the crown block, sheave block, fast line, and dead line sheave clusters (Figures 2 and 3).

FIGURE 1: CROWN MOUNTED COMPENSATOR (CMC) LOCATION (OEM USER MANUAL)

FIGURE 2: CMC ASSEMBLY - SHEAVES ARE INTERCHANGEABLE (OEM USER MANUAL)

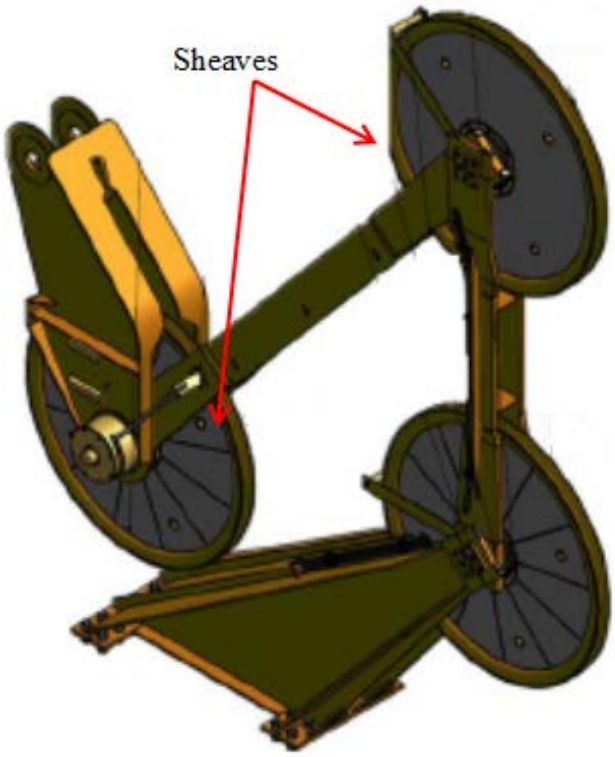


FIGURE 3: SHEAVES - FASTLINE ASSEMBLY (OEM PIB#87819987)

For this particular design, the crown block uses seven interchangeable 78-inch diameter dual web design sheaves to control the 2 1/8" drill line. Ten drilling rigs were constructed using the 78-inch diameter dual web design manufactured by NOV.

On February 7, 2015, while performing drilling operations off the coast of Colombia on the Bolette Dolphin drilling rig for Ecopetrol-Anadarko, Dolphin Drilling/Fred Olsen Energy identified the first sheave failure and reported to NOV. On March 8, 2015, while conducting maintenance inspections of the CMC, the drilling crew discovered large cracks on the dual web fast line sheaves on the Rowan Resolute drilling rig operating in the GOM. The OEM reported these sheave failures to BSEE. These sheave failures prompted the OEM to initiate an engineering RCA and a third-party metallurgical RCA of the failed sheave. The affected sheaves were dual web design sheaves, see Figure 4.

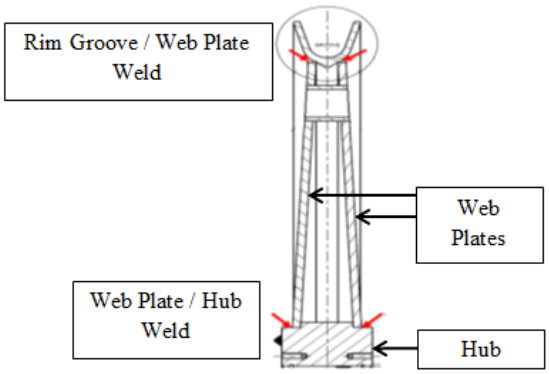


FIGURE 4: DUAL WEB DESIGN SHEAVE ASSEMBLY - WELD LOCATIONS IN RED (OEM PIB#87819987)

NOV also informed BSEE about several offshore 78-inch diameter dual web design sheave incidents occurring between February 7, 2015, and December 6, 2015.

A time line of these dual web design sheave incidents is as follows:

1. On February 7, 2015, while conducting drilling operations off the coast of Colombia for Ecopetrol-Anadarko, the Fred Olsen drilling crew discovered a sheave failure on the Bolette Dolphin drilling rig. A crack was identified in the hub weld seam of the fastline sheave.
2. On March 8, 2015, while conducting drilling operations in the GOM for Anadarko, the drilling crew identified a sheave failure on the Rowan Resolute drilling rig. NOV contracted an independent third-party laboratory, Howard and Associates International (HAI), to perform a metallurgical RCA of this particular failed sheave. HAI completed the RCA for the sheave failure on August 6, 2015.
3. On August 14, October 2, and October 22, 2015, while conducting drilling operations in the GOM for Anadarko, the Rowan drilling crew discovered additional sheave failures on the Rowan Resolute drilling rig. For the October 22, 2015, incident, four of the seven sheaves failed on the crown block.
4. On October 7, 2015, while conducting drilling operations in the GOM for Freeport-McMoRan Oil & Gas, the Noble drilling crew discovered a sheave failure on a Sam Croft drilling rig. This sheave failure was reported to BSEE on October 8, 2015, as a near-miss incident. The sheave was in service for five months.
5. On November 10, 2015, while conducting drilling operations in the GOM for Repsol, the drilling crew reported a sheave failure on the Rowan Renaissance drilling rig.
6. On November 12, 2015, while conducting drilling operations in the GOM for Shell Offshore Inc., the Noble drilling crew reported a sheave failure on the Don Taylor drilling rig. A crack was identified on the first-reduction crown cluster dual web design sheave, which failed while under load. The sheave was in service for approximately two years.
7. On November 24 and December 6 of 2015, while conducting drilling operations off the coast of Colombia for Ecopetrol-Anadarko, the Fred Olsen drilling crew discovered additional sheave failures on the Bolette Dolphin drilling rig. The number of sheave failures on this rig was not reported by the operator.

Table 1

SHEAVE WEB PLATES AND HUB FAILURES				
Failure Date	**Operator**	**Rig**	**Contractor**	**Location**
Feb 7, 2015	Ecopetrol – Anadarko	Bolette Dolphin	Dolphin Drilling / Fred Olsen	Colombia
Nov 24, 2015	Ecopetrol – Anadarko	Bolette Dolphin	Dolphin Drilling / Fred Olsen	Colombia
Dec 6, 2015	Ecopetrol – Anadarko	Bolette Dolphin	Dolphin Drilling / Fred Olsen	Colombia
Mar 8, 2015	Anadarko	Rowan Resolute	Rowan Drilling	GOM
Aug 14, 2015	Anadarko	Rowan Resolute	Rowan Drilling	GOM
Oct 2, 2015	Anadarko	Rowan Resolute	Rowan Drilling	GOM
Oct 22, 2015	Anadarko	Rowan Resolute	Rowan Drilling	GOM
Oct 7, 2015	Freeport McMoRan Oil & Gas	Sam Croft	Noble Drilling	GOM
Nov 10, 2015	Repsol	Rowan Renaissance	Rowan Drilling	GOM
Nov 12, 2015	Shell	Don Taylor	Noble Drilling	GOM

The dual web design sheaves can be interchanged with the single web design sheave. The RCA conducted by the OEM stated that the dual web design sheave prevented weld filler metal from penetrating deep enough to fill the gap on the inside of the hub-web weld joint. Thus, a crack initiated at the gap of the root of the weld and propagated through the weld seam into the web plate (Figures 5 and 6).

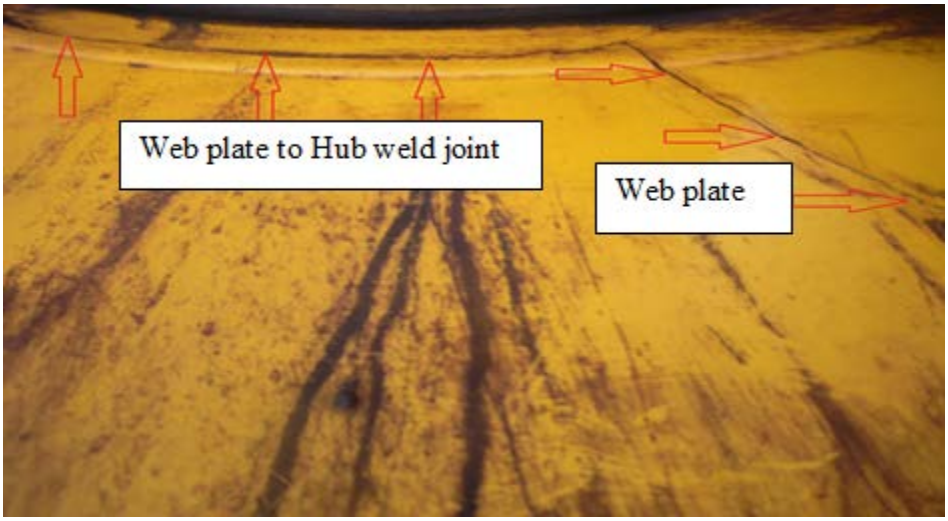


FIGURE 5: CRACKS IN WELD JOINT AND WEB PLATES INDICATED BY RED ARROWS (OEM PIB#87819987)

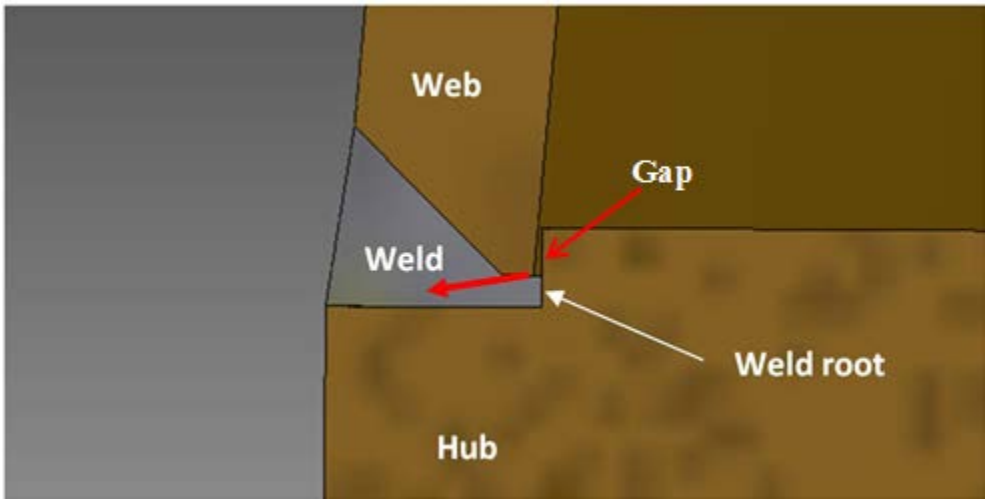


FIGURE 6: DETAILED CROSS-SECTION OF WEB PLATES TO HUB WELD SECTION CRACK INITIATION AT THE GAP AND PROPOGATION PATH SHOWN BY THE RED ARROW (RCA REPORT)

The 78-inch diameter dual web design sheaves were designed per API Specification 8C, Fifth Edition, 2012, *"Drilling and Production Hoisting Equipment."* The welding procedure specified a manually welded root pass followed by an automated Submerged Arch Welding (SAW) technique. This weld procedure did not allow for full penetration of the weld filler metal deep into the hub-web weld joint. Additionally, during the initial design stage of the sheave, the hub dimensions were reduced from 600 mm to 550 mm to decrease the moment of inertia. The web plates' thickness of 12 mm was not changed, which resulted in load rating being increased by approximately 11%. The stress levels on the inside of the web plates exceeded the allowable stress limits for compression by 27%, which resulted in fatigue fracture failure.

Following the RCA results, NOV issued two PIB's 87819987 (Revisions 0 and 1) (Appendix 2) for all users to visually inspect for cracks on a weekly basis at the hub weld on the 78-inch diameter dual web design sheave and initiated replacement of all the dual web design sheaves with single web design sheaves. The single web design sheave allows welding on both sides of the hub-web weld joint, as opposed to welding only one side for the dual web design sheave. This change results in a more robust weld joint as the weld filler metal will fill the gap of the root of the weld joint.

ASSESSMENT

Following the discovery of the sheave failure on the Sam Croft drilling rig on October 8, 2015, BSEE convened the QC-FIT within the Office of Offshore Regulatory Programs to evaluate any technology or safety issues associated with the use of 78-inch dual web design sheave equipment on the OCS. The QC-FIT was tasked with determining if there were QA/QC, technology, safety, or environmental concerns that required further action by BSEE and/or industry, especially if these concerns related to the design, manufacture, and use of sheaves either on the OCS or globally. The OEM initiated an RCA evaluation to determine the root cause for an earlier March 8, 2015 sheave failure that occurred on the Rowan Resolute rig in the GOM.

OEM ENGINEERING RCA

The OEM initiated an Engineering RCA investigation to determine the root cause of the dual web design sheave failures with cracks in the hub-web weld joint. The Engineering RCA investigation included a review of the sheave design, loading conditions, and manufacturing and maintenance procedures. A summary of the OEM's RCA findings are listed below:

- The OEM verified that the sheave failure was due to high nominal stress levels in the sheave hub-web connection in combination with the additional stress concentration caused by the dual web design, which prevented welding of the inside of the hub-web weld joint and resulted in a gap. This stress concentration caused the crack initiation at the gap of the weld, which propagated through the weld into the web plates (Figures 5 and 6).
- The OEM specified a hand weld root pass procedure, followed by an automated SAW technique welding procedure. This procedure did not allow for a full penetration depth of the weld filler metal on the inside of the hub-web weld joint, creating a stress concentration.
- During the initial design phase, the hub dimensions were reduced from 600 mm to 550 mm to decrease the moment of inertia. The web plates' thickness of 12 mm was not changed. As a result of the hub dimension reduction, the sheaves' load rating was increased by approximately 11%. The stress levels and the impact of the design change were not fully evaluated by the OEM. The stress levels on the inside of the web plates exceeded allowable stress limits for compression by 27%, resulting in fatigue failure.

THIRD-PARTY METALLURGICAL RCA

On August 6, 2015, the independent third party HAI provided the RCA report to the OEM for the metallurgical analysis of the March 8, 2015 sheave failure on Rowan Resolute rig. The metallurgical analysis included an evaluation of the sheaves' chemical composition; material properties; microstructure of the weld joint; and evaluation of the material specifications for the sheave bearing hub and the web plates. A summary of the third party's metallurgical RCA findings are listed below:

- The hand welding at the hub-web weld joint followed by an automated SAW did not allow the weld filler metal to fully penetrate at the root of the weld between the web plates and the hub. This led to a gap on the inside of the hub-web weld joint, creating a primary stress riser that caused initiation of cracks in the weld.
- Cracks were observed in two locations (at the hub to the plate weld joint and across the web plates). The cracks initiated at the gap of the root of the weld and propagated through the weld into the web plate (Figures 4 and 5).
- At the time of the RCA, the material test certificate for the hub and web plate from the steel supplier was not available to the test laboratory to verify with the OEM's specified materials specification (alloy composition, material properties, heat treatment) for the analysis performed by the test laboratory.

BSEE's Recommendations:

In response to the described RCAs, BSEE recommends the following:

1. The OEM should conduct a finite element analysis (FEA) on the new single web sheave design to ensure that the operational stress concentrations and load levels remained within the load limits and that the sheaves had a built-in safety factor to assure safe operation.
2. The OEM should verify the material test certificates for the sheave hub and the web plates conforms to the specified material design specification requirements (alloy chemistry, material properties, heat treatment, etc.).

Potential Contributing Factors

The RCA investigation identified the following potential contributing factors to the sheave failure:

- The 78-inch dual web design sheave service life cannot be traced because they can be interchanged within the CMC.
- The Engineering RCA investigation attributed that the reduction in hub dimensions from 600 mm to 550 mm diameter to decrease the moment of inertia with the same web plates thickness of 12 mm resulted in overloading conditions leading to the fracture of the sheave.
- The Metallurgical RCA investigation attributed the sheaves' failure to the dual web design of the sheave. The dual web design prevented welding on the inside of the web plates to the hub. The OEM specified a manually welded root pass, followed by an automated SAW technique welding procedure. This procedure did not allow for a full penetration depth of the weld filler metal, which resulted in a gap between the inside of the web plate to the hub weld joint. This gap between the inside of the web plate to the hub weld joint allowed for stress concentration and crack initiation at the gap of the root of the weld (Figure 6).

Applicable Industry Standards

Design

The dual web design was based on onshore static loading conditions in accordance with API Specification 8C, Fifth Edition, 2012 *"Drilling and Production Hoisting Equipment."*

API Specification 8C specifies the following:

- Sheaves are considered to be hoisting equipment. Hoisting equipment is designed, manufactured, and tested so that it is fit for its intended purpose. The equipment must be designed for simple, safe operation and safely transfer the load for which it was intended.
- The design should consider both the static and the dynamic load conditions, and a design safety factor for the design of the sheaves of the CMC assembly. The equipment design should be assessed for fit for service and should address excessive yielding, fatigue loading, and buckling as possible failure modes.

MATERIAL

API 8C Specification, Fifth Edition, Section 6 "Material Requirements" should define specific material properties requirements, design load conditions, and manufacturing processes that support reproducibility and verification of the equipment's function and fitness for service.

WELDING

API Specification 8C, Fifth Edition, Section 7 specifies 'Welding Requirements' for primary load-carrying components. The weld's mechanical properties, as determined by the welding procedure qualification test, shall at a minimum meet the specified design materials mechanical property requirements. The welding design should ensure complete fusion of the weld with the base metal.

All welding processes performed on sheave components should be performed per qualified welding procedures in accordance with the following:

- Product Specification Level 1 (PSL1): American Society of Mechanical Engineers (ASME) B31.3 *"Process Piping Codes,"* (2014);
- American Society of Mechanical Engineers Boiler Pressure Vessel Code (ASME BPVC) Section IX *"Welding, Brazing, and Fuzing Procedures, Welders, Brazers, and Welding, Brazing, and Fusing Operators – Welding, Brazing and Fusing Qualifications,"* (2014);
- American Welding Society (AWS) D1.1 *"Structural Welding Code,"* Twenty-Third Edition (2015); ISO 15614-1 *"Specification and Qualification of Welding Procedures for Metallic Materials, — Welding Procedure Test — Part 1: Arc and Gas Welding of Steels and Arc Welding of Nickel and Nickel Alloys,"* First Edition (2012);
- American Society of Testing Materials (ASTM) A488 *"Standard Practice for Steel Castings, Welding, Qualifications of Procedures and Personnel,"* (2016).

In the case of this evaluation, the OEM's welding parameters should have specified that sufficient heat be applied to achieve a wider, deeper penetration along the backing surface gap of the root of the weld. This would have enabled the weld to be more resistant to crack initiation.

QUALITY ASSURANCE

API Specification Q1, Ninth Edition, provides guidance for OEM's QMS and establishes the minimum requirements for organizations that manufacture products or provide services or service-related products for use in the petroleum and natural gas industry. The purpose of this guidance is to help ensure that the equipment is manufactured per the OEM's QMS-specified requirements. API Spec Q1 also provides guidance for the following:

- The oversight and auditing of subcontracted second-tier and third-tier vendors who perform a manufacturing process in the manufacturing chain. This ensures proper manufacturing at the lowest levels.
- Verification of the design and manufacturing processes at each stage of an OEM's supply chain. QA/QC practices should include controls for producing expected products, identifying nonconformities, and ensuring compliance with the requirements of the applicable API product specification(s) and/or standard(s).

In the case of this evaluation, sheave failure falls under the "Control of Nonconforming Product" section of API Spec Q1 which specifies guidance for identifying product failures after delivery and the appropriate action to address the effects of the nonconformance. The design and development process for this designed sheave was not followed appropriately; therefore, the verification/validation of the dual web sheave design was not evaluated per this standard. If the design and risk assessment criteria were followed during the sheaves' design change procedure, per API Specification Q1 the associated risk may have been identified.

SUMMARY OF RECOMMENDATIONS

As a result of these findings from this QC-FIT evaluation, in the interest of safety, BSEE recommends the following:

- The OEM should investigate why multiple sheave failures occurred on one rig.
- Since the sheaves are interchangeable in other locations within the CMC assembly, tracking the sheaves' service life is challenging, therefore, operators and inspectors should conduct daily visual inspections of sheaves for cracks between the hub-web weld joint.
- BSEE agrees with the OEM's recommendation that all CMC dual web design sheaves should be replaced with single web design sheaves. The single web design sheave results in a more robust hub-web weld joint and is not as susceptible to cracking as the dual web design sheave.
- The OEM should conduct a finite element analysis (FEA) on the new single web sheave design to ensure that the operational stress concentrations and load levels remain within the load limits and have a built-in safety factor to assure safe operation.
- The OEM should follow API Recommended Practice (RP), 8B Eighth Edition, 2014, "*Recommended practices for procedures for inspections, maintenance, repair, and remanufacture of hoisting equipment,*" [6] section 5.3.2.2, Category I and request that the operators and/or contractors should conduct daily visual inspections of the CMC 78-inch diameter dual web design sheaves for cracks until they are replaced.
- The OEM should follow appropriate sections of API Specification (Spec) 8C, Fifth Edition, 2012, *"Drilling and Production Hoisting Equipment,"* [7] as follows:

[6] API RP 8B is not incorporated by reference in BSEE regulations.
[7] API SPEC 8C is not incorporated by reference in BSEE regulations.

- Section 3.1.9 ‘Load Rating’ and Section 4.7 ‘Design Safety Factor’ specifies consideration of both the static and the dynamic load conditions; and design safety factors for the design of the sheaves of the CMC assembly.
- Section 8.4 ‘Quality Control for Specific Equipment and Components’ requires verification that the material test certificates for the sheave bearing hub and the web plates meet the OEM’s specified material specifications requirements (alloy chemistry, materials mechanical properties, heat treatment, etc.). The OEM should also define the specific material properties, stress load conditions, manufacturing processes, and related welding procedures for the sheave intended functional purpose.

- In this case of welding the dual web or a single web design sheave, weld cross-sections should be evaluated for weld integrity before engaged in for field service.
- Industry should evaluate API Specification Q1, Ninth Edition, 2013, *“Specification for Quality Management System Requirements for Manufacturing Organizations for the Petroleum and Natural Gas Industry,”* [8] for the following:
  - Industry should ensure that information on equipment failures are reported, analyzed, and reported to the industry via the API Monogram Program and the SAFEOCS Program.
  - Develop and implement improvements to API Spec Q1 Ninth Edition to address OEM’s oversight and auditing of subcontracted second-tier, third-tier, and lower-tiered vendors who perform a manufacturing process in the manufacturing chain. This would ensure proper manufacturing at the lowest levels.
  - Develop improved QA/QC practices to verify design and inspection of manufacturing processes at each stage of an OEM’s supply chain. QA/QC practices should include controls for producing products and identifying nonconformities to industry standards and specifications.

[8] API Q1 Eighth Edition is incorporated by reference in BSEE regulations, not API Q1 Ninth Edition.

ACRONYMS

API	American Petroleum Institute
ASME	American Society for Mechanical Engineers
ASTM	American Society for Testing Materials
AWS	American Welding Society
BPVC	Boiler Pressure Vessel Code
BSEE	Bureau of Safety and Environmental Enforcement
CMC	Crown Mounted Compensator
FEA	Finite Element Analysis
GC	Grand Canyon
GOM	Gulf of Mexico
HAI	Howard and Associates International
HC	Hydraulic Connector
IRF	International Regulators Forum
ISO	International Organization for Standardization
NOV	National Oilwell Varco
OCS	Outer Continental Shelf
OEM	Original Equipment Manufacturer
PIB	Product Information Bulletin
PSL	Product Specification Level
QA	Quality Assurance
QC	Quality Control
QC-FIT	Quality Control Failure Incident Team
QMS	Quality Management System
RCA	Root Cause Analysis
RP	Recommended Practice
SAW	Submerged Arch Welding

APPENDIX I

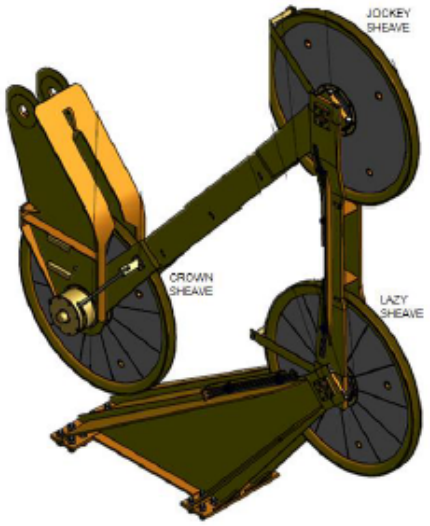
NATIONAL OILWELL VARCO

PRODUCT INFORMATION

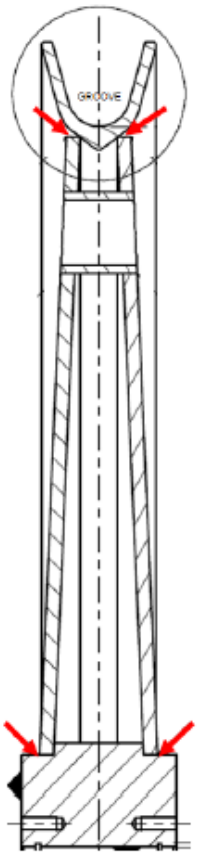
Product Bulletin No.: 87819987
Rev. 0
Motion Compensation

Date: 29-Sep-2015

Subject:	**Incidents Reported for CMC Fastline Sheaves**
Product Model:	Crown Mounted Compensator (CMC), CMC-1000-25 / 2500, with 78" sheaves
Affected Assemblies:	Fastline linkage arm assembly D1104-A4001, D1104-A4002 (jockey sheave item D1104-A4601)
Objective:	Inform user on reported CMC 78" sheave incidents, stress the importance of frequent sheave inspections according to the Maintenance Instructions, and recommend replacement of the most exposed fastline sheave.
Issue:	Hub weld cracking incidents have been reported for the CMC's 78" fastline jockey sheave (the middle of the three sheaves in the fastline linkage arm assembly). These cracks propagate from weld defects near the root of the weld between the web plates and the hub.
Solution:	NOV recommends that the present fastline jockey sheave be replaced with a single-web sheave. Until replacement is performed, the critical welds of the sheaves in the fastline linkage arm assembly should be visually inspected for cracks on a weekly basis. The Critical Welds are shown in the Maintenance Instructions and in the figure below. Additionally, users should ensure that appropriate fastline stabilizers are installed, as these significantly lower the dynamic high-frequency side loading on the sheaves.



NOV Product Information Bulletin Number 87819987 Rev 0



Illustrations: Above: Example of crack at hub of old fastline sheave. Right: Cross-section of typical sheave. The red arrows are pointing at the welds that supplier defines as "critical".

Ordering Information/ Contact Information: Please contact your local National Oilwell Varco (NOV) Service Center, with reference to PB 87819987, for further assistance. Also state the NOV project number for your CMC.

Economical and Cost Issues: A new fastline jockey sheave with bearing installed will be supplied by NOV free of charge. Delivery terms: Incoterms FCA. Send a Warranty Claim together with a Purchase Order, value "0", and request the sheave. Installation will be at owner's cost. For CMC still under Warranty at date of this bulletin, the Warranty terms and conditions in the Contract apply.

Operators should also refer to previous NOV Product Information Bulletins and Safety Alerts for additional information related to this issue and information regarding safe operation, maintenance, and inspection criteria by signing in to your MYNOV account at https://portal.mynov.com and then searching with the Product Bulletin Search available below the heading 'Application Groups'. For information on registering, please visit https://www.nov.com/Search/register.aspx.

Failure to follow the recommendations and/or guidance in NOV Manuals and Product Bulletins may result in death, bodily injury or property damage.

Please contact your local National Oilwell Varco (NOV) Service Center if you have any questions regarding this bulletin.

NOTE! This Product Information Bulletin is project specific. All customers with equipment affected by the described issue will receive the Product Information Bulletin formally on a transmittal from NOV, to their registered email address for NOV Product Bulletins.

NATIONAL OILWELL VARCO

PRODUCT INFORMATION

Product Bulletin No.: 87819987
Rev. 1
Motion Compensation

Date: 14-Dec-2015

Subject: **Incidents Reported for CMC Wire Sheaves**

Product Models: Crown Mounted Compensator (CMC), CMC-1000-25 / 2500, using 78" wire sheaves with NOV item no. 207785 and 207786.

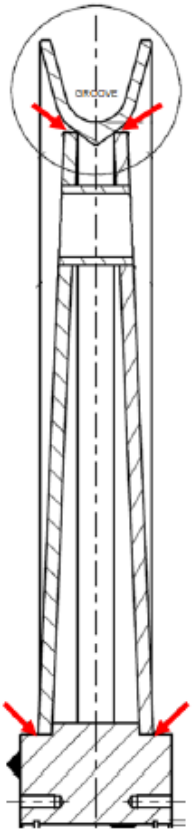
Affected Assemblies: Crown block sheave block D1104-A2700, with seven regular sheaves.
Fastline and deadline linkage arm assemblies D1104-A4000/A4001/A4002; - each assembly with one regular sheave and two light-weight sheaves.

Objective: To inform the user about the reported CMC 78" sheave incidents, to stress the importance of frequent sheave inspections according to the Maintenance Instructions, and to recommend replacement of the sheaves. Compared to the previous revision of this bulletin, this revision extends the coverage to include the cluster sheaves in addition to the originally covered jockey sheave position.

Issue: Hub weld cracking incidents have been reported for the fastline jockey sheave (the middle of the three sheaves in the fastline linkage arm assembly) and among the crown block sheaves. The cracks propagate from weld defects near the root of the weld between the web plates and the hub.

Solution: NOV recommends that all 78" CMC wire sheaves with item no. 207785 and 207786 be replaced with single-web sheaves. Until replacement is performed, the critical welds of the sheaves should be visually inspected for cracks on a weekly basis. The Critical Welds are shown in the Maintenance Instructions and in the figure below. Additionally, users should ensure that appropriate fastline stabilizers are installed, as these significantly lower the dynamic high-frequency side loading on the sheaves.

NOV Product Information Bulletin Number 87819987 Rev 1



Illustrations: Above: Example of crack at hub of old fastline sheave. Right: Cross-section of typical sheave. The red arrows are pointing at the welds that supplier defines as "critical".

Ordering Information/ Contact Information:	Please contact your local National Oilwell Varco (NOV) Service Center, with reference to PB 87819987, for further assistance. Also state the NOV project number for your CMC.
Economic and Cost Issues:	**New sheaves with bearings, plus new spacers, will for a period of one year from date of this Bulletin be supplied by NOV Incoterms FCA. Installation is at customer cost.** For plants/equipment still under warranty, parts and installation will be provided as per terms of contract. Send a Warranty Claim with reference to PB 87819987 to NOV.

Operators should also refer to previous NOV Product Information Bulletins and Safety Alerts for additional information related to this issue and information regarding safe operation, maintenance, and inspection criteria by signing in to your MYNOV account at https://portal.mynov.com and then searching with the Product Bulletin Search available below the heading 'Application Groups'. For information on registering, please visit https://www.nov.com/Search/register.aspx.

Failure to follow the recommendations and/or guidance in NOV Manuals and Product Bulletins may result in death, bodily injury or property damage.

Please contact your local National Oilwell Varco (NOV) Service Center if you have any questions regarding this bulletin.

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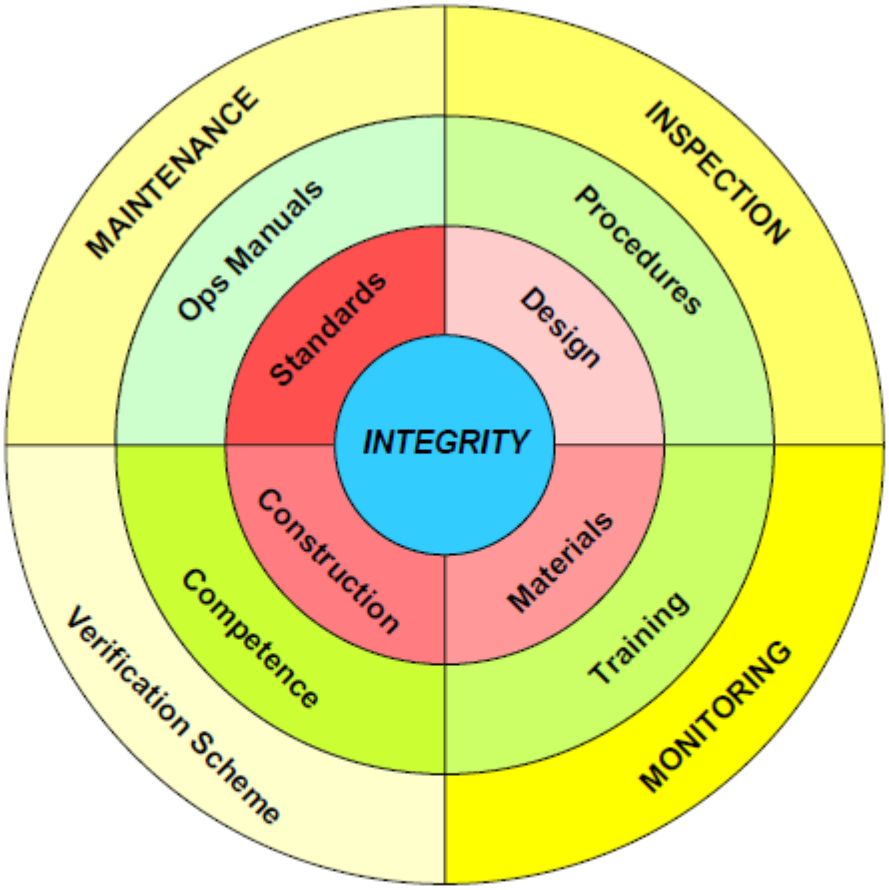
APPENDIX II

Asset Integrity Management



Contributors to Asset Integrity

Reference: Asset Integrity Management Handbook, Peter McClean Millar, 2015.

Sections that were evaluated are design, materials, standards, construction (manufacture), inspection, etc.