

***SUMMARY OF BLOWOUT PREVENTER (BOP)
FAILURE MODE EFFECT CRITICALITY ANALYSES (FMECAs)
FOR THE BUREAU OF SAFETY AND ENVIRONMENTAL
ENFORCEMENT***

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SUMMARY

As part of the Blowout Preventer (BOP) Maintenance and Inspection for Deepwater Operations study (Bureau of Safety and Environmental Enforcement [BSEE] Contract Number M11PC00027), American Bureau of Shipping (ABS) and ABSG Consulting Inc. (ABS Consulting) performed three Failure Mode, Effect, and Criticality Analyses (FMECAs) on specific BOP subsystems and equipment. The three FMECAs were performed by three different teams, which consisted of personnel from the operating company, drilling contractors, and original equipment manufacturers (OEMs). This draft report summarizes and compares the results of the three FMECAs and represents the study deliverable associated with Task 6.2.2.4 as outlined in the contract.

The objectives of each FMECA were to (1) establish the relationship between a specific subsystem/equipment failure and a loss of system functionality; (2) identify the critical failures by using risk-ranking methods; and (3) align the current Maintenance, Inspection, and Testing (MIT) practices and their associated frequencies with each functional failure and the associated subsystem and equipment failures. This report presents the objective and scope of the FMECA studies and this summary report; a discussion of the FMECA methodologies used; a comparison of the results from the three FMECAs; and the transmittal of the updated FMECA reports.

Section 2 of this report provides an overview of the FMECA methodologies used for the three studies and discusses the differences in the three study approaches. Specifically, all three studies employed a functional-level FMECA followed by an equipment-level FMECA. The functional-level FMECAs were used to establish the end effects of functional failures and to link these functional failures to specific equipment-level failure modes. The equipment-level FMECAs were conducted to identify the impact of major equipment and component failures on the BOP performance by evaluating equipment-level failure modes, identifying specific equipment-level causes, identifying the safeguards to prevent or detect the failure modes, and ranking the criticality of failure modes. In addition, the equipment-level FMECAs were used to align MIT activities with equipment-level failure modes and specific equipment failures.

Section 3 of this report contains a comparison of the results from the three FMECAs. In this section, the risk-ranking and maintenance task results are compared. Specifically, comparisons of equipment-failure mode risk, frequency of occurrence, and detectability are provided. Comparisons of the maintenance tasks associated with equipment/failure modes and frequency of being applied as a protection are included as a part of the maintenance task results.

This report summarizes and compares the results of the three FMECAs. Section 4 provides concluding remarks on (1) the FMECA methodologies and (2) the study results.

The comparison of the risk ranking and MIT activities identified trends related to:

- Most Important Equipment Failures
- Most Frequently Occurring Equipment Failures
- Hardest to Detect Failure Modes
- Most Frequently Listed MIT Items As a Means to Detect or Prevent Failures

The most important equipment failures were:

- Blind Shear Rams (in all three FMECAs)
- Casing Shear Rams (in two of the three FMECAs)
- Connectors (in two of the three FMECAs)
- Blue and Yellow POD hydraulics (in two of the three FMECAs)
- Choke and Kill Lines and Valves (in two of the three FMECAs)
- Pipe Rams (in two of the three FMECAs)
- Hydraulic Supply Lines (in two of the three FMECAs)
- Subsea Accumulators (in two of the three FMECAs)

The most frequently occurring equipment failures were found to be:

- Control Systems (both the electric or hydraulic portions) (in all three FMECAs)
- Pipe Rams (in two of the three FMECAs)
- Choke and Kill Lines and Valves (in two of the three FMECAs)
- Blind Shear Rams (in two of the three FMECAs)

The hardest to detect failures were related to the following equipment:

- Autoshear System (in all three FMECAs)
- Connector (in two of the three FMECAs)
- Rigid Conduit (in two of the three FMECAs)

Finally, a sort and review of the MIT tasks listed as a means to detect or prevent equipment failures found the following to be the most frequently listed MIT tasks:

- Function Test (in all three FMECAs)
- Pressure Test (in all three FMECAs)
- Dimensional/Ultrasonic Testing (in two of the three FMECAs)
- Rebuilding/Replacing Equipment (in two of the three FMECAs)

These result trends provide information related to the more important equipment failures (in terms of risk, frequency of occurrence, and failure detectability) and MIT tasks.

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LIST OF ACRONYMS

ABS	—	American Bureau of Shipping
ABS Consulting	—	ABSG Consulting Inc.
API	—	American Petroleum Institute
BOP	—	Blowout Preventer
BSEE	—	Bureau of Safety and Environmental Enforcement
C&K	—	Choke and Kill
CCSV	—	Compensated Chamber Solenoid Valve
DDV	—	Direct Drive Valve (solenoid valve)
ECS	—	Emergency Control System
EDS	—	Emergency Disconnect System
FMECA	—	Failure Mode, Effect, and Criticality Analysis
GoM	—	Gulf of Mexico
HKR	—	Remote Hydraulic Regulator
HPU	—	Hydraulic Power Unit
IP	—	Industry Participant
LMRP	—	Lower Marine-Riser Package
MIT	—	Maintenance, Inspection, and Test
MKR	—	Manual Hydraulic Regulator
MUX	—	Multiplex
OEM	—	Original Equipment Manufacturer
P/T	—	Pressure / Temperature
ROV	—	Remote Operated Vehicle
RP	—	Recommended Practices
RPN	—	Risk Priority Number
SEM	—	Subsea Electronic Module
SPM	—	Subsea Plate-mounted (valve)
UPS	—	Uninterruptible Power Supply

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1.0 INTRODUCTION

As part of the Blowout Preventer (BOP) Maintenance and Inspection for Deepwater Operations study (Bureau of Safety and Environmental Enforcement [BSEE] Contract Number M11PC00027), American Bureau of Shipping (ABS) and ABSG Consulting Inc. (ABS Consulting) performed three Failure Mode, Effect, and Criticality Analyses (FMECAs) on specific BOP subsystems and equipment. The three FMECAs were performed by three different teams, which consisted of personnel from operating companies, drilling contractors, and original equipment manufacturers. This draft report summarizes and compares the results of the three FMECAs and represents the study deliverable associated with Task 6.2.2.4 as outlined in the contract.

This report presents the objective and scope of the FMECA studies and this summary report; a discussion of the FMECA methodologies used; a comparison of the results from the three FMECAs; and the transmittal of the updated FMECA report.

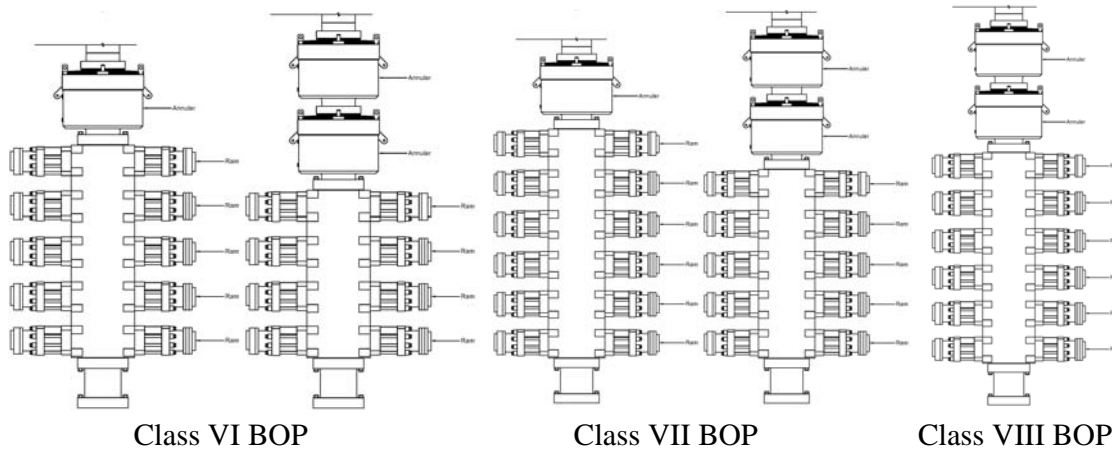
1.1 OBJECTIVES

The objectives of this summary FMECA report are to (1) provide a discussion of the FMECA approaches employed and their potential application to additional BOP studies, (2) compare the risk ranking and maintenance task results from the three FMECAs, and (3) provide the final FMECA reports.

1.2 FMECAS SCOPES

The basic scopes for all three FMECAs were essentially the same and consisted of analyses of a selected BOP and associated equipment from one of the original equipment manufacturers (OEMs), drilling contractors and operators participating in the study who meet the following criteria:

- Operation Location – Gulf of Mexico (GoM) (majority of the operation and maintenance to be from the GoM)
- Operating Depth – 5,000 Feet and Deeper
- BOP Configurations:
 - **Class VI BOP**, five ram configuration and single annular or a four ram and dual annular.
 - **Class VII BOP**, five ram configuration and dual annular or a six ram and single annular.
 - **Class VIII BOP**, six ram configuration and dual annular (ram configurations can consist of a combination of blind/shear ram, non-sealing casing ram and pipe ram preventers).



All analyses included the compilation of information from the Industry Participants (IPs), followed by the review and analysis of the selected BOP and associated control systems used by the drilling contractors. These drilling systems are summarized in Table 1-1.

Table 1-1: Summary of BOP and Associated Control Systems

	Surface Control System	Subsea Control System	BOP Stack
FMECA 1	OEM A with 3 rd -party hydraulic power unit (HPU)	OEM A	OEM A
FMECA 2	OEM A	OEM A	OEM A
FMECA 3	OEM B	OEM B	OEM B

The initial analytical scope for the functional-level FMECA consisted of the evaluation of the eight BOP functions specified in American Petroleum Institute (API) Recommended Practice (RP) 53 Standard, Section 7.1.3, and the additional functions identified by each analysis team. During the FMECA session, the “shear the drill pipe and seal the wellbore” function was broken down into three functions based on differing operating conditions and logic. A total of 11 major BOP functions and 52 functional failures were identified and agreed upon. The following BOP functions were evaluated in these studies:

1. Close and seal on the drill pipe and allow circulation on demand.
2. Close and seal on open hole and allow volumetric well control operations on demand.
3. Strip the drill string using the annular BOP(s).
4. Hang-off the drill pipe on a ram BOP and control the wellbore.
5. Controlled operation – Shear the drill pipe and seal the wellbore.
6. Emergency operation – Auto-Shear – Shear the drill pipe and seal the wellbore.
7. Emergency operation – Emergency Disconnect System (EDS) – Shear the drill pipe and seal the wellbore.
8. Disconnect the Lower Marine-Riser Package (LMRP)/BOP.
9. Circulate the well after drill pipe disconnect.

10. Circulate across the BOP stack to remove trapped gas.
11. Connect BOP and LMRP at Landing (not included in API RP 53 Standard).

For the equipment-level FMECA, the BOP was initially divided into 3 major BOP subsystems and 20 major equipment items. The following represents the selected functions and BOP systems/equipment for the FMECAs:

1. Surface Control System
 - 1.1. HPU
 - 1.2. Power
 - 1.3. Multiplex (MUX) System and Communication Cables
 - 1.4. Hydraulic Supply
 - 1.5. Control Panels
 - 1.6. Accumulators – Surface
 - 1.7. Fluid Reservoir Unit

2. Subsea Control System
 - 2.1. Blue and Yellow Control Systems – EH Section
 - 2.2. Blue and Yellow Control Systems – Lower Valve Section
 - 2.3. Accumulators – Subsea
 - 2.4. Emergency Control Systems
 - 2.5. Secondary Control Systems (Remote Operated Vehicle [ROV])
 - 2.6. Emergency Control Systems (ECS) (Autoshear/Deadman)

3. BOP Stack
 - 3.1. Annulars
 - 3.2. Blind Shear Ram
 - 3.3. Shear Ram (Casing)
 - 3.4. Pipe and Test Rams
 - 3.5. Choke and Kill (C&K) Lines and Valves
 - 3.6. Connectors
 - 3.7. Spools

In addition, boundaries were established for each major equipment item to identify all of the specific components to be included with each major equipment item. Table 1-2 lists the boundaries used in these analyses.

Table 1-2: Equipment-Level FMECA Major Component Boundaries

Major Component	Specific Components Included With Major Component Boundary
Surface Control System	
HPU	HPU including three HPU pumps and associated piping and regulators
Power	Power including Blue and Yellow Power Distribution Panels, Power Isolation J-box; Blue and Yellow Uninterruptible Power Supply (UPSs), Blue and Yellow Subsea Transformers, and Blue and Yellow Distribution Panels, Umbilical J-box; and connections to associated cabinets and equipment (e.g., MUX, control panels)
MUX System Communication Cables	MUX System, including Central Control Unit with Process Array, Blue and Yellow Processor Array, and associated equipment and cabinets; MUX cable reels and MUX cables (to connections with Blue and Yellow Pods)
Hydraulic Supply	Hydraulic Supply including Blue and Yellow Hotline Reels, Hotline Hoses (to connection at Blue and Yellow Pods) and Rigid Conduit (to connection with subsea accumulator system)
Control Panels	Control Panels including Driller’s Panel with System Controller and Tool Pusher’s Panel with System Controller
Accumulators – Surface	Accumulators - Surface including one 300 gallon, 5K rack; one 180 gallon 5K accumulator rack and associated ball valve; and connectors to HPU
Fluid Reservoir Unit	Fluid Reservoir Unit, including 650 gallon glycol, 550 gallon concentrate, and 1350 gallon mixed fluid reservoirs; glycol, concentrate, and mixed fluid pumps; and associated piping, and mixing system
Subsea Control System	
Blue and Yellow Control Systems – EH Section	Blue and Yellow Control Systems including MUX control, MUX POD power and communication, hydraulic connections within the pod, E/H section (hydraulics, power, communication, subsea electronic module (SEM) interface, pressure, temperature, and water sensors, transformer, pod cabling, solenoid boards, solenoids.
Blue and Yellow Control Systems – Lower Valve Section	Blue and Yellow Control Systems - Lower Valve Section including regulators and Subsea plate-mounted (SPM) valves to the shuttle valve
Accumulators – Subsea	Accumulators - Subsea including associated hydraulic piping and connections such as MUX pod and rigid conduit connections, 16 x 80-gallon bottles
ECS	Secondary and ECS - Subsea including POD angle sensor, inclinometer, acoustic, and deadman
Secondary Control Systems (ROV)	Secondary and ECS - Subsea including POD angle sensor, inclinometer, acoustic, and deadman
ECS (autoshear/deadman)	Secondary and ECS - Subsea including POD angle sensor, inclinometer, acoustic, and deadman

Table 1-2: Equipment-Level FMECA Major Component Boundaries (cont'd)

Major Component	Specific Components Included With Major Component Boundary
BOP Stack	
Annulars	BOP that uses a shaped elastomeric sealing element to seal the space between the tubular and the wellbore or an open hole, including both lower and upper annulars and hydraulic supply
Blind Shear Ram	Ram BOP whose Ram Blocks incorporate a cutting blade to shear the pipe and sealing elements to contain well bore pressure upon shearing of the pipe, including hydraulic supply
Shear Ram	Ram BOP whose Ram Blocks incorporate a cutting blade to cut casing and/or heavier grade tubulars within a specific range. They do not seal the well bore.
Pipe and Test Rams	Pipe Ram: A closing and sealing component in a ram BOP that seals around the outside diameter of a tubular in the wellbore. Test Ram: A Variable Bore Ram located in the lower most Ram Cavity with ram block installed in inverted position to seal pressure from the top and enable testing of the BOP Stack without running a Test Tool.
Choke & Kill Lines and Valves	Valves and pipes assembly enabling communication to or from the well bore to the surface C&K manifold to circulate well, control kicks or kill well. C&K Lines & Valves on both LMRP and Stack.
Connectors	Connectors at Wellhead, LMRP/BOP Stack and Hydraulic Actuators
Spool	Spacer Spools including connections to other BOP stack equipment

1.3 FMECA TEAM MEMBERS AND MEETING SCHEDULE

The analysis teams for each study included personnel from three IPs, ABS, and ABS Consulting. The participating IPs included one or more representatives from an OEM, drilling contractor, and operator. These individuals provided knowledge of the design, engineering, operation, and maintenance of the BOP being evaluated. Table 1-3 lists and compares the functional positions for the IP personnel who participated in each study.

In addition to the IP representatives, personnel from ABS and ABS Consulting participated in the FMECA sessions. Specifically, ABS personnel provided knowledge of the overall BOP operations and class society and regulatory requirements applicable to BOP design and operation. ABS Consulting personnel facilitated and documented the FMECA studies. Table 1-4 lists the ABS and ABS Consulting personnel participating in each study.

Table 1-3: IP FMECA Team Members

IP Organization	Position/Expertise		
	FMECA 1	FMECA 2	FMECA 3
BOP OEM	Engineering Manager, Drilling Products	Engineering Manager, Drilling Products	Engineering Director
	Manager, Reliability Engineering/Drilling and Production	Manager, Reliability Engineering/Drilling and Production	Project Manager
	Electrical Engineering Manager, Drilling and Production	Electrical Engineering Manager, Drilling and Production	Manager – Pressure Control
	Sub Section Manager, Stacks, Mechanical Controls and Risers	Sub Section Manager, Stacks, Mechanical Controls and Risers	Electrical Supervisor – Pressure Control
Engineering Consultant – Pressure Control			
Drilling Contractor	Corporate Subsea Operation Manager	Director, Subsea Operation Manager	Manager – Subsea Systems
	Subsea Superintendent		
	Subsea MUX System SME		
Operator	Subsea Intervention Engineer	Well Technology	Well Delivery Manager
	Engineer Operations, Drilling and Completions		Drilling Supervisor

Table 1-4: ABS and ABS Consulting FMECA Team Members

Name	Organization	Title	Study Role	FMECA 1	FMECA 2	FMECA 3
David Cherbonnier	ABS	Staff Consultant, Corporate Offshore Technology	Subsea Engineer	Both FMECAs*	Both FMECAs	
Bibek Das	ABS	Senior Engineer II, Corporate Shared Technology	Senior Engineer II (Risk and Reliability), Corporate Technology and Workshop Facilitator	Both FMECAs		Both FMECAs (Facilitator)

Table 1-4: ABS and ABS Consulting FMECA Team Members (cont'd)

Name	Organization	Title	Study Role	FMECA 1	FMECA 2	FMECA 3
Phil Howard	ABS Consulting		Workshop Scribe		Both FMECAs	
Darshan Lakahani	ABS Consulting		Workshop Scribe			Both FMECAs
Randy Montgomery	ABS Consulting	Senior Director, Integrity Management	Project Technical Lead	Functional-level FMECA	Functional-level FMECA	
Farzin Nouri	ABS Consulting		Workshop Facilitator		Both FMECAs	
Kamran Nouri	ABS Consulting	Senior Risk and Reliability Engineer	Workshop Facilitator	Both FMECAs		
Andrew Quillin	ABS Consulting	Lead Engineer	Workshop Scribe	Both FMECAs		
Harish Patel	ABS	Manager, Corporate Technology - Drilling and Process	Overall Project Manager	Both FMECAs		Both FMECAs

*- Indicates participation in both the functional- and equipment-level FMECA sessions

The functional-level FMECA study was conducted by the analysis teams during 3-day sessions. The equipment-level FMECA was conducted during 4- or 5-days sessions. Table 1-5 provides the dates for FMECA sessions.

Table 1-5: FMECA Study Dates

FMECA Study	Functional-level FMECA	Equipment-level FMECA	Comments
FMECA 1	September 10 – 12, 2012	September 24 – 28, 2012	Two additional risk priority number (RPN) scoring sessions were conducted on December 7, 2012, and December 14, 2012
FMECA 2	September 18 – 20, 2012	October 1 – 5, 2012	
FMECA 3	September 18 – 20, 2012	October 1 – 5, 2012	

1.4 REPORT ORGANIZATION

Section 2 of this report provides a discussion of FMECA methodology used and the differences in the analysis teams' approaches. Section 3 compares the criticality/risk ranking and maintenance, inspection, and test results from the three FMECAs. Section 4 provides concluding remarks on these FMECA analyses and their results.

2.0 DISCUSSION OF FMECA METHODOLOGIES

In order to evaluate BOP Maintenance, Inspection, Testing practices, assess the risk of failures, and improve the reliability of BOP performance, the identification of the BOP's critical failure modes and their effects is essential. Therefore, ABS and ABS Consulting selected and employed both functional- and equipment-level FMECA methodologies to evaluate BOP functions and identify specific subsystem and equipment failures of interest as outlined in Section 1.2, FMECA Scope.

This analysis methodology was chosen because it provided a means to establish a relationship among (1) BOP functions, (2) BOP equipment failures, and (3) BOP maintenance, inspection, and test (MIT) practices by

- Identifying the potential effects resulting from deviations to BOP functions (i.e., functional failures) and equipment-level failure modes causing the BOP functional failures.
- Identifying the potential functional failures resulting from BOP equipment failure modes and specific equipment failures causing the BOP equipment failure modes.
- Linking specific equipment failures to BOP functional failures.
- Identifying and aligning the MIT activities (Indication / Protection / Maintenance) currently provided for preventing specific equipment failures resulting in BOP functional failures and their potential end effects.
- Risk-ranking the equipment-level failure modes.

2.1 OVERVIEW OF THE FMECA METHODOLOGY

An FMECA is an inductive reasoning approach that (1) considers how the functional failures of each system function or how the failure modes of each component could result in system performance problems and (2) helps to evaluate the safeguards that are in place (including engineered safeguards and monitoring systems, human actions, and maintenance activities) to prevent, detect, or mitigate such problems. The main focus of an FMECA is to (1) establish the cause-and-effect relationship between potential equipment failures, functional failures, and the end effect(s) of those failures and (2) evaluate the criticality of the postulated functional failure/failure mode.

Figure 2-1 represents the general FMECA steps used in evaluating the BOP system. Specifically, this study employed both functional- and equipment-level FMECA approaches (see Step 3) with the explicit purpose of transitioning the functional-level FMECA to a more detailed level to better ensure the alignment of MIT activities with specific equipment failures and to link the specific equipment failures to potential BOP performance issues via functional failures. This FMECA approach is very similar to the approach employed in many classical reliability-centered maintenance approaches, which have the overall objective of determining the optimal maintenance strategy for preserving system functionality by detecting and preventing equipment failures.

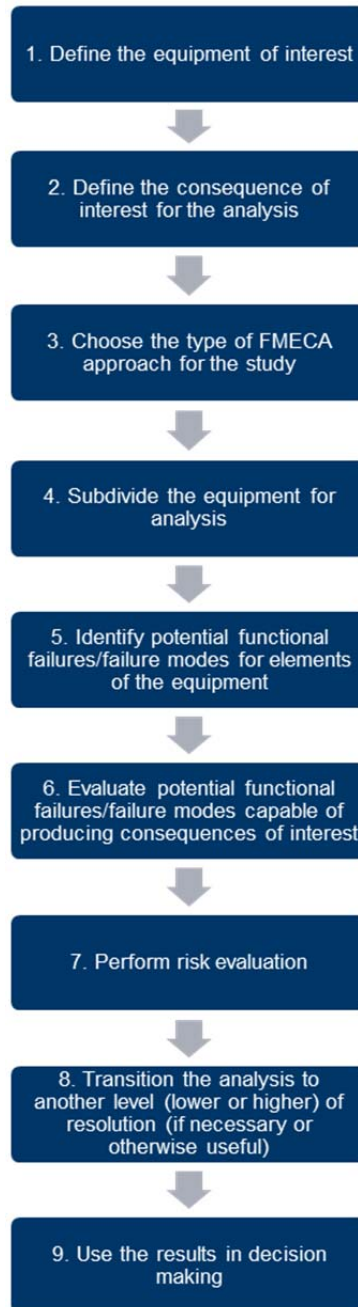


Figure 2-1. General FMECA Approach

Following this basic approach, each team performed functional- and equipment-level FMECAs and used the RPN approach to rank each of the equipment failure modes and their associated functional failure effects. ABS Consulting's Enterprise LEADER software tool was used for the analysis and documentation of both the functional- and equipment-level FMECAs, and RPN risk rankings.

2.1.1 Functional -Level (Top-Down) FMECA

To perform the functional level FMECAs, three separate functional-level FMECA workshops were held. Depending on the workshop and system configuration, each analysis team identified 11 to 14 BOP functions and evaluated 48 to 56 associated functional failures.

Each function and its associated functional failures were evaluated in detail by identifying (1) the potential end effects resulting from the functional failure, (2) equipment-level causes and failure modes potentially resulting in the functional failure, and (3) safeguards used to prevent or detect the potential functional failure and its associated equipment-level causes. The equipment-level causes and failure modes were then studied in detail during the equipment-level FMECA workshop.

2.1.2 Equipment-Level (Bottom-Up) FMECA

The equipment-level FMECA was performed by analyzing each major piece of equipment including associated components using equipment-level failure modes. The major equipment items were identified in the functional-level FMECA as critical equipment whose failure contributed to a functional failure of interest (i.e., a specific functional failure which can result in an end of interest). To evaluate each equipment item, a list of the general failure modes was developed and used for the initial failure mode discussions. As necessary, the analysis team modified these general equipment failure modes to describe the means in which each major component can fail.

During the equipment-level FMECA workshop, each analysis team evaluated each major equipment item by first identifying potential equipment-level failure modes and then postulating on specific equipment failure causes resulting in each failure mode. The team then identified the potential effects resulting from each failure mode. The effects were then identified and classified into various BOP functional failures. Based on this classification, the equipment-level failure modes were linked to the corresponding BOP functional failure. Once these links were established, the team identified any safeguards that are currently in place to detect, prevent or mitigate the equipment-level failure mode. Next, the analysis team identified specific MIT practices currently employed to detect or prevent the specific equipment causes.

2.1.3 Evaluation and Ranking of Equipment Failure Modes (Criticality/Risk Ranking)

To provide a consistent means to (1) evaluate the relative criticality of the major BOP equipment failures and (2) help judge the adequacy of MIT activities performed to detect and prevent failures, an RPN ranking scheme based the following factors was employed:

- Frequency of failure of the equipment failure mode.
- Level of redundancy to prevent a specific failure from resulting in the complete loss of safety critical functions.
- Ability to detect and prevent the failure mode via system monitoring and MIT practices.
- Severity of the end effect for each BOP functional failure

An RPN ranking for each functional failure associated with an equipment-level failure mode was based on the product of the following three independent factors:

- Severity Rating – This rating assesses the severity of the worst-case end effect for a given functional failure. (Note: The functional failure end effects documented in the functional-level FMECA were used to determine this rating assuming no redundancies are present.). The severity was rated for potential hazard to personnel on the rig, potential environmental impact, and potential downtime.
- Occurrence Rating – This rating assesses the likelihood of the failure mode resulting in the functional failure and its stated end effect. Such an assessment is made by evaluating the causes listed for the failure mode. The presence of redundant components and systems is explicitly considered in this rating.
- Detection Rating – This rating assesses the likelihood of the current applicable MIT activities and system monitoring techniques to detect the failure mode before it results in the functional failure.

These ratings were then used to calculate a single RPN ranking for each functional failure effect and equipment failure mode pair (i.e., RPN ranking for each functional failure associated with an equipment-level failure mode) using the following equation:

$$\text{RPN} = \text{Severity Rating} \times \text{Occurrence Rating} \times \text{Detection Rating}$$

The individual RPN rankings provide a relative ranking of the risk associated with a given functional failure effect-equipment failure mode pair. Thereby, providing a means to identify the more important equipment-level failure modes relative to overall BOP performance, as well as identifying the more important failure modes associated with a specific BOP functional failure. Appendix A contains additional information on the specific RPN ranking scheme.

2.2 DISCUSSION OF FMECA METHODOLOGY DIFFERENCES

While each of the analysis teams employed the same basic approach in performing the FMECAs, each analysis was performed slightly differently. The differences occurred for many reasons, such as (1) the BOP system configurations were slightly different, (2) operational differences, and (3) team members' or analysts' desire to evaluate functions or equipment in differing manners. Specifically, the most significant methodology differences involved the following three areas:

1. Functions and Functional Failures Evaluated During the Functional-Level FMECA
2. Equipment Hierarchy Used in the Equipment-Level FMECAs
3. RPN Scoring Approach

In evaluating the differences in the functions and functional failures evaluated, the differences are minor and only consist of two additional items that were evaluated by the FMECA 3 team. These two items were the acoustic system and ROV intervention functionality. This team elected to

evaluate these two items because of their importance as a secondary protection system. Both FMECA 1 and 2 identified these as secondary protective systems, as well as, but did not explicitly evaluate their functionality. However, some failures associated with systems were discussed during the equipment-level FMECA. The impact of this difference was found to be minor. Table B-1 in Appendix B provides additional details on these differences.

The differences related to the equipment hierarchy mostly involved the level of indenture in which the major equipment are subdivided. Specifically, the equipment hierarchy in FMECA 3 is divided into more discrete components than FMECAs 1 and 2. However, most all of the components in FMECA 3 were included with a major component and represented by discrete failure causes of associated major component failure modes in FMECAs 1 and 2. However, some of the causes of component failures in FMECA 3 are more specific than the causes listed in FMECA 1 and 2. For example, FMECA 3 includes the following UPS-related failures: battery malfunction, inverter failure, and inverter fuse blown as causes of loss of or degraded power, while FMECA 1 has UPS failure (transformer, conductor/cable) as the UPS-related cause. Another example is that FMECA 1 includes the following causes for external leak/rupture for the HPU system as a whole: Plunger packing on HPU pump leaking, flange connections fail, relief valve failure, and pump leaking, while FMECA 3 has piping degradation, relief valve leak, leak on discharge piping, pump flange leak, suction gate valve leak, suction hose leak, and drain valve leak for the HPU pump and suction strainer. These are essentially the same results with varying degrees of detail. In addition, the protections and maintenance items listed in both analyses are almost identical. While there are some differences in the level of detail, there does not appear to be a significant impact on the key result related to aligning the maintenance tasks to component failures. Table B-2 in Appendix B provides additional details on the equipment hierarchy differences.

The last significant difference involves the RPN rankings. There are several potential reasons for these varying results, with the most important reasons being:

- Since the FMECA 3 equipment hierarchy contains more detailed components, there are some instances in which the occurrence rankings will be less for a lower-level component than a major component.
- There can be wide variation in rankings because a degree of subjectivity in assigning rankings based on team's experiences and knowledge. This appears to be the case for some of the detectability rankings.
- There can be design and operation differences which often influence the occurrence ranking.

While there are differences in the RPN rankings and these differences prevent an analysis to analysis comparison of the actual ranking values, the RPN rankings are still useful as relative ranking within a given analysis (e.g., which components have the highest risk, which failure modes are the hardest to detect) . These results (i.e., the relative rankings vs. the actual RPN values) can be used to compare the three analyses for result trends and differences. This is approach used in the following section.

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3.0 COMPARISON OF FMECA RESULTS

While each FMECA included individual results, this report section provides a comparison of the FMECAs by identifying common and differing results. Specifically, this section provides comparisons of (1) key FMECA risk ranking results, and (2) MIT task results that are identified as being key to the detection and prevention of equipment-level failure modes. The following sections discuss both of the comparisons.

3.1 OVERVIEW OF COMPARISON APPROACH

This section describes the information compared in this section and how the information was extracted from the three FMECA reports. Specifically for the risk-ranking results comparison, the key results presented in Section 3 of each individual report was extracted and combined in a series of tables for comparison. These data were taken as found in the reports with no additional analysis performed.

For the MIT information, the maintenance tasks identified in both the functional-level and equipment-level were extracted from the respective FMECA worksheet tables. This information extraction involved sorting the Indications/Safeguards data by “type” for each FMECA. Total instances of each unique maintenance item were tallied and used to determine the most frequently occurring maintenance items as a percentage of all maintenance items.

Each result comparison was reviewed to identify any notable trends in regards to common and differing results. Any differing results were then evaluated to determine if the potential causes were due to one or more of the following issues:

- Design Differences (e.g., differing redundancy)
- Operating Differences
- MIT Differences
- Analysis Differences

3.2 CRITICALITY/RISK RANKING COMPARISON

The criticality/risk ranking model used in all three FMECAs provides a relative risk ranking of failure modes and functional failures. In addition, the RPN approach allowed the analysis team to assess the occurrence of a failure mode based on the equipment failure frequency and redundancy. This method also provided a means to assess the detectability of the failure mode based on the current MIT practices. Therefore, this criticality/risk ranking approach provided a means to identify the following:

- Higher Risk Equipment Failure Modes
- Equipment Failure Modes with Highest Occurrences
- Equipment Failure Modes Which Are the Hardest to Detect (I.E. Worst Detectability Ranking)

Table 3-1 lists the failure modes with the highest RPN scores for the three FMECAs. The highlighted items all result in failure of the blind shear ram. This suggests that all three FMECAs have identified that failure of the blind shear ram is one of the most significant equipment failure and is driven by the difficulty of detecting those failures. The double acting SPM valves in FMECA 3 are specific to the autoshear system and therefore the blind shear ram.

Several items have appeared as the highest ranking in two of the FMECAs. The casing shear rams, connectors, and blue and yellow pod hydraulics are identified in both FMECAs 1 and 2. The choke and kill lines and valves, pipe rams, and hydraulic supply lines are identified in both FMECAs 2 and 3. The subsea accumulators are identified in both FMECAs 1 and 3. These commonalities are primarily driven by the detection and occurrence ratings.

Table 3-2 presents the equipment failures that occur most frequently. Control systems, both electric and/or hydraulic systems, appear to be the most frequently occurring failures and are identified in all three FMECAs. Since the control systems are required for all BOP functions, it makes sense that they are the most frequently failing items. Failure of the pipe rams and failure of the choke and kill lines and valves are identified in both FMECAs 2 and 3 as being some of the most frequently occurring failures. Failure of the blind shear rams is identified in both FMECAs 1 and 2 as being some of the most frequently occurring failures.

Items in Table 3-3 are the items that have failures that could be very hard to detect. The detection rankings are based on the ability to detect the hardest to detect failure cause before a function is required for well control. All items included in the table are ranked very high because the discovery of these failures either (1) requires pulling the BOP and conducting major maintenance or (2) because there are no design controls currently in place to discover such failures. All three FMECAs have identified component failures associated with the autoshear system as being some of the hardest failures to detect. FMECAs 1 and 2 also identified connector failures as being hard to detect. Failure of the connectors is hard to detect because the BOP connectors are not an item that is normally tested. FMECAs 2 and 3 have both identified failure of the rigid conduit as being hard to detect.

Table 3-1: Failure Modes with Highest RPN Scores

FMECA 1							FMECA 2						FMECA 3							
Equipment / Subsystem	Failure Mode	Severity (S)	Occurrence (O)	Detection (D)	RPN (SxOxD)	# of Effects (Functional Failures)	Equipment / Subsystem	Failure Mode	Severity (S)	Occurrence (O)	Detection (D)	RPN (SxOxD)	# of Effects (Functional Failures)	Equipment / Subsystem	Failure Mode	Severity (S)	Occurrence (O)	Detection (D)	RPN (SxOxD)	# of Effects (Functional Failures)
Blind Shear Ram - BOP Stack	Mechanical Failure	10	3	7	210	18	Choke & Kill Lines & Valves - BOP Stack	Plugged	10	4	4	160	4	SPM Valve - Double acting - Subsea Control: Hydraulic	External Leak	10	5	6	300	1
Blind Shear Ram - BOP Stack	Loss of Function (general)	10	3	7	210	24	Blind Shear Ram - BOP Stack	External Leak/Rupture	9	5	3	135	1	Choke & Kill Lines & Valves - BOP Stack	Mechanical Failure	9	5	6	270	4
Accumulators - Subsea - Subsea Control Systems	Mechanical Failure (Internal wear is included)	10	2	7	140	13	Blind Shear Ram - BOP Stack	Mechanical Failure	9	5	3	135	1	SPM Valve - Double acting - Subsea Control: Hydraulic	Internal Leak	10	4	6	240	1
Shear Ram - BOP Stack	Mechanical Failure	10	2	7	140	8	Blind Shear Ram - BOP Stack	Wear	9	5	3	135	1	Choke & Kill Lines & Valves - BOP Stack	Mechanical Failure	8	5	6	240	5
Shear Ram - BOP Stack	Loss of Function (general)	10	2	7	140	12	Casing Shear Ram - BOP Stack	External Leak/Rupture	9	5	3	135	1	Pipe Ram - BOP Stack	External Leak/Rupture	10	5	4	200	2
Control Panels - Surface Control Systems	Erratic output	10	4	3	120	15	Casing Shear Ram - BOP Stack	Mechanical Failure	9	5	3	135	1	Pipe Ram - BOP Stack	Mechanical Failure	10	5	4	200	2
Control Panels - Surface Control Systems	Fails to respond to input	10	4	3	120	14	Casing Shear Ram - BOP Stack	Wear	9	5	3	135	1	Annulars - BOP Stack	Mechanical Damage	8	4	6	192	4
Control Panels - Surface Control Systems	Processing error	10	4	3	120	14	Pipe & Test Rams - BOP Stack	External Leak/Rupture	9	5	3	135	1	Choke & Kill Lines & Valves - BOP Stack	Internal Leak	8	6	4	192	2
Secondary (ROV) - Subsea Control Systems	Loss of function (general)	10	2	6	120	10	Pipe & Test Rams - BOP Stack	Mechanical Failure	9	5	3	135	1	SPM Valve - Double acting - Subsea Control: Hydraulic	Mechanical Failure/Wear	10	3	6	180	1
ECS (Autoshear/Deadman) - Subsea Control Systems	Loss of function (general)	10	2	6	120	8	Choke & Kill Lines & Valves - BOP Stack	External Leak/Rupture	9	5	3	135	1	Shuttle Valve - BOP Stack	External Leak	10	6	3	180	8
Blind Shear Ram - BOP Stack	External Leak / Rupture	10	3	4	120	15	Choke & Kill Lines & Valves - BOP Stack	Mechanical Failure	9	5	3	135	1	Subsea Accumulator (POD) - Subsea Control: Hydraulic	External Leak/Rupture	7	4	6	168	1
Blind Shear Ram - BOP Stack	Internal Leak	10	3	4	120	9	Blue & Yellow Control Systems - Hydraulics - Subsea Control Systems	Mechanical Failure	9	2	7	126	1	Subsea Accumulator (POD) - Subsea Control: Hydraulic	Internal Leak	7	4	6	168	1

Table 3-1: Failure Modes with Highest RPN Scores (cont'd)

FMECA 1							FMECA 2							FMECA 3						
Equipment / Subsystem	Failure Mode	Severity (S)	Occurrence (O)	Detection (D)	RPN (SxOxD)	# of Effects (Functional Failures)	Equipment / Subsystem	Failure Mode	Severity (S)	Occurrence (O)	Detection (D)	RPN (SxOxD)	# of Effects (Functional Failures)	Equipment / Subsystem	Failure Mode	Severity (S)	Occurrence (O)	Detection (D)	RPN (SxOxD)	# of Effects (Functional Failures)
Connectors - BOP Stack	Loss of Function (general)	10	1	10	100	4	Blue & Yellow Control Systems - Hydraulics - Subsea Control Systems	Corrosion/Erosion	9	2	7	126	1	Shuttle Valve - BOP Stack	External Leak	9	6	3	162	2
Blue & Yellow Control Systems - EH Section - Subsea Control Systems	Loss of Hydraulic Power	10	3	3	90	3	Hydraulic Supply: Rigid Conduit and Manifold - Subsea Control Systems	Mechanical Failure	9	2	7	126	1	Annulars - BOP Stack	External Leak/Rupture	8	5	4	160	6
Connectors - BOP Stack	Corrosion / Erosion	7	2	6	84	2	Hydraulic Supply: Rigid Conduit and Manifold - Subsea Control Systems	Corrosion/Erosion	9	2	7	126	1	Annulars - BOP Stack	Mechanical Failure	8	5	4	160	4
Connectors - BOP Stack	Loss of Function (general)	7	2	6	84	2	Connectors - BOP Stack	Mechanical Failure	9	2	7	126	1	Shuttle Valve - BOP Stack	External Leak	8	6	3	154	1
Blind Shear Ram - BOP Stack	Plugged	10	2	4	80	11	Autoshear System - BOP Stack	Mechanical Failure	9	2	7	126	1	Tubing and piping - Subsea Control: Hydraulic	External Leak/Mechanical Failure	10	5	3	150	17
Shear Ram - BOP Stack	External Leak / Rupture	10	2	4	80	9								Compensated Chamber Solenoid Valve (CCSV)/Direct Drive Valve (DDV) Fluid End - Subsea Control: Hydraulic	Plugged	10	5	3	150	13

Table 3-2: Failure Modes with Worst Occurrence Ratings

FMECA 1							FMECA 2							FMECA 3						
Equipment / Subsystem	Failure Mode	Severity (S)	Occurrence (O)	Detection (D)	RPN (SxOxD)	# of Effects (Functional Failures)	Equipment / Subsystem	Failure Mode	Severity (S)	Occurrence (O)	Detection (D)	RPN (SxOxD)	# of Effects (Functional Failures)	Equipment / Subsystem	Failure Mode	Severity (S)	Occurrence (O)	Detection (D)	RPN (SxOxD)	# of Effects (Functional Failures)
Control Panels - Surface Control Systems	Erratic output	10	4	3	120	16	EDS - Subsea Control Systems	Ground Fault	2	7	1	14	1	SPM Valve - Single acting - Subsea Control: Hydraulic	External Leak	10	6	2	120	31
Control Panels - Surface Control Systems	Fails to respond to input	10	4	3	120	15	Blind Shear Ram - BOP Stack	External Leak/Rupture	9	5	3	135	1	SPM Valve - Single acting - Subsea Control: Hydraulic	Mechanical Failure/Wear	10	6	2	120	26
Control Panels - Surface Control Systems	Processing error	10	4	3	120	15	Blind Shear Ram - BOP Stack	Mechanical Failure	9	5	3	135	1	CCSV/DDV Fluid End - Subsea Control: Hydraulic	External Leak	10	6	2	120	31
Blue & Yellow Control Systems - EH Section - Subsea Control Systems	Loss of Hydraulic Power	10	3	3	90	3	Blind Shear Ram - BOP Stack	Wear	9	5	3	135	1	Rigid Conduit Manifold - SPM valves - Subsea Control: Hydraulic	External Leak	1	6	2	12	1
Blind Shear Ram - BOP Stack	External Leak / Rupture	10	3	4	120	15	Casing Shear Ram - BOP Stack	External Leak/Rupture	9	5	3	135	1	Rigid Conduit Manifold - SPM valves - Subsea Control: Hydraulic	Mechanical Failure/Wear	10	6	2	120	27
Blind Shear Ram - BOP Stack	Internal Leak	10	3	4	120	9	Casing Shear Ram - BOP Stack	Mechanical Failure	9	5	3	135	1	Choke & Kill Lines & Valves - BOP Stack	External Leak/Rupture	1	6	2	12	12
Blind Shear Ram - BOP Stack	Mechanical Failure	10	3	7	210	18	Casing Shear Ram - BOP Stack	Wear	9	5	3	135	1	Choke & Kill Lines & Valves - BOP Stack	Internal Leak	8	6	4	192	2
Blind Shear Ram - BOP Stack	Loss of Function (general)	10	3	7	210	24	Pipe & Test Rams - BOP Stack	External Leak/Rupture	9	5	3	135	1	Shuttle Valve - BOP Stack	External Leak	9	6	3	162	12
							Pipe & Test Rams - BOP Stack	Mechanical Failure	9	5	3	135	1	Function Hose - BOP Stack	External Leak	1	6	2	12	1
							Choke & Kill Lines & Valves - BOP Stack	External Leak/Rupture	9	5	3	135	1	Function Hose - BOP Stack	Wear	1	6	6	36	1
							Choke & Kill Lines & Valves - BOP Stack	Mechanical Failure	9	5	3	135	1	Function Hose - BOP Stack	Corrosion/Erosion	1	6	6	36	1
							Blind Shear Ram - BOP Stack	External Leak/Rupture	8	5	2	80	1	HPU Pump & suction strainer - Surface Control: Hydraulic	Plugged	1	5	4	20	1

Table 3-2: Failure Modes with Worst Occurrence Ratings (cont'd)

FMECA 1							FMECA 2						FMECA 3							
Equipment / Subsystem	Failure Mode	Severity (S)	Occurrence (O)	Detection (D)	RPN (SxOxD)	# of Effects (Functional Failures)	Equipment / Subsystem	Failure Mode	Severity (S)	Occurrence (O)	Detection (D)	RPN (SxOxD)	# of Effects (Functional Failures)	Equipment / Subsystem	Failure Mode	Severity (S)	Occurrence (O)	Detection (D)	RPN (SxOxD)	# of Effects (Functional Failures)
Many more less significant failure modes not listed	Blind Shear Ram - BOP Stack	Internal Leak	8	5	2	80	1	HPU Pump & suction strainer - Surface Control: Hydraulic	Loss of Function (general)	1	5	4	20	1						
	Blind Shear Ram - BOP Stack	Mechanical Failure	8	5	2	80	1	Surface Accumulator - Surface Control: Hydraulic	Internal Leak	1	5	4	20	1						
	Blind Shear Ram - BOP Stack	Wear	8	5	2	80	1	Well bore pressure/temperature (P/T) Probe - Subsea Control: MUX Electrical	Failure of P/T Probe And Loss Of Signal	2	5	3	30	1						
	Casing Shear Ram - BOP Stack	Mechanical Failure	8	5	2	80	1	LMRP P/T Probe - Subsea Control: MUX Electrical	Failure of P/T Probe And Loss Of Signal	2	5	3	30	1						
	Casing Shear Ram - BOP Stack	Wear	8	5	2	80	1	HKR Regulator - Subsea Control: Hydraulic	External Leak	10	5	2	100	33						
	Connectors - BOP Stack	External Leak/Rupture	2	5	3	30	1	Remote Hydraulic Regulator (HKR) Regulator - Subsea Control: Hydraulic	Internal Leak	7	5	1	35	1						
	Connectors - BOP Stack	Mechanical Failure	2	5	3	30	1	HKR Regulator - Subsea Control: Hydraulic	Mechanical Failure/Wear	10	5	2	100	29						
	Connectors - BOP Stack	Loss of Function (general)	2	5	3	30	1	SPM Valve - Double acting - Subsea Control: Hydraulic	External Leak	10	5	6	300	1						
								Tubing and piping - Subsea Control: Hydraulic	External Leak/Mechanical Failure	10	5	3	150	31						
								CCSV/DDV Fluid End - Subsea Control: Hydraulic	Plugged	10	5	3	150	27						
								Manual Hydraulic Regulator (MKRI) Regulator - Subsea Control: Hydraulic	External Leak	10	5	2	100	33						
								MKR Regulator - Subsea Control: Hydraulic	Internal Leak	7	5	1	35	1						
								MKR Regulator - Subsea Control: Hydraulic	Mechanical Failure/Wear	10	5	2	100	29						

Table 3-2: Failure Modes with Worst Occurrence Ratings (cont'd)

FMECA 1						FMECA 2						FMECA 3								
Equipment / Subsystem	Failure Mode	Severity (S)	Occurrence (O)	Detection (D)	RPN (SxOxD)	# of Effects (Functional Failures)	Equipment / Subsystem	Failure Mode	Severity (S)	Occurrence (O)	Detection (D)	RPN (SxOxD)	# of Effects (Functional Failures)	Equipment / Subsystem	Failure Mode	Severity (S)	Occurrence (O)	Detection (D)	RPN (SxOxD)	# of Effects (Functional Failures)
Many more less significant failure modes not listed														MKR Regulator - Subsea Control: Hydraulic	Loss of Function (4th gen)	10	5	2	100	1
														Subsea Accumulator (POD) - Subsea Control: Hydraulic	Internal Leak	2	5	6	60	1
														Subsea Accumulator (LMRP) - Subsea Control: Hydraulic	Internal Leak	2	5	6	60	1
														Rigid Conduit Manifold - SPM valves - Subsea Control: Hydraulic	External Leak	10	5	2	100	31
														Annulars - BOP Stack	External Leak/Rupture	8	5	4	160	6
														Annulars - BOP Stack	Mechanical Failure	8	5	4	160	4
														Pipe Ram - BOP Stack	External Leak/Rupture	10	5	4	200	2
														Pipe Ram - BOP Stack	Mechanical Failure	10	5	4	200	2
														Choke & Kill Lines & Valves - BOP Stack	Mechanical Failure	1	5	6	30	10
														Choke & Kill Lines & Valves - BOP Stack	Corrosion/Erosion	8	5	2	80	1

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Table 3-3: Failure Modes with Worst Detection Ratings

FMECA 1							FMECA 2						FMECA 3							
Equipment / Subsystem	Failure Mode	Severity (S)	Occurrence (O)	Detection (D)	RPN (SxOxD)	# of Effects (Functional Failures)	Equipment / Subsystem	Failure Mode	Severity (S)	Occurrence (O)	Detection (D)	RPN (SxOxD)	# of Effects (Functional Failures)	Equipment / Subsystem	Failure Mode	Severity (S)	Occurrence (O)	Detection (D)	RPN (SxOxD)	# of Effects (Functional Failures)
Connectors - BOP Stack	Loss of Function (general)	10	1	10	100	4	Blue & Yellow Control Systems - Hydraulics - Subsea Control Systems	Mechanical Failure	9	2	7	126	1	Tubing and piping - Subsea Control: Hydraulic	Corrosion/Erosion	2	1	10	20	1
Accumulators - Subsea - Subsea Control Systems	Mechanical Failure (Internal wear is included)	10	2	7	140	14	Blue & Yellow Control Systems - Hydraulics - Subsea Control Systems	Corrosion/Erosion	9	2	7	126	1	Rigid Conduit Manifold - SPM valves - Subsea Control: Hydraulic	Corrosion/Erosion	2	4	9	72	1
Blind Shear Ram - BOP Stack	Mechanical Failure	10	3	7	210	18	Hydraulic Supply: Rigid Conduit and Manifold - Subsea Control Systems	Mechanical Failure	9	2	7	126	1	SPM Valve - Single acting - Subsea Control: Hydraulic	Corrosion/Erosion	2	4	9	72	1
Blind Shear Ram - BOP Stack	Loss of Function (general)	10	3	7	210	24	Hydraulic Supply: Rigid Conduit and Manifold - Subsea Control Systems	Corrosion/Erosion	9	2	7	126	1	SPM Valve - Double acting - Subsea Control: Hydraulic	Corrosion/Erosion	2	3	9	54	1
Shear Ram - BOP Stack	Mechanical Failure	10	2	7	140	8	Connectors - BOP Stack	Mechanical Failure	9	2	7	126	1	Solenoid Valve - Subsea Control: MUX Electrical	Short	10	1	7	70	12
Shear Ram - BOP Stack	Loss of Function (general)	10	2	7	140	12	Autoshear System - BOP Stack	Mechanical Failure	9	2	7	126	1							

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3.3 MIT COMPARISON

This section compares the MIT information extracted from the FMECA tables. As discussed in Section 2, each FMECA identified MIT tasks and associated frequencies currently performed on equipment and components identified as causes of functional failures or equipment failure modes. These MIT activities are important because they are key to reducing risk of failures by detecting or preventing equipment failures prior to occurrence as well as testing redundant systems to ensure these systems are operational. The purpose of the MIT comparison is to identify those more important tasks identified during the FMECA based on the following attributes:

- Most frequently listed tasks (e.g. tasks related to detection or prevention of the most failure modes).
- MIT Tasks associated with higher risk equipment failure modes.
- MIT Tasks associated with easiest detected failure modes (these indicate potential highly-effective tasks at detecting or preventing failures).
- MIT Tasks associated with more difficult to detect failures (these indicate potential low-effective tasks at detecting or preventing failures).

Table 3-4 lists the top ten most frequently occurring maintenance items for each FMECA. The function test is the number one MIT task for all three FMECAs. FMECAs 1 and 2 both have dimensional/ultrasonic testing as a top ten MIT task. FMECAs 1 and 3 both have pressure testing and rebuilding/replacing equipment as applying to a large number of items.

The higher risk equipment failure modes are usually due to a high detectability score. These high scores are due to maintenance tasks that are very infrequent. For example, the blind shear and casing shear rams are function tested but are never tested under load while subsea. This could result in a dormant failure going undetected until the next time the BOP is rebuilt.

The failures that are the easiest to detect usually have some self diagnostic capability or alarms associated with them and are not necessarily discovered due to maintenance tasks. However, the maintenance tasks associated with the easiest to detect failure modes are in general the tasks that occur most frequently, such as a daily inspection, daily test and daily connection monitoring.

The higher risk equipment failure modes are usually due to a high detectability score. A detectability score is based on the cause that is hardest to detect and does not necessarily reflect the detectability of all possible causes of failure. As a result, the majority of MIT tasks listed for a certain failure mode may only apply to the causes that are easiest to detect. These high scores are due to causes of failure whose maintenance tasks are very infrequent. For example, the blind shear and casing shear rams are function tested weekly but are never tested under load while subsea. This could result in a dormant failure going undetected until the next time the BOP is rebuilt. In general, the maintenance tasks for the higher ranking detectability scores require pulling the BOP and possibly a major overhaul. Refer to Table A-3.

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Table 3-4: Top 10 Maintenance Tasks Identified in Equipment Level FMECA

FMECA 1			FMECA 2			FMECA 3		
Maintenance	Total Instances	% of Total	Maintenance	Total Instances	% of Total	Maintenance	Total Instances	% of Total
Function test	56	17.55%	Weekly function test	54	10.25%	Weekly function test	40	11.83%
Pressure test	37	11.60%	Soak and stump tests between wells	39	7.40%	Rebuild/rotation - 18 months	22	6.51%
Rebuild/replace 20% / year (5-year cycle)	18	5.64%	ROV inspection every 3 days	33	6.26%	Soap test on surface	17	5.03%
Seals inspected & replaced	13	4.08%	Hydraulic system testing - Surface and subsea	28	5.31%	Test on test bench after every rebuild/repair	12	3.55%
Visual inspection	11	3.45%	Wellbore test are conducted between wells and every 14 days while drilling	22	4.17%	Pressure test	10	2.96%
Drawdown test	9	2.82%	Five year inspection and maintenance of BOP	21	3.98%	Surface Function test	7	2.07%
Seals tested or replaced everytime element is replaced	9	2.82%	Overhauling nuts replaced every 2 years	16	3.04%	Bladder on pod pilot accumulator bottle - rotational maintenance (install new bladder kit) - 5 years	6	1.78%
Check pre-charge	8	2.51%	Between Wells - Replace all seals/rubber goods on ram blocks	15	2.85%	Change filters and seals every time LMRP is pulled to surface	6	1.78%
Operator test	8	2.51%	Quarterly electrical system maintenance (visually inspect, tighten connections, rust/corrosion, general condition, transformer condition, clean with vacuum/low pressure air)	15	2.85%	DDV maintenance 15-20% on rotating basis - between wells (4th gen)	5	1.48%
Ultrasonic testing	8	2.51%	Annual - Dimensional checks, chamber testing, MPL signature testing (predictive), MPL bearings replaced, NDT on ram blocks, connecting rods, and blades.	14	2.66%	Solenoid replacement every five years	5	1.48%

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4.0 CONCLUDING REMARKS

This report summarizes and compares the results of the three FMECAs. This section provides concluding remarks on (1) the FMECA methodologies and (2) the study results.

4.1 FMECA METHODOLOGIES

All three studies employed a functional-level FMECA followed by an equipment-level FMECA. While each of the analysis teams employed the same basic approach in performing the FMECAs, each analysis was performed slightly differently with the following being the major differences:

1. Functions and functional failures evaluated during the functional-level FMECA.
2. Equipment hierarchy used in the equipment-level FMECAs.
3. RPN scoring approach

A review of the functional failure differences concluded that all of the analyses essentially evaluated the same functions either in the functional- or equipment-level FMECAs. The equipment hierarchy differences resulted in a more detailed listing of failure causes in FMECA 3 (as compared to FMECAs 1 and 2) and a differing basis for the RPN rankings, but the end result was the FMECA teams were able to align MIT activities with specific equipment-level failure modes and assign RPN rankings. However, there is likely differing fidelity in the results, but this was not identified as having a significant impact on the results.

Finally, the most significant difference in the FMECAs is related to the RPN rankings. These differences resulted because of differing (1) levels of indenture in the individual analyses' equipment hierarchy and (2) analysis teams' experiences. These differences prevent direct comparison of RPN scores between analyses (e.g. comparing RPN scores for the same component between two FMECAs). This is not surprising since the RPN approach is intended to be a relative risk ranking tool (vs. absolute rank). While the RPN scores from differing FMECAs can't be directly compared, the relative ranking order of more important risk items can be compared.

4.2 STUDY RESULTS

The comparison of the risk ranking and MIT activities identified trends related to:

- Most Important Equipment Failures
- Most Frequently Occurring Equipment Failures
- Hardest To Detect Failure Modes
- Most Frequently Listed MIT Items As A Means To Detect or Prevent Failures

The most important equipment failures were:

- Blind Shear Rams (in all three FMECAs)
- Casing Shear Rams (in two of the three FMECAs)
- Connectors (in two of the three FMECAs)
- Blue and Yellow POD hydraulics (in two of the three FMECAs)
- Choke and Kill Lines and Valves (in two of the three FMECAs)
- Pipe Rams (in two of the three FMECAs)
- Hydraulic Supply Lines (in two of the three FMECAs)
- Subsea Accumulators (in two of the three FMECAs)

The most frequently occurring equipment failures were found to be:

- Control Systems (both the electric or hydraulic portions) (in all three FMECAs)
- Pipe Rams (in two of the three FMECAs)
- Choke and Kill Lines and Valves (in two of the three FMECAs)
- Blind Shear Rams (in two of the three FMECAs)

The hardest to detect failures were related to the following equipment:

- Autoshear System (in all three FMECAs)
- Connector (in two of the three FMECAs)
- Rigid Conduit (in two of the three FMECAs)

Finally, a sort and review of the MIT tasks listed as a means to detect or prevent equipment failures found the following to be the most frequently listed MIT tasks:

- Function Test (in all three FMECAs)
- Pressure Test (in all three FMECAs)
- Dimensional/Ultrasonic Testing (in two of the three FMECAs)
- Rebuilding/Replacing Equipment (in two of the three FMECAs)

These result trends provide information related to the more important equipment failures (in terms of risk, frequency of occurrence, and failure detectability) and MIT tasks.

APPENDIX A – RPN SCORING SYSTEM

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Objective:

To provide a consistent means to evaluate the criticality of BOP subsystem/component failures to help judge the sufficiency of Maintenance, Inspection, and Test (MIT) activities performed to prevent and detect the failures. The criticality needed to consider the following factors:

- Frequency of failure in terms of the subsystem/component failure mode.
- Level of redundancy to prevent the failure from resulting in complete loss of critical safety functions.
- Ability to detect and prevent the failures via MIT.
- Severity of effect on BOP functionality (e.g., partial loss of functionality, complete loss of functionality) resulting from a single failure of a subsystem/component.

Criticality System Used:

A conventional RPN approach based on the product of three ratings (severity, occurrence and detection/prevention) was used.

Procedure:

1. RPN is applied to the subsystem/component failure modes (e.g., annular wear).
2. Severity rating is assessed by:
 - a. Evaluating each BOP functional failure resulting from the failure mode (i.e., the effect in the e-leader table the subsystem/component failure level).
 - b. Determining whether the failure mode is likely to result in total or partial loss of the BOP function (w/o consideration of redundancy).
 - c. If total or partial loss of BOP function is likely occur, the functional-level FMECA results are used to determine whether the total or partial loss can result in a safety or downtime end effect.
 - d. Identifying the level of redundancy (e.g., second annular) present to failure mode from progressing to the functional failure and end effect.
 - e. Determining the severity score based on safety and/or downtime end effect, total or partial loss of BOP function, and level of redundancy.
3. Occurrence rating is assessed by:
 - a. Using the failure event data to determine the subsystem/component failure mode frequency. Typically, the fleet-wide composite frequency will be applied. However, Individual rig failure frequencies can be review and the highest failure mode frequency for an individual rig being used.
 - b. Alternatively, if insufficient data are available or believed to be incorrect, the teams experience can be used to determine the occurrence rating. If this method is used, it is to be noted in the comments for the failure mode effect.

Note: Care must be taken not consider redundancy when determining occurrence ratings. In general redundancy is considered in the severity rating.

4. Detection rating is assessed by:
 - a. Reviewing the current MIT activities for the subsystem/component.
 - b. Evaluating the current MIT activities to determine the activities most likely to detect the failure mode.
 - c. Identify the MIT activities most likely to detect the failure mode.
 - d. Selecting rating based on the most likely MIT activities to detect the failure mode.
5. Calculate the RPN for each subsystem/component effect.
6. Summarize by sorting failure mode-effect RPNs from high to low.
7. Roll up RPNs to functional failure level for composite score and ranking.

The ratings shown in Table A-1 were used.

Table A-1: Severity Ratings

An assessment based on the functional failure resulting from the subsystem/component failure mode and the primary functional failure end effects.

Severity Rank	Significance	Personnel	Environment	Down Time
1	Does not affect BOP functionality; no impact on safety and environment.	No impact	No impact	No downtime, repair can be done while drilling continues.
2	Does not affect BOP functionality but needs to be corrected; no impact on safety and environment.	No impact	No impact	No downtime, repair can be done at next opportunity, drilling continues.
3	Partial loss of BOP function; no loss of well control.	No impact	No impact	Downtime of less than a shift, stop drilling, intervene and repair.
4	Partial loss of BOP function; no loss of well control.	No impact	No impact	Downtime between a shift and 24 hours, stop drilling, intervene and repair.
5	Partial loss of BOP primary function if not corrected immediately.	No impact	No impact	Downtime between 1 and 7 days - stop drilling, intervene and repair (surface only).
6	Partial loss of BOP primary function if not corrected immediately.	Minor Injury; no recordable lost time	Minor external subsea leak (e.g., C&K connector leak)	Downtime between 8 and 21 days - stop drilling, intervene and repair (surface only).

Table A-1: Severity Ratings (cont'd)

Severity Rank	Significance	Personnel	Environment	Down Time
7	Loss of BOP primary function.	Minor Injury; some lost time.	Significant external subsea leak (e.g., major connector leak)	Pulling LMRP only.
8	Loss of BOP primary function.	Serious Injury; significant lost time.	<1000 bbl	Pulling LMRP/BOP stack.
9	Loss of BOP primary function.	Single Fatality; multiple serious injuries.	>1000 bbl	Shut down of operations; drilling stopped and major regulatory implications; changes to drilling schedule > 3 months.
10	Loss of BOP primary function.	Multiple fatalities and injuries.	>10,000 bbl and severe environmental damage over a large area.	Shut down of operations; drilling stopped and major regulatory implications; total loss of asset.

Table A-2: Occurrence Ratings

An assessment based on the failure mode frequency occurring with current level of MIT activities and considering any redundancy.

Occurrence Ratings	Frequency/Rig Yr.	Occurrence
10	>50+ events/ rig yr.	Once a week or more often
9	<50 events /rig yr. to 10 events /rig yr.	Less than once a week to once a month
8	<10 events /rig yr. to 4 events /rig yr.	Less than once a month to once a quarter
7	<4 events /rig yr. to 2 events /yr.	Less than once a quarter to twice a year
6	<2 events /rig yr. to 1 event/yr.	Less than twice a year to once a year
5	<1 event /rig yr. to 1 event every 2 years	Less than once a year to once every 2 years
4	<1 event every 2 years to 1 event every 5 years	Less than once every 2 years to once every 5 years
3	<1 event every 5 years to 1 event every 10 years	Less than once every 5 years to once every 10 years
2	<1 event every 10 years to 1 event every 100 years	Less than once every 10 years to 10% chance every 10 years of operation
1	<1 event every 100 years	Less than 1% chance every 10 years of operation

Table A-3: Detection Ratings

An assessment of the probability that the MIT activities and/or Operations will detect the failure mode so that it can be corrected.

Detection Rating	Detection	Likelihood of Detection
1	Almost Certain	Very high probability of detection (>90% probability of detection) by design controls (redundant or independent self-diagnostic capability, independent alarms) will certainly detect failures
2	Very High	High probability of detection (50 to 90% of detection) by design controls (single device self-diagnostic capability, single alarms, visual monitoring, leak monitoring, loss of fluid etc.) will certainly detect failures
3	High	Probability of detection via weekly on-stream tests/inspections will provide immediate detection of the failure
4	Moderately high	Probability of detection via monthly on-stream tests/inspections will provide immediate detection of the failure
5	Moderate	Probability of detection via quarterly on-stream tests/inspections will provide immediate detection of the failure
6	Low	Can only be detected during routine inspections/tests while the BOP is pulled from the well
7-8	Very Low	Can only be detected during major PMs while the BOP is pulled from the well
9	Remote	Can only be detected and/or corrected during major overhaul or rebuilding-type activities
10	Absolute Uncertainty	Currently no design controls or maintenance techniques in place

APPENDIX B – FMECA METHODOLOGY DIFFERENCES

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This appendix provides additional details regarding the FMECA methodology differences discussed in Section 2.3. Specifically, additional detailed information related to the following is provided.

1. Functions and functional failures evaluated during the functional-level FMECA.
2. Equipment hierarchy used in the equipment-level FMECAs.
3. RPN scoring approach.

Table B-1 provides a comparison of the functions and functional failures evaluated by each FMECA team. This table shows all the FMECAs evaluated the same 11 functions and associated functional failures. FMECA 3 team evaluated two additional items: Acoustic System and ROV Intervention. It should be noted these two items are not functional failures, but they were evaluated during the functional-level FMECA as the team considered this systems as a vital contributor for safe operation of the BOP stack and drilling rig. As they were considered as a standalone system and not analyzed in the equipment-level FMECA, therefore there are no links between these items and the equipment-level FMECA.

Table B-1: Comparison of Functions and Functional Failures

No.	Function	Functional Failures	FMECA 1	FMECA 2	FMECA 3
1	Close and seal on the drill pipe and allow circulation on demand	Failure to close on drill pipe through annular(s)	X	X	X
		Failure to close on drill pipe through pipe rams	X	X	X
		Failure to seal or partial seal on drill pipe through annular(s)	X	X	X
		Failure to seal or partial seal on drill pipe through pipe rams	X	X	X
		Unintentional closing/opening	X	X	X
		Failure to open/close fail-safe valves to seal	X	X	X
		Close too slowly	X	X	X
		Loss of containment	X	X	X
2	Close and seal on open hole and allow volumetric well control operations on demand	Failure to close on open hole through blind-shear rams	X	X	X
		Unintentional closing/opening	X	X	X
		Failure to open/close fail-safe valves	X	X	X
		Close too slowly	X	X	X
		Loss of containment	X	X	X

Table B-1: Comparison of Functions and Functional Failures (cont'd)

No.	Function	Functional Failures	FMECA 1	FMECA 2	FMECA 3
3	Strip the drill string using the annular BOP(s)	Failure to close annular	X	X	X
		Failure to maintain stripping pressure	X	X	X
		Failure to seal	X	X	X
4	Hang-off the drill pipe on a ram BOP and control the wellbore	Failure of hang-off ram to close	X	X	X
		Failure to maintain closing pressure	X	X	X
		Failure to maintain locking	X	X	X
5	Controlled Operation-Shear the drill pipe and seal the wellbore	Failure to close	X	X	X
		Failure to shear the drill pipe	X	X	X
		Failure to seal the wellbore	X	X	X
		Unintentional closing/opening	X	X	X
		Close too slowly	X	X	X
		Loss of containment	X	X	X
6	Emergency Operation-Auto shear- Shear the drill pipe and seal the wellbore	Failure to arm	X	X	X
		Failure to close	X	X	X
		Failure to shear the drill pipe	X	X	X
		Failure to seal the wellbore	X	X	X
		Unintentional closing/opening	X	X	X
		Close too slowly	X	X	X
		Loss of containment	X	X	X
7	Emergency Operation-EDS- Shear the drill pipe and seal the wellbore	Failure to close	X		X
		Failure to shear the drill pipe	X		X
		Failure to seal the wellbore	X		X
		Unintentional closing/opening	X		X
		Close too slowly	X		X
		Loss of containment	X		X
		Failure to disconnect the LMRP	X	X	X
		Failure to receive EDS Signal		X	
		Unintentional disconnect of the riser		X	
8	Disconnect LMRP/BOP	Failure to disconnect the LMRP/BOP	X	X	X
		Unintentional disconnect of the LMRP/BOP	X	X	X

Table B-1: Comparison of Functions and Functional Failures (cont'd)

No.	Function	Functional Failures	FMECA 1	FMECA 2	FMECA 3
9	Circulate the well after drill pipe disconnect	Failure to circulate	X	X	X
		Failure to circulate at desired flow rate	X	X	X
		Failure to open/close fail-safe valves	X	X	X
		Failure to seal wellbore after drill pipe disconnect	X	X	X
		Loss of containment	X	X	X
10	Circulate across the BOP stack to remove trapped gas	Failure to circulate	X	X	X
		Failure to circulate at desired flow rate	X	X	X
		Failure to open/close fail-safe valves	X	X	X
		Loss of containment	X	X	X
11	Connect BOP and LMRP at landing	Inadequate BOP connection	X	X	X
		Inadequate LMRP connection	X	X	X
12	Secondary – Acoustic	Failure to disarm			X
		Failure to arm			X
13	Secondary – ROV	Failure to perform ROV intervention			X

Table B-2 provides a comparison of the equipment hierarchies used in the equipment-level FMECAs. This table shows which section specific components were included in.

Table B-2: Comparison of BOP Systems and Equipment

BOP System	Equipment	FMECA 1	FMECA 2	FMECA 3
Surface Control: Power & MUX	Power - UPS	X	X	X
	CCU	X ³	X ³	X
	Driller Control Panel /RMP/SEP	X ²	X ²	X
	MUX Reel	X ³	X ³	X
	Slip ring	X ³	X ³	X
	MUX Communication - Fiber optic ring	X ³	X ³	X
	HPU Panel	X ²	X ²	X
	MUX Cable/Connector	X ³	X ³	X

Table B-2: Comparison of BOP Systems and Equipment (cont'd)

BOP System	Equipment	FMECA 1	FMECA 2	FMECA 3
Surface Control: Hydraulic	Glycol and soluble oil tank	X ¹⁰	X ¹⁰	X
	Filter & Glycol and soluble oil Pump	X ¹⁰	X ¹⁰	X
	MRU and level switches	X ¹⁰	X ¹⁰	X
	Mixing Pump	X ¹⁰	X ¹⁰	X
	HPU Pump & suction strainer	X ⁴	X ⁴	X
	High Pressure Discharge Filter	X ⁴	X ⁴	X
	Rigid Conduit	X	X	X
	Hotline	X	X	X
	Surface Accumulator	X	X	X
	Subsea Control: MUX & Electrical	SEM	X ⁵	X ¹¹
Solenoid Valve		X ⁵	X ^{11,12}	X
Well bore P/T Probe		N/A	N/A	X
Electronic Riser Angle		N/A	N/A	X
LMRP P/T Probe		N/A	N/A	X
Subsea Control: Hydraulic	SPM Manifold	X ⁶	X ¹²	X
	Compensation Chamber and depth compensated bladder	N/A	N/A	X
	HKR Regulator	X ⁶	X ^{12,13}	X
	SPM Valve - Single acting	X ⁶	X ¹²	X
	SPM Valve - Double acting	X ⁶	X ¹²	X
	Pilot operated check Valve (POCV)	X ⁶	X ¹²	X
	Tubing and piping	X ⁶	X ¹³	X
	CCSV/DDV Fluid End	N/A	N/A	X
	MKR Regulator	X ⁶	X ^{12,13}	X
	Subsea Accumulator (POD)	N/A	X ¹²	X
	Subsea Accumulator (LMRP)	X ⁷	X ⁷	X
	Pilot Manifold and Pilot Filter	X ⁶	X ^{12,13}	X

Table B-2: Comparison of BOP Systems and Equipment (cont'd)

BOP System	Equipment	FMECA 1	FMECA 2	FMECA 3
	Inlet/supply Manifold and Supply Filter	X ⁶	X ^{12,13}	X
	Rigid Conduit Manifold - SPM valves	X ⁶	X ^{12,13}	X
	Gripper Assembly	X ⁹	X ⁹	X
BOP Stack	Annulars	X	X	X
	Blind Shear Ram	X	X	X
	Pipe Ram	X	X	X
	Casing Shear Ram	X ¹⁴	X	X
	Choke & Kill Lines & Valves	X	X	X
	C & K Hose	X ⁸	X ⁸	X
	LMRP Connectors	X ⁹	X ⁹	X
	Well head Connectors	X ⁹	X ⁹	X
	Spools	X	N/A	N/A
	Shuttle Valve	X ⁶	X ^{12,13}	X
	Clamps for C&K hot connection	X ⁸	X ⁸	X
	Function Hose	X ¹	X ¹	X
	Accumulator DCB/Autoshear	X ⁷	X ⁷	X

¹- Included with each specific preventer

²- Included in the control panel FMECA section

³- Included in the MUX System Communication Cables FMECA section

⁴- Included in the HPU FMECA section

⁵- Included in the Blue & Yellow Control System EH FMECA section

⁶- Included in the Blue & Yellow Control System Lower Valve FMECA section

⁷- Included in the Accumulators Subsea FMECA section

⁸- Included in the Choke & Kill Lines & Valves FMECA section

⁹- Included in the Connectors FMECA section

¹⁰- Included in the Fluid Reservoir Unit FMECA section

¹¹- Included in the Blue & Yellow Control Systems - Electrical FMECA section

¹²- Included in the Blue & Yellow Control Systems – Hydraulics FMECA section

¹³- Included in the Hydraulic Supply: Rigid Conduit and Manifold FMECA section

¹⁴- Included in the Shear Ram FMECA section

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APPENDIX C – FMECA 1, 2, AND 3 REPORTS

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***BLOWOUT PREVENTER (BOP)
FAILURE EVENT AND MAINTENANCE, INSPECTION
AND TEST (MIT) DATA ANALYSIS
FOR
THE BUREAU OF SAFETY AND ENVIRONMENTAL ENFORCEMENT
(BSEE)***

2650788-DAS-C1	3	Final Report	6/26/2013
2650788-DAS-C1	2	Revised MTTF Calculations	4/29/2013
2650788-DAS-C1	1.1	Issued for BSEE review	3/21/2013
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June 2013

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SUMMARY

As part of the Blowout Preventer (BOP) Maintenance and Inspection for Deepwater Operations study (BSEE contract number M11PC00027), the American Bureau of Shipping (ABS) and ABSG Consulting Inc. (ABS Consulting) compiled and analyzed data related to BOP system failure events and maintenance, inspection, and test (MIT) activities. This report represents the deliverable associated with Tasks 6.1.1, 6.1.2 and 6.1.3, as outlined in the contract.

The objectives of this effort were to (1) provide as much up-to-date and relevant failure event and MIT activity data to support the failure mode, effect, and criticality analyses (FMECAs) and reliability, availability, and maintainability (RAM) studies and (2) provide failure event and MIT activity data and trends to identify MIT improvements. This preliminary report summarizes the data provided by two original equipment manufacturers (OEMs) and three drilling contractors. This report presents the analysis of data for BOP system, associated control systems, and components meeting the following criteria:

- Operation Location – Gulf of Mexico (GoM)
- Operating Depth – 5000 feet and deeper
- BOP Configurations:
 - **Class VI BOP**, five ram configuration and single annular or a four ram and dual annular*
 - **Class VII BOP**, five ram configuration and dual annular or a six ram and single annular*
 - **Class VIII BOP**, six ram configuration and dual annular*

*Ram configurations can consist of a combination of blind/shear ram, non-sealing casing ram and pipe ram preventers.

Section 1 of this report provides the report objectives, scope, assumptions, limitations, and describes the report organization in more detail.

Section 2 of the report outlines the approach used to collect and analyze the failure event and maintenance task data. Both the failure event data and maintenance activity data were sorted and analyzed for trends. Specifically, the data analysis included more than 430 failure events and 88,000 maintenance task activity records from 23 rigs.

To identify data trends, pie charting, Pareto analysis, and scatter plotting techniques were employed. The final element of the failure event data analysis was the calculation of the mean time to failure (MTTF) for each of the three BOP systems (Surface Control System, Subsea Control System, BOP Stack) and the entire BOP system.

Section 3 of this report summarizes the results from the analysis of the failure events and maintenance task activities. Specifically, this section includes a summary of the failure event data

analysis for all rigs combined (vs. rig-by-rig analysis). Similarly, the maintenance task data analysis is for all rigs combined.

The results indicate the surface and subsea control system failures account for 61% of the BOP system failures (28% and 38% respectively). The BOP Stack accounts for the remaining 32% of the failures. (Note: Approximately 7% of the failure data were unspecified because the failed components could not be identified or the failure could not be assigned to a single BOP system, because failure might have involved more than one system.) Further analysis of the failure events indicate that the following five major components account for 75% of the BOP system failures (excluding unspecified failures):

1. Blue & Yellow Subsea Control System (Subsea Control System) – 36%
2. Multiplex (MUX) Control System (Surface Control Systems) – 15%
3. Pipe & Test Rams (BOP Stack) – 10%
4. Connectors* (BOP Stack) – 7%
5. Choke & Kill (C&K) Valves and Lines (BOP Stack) – 7%

*The "Connector" category contains all subsea connectors including the wellhead and Lower Marine Riser Package (LMRP) connectors, as well as other connectors such as stabs and wet mate connectors. If the connectors are subdivided, the wellhead, LMRP, and riser connectors account for 3% of the BOP system failures (excluding unspecified failures).

This section also includes results related to the dominant failure modes and shows that seven failure modes account for 76% of the BOP system failures. Also, Section 3 includes MTTF estimates for the entire BOP system and the three BOP systems separately (surface control, subsea control and BOP stack). The estimated MTTF for the entire BOP system was calculated to be 48.1 BOP operating days and 177.5 for the Surface Control System, 118.4 for the Subsea Control System, and 148.6 for the BOP Stack, all with units of BOP operating days. (Note: Because of the level of BOP redundancy, these MTTF estimates are not reflective of MTTF for failures resulting in a BOP system failure, but rather the numbers are reflective MTTF for failures requiring a repair action.)

Finally, Section 3 contains the maintenance task analyses, which include analysis of the corrective and proactive maintenance tasks performed, and an assessment of the effectiveness of maintenance tasks in detecting and preventing BOP system failures. The results indicate a high level of proactive maintenance being performed on BOP system and less than 5% of maintenance activities related to correcting failed or failing components (i.e., corrective maintenance). Specifically, 4.5% of the BOP system maintenance tasks performed are related to correcting failed or failing components (i.e., corrective maintenance) and more than 95% of the BOP system maintenance tasks performed are related to detecting or preventing failures. In general, this is good ratio of the proactive (corrective maintenance) to the preventative maintenance. However, based on the data analyzed, the ratio of the corrective maintenance to PM is good when compared to other industries in general. The percentage of PdM activities being performed is slightly more than 1% of the BOP maintenance which is lower than anticipated.

In addition, the maintenance task analyses indicate a strong correlation between increased percentages of corrective maintenance and number of component failures with increased percentages of planned maintenance. Similar correlations have been found in other industry maintenance studies and it is recommended that this correlation be further investigated. In addition, a significant percentage (more than 25%) of the most frequent failure modes are being detected during operation (versus during proactive maintenance). (Note: The terminology "failures detected during operations," is used to indicate failures discovered while the BOP is latched on the well and not detected by test, inspection, or other type of proactive maintenance activity. This terminology is not meant to exclusively indicate failures detected during active operation of a BOP system function.) This may be an indication of a need to change or improve current proactive maintenance tasks designed to detect or prevent these specific failure modes.

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LIST OF ACRONYMS

ABS	—	American Bureau of Shipping
ABS Consulting	—	ABSG Consulting Inc.
BOP	—	Blowout Preventer
BSEE	—	Bureau of Safety and Environmental Enforcement
C&K	—	Choke & Kill (valves, lines)
CCC	—	Central Command Center
CCU	—	Central Control Unit
CMMS	—	Computerized Maintenance Management System
DCP	—	Drillers Control Panel
FMECA	—	Failure Mode, Effect, and Criticality Analysis
HPU	—	Hydraulic Power Unit
IP	—	Industry Participant
MTTF	—	Mean Time To Failure
MIT	—	Maintenance, Inspection and Test
MUX	—	Multiplex
LMRP	—	Lower Marine Riser Package
O&M	—	Operation and Maintenance
PdM	—	Predictive Maintenance
PM	—	Preventive Maintenance
OEM	—	Original Equipment Manufacturer
RAM	—	Reliability, Availability, and Maintainability
ROV	—	Remotely Operated Vehicle
SEM	—	Subsea Electronic Module
SPM	—	Sub-Plate Mounted (Valve)
TRIMM	—	Tool for Reliability Inspection and Maintenance Management

GLOSSARY

BOP Operating Days	—	The number of recorded days in which the BOP is latched on a well site before first failure occurs or between consecutive failures.
BOP System	—	The first level of indenture in the BOP hierarchy used in this study. It represents a collection of major BOP components and their associated individual components
Corrective Maintenance Failure Event	—	A maintenance event to repair, restore or replace a failing or failed component
Failure Mode	—	An unplanned event resulting in partial or total loss of a BOP function where a work order is issued, and some maintenance repair, restoration or replacement action is carried out
Major BOP Component	—	The observed way or mechanism in which a system, sub-system, or component fails
Maintenance Task	—	The second level of indenture of the BOP hierarchy used for this study. It is defined by a major BOP component (e.g., MUX system, annular), and its sub-components or individual components
Mean Time To Failure (MTTF)	—	Any corrective (planned or unplanned) maintenance event to repair, restore or replace a failed component; or a planned maintenance event, such as planned maintenance, predictive maintenance, inspection, or test, performed to detect or prevent a component from failing
Pareto Analysis	—	Average elapsed operating time to a system, sub-system, or component failure
Planned Maintenance	—	The practice of using a bar chart to show the most frequently occurring events or causes of the events. For this study, the events were failure events or maintenance tasks
Predictive Maintenance (PdM)	—	A time-based activity designed to prevent a BOP component failure by maintaining/restoring the component's reliability through servicing and/or repairing or replacing specific BOP components
Proactive Maintenance	—	An activity designed to detect the onset of failure by measuring and analyzing key component operating or performance parameters related to the failure mode of interest
Scheduled Inspection	—	A scheduled maintenance event, such as planned maintenance, PdM, inspection, or test, performed to detect or prevent a component from failing
Scheduled Test	—	A scheduled activity designed to check or verify the condition of a BOP component, usually taken to be a visual inspection or some type of non-destructive testing
	—	A scheduled activity designed to detect the condition related to the onset of failure or hidden failure of a BOP component, usually via a functional or performance test

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1.0 INTRODUCTION

As part of the Blowout Preventer (BOP) Maintenance and Inspection for Deepwater Operations study (BSEE contract number M11PC00027), the American Bureau of Shipping (ABS) and ABSG Consulting Inc. (ABS Consulting) compiled and analyzed data related to BOP system failure events and maintenance, inspection, and test (MIT) activities. This report represents the deliverable associated with Tasks 6.1.1, 6.1.2 and 6.1.3, as outlined in the contract.

1.1 OBJECTIVES

The objectives of this effort were to provide as much up-to-date and relevant failure event and MIT activity data to support the failure mode, effect, and criticality analyses (FMECAs) and reliability, availability, and maintainability (RAM) studies and (2) provide failure event and MIT activity data and trends to identify MIT improvements. This report summarizes the data provided by two original equipment manufacturers (OEMs) and three drilling contractors.

1.2 SCOPE

The scope of this effort included the compilation and analysis of data related failure events and MIT activities as recorded in the relevant industry partners' (IPs') systems, such as computerized maintenance management system (CMMS), rig operating logs, trouble ticket logs, and other computerized tracking systems. This report presents the analysis of data for BOPs and associated control systems meeting the following criteria:

- Operation Location – Gulf of Mexico (GoM) (i.e., BOP data related to operations and maintenance in the GoM)
- Operating Depth – 5000 feet and deeper
- BOP Configurations:
 - **Class VI BOP**, five ram configuration and single annular or a four ram and dual annular*
 - **Class VII BOP**, five ram configuration and dual annular or a six ram and single annular*
 - **Class VIII BOP**, six ram configuration and dual annular*

*Ram configurations can consist of a combination of blind/shear ram, non-sealing casing ram and pipe ram preventers

To help facilitate the management and analysis of the data, ABS Consulting used a proprietary database called Tool for Reliability Inspection and Maintenance Management (TRIMM). Appendix A contains a one-page overview of TRIMM. This database included several database entry fields, which allowed tracking and sorting of the data. The basic structure of TRIMM is based on the following BOP system equipment hierarchy.

Surface Control System

- Hydraulic Power Unit (HPU)
- Electrical Power
- Multiplex (MUX) Control System
- Rigid Conduit & Hotline

- Surface Accumulators
- Control Panels

Subsea Control System

- Blue & Yellow Control Systems
- LMRP-mounted Accumulators
- Emergency & Secondary Controls

BOP Stack

- Annulars
- Blind Shear Ram
- Casing Shear Ram
- Pipe & Test Rams*
- Choke & Kill (C&K) Lines and Valves, Gas Bleed Valves
- Connectors**
- Stack-mounted Accumulators (Autoshear)

*This major component category includes a range of pipe ram types and the test ram

**This major component category contains all subsea connectors including wellhead, LMRP, and riser connectors, as well as, stabs, wet mate connectors, pod connectors, etc.

This analysis involved the review and trending of 430 failure events and 88,000 maintenance tasks from 23 rigs for a nominal 5-year time period (i.e., January 1, 2007 through May 1, 2012) of operations in the GoM. (Note: Available records from one drilling contractor covered approximately 2 years of operation.) The analysis focused on sorting and trending the data to identify the following failure event trends and calculations:

- Number and percentage of failures associated with the three BOP systems (namely, surface control, subsea control and BOP Stack)
- Number and percentage of failures associated with the major BOP system components (example: HPU, Annular etc.)
- Frequency and cumulative percentage of failure modes for the entire BOP system
- Frequency and cumulative percentage of failure modes by the three BOP systems (Surface Control System, Subsea Control System, BOP Stack)
- Estimations of the mean time to failure (MTTF) for the three BOP systems and entire BOP system

In addition, the analysis for maintenance activities focused on identifying:

- Percentage of corrective maintenance and proactive maintenance performed for the entire BOP system
- Percentage of corrective maintenance and proactive maintenance performed on the major BOP system components

- Correlation between corrective maintenance and number of failures and types of the proactive maintenance tasks performed
- Percentage of activities detecting dominant failure modes

1.3 ANALYSIS ASSUMPTIONS AND LIMITATIONS

The analysis results presented in this report are based on the following assumptions:

1. The raw failure and maintenance event data provided by the IPs were assumed to be accurate and complete. When possible, ABS, ABS Consulting, and the relevant IPs attempted to correct any identified data anomalies
2. Duplicate events in data sets (e.g., failures recorded by both OEM and drilling contractor, duplicate maintenance work orders) were identified when duplications could be confirmed. Otherwise, potential duplicate events were included in the data.
3. In determining time to failure, BOP operating days were calculated from the day the BOP was latched on the well head to the first failure event or from the day when the BOP was returned to service to next event. Therefore, it was assumed the BOP was operating the entire time period in between the days of these events.

The limitations of the data analysis include:

1. Because of data unavailability, the mean-time-to-failure analysis was limited to the overall BOP system and its three systems (Surface Control, Subsea Control and BOP Stack).
2. Because of lack of details for some failure events, specific components which failed and the specific mode of failure could not be determined for approximately 6% of the events. These events are indicated as unspecified failures and/or failure modes.
3. Because many of the proactive maintenance events recorded by the IPs involve many tasks (e.g., a scheduled test may actually include three distinct tests) and include multiple components, the analysis of maintenance events evaluate these as single event for major component (i.e., no attempt was made to separate tasks into discrete maintenance tasks and the specific components associated with each task).

1.4 REPORT ORGANIZATION

Section 2 of this report provides an overview of the approach used to collect and analyze the failure event and maintenance task data. Section 3 discusses the results of the effort, and Section 4 provides the observations about the data and concluding remarks.

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2.0 DATA COLLECTION AND ANALYSIS

This section of the report outlines the approach used to collect the failure event and maintenance task data, and the analysis of these data. The ABS and ABS Consulting personnel led the data collection and analysis efforts, and the industry participants were involved by:

- Compiling and provided failure event and maintenance task data from available data sources
- Assisting in identifying and classifying specific data
- Providing input on the system hierarchy and failure mode classifications used
- Reviewing this report to help ensure the data analysis reflects performance

2.1 DATA COLLECTION

The data collection effort began with the identification of the types of data needed to support the project, including FMECAs and RAM studies. Next, ABS Consulting and ABS personnel identified and documented potential sources of the needed data. Table 2-1 summarizes the failure event and maintenance task data collection plan for this project.

ABS Consulting and ABS personnel then met with each industry participant for 1 to 3 days to (1) discuss the data being requested, (2) help identify potential data sources (e.g., CMMS, repair tracking logs), (3) review examples of the data records (to confirm the available records contain the specific data) and (4) discuss data compilation. During the data collection process, ABS Consulting and IPs routinely discussed the data and progress in compiling the data.

The IPs then collected the data from a variety of electronic and paper sources. Specific data sources included in this effort, but not limited to, were computerized maintenance management systems, electronic trouble ticket logging systems, paper and electronic operating logs, and paper copies of trouble tickets/work orders.

This data analysis was limited to available records containing failure and MIT event information because much of the information indicated in the data capture plan was not readily available in a usable format. The primary available information for these events is listed in Table 2-2. In addition, the comment column in Table 2-2 provides indication of the available data quality and possible limitations.

Table 2-1: Data Collection Plan

			OEM	Drilling Contractor
1	Operational Information: On-Well			
	.1	Drilling log		X
	.2	Down time report		X
	.3	BOP retrieval data / log / history		X
	.4	Operational history and period of time that the BOP operated without a failure event		X
	.5	Number of failure events/data ² and details, including failure mode, observed over a “X” period of time		X
2	Maintenance Procedures and Records: On-Well and Between Wells			
	.1	Maintenance manuals and procedures for repair, preventative maintenance (PM) or predictive maintenance (PdM)		X
	.2	Repair log / history	X	X
	.3	Maintenance history log / records		X
	.1	Maintenance schedule	X	X
	.2	Work orders, with associated bill of materials used, for PM (including rebuilds), PdM or corrective maintenance (e.g., unplanned repairs, restore, and/or replacements). (Note: Work orders should include all data associated with event including time to repair information)	X	X
	.4	Spare parts orders and records (i.e., purchasing history for spare parts)	X	X
	.5	PM or PdM program log / records (if performed)	X	X
	.4	Corrective maintenance (e.g. unplanned repairs, restoration/ replacement activities performed as a result of an inspection, test or operational failure. or rebuild)		X
3	Inspection and Testing Procedures and Records: On-Well and Between Wells			
	.1	Inspection and testing procedures		X
	.2	Inspection schedule, plans, frequency and tasks		X
	.3	Inspection log, results and findings		X
	.4	Testing schedule, plans, frequency and types		X
	.5	Testing log, and results		X
	.6	Pressure test data/report with associated results		X
	.7	Functional test data/report with associated results		X
	.8	PM or PdM reports / results (if performed)		X

Table 2-2: Primary Data Records

IP	Primary Failure Event Data Records	Primary MIT Event Data Records	Comments
Drilling Contractor A	<ul style="list-style-type: none"> • CMMS data • Failure event log 	<ul style="list-style-type: none"> • CMMS data • OEM manuals • Well control manual 	CMMS data had good detail on MIT events, including corrective maintenance.
Drilling Contractor B	<ul style="list-style-type: none"> • Rig downtime report 	<ul style="list-style-type: none"> • Rig downtime report • OEM manuals • Well control manual 	The downtime log was a good source of MIT events and corrective maintenance that required or resulted in downtime. However, some MIT activities and corrective maintenance not involving downtime are probably not recorded in these records.
Drilling Contractor C	<ul style="list-style-type: none"> • CMMS data • Failure event data 	<ul style="list-style-type: none"> • CMMS data • OEM manuals • Well control manual 	CMMS data was a good source of MIT events and most corrective maintenance. However, it was observed that some MIT events and corrective maintenance may not have been recorded in the CMMS.
OEM 1	<ul style="list-style-type: none"> • Customer service tickets 	<ul style="list-style-type: none"> • Operation and Maintenance (O&M) Manuals 	O&M manuals were a good source of suggested MIT practices.
OEM 2	<ul style="list-style-type: none"> • CMMS data • Customer complaint report 	<ul style="list-style-type: none"> • O&M Manuals 	O&M manuals were a good source of suggested MIT practices.

To assist with the transfer of the volumes of data, a secure SharePoint site was established. As the data were compiled, IPs uploaded the information to this secure site.

2.2 DATA CATEGORIZATION AND DATABASE ENTRY

Once the data were received from the IPs, ABS and ABS Consulting began reviewing, categorizing, and preparing the data for entry. Specifically, the review consisted of examining the data to (1) identify any data pertaining to equipment items not included in the scope of this study (e.g., rig’s power supply, data loggers), (2) review relevant data to help ensure they provided the needed information, and (3) determine any questionable data or data needed clarification. Next, the data were sorted and organized into categories based on three primary attributes:

1. Identification of data type (i.e., Failure Event or Maintenance Task)
2. Applicable BOP system and associated components,
3. Failure mode or maintenance task type (as applicable)

For this report and project, the following descriptions define failure event and maintenance task activity:

- **Failure Event** is defined as an unplanned event, which can be identified during operations or performance of a proactive maintenance task, resulting in partial or total loss of a BOP system function where a work order is issued, and some maintenance repair, restoration or replacement action is carried out.
- **Maintenance Task** is defined as any corrective maintenance event to repair, restore or replace a failing or failed component; or a proactive maintenance event, such as planned maintenance, PdM, scheduled inspection, or scheduled test, performed to detect or prevent a component from failing.

The categorization into one of the three major BOP systems (i.e., Surface Controls, Subsea Controls, and BOP Stack) and the associated major components was based on the hierarchy provided in Section 1.2 of this report. To further define the major equipment categories, the specific BOP system equipment items included the major component categories were defined and are represented by the boundaries in Table 2-3.

To provide additional categorization of the failure events, failure modes were identified for each event, when sufficient information was available to make such a determination. Table 2-4 provides a list of general failure modes for electrical and mechanical components. Two additional failure modes were used for both mechanical and electrical failures. These additional failure modes are (1) substandard workmanship, which was assigned to failures caused by procedural issues, communication issues, and other human error issues, and (2) out of specification component, which was assigned to failures caused by manufacturing issues, wrong parts installed/used, or other similar issues. These failure modes were used to guide the failure mode categorization, but some additional failure modes were added as needed to properly categorize events.

Table 2-3: Major Component Boundaries

Major Component	Major Component Boundary
Surface Control System	
HPU	Mixing system: Storage tanks, pumps and associated pipes and manifolds to mix storage tank contents with a fresh water supply and store in a mixing tank with level indicators and mixing pump. HPU: Distribution piping, hydraulic pumps with associated electric motors, suction strainers, high pressure discharge filters, check and isolation valves in discharge manifold, hydraulic manifolds supplying to accumulator banks, rigid conduit and hose reels inclusive of isolation and relief valves.

Table 2-3: Major Component Boundaries

Major Component	Major Component Boundary
Electrical Power	Uninterruptible power supply, blue and yellow UPS, inclusive of independent control and distribution, battery - charged from primary generators or emergency generator, power distribution panels, power isolation junction box (J-box) providing isolation and/or cross-feed of UPS output, distribution panel distributing power to the various MUX control system, umbilical J-box providing control voltage to subsea functions.
MUX Control System	<p>Central Command Center/Unit (CCC/CCU): The primary processor including:</p> <ul style="list-style-type: none"> • Processing array's for communication and distribution • Power distribution and communication to associated equipment • Flash drives: pre-programmed hard disk drives with processing software programmed by the OEM • Climate-controlled purged cabinets <p>MUX Reels: Drive motors, level winds, brakes and control panels. The MUX electrical cable supplies power and communications for control of the subsea control pods. The MUX cable is run, retrieved, and stored on a cable reel.</p> <p>Slip Rings: Fiber optic and electrical rings providing communication during rotation of the rig</p>
Rigid Conduit & Hotline	<ul style="list-style-type: none"> • Pipes, tubes and/or flexible hoses (hotline, hydraulic hose, rigid piping and tubing) • Hydraulic Supply Line (Hard/Rigid Conduit) • Reels: Drive motors, level winds, brakes and control panels. • Swivel: Devices providing hydraulic communication between supply and hose on the reel during rotation of the rig
Surface Accumulators	Pressure vessel with internal pressurized bladder (bag), charging valve, manifold and racks to mount and segregate multiple bottles, isolation valves, relief valves and check valves.
Control Panels	<p>Control station/panels, including the following equipment:</p> <ul style="list-style-type: none"> • Human-Machine Interface • Monitors • Indicator to display data • Processor nodes and/or cards • Flash drives (software programmed by OEM) • Sensors and alarms for control system & BOP status • Cabinet purge system with sensors and alarms • Tool Pushers Control Panel, Drillers Control Panel (DCP), Hydraulic control panel and local panels

Table 2-3: Major Component Boundaries

Major Component	Major Component Boundary
<i>Subsea Control System</i>	
Blue & Yellow Subsea Control System	Control pod including the following devices <ul style="list-style-type: none"> • Subsea Electronic Module (SEM) • Compensated Chamber • Solenoid Valves • Sub-plate Mounted (SPM) Valves • Hydraulic Manifold • Pilot Operated Valves (POCV and SSV) • Manual Pressure Regulator • Remote Pressure Regulator • Pilot and Supply Manifold Filters • Tubing • Shuttle Valves • Flexible Hoses • Pod Receptacles • Pod Flow Meters • MUX Subsea
LMRP-mounted Accumulators	LMRP-mounted accumulator pressure vessel related to specific BOP functions
Emergency and Secondary Controls	Emergency and Secondary control systems including the following systems: <ul style="list-style-type: none"> • Emergency Disconnect System • Autoshear • Deadman • Acoustic Control (Secondary control) • ROV Operation (Secondary control)
<i>BOP Stack</i>	
Annulars	Annular including all internal components
Blind Shear Ram	Blind shear ram, including actuator and all internal components
Casing Shear Ram	Casing shear ram, including actuator and all internal components
Pipe and Test Rams	The following types of pipe and test rams, including actuators and all internal components <ul style="list-style-type: none"> • Pipe ram • Ram Blowout Preventer • Fixed Pipe Ram • Variable Pipe Ram • Test Ram
C&K Valves and Lines	<ul style="list-style-type: none"> • C&K Line Subsea C&K Kill Valves • Bleed Valves • C&K Line Test Valves Flanges and Spools • Spacer Spool Flex Loop & Jumper Hoses Drape Hoses

Table 2-3: Major Component Boundaries

Major Component	Major Component Boundary
Connectors	<ul style="list-style-type: none"> • Hydraulic connector • LMRP Connector • Well Head Connector • C&K Stabs • Conduit and Hotline Hydraulic Stab • Wet mate Connector • HPHT Sensors • ERA Sensors
Stack-mounted Accumulators (Autoshear)	Stack-mounted accumulator pressure vessel for the autoshear system

Table 2-4: Equipment-level Mechanical and Electrical Component Failure Modes

Mechanical Components	Electrical Components
External Leak or Rupture	Loss of or Degraded Power
Internal Leak	Fails with No Output Signal or Communication
Plugged	Fails with Low or High Output Signal
Mechanical Failure (e.g., fracture, galling, fatigue)	Erratic Output
Mechanical Damage (e.g., broken by external forces)	Fails to Respond to Input
Wear	Processing Error
Corrosion or Erosion	Electrical Short
Loss of Function (when possible the specific functionality was defined)	Loss of Function (when possible the specific functionality was defined)
Loss of (Hydraulic) Pressure	

Similarly, the maintenance events were categorized as (1) corrective maintenance, which includes maintenance tasks to repair a failed component whether it was identified during operation or as the results of the performance of a maintenance, inspection, or test activity, and (2) proactive maintenance, which includes scheduled inspections, scheduled tests, planned maintenance, or PdM activities.

The initial categorizations were provided by the IPs based on their own maintenance categories. However, a review of these categorizations indicated inconsistencies with the maintenance category definitions needed for this study. Therefore, ABS Consulting personnel reviewed all of the maintenance events and made an effort to categorize the maintenance events in accordance with the study maintenance category definitions. Table 2-5 provides a summary of the type of changes made during this categorization process. During this review and re-categorization, 27,498 maintenance event records (approximately 30%) were deleted because the records were (1) duplicated, (2) not

directly related to the task execution (e.g., ordering of parts, adjusting store inventory), and/or (3) merely documented information regarding equipment or a maintenance-related activity. Therefore, the total number of maintenance event records analyzed in the report is 61,331.

Table 2-5: MIT Categorization Summary

IP	IP Categorization	ABS Consulting Changes	Comments
Drilling Contractor A	All events categorized as either corrective maintenance or PM. Many MIT records related to the ordering of parts, the correction of spare part inventory, or informational communication were included in the data set.	<ul style="list-style-type: none"> Reviewed all PM events and re-categorized each event into one of four proactive maintenance categories Reviewed and deleted all records not directly related to execution of corrective or proactive maintenance activity 	PM event descriptions were provided sufficient details for re-categorization of events. The majority of MIT events in the data set were provided by this IP.
Drilling Contractor B	Events categorized as repair or corrective maintenance, PM, or inspection	Reviewed all PM and inspection events and re-categorized each event into one of four proactive maintenance categories	PM and inspection event descriptions were concise statements but still allowed consistent re-categorization of events
Drilling Contractor C	Events were not categorized	Reviewed all events and categorized as corrective maintenance or the appropriate proactive maintenance category	Event information was inconsistent and limited, likely resulting in inconsistent categorization of the data. However, the number of events from this IP is less than 2% of the maintenance event data set.

The final step of this process was entry or importing of the categorized data into TRIMM. Separate entry fields were defined for the two types of data: Failure Events and Maintenance Task Activities. In addition, TRIMM included data fields which allowed the failure event and maintenance tasks to be sorted and analyzed by system, failure mode, type of MIT activity, and by rig. Once the data were entered, ABS Consulting and ABS personnel performed quality assurance reviews of the data.

2.3 DATA ANALYSIS

Both the failure event and maintenance task data were sorted and analyzed for trends. Specifically, the data analysis included 430 failure events and more than 61,000 maintenance task activity records from 23 rigs. The majority of the failure event data and maintenance data presented in this report

include data from both the OEMS and drilling contractors. Specifically, the pie and Pareto charts included data from both. However, the calculated values (e.g., MTTF) only include failure event data from the drilling contractor because only these data included BOP operating day data.

To identify data trends, ABS Consulting employed pie charting and Pareto analysis techniques. Specifically, the failure event data analysis includes the following:

- Number and percentage of failures associated with the three BOP systems (namely, surface control, subsea control and BOP Stack)
- Number and percentage of failures associated with the major BOP components (example: HPU, Annular etc.)
- Frequency and cumulative percentage of failure modes for the entire BOP
- Frequency and cumulative percentage of failure modes by the three BOP systems

In addition, the analysis for maintenance activities focused on identifying:

- Percentage of corrective maintenance and proactive maintenance performed for the entire BOP
- Percentage of corrective maintenance and proactive maintenance performed on the major BOP components
- Correlation between corrective maintenance and number of failures and types of the proactive maintenance tasks performed
- Percentage of activities detecting dominant failure modes

The final element of the failure event data analysis was the calculation of the MTTF for the entire BOP system and the three BOP systems. These MTTFs were calculated using a subset of the overall failure event data. This data subset consisted of failure events in which BOP operating days were recorded. Specifically, 117 of 430 failure events included sufficient BOP operating days to be included in the MTTF calculations (i.e., BOP operating day data were not available for all failure events).

To calculate the MTTF for the entire BOP system, the MTTF for each of the three BOP systems was first calculated by dividing the total number of failures (with BOP operating day data) into the total BOP operating days associated with each of the three systems. Then the failure rates for each BOP system (with units of failure events per BOP operating day) were calculated. The following equations were used to calculate these values for each BOP system:

$$MTTF = \frac{\sum TTF}{N} \text{ (eqn.1)}$$

Where, MTTF = Mean Time To Failure, BOP operating days
TTF = Time To Failure (for a specific failure), BOP operating days
N = Number Of Failures

$$\lambda = \frac{1}{MTTF} \text{ (eqn. 2)}$$

Where, λ = Failure Rate, events per BOP operating day
MTTF = Mean Time To Failure, BOP operating days

Then the individual BOP system failure rates were used to calculate the entire BOP failure rate. Finally, the entire BOP failure rate was calculated using the following equations:

$$\lambda (BOP) = \lambda(surface) + \lambda(subsea) + \lambda(stack) \text{ (eqn. 3)}$$

Where, λ (system) = System Failure Rate, events per BOP operating day

$$MTTF (BOP) = \frac{1}{\lambda(BOP)} \text{ (eqn. 4)}$$

Where, λ (BOP) = BOP Failure Rate, events per BOP operating day
MTTF (BOP) = BOP Mean Time To Failure, BOP operating days

Additional statistical analyses at the major component level, similar to those described above, are planned to support the RAM studies.

3.0 DATA ANALYSIS RESULTS

This section summarizes the results from the analysis of the failure events and maintenance task data. Specifically, this section includes a summary of the failure event data analysis for all rigs combined. The maintenance task data analysis includes analysis of rigs combined. A rig by rig analysis is not presented to respect the confidentiality agreements with the IPs.

3.1 FAILURE EVENT DATA ANALYSIS RESULTS

The failure event data analysis results included evaluations of the failure data in terms of the overall BOP, each of three BOP systems (Surface Control System, Subsea Control System and BOP Stack), and estimation of the MTTF for each BOP system and overall BOP system. The overall BOP system and three BOP system evaluations consisted of an analysis of the number of failure events and failure modes at the system level and then by dominant component failures for a BOP system. Correspondingly, the section is divided into the following sections:

- Data Analysis Result Summary
- Overall BOP system Results
- Surface Control System Results
- Subsea Control System Results
- BOP Stack Results
- BOP and BOP System MTTF Estimation

3.1.1 Data Analysis Result Summary

This section summarizes the results presented in subsequent sections. Specifically, this summary provides an overall view of the dominant failures and failure modes for the overall BOP and each of the three BOP systems. These results are based on the number of recorded failures and corresponding failure modes included in the IP-provided data. Table 3-1 summarizes the dominant contributor results for the entire BOP system, and Table 3-2 summarizes the failure mode results. (Note: these results exclude unspecified failures and failure modes.)

Table 3-1: Overall BOP Dominant Failure Contributors by BOP System and Major Component

System	No of Failures	Percent of Overall BOP Failures	Dominant BOP System Major Component	No of Failures	Percent of Overall BOP Failures
Subsea Control System	165	41%	Blue & Yellow Subsea Control System	140	35%
			Emergency & Secondary Controls	16	4%
BOP Stack	138	34%	Pipe & Test Rams	38	9%
			Connectors*	29	7%
			C&K Valves and Lines	28	7%

Table 3-1: Overall BOP Dominant Failure Contributors by BOP System and Major Component

System	No of Failures	Percent of Overall BOP Failures	Dominant BOP System Major Component	No of Failures	Percent of Overall BOP Failures
Surface Control System	99	25%	Mux Control System	59	15%
			Control Panels	13	3%
			HPU	10	2%
Total	402	100%		333	83%

Table 3-2: Overall BOP Dominant Failure Modes

Failure Mode	No. of Failures	Percent of Overall BOP Failures
External Leakage	102	25%
Mechanical Damage	49	12%
Mechanical Failure	49	12%
Substandard Workmanship	41	10%
Hardware Failure	26	6%
Component Out of Specification	21	5%
Processing Error	19	5%
Total	307	76%

The next two tables provide the dominant component failures and associated dominant component failure modes for each of the three BOP systems. Specifically, Tables 3-3 and 3-4 summarizes the Surface Control System results. These tables show (1) the three major components account for the 83% of the 99 Surface Control System failure events, (2) the ten listed components account for 71% of the Surface Control System failures, and (3) the associated eight failure modes account for more than 85% of this system failures. Again, these results exclude unspecified component failures and failure modes

Table 3-3: Surface Control System Dominant Component Failure Contributors

System Major Component	No. of Failures	Percent of Surface Control System Failures	Component	No. of Failures	Percent of Surface Control System Failures
MUX Control System	59	60%	CCU	34	34%
			MUX Reel, Cables, and Connectors	13	13%
			MUX Cable (only)	4	4%
Control Panels	13	13%	DCP	5	5%
			HPU control panel	3	3%
			CCU Panel	2	2%

Table 3-3: Surface Control System Dominant Component Failure Contributors

System Major Component	No. of Failures	Percent of Surface Control System Failures	Component	No. of Failures	Percent of Surface Control System Failures
HPU	10	10%	Flowmeter	3	3%
			Filters and tank	2	2%
			HPU System	2	2%
			Regulators	2	2%
Total	82	83%		70	71%

Table 3-4: Surface Control System Dominant Major Component Failure Modes

Component Failure Mode	No. of Failures	Percent of Surface Control System Failures
Processing Error	18	20%
Hardware Failure	18	20%
External Leakage	10	11%
Mechanical Damage	8	9%
Component Out of Specification	7	8%
Substandard Workmanship	6	7%
Mechanical Failure	5	5%
Instrument Error	5	5%
	77	85%

Tables 3-5 summarize the Subsea Control System results. Because Blue & Yellow Subsea Control System accounts for 85% of the 165 Subsea Control System failure events, this single table contains both the dominant component failure contributors and failure modes and only provides two separate lists related to the Blue & Yellow Subsea Control System. The results list the 10 components and 9 failure modes, which account for 70% and 69% of the Subsea Control System failures, respectively (excluding unspecified component failures and failure modes).

Table 3-5: Subsea Control System Dominant Component Failure Contributors and Failure Modes

System Major Component	No. of Failures	Percent of Subsea Control System Failures	Component	No. of Failures	Percent of Subsea Control System Failures	Failure Mode	No. of Failures	Percent of Subsea Control System Failures
Blue & Yellow Subsea Control System	140	85%	SPM Valve & Manifold	26	16%	External Leakage	53	32%
			SEM	25	15%	Mechanical Failure	13	8%
			Regulators	17	10%	Electrical Short	11	7%
			Pod Receptacles	10	6%	Substandard Workmanship	9	5%
			MUX System – Subsea	8	5%	Mechanical Damage	8	5%
			Flowmeter	8	5%	Erratic output	7	4%
			Shuttle valves	6	4%	Hardware Failure	6	4%
			Tubing	6	4%	Component Out of Specification	4	2%
			POCV	5	3%	Fails with no communication	3	2%
			Solenoids	4	2%			
Total	140	85%		115	70%		114	69%

Tables 3-6 and 3-7 summarize the BOP Stack results. These tables show the three major components account for the 75% of the 127 BOP Stack. Table 3-6 lists the components contributing to three BOP Stack major components. Unfortunately, the IP-provided data did not provide sufficient information to identify failures associated with specific Pipe & Test Ram components. Therefore, the eleven listed components only account for about 44% of the BOP Stack failure events. However, the IP-provided data included failure mode information, which is shown in Table 3-7. This table lists the top 14 failure modes that account for 71% of the BOP Stack failure events. Again, these results exclude unspecified component failures and failure modes. (Note: Given the recent industry interest in connectors, wellhead, LMRP, and riser connector data are provided in the following tables. These data are contained in the parenthetical values in the data tables.)

Table 3-6: BOP Stack Dominant Component Failure Contributors

System Major Component	No. of Failures	Percent of BOP Stack Failures	Component	No. of Failures	Percent of BOP Stack Failures
Pipe & Test Rams	38	30%	Data Not Supplied		
Connectors*	29	23%	Riser Connector	9	7%
(Wellhead, LMRP, & Riser Connectors)	(12)	(9.4%)	C&K Stabs	7	6%
			Hydraulic Stabs	5	4%
			POD Connector	4	3%
			Wellhead Connector	3	2%
C&K Valves and Lines	28	22%	Connection & Spool Pieces	9	7%
			C&K Lines	6	5%
			C&K Valves	5	4%
			Jumper Hose or Flex Loop	3	2%
			Unspecified	3	2%
			Bleed Valves	2	2%
Total	95	75%		56	44%

*The "Connectors" category contains all subsea connector including the wellhead and LMRP connectors, as well as other connectors such as stabs and wet mate connector. If the connectors are subdivided, the wellhead, LMRP, and riser connectors account for 9.4% of the BOP Stack failures, excluding unspecified failures.

Table 3-7: BOP Stack Dominant Major Component Failure Modes

System Major Component	No. of Failures	Percent of BOP Stack Failures	Failure Mode	No. of Failures	Percent of BOP Stack Failures
Pipe & Test Rams	38	30%	Mechanical Failure	9	7%
			Substandard Workmanship	9	7%
			Mechanical Damage	8	6%
			External Leakage	3	2%
			Component Out of Specification	2	2%
Connectors* (Wellhead, LMRP, & Riser Connectors)	29	23%	External Leakage	8	6%
	(12)	(9.4%)	Mechanical Damage	8	6%
			Substandard Workmanship	5	4%
			Mechanical Failure	3	2%
			Component Out of Specification	2	2%
C&K Valves and Lines	28	22%	External Leakage	12	9%
			Substandard Workmanship	5	4%
			Mechanical Failure	2	2%
			Plugging	1	1%
Total	95	75%		90	71%

*The “Connectors” category contains all subsea connectors including the wellhead and LMRP connectors, as well as other connectors such as stabs and wet mate connector. If the connectors are subdivided, the wellhead, LMRP, and riser connectors account for 9.4% of the BOP Stack failures, excluding unspecified failures.

3.1.2 Overall BOP Results

The analysis of the failure event data began at the system level to begin understanding whether one of the three BOP systems (i.e., Surface Controls, Subsea Control, and BOP Stack) was the dominant cause of BOP failures. Figure 3-1 provides a pie chart showing the percent distribution of the 430 BOP failure events based on the number of failures. (Note: The unspecified failures represent events in which the failure event data did not contain sufficient information to assign the failure to a specific system or involved more than one BOP system.) To further evaluate the BOP system failures, Figures 3-2 and 3-3 provide the percentage of failures by BOP system (without the unspecified failures) based on the number of failures and failures per BOP day (i.e., estimated failure rate.)

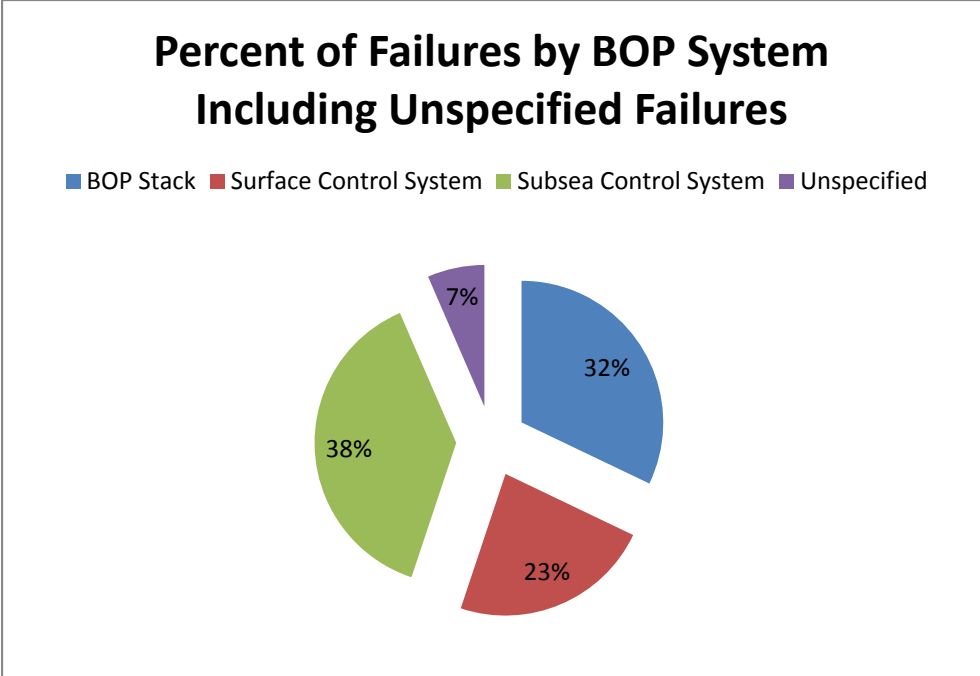


Figure 3-1. Percent of Failures by BOP System, including Unspecified Failures

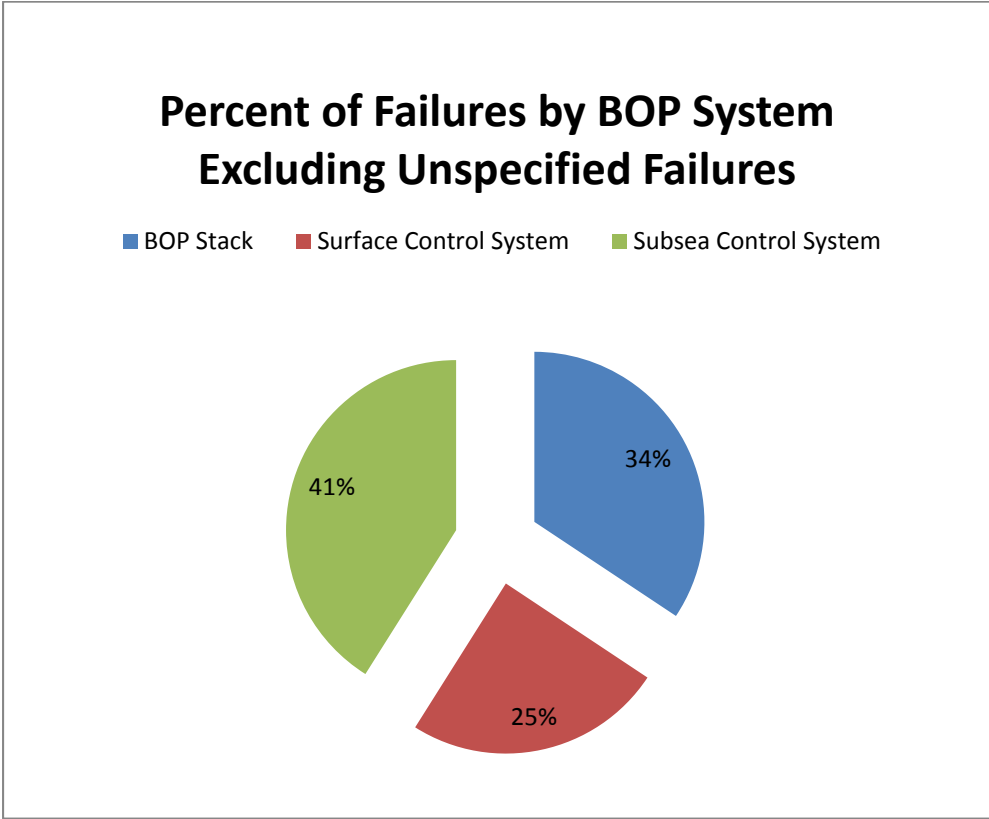


Figure 3-2. Percent of Failures by BOP System, Excluding Unspecified Failures

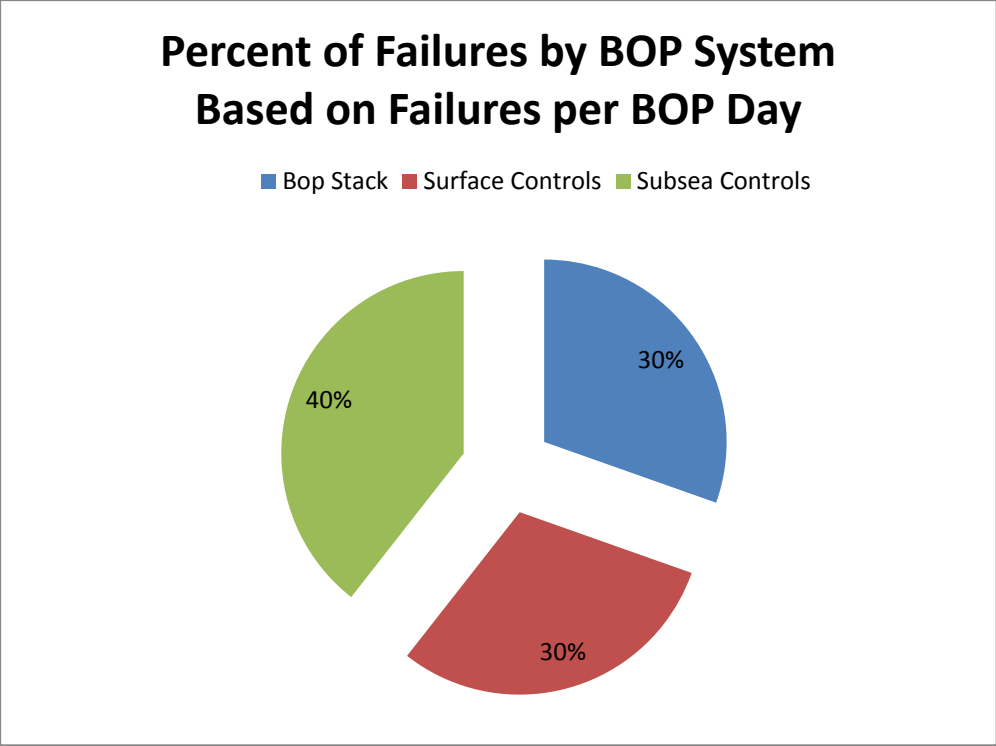


Figure 3-3. Percent of Failures by BOP System Based on Failures per BOP Day

All three of these pie charts indicate that subsea control system failures represent the highest percentage of failures, as anticipated. Based on this analysis, the failure of the Subsystem Control System failures occur 20% to 60% more often than either the failure of the Surface Control System or BOP Stack.

The next level of analysis involved Pareto analyses to identify the major components and failure modes associated with the BOP system failures. Table 3-8 contains the failure data for the major BOP components and Figure 3-4 provides the Pareto chart of these major component failures. (Note: When reading the Pareto Charts in this report, the bars represent the number of events and are associated with left-hand axis. The line represents the cumulative percentage of the events being charted.) These data indicate that the top five major component failures are associated with Blue & Yellow Subsea Control system, MUX control system, pipe & test rams, connectors, and C&K valves/lines. These major components (and their associated sub-components) account for more than 75% of the BOP system failures (without the unspecified failures). The Blue & Yellow Subsea Control system is the dominant failure cause, accounting for 36% of the overall BOP failures, which is more than twice the MUX control system failures.

Table 3-8 Major Component Failure Data Summary

Major BOP Component	No. of Failures	Percent of Failures, including Unspecified Failures	Cumulative Percent of Failures, including Unspecified Failures	Percent of Failures, excluding Unspecified Failures	Cumulative Percent of Failures, excluding Unspecified Failures
Blue & Yellow Subsea Control System	140	33%	33%	36%	36%
MUX Control System	59	14%	46%	15%	51%
Unspecified	39	9%	55%		
Pipe & Test Rams	38	9%	64%	10%	61%
Connectors*	29	7%	71%	7%	68%
C&K Valves and Lines	28	7%	77%	7%	75%
Emergency & Secondary Controls	16	4%	81%	4%	79%
Annulars	13	3%	84%	3%	83%
Control Panels	13	3%	87%	3%	86%
HPU	10	2%	90%	3%	88%
Blind Shear Ram	9	2%	92%	2%	91%
LMRP-mounted Accumulators	9	2%	94%	2%	93%
Rigid Conduit and Hotline	9	2%	96%	2%	95%
Electrical Power	7	2%	97%	2%	97%
Casing Shear Ram	7	2%	99%	2%	99%
Stack-mounted Accumulators (Autoshear)	3	1%	100%	1%	100%
Surface Accumulators	1	<1%	100%	<1	100%

*This connector category contains all subsea connectors including the wellhead and LMRP connectors, as well as other connectors such as stabs and wet mate connector. If the connectors are subdivided, the wellhead, LMRP, and riser connector account for 3% of the BOP failures (excluding unspecified failures).

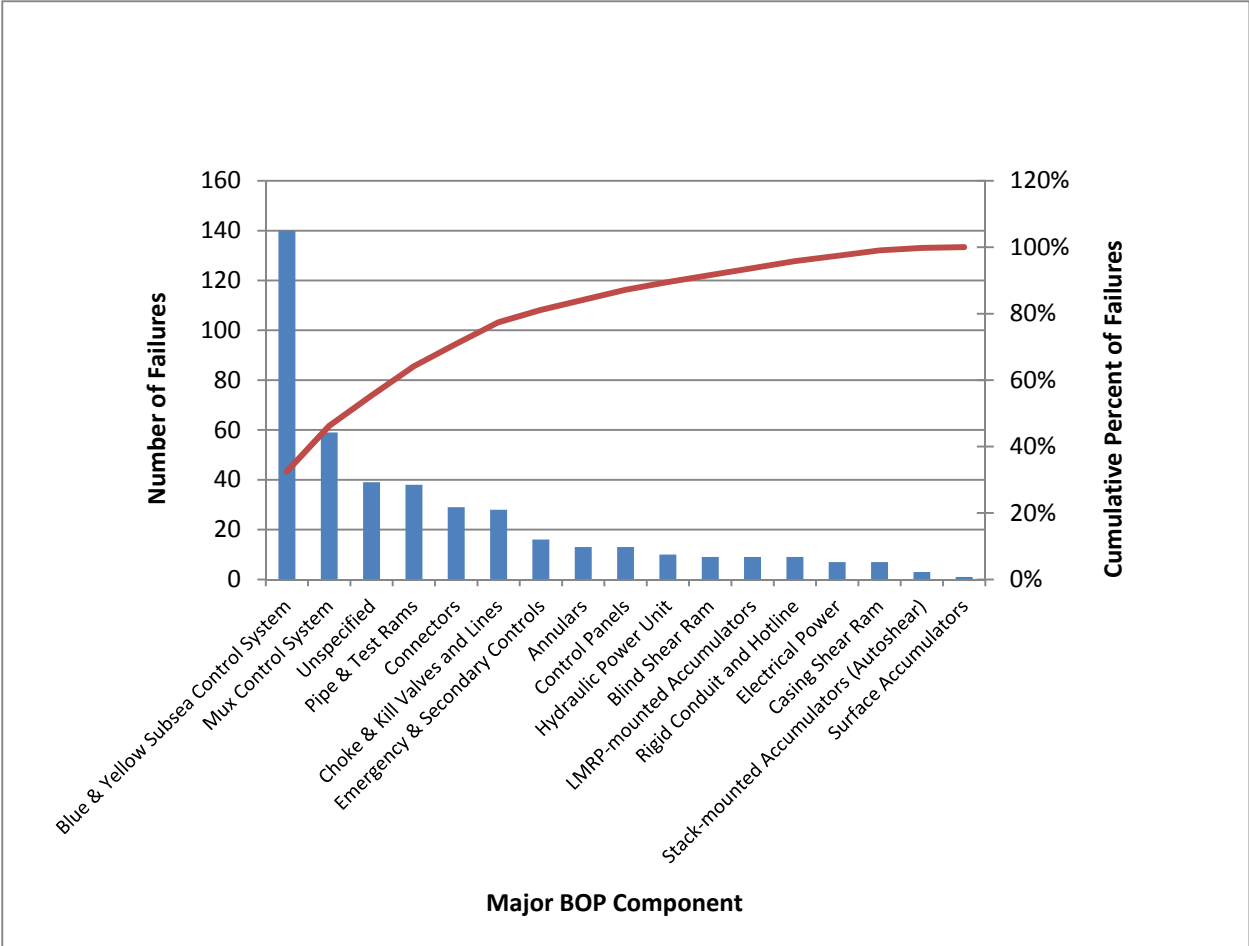


Figure 3-4. Major Component Pareto Chart

To further trend the failures, a Pareto analysis of the failure modes was performed and these results are provided in Table 3-9 and Figure 3-5. These results indicate the dominant failure modes (excluding unspecified failure mode) are external leakage, mechanical damage, mechanical failure, substandard workmanship (i.e., human error), hardware failure, component out of specification, and processing error. These failure modes account for a little more than 80% of the BOP system failures. The presence of at two of the dominant failure modes substandard workmanship and component out of specification might be indication of causes of infant mortality failures.

Table 3-9: BOP Failure Mode Data Summary

Failure Mode	No. of Failures	Percent of Failures including Unspecified Failure Modes	Cumulative Percent of Failures including Unspecified Failure Modes	Percent of Failures excluding Unspecified Failure Modes	Cumulative Percent of Failures excluding Unspecified Failure Modes
External Leakage	102	24%	24%	27%	27%
Unspecified	52	12%	36%		
Mechanical Damage	49	11%	47%	13%	40%
Mechanical Failure	49	11%	59%	13%	53%
Substandard Workmanship	41	10%	68%	11%	64%
Hardware Failure	26	6%	74%	7%	71%
Component Out of Specification	21	5%	79%	6%	76%
Processing Error	19	4%	83%	5%	81%
Electrical Short	14	3%	87%	4%	85%
Erratic output	11	3%	89%	3%	88%
Communication problem	8	2%	91%	2%	90%
Instrument Error	7	2%	93%	2%	92%
Plugging	7	2%	94%	2%	94%
Fails with no communication	5	1%	96%	1%	95%
Loss of communication	4	1%	97%	1%	96%
Design Issue	3	1%	97%	1%	97%
Internal Leakage	3	1%	98%	1%	98%
Configuration issue	2	<1%	98%	1%	98%
Loss of Power	2	<1%	99%	1%	99%
Loss of, or degraded power	2	<1%	99%	1%	99%
Fails to respond to input	1	<1%	100%	<1%	99%
Installation & Commissioning	1	<1%	100%	<1%	100%
Loss of Pressure	1	<1%	100%	<1%	100%

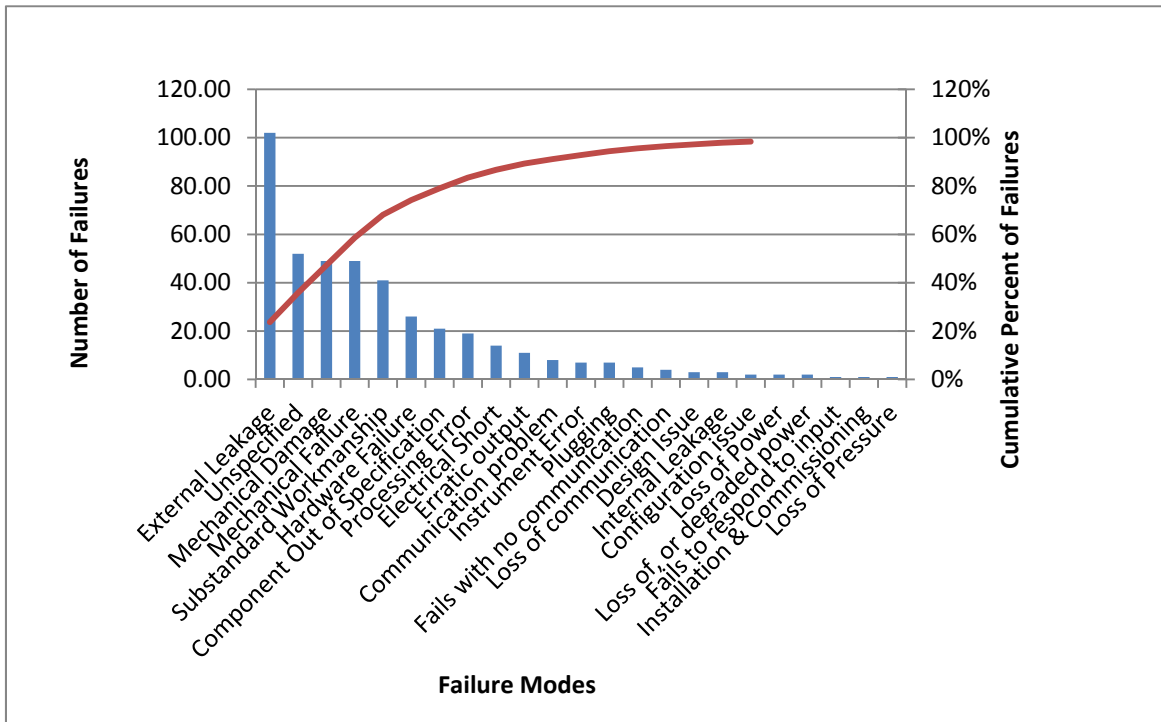


Figure 3-5. Failure Mode Pareto Chart

Next, Pareto analyses of the major component failures (including associated sub-component failures) and their failure modes was performed for each of the three BOP systems (i.e., Surface Controls, Subsea Controls, and BOP Stack).

3.1.3 Surface Control System Results

This section summarizes the data analysis of the Surface Control System failures. Table 3-10 and Figure 3-6 provide the relevant Pareto charts for the surface control system major component failures. These results indicate the MUX control system failures account for 60% the surface control system failures. The control panels, HPU, and rigid conduit and hoses combine for next 32% of the surface control system failures.

Table 3-10: Surface Control System Major Component Failure Data Summary

Surface Control System Major Component	No. of Failures	Percent of Failures	Cumulative Percentage of Failures
Mux Control System	59	60%	60%
Control Panels	13	13%	73%
HPU	10	10%	83%
Rigid Conduit and Hotline	9	9%	92%
Electrical Power	7	7%	99%
Surface Accumulators	1	1%	100%

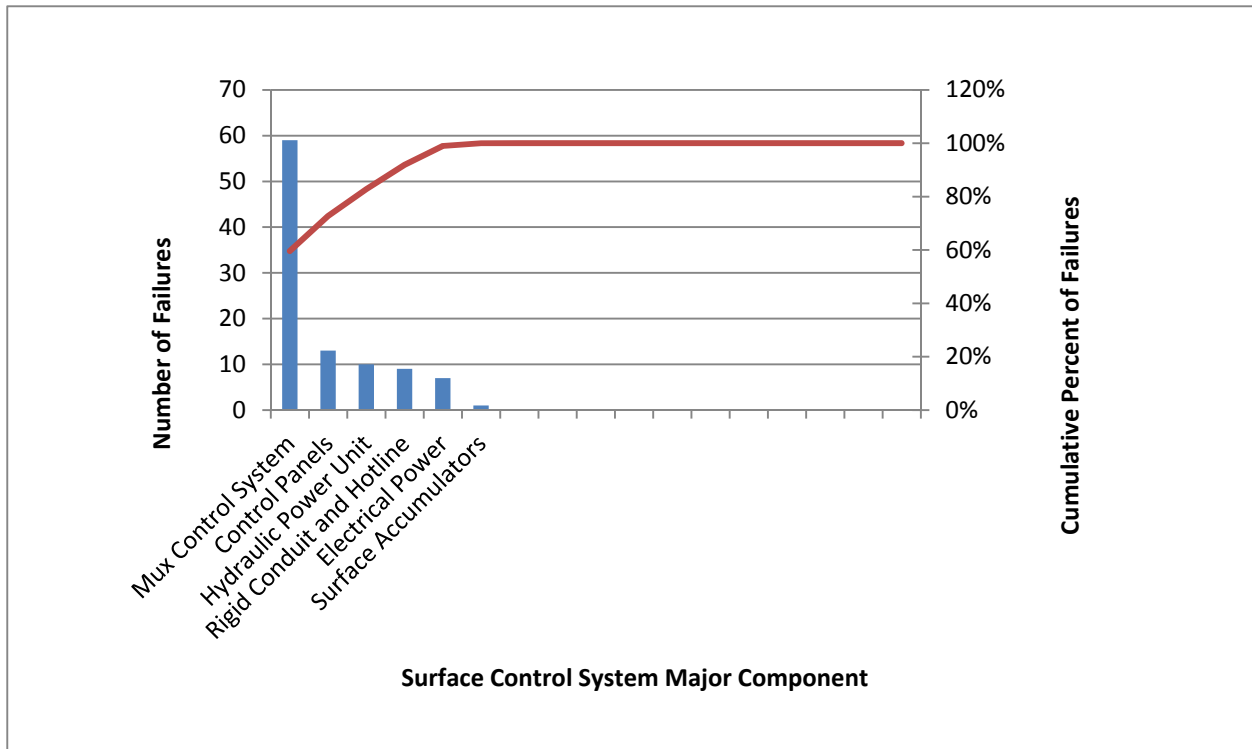


Figure 3-6. Surface Control System - Major Component Pareto Chart

To further evaluate surface control system failures, Pareto analysis was performed on the surface control system failure modes. Table 3-11 and Figure 3-7 contains these results, which show the dominant failure modes for the surface control system failures (excluding unspecified failure modes) are processing error, hardware failures, external leakage, mechanical damage, substandard workmanship, and component out of specification are the dominant failure modes, which account for 75% of the surface control system failures.

Table 3-11: Surface Control System Failure Mode Data Summary

Surface Control System Failure Mode	No. of Failures	Percent of Failures Including Unspecified Failure Mode	Cumulative Percent of Failures Including Unspecified Failure Mode	Percent of Failures excluding Unspecified Failure Modes	Cumulative Percent of Failures, excluding Unspecified Failure Modes
Processing Error	18	18%	18%	20%	20%
Hardware Failure	18	18%	36%	20%	40%
External Leakage	10	10%	46%	11%	51%
Mechanical Damage	8	8%	55%	9%	59%
Unspecified	8	8%	63%		
Substandard Workmanship	6	6%	69%	7%	66%

Table 3-11: Surface Control System Failure Mode Data Summary

Surface Control System Failure Mode	No. of Failures	Percent of Failures Including Unspecified Failure Mode	Cumulative Percent of Failures Including Unspecified Failure Mode	Percent of Failures excluding Unspecified Failure Modes	Cumulative Percent of Failures, excluding Unspecified Failure Modes
Component Out of Specification	7	7%	76%	8%	74%
Mechanical Failure	5	5%	81%	5%	79%
Instrument Error	5	5%	86%	5%	85%
Erratic output	3	3%	89%	3%	88%
Fails with no communication	2	2%	91%	2%	90%
Electrical Short	2	2%	93%	2%	92%
Loss of communication	2	2%	95%	2%	95%
Loss of, or degraded power	2	2%	97%	2%	97%
Communication problem	1	1%	98%	1%	98%
Plugging	1	1%	99%	1%	99%
Configuration issue	1	1%	100%	1%	100%

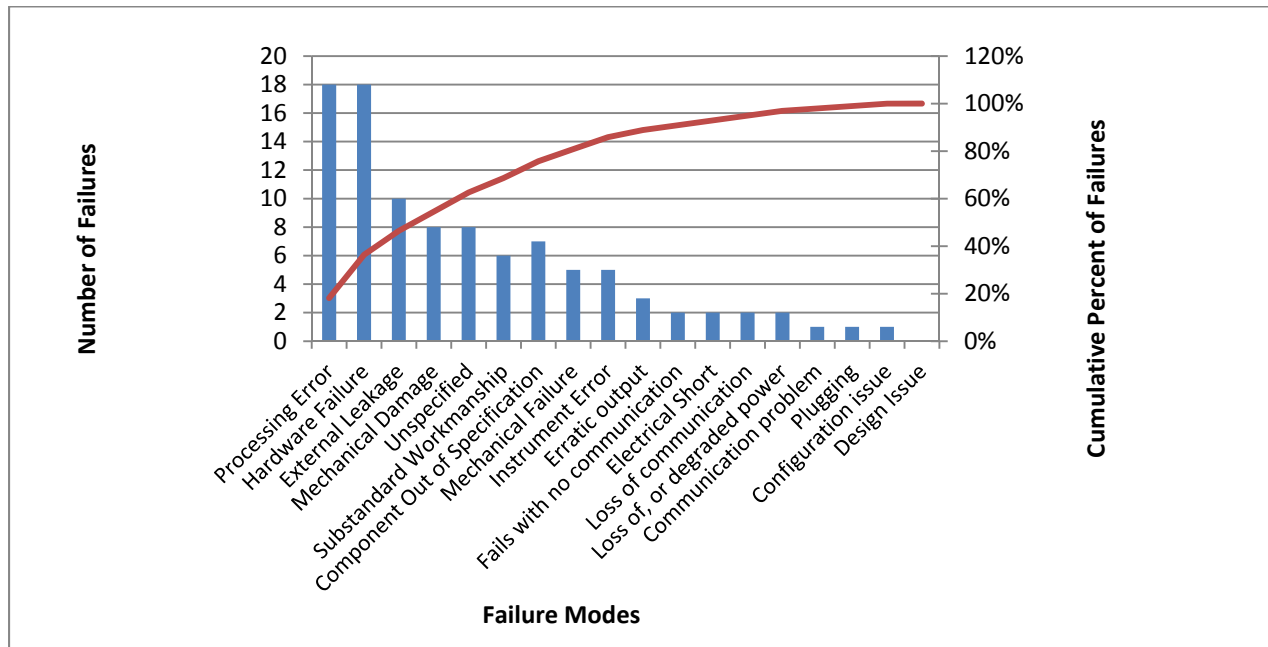


Figure 3-7. Surface Control System Failure Mode Pareto Chart

To further analyze the surface control system failures, details of the MUX control system failures, which is the dominant major component failing in the surface control system, were analyzed. Specifically, the MUX control system component failures were identified and are summarized in Table 3-12 and Figure 3-8. These data indicate the CCU and MUX reels, cables, and connectors are the dominant causes of the MUX control system failures. The MUX control system failure mode data are provided in Table 3-13 and Figure 3-9. These data indicate the dominant failure modes (excluding unspecified failure mode) are processing error, hardware failure, component out of specification, mechanical damage, substandard workmanship (i.e., human error), and erratic output.

Table 3-12: MUX Control System Component Failure Data Summary

MUX Control System Component	No. of Failures	Percent of Failures Including Unspecified Failures	Cumulative Percent of Failures Including Unspecified Failures	Percent of Failures excluding Unspecified Failures	Cumulative Percent of Failures, excluding Unspecified Failures
CCU	34	58%	58%	63%	63%
MUX Reel, Cables, and Connectors	13	22%	80%	24%	87%
Unspecified	5	8%	88%		
MUX Cable (only)	4	7%	95%	7%	94%
MUX Communication	2	3%	98%	4%	98%
MUX System General	1	2%	100%	2%	100%

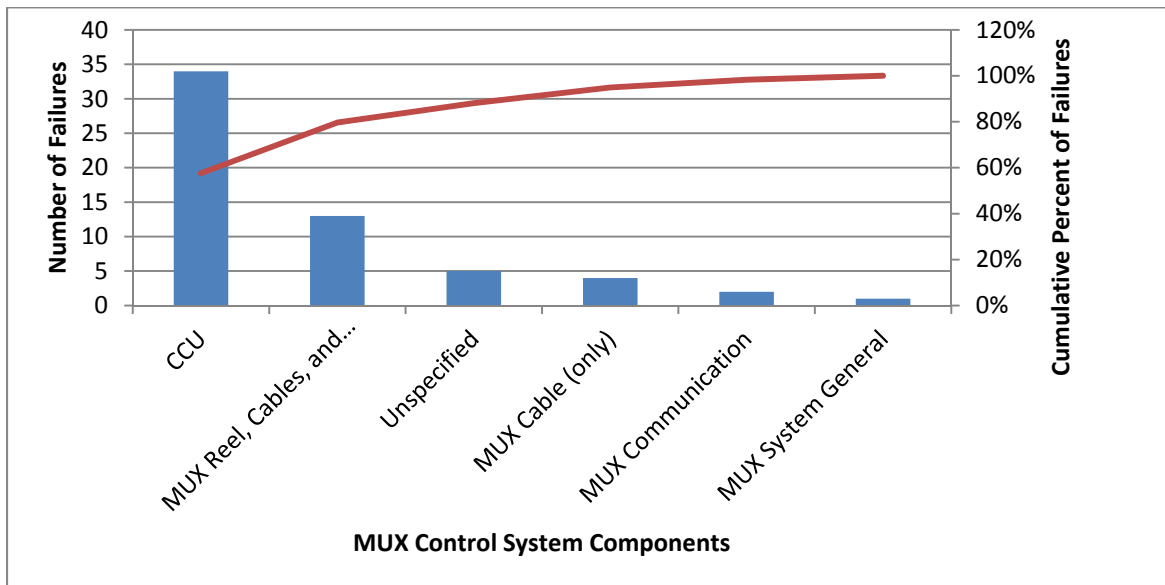


Figure 3-8. MUX Control System Component Pareto Chart

Table 3-13 MUX Control System Failure Mode Data Summary

MUX Control System Failure Mode	No. of Failures	Percent of Failures Including Unspecified Failure Modes	Cumulative Percent of Failures Including Unspecified Failure Modes	Percent of Failures excluding Unspecified Failure Modes	Cumulative Percent of Failures excluding Unspecified Failure Modes
Processing Error	15	25%	25%	28%	28%
Hardware Failure	9	15%	41%	17%	44%
Component Out of Specification	6	10%	51%	11%	56%
Mechanical Damage	5	8%	59%	9%	65%
Unspecified	5	8%	68%		
Substandard Workmanship	5	8%	76%	9%	74%
Erratic output	3	5%	81%	6%	80%
Mechanical Failure	3	5%	86%	6%	85%
Fails with no communication	2	3%	90%	4%	89%
Loss of communication	2	3%	93%	4%	93%
Electrical Short	2	3%	97%	4%	96%
Communication problem	1	2%	98%	2%	98%
Configuration issue	1	2%	100%	2%	100%

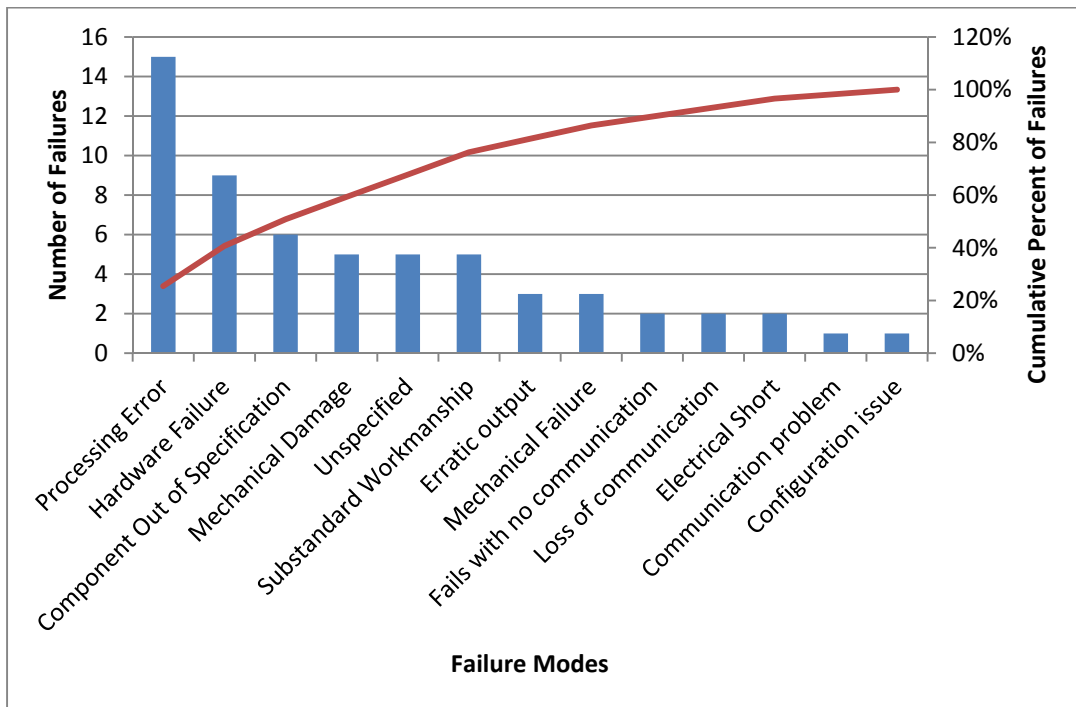


Figure 3-9. MUX Control System Failure Mode Pareto Chart

3.1.4 Subsea Control System Results

Similar to section 3.1.3, this section summarizes the failure data analysis results for the subsea control system. Specifically, Pareto analyses were performed to identify the dominant failed major components and associated failure modes for the Subsea Control system. Table 3-14 and Figure 3-10, provide the data summary and the Pareto charts for the subsea control system relative to the major component failures and failure modes. As expected, these data indicate the Blue & Yellow Control system and its associated sub-components are the dominant contributors to subsea control system failures.

Table 3-14 Subsea Control System Failure Data Summary

Subsea Control System Major Component	No. of Failures	Percent of Failures	Cumulative Percent of Failures
Blue & Yellow Subsea Control System	140	85%	85%
Emergency & Secondary Controls	16	10%	95%
LMRP-mounted Accumulators	9	5%	100%

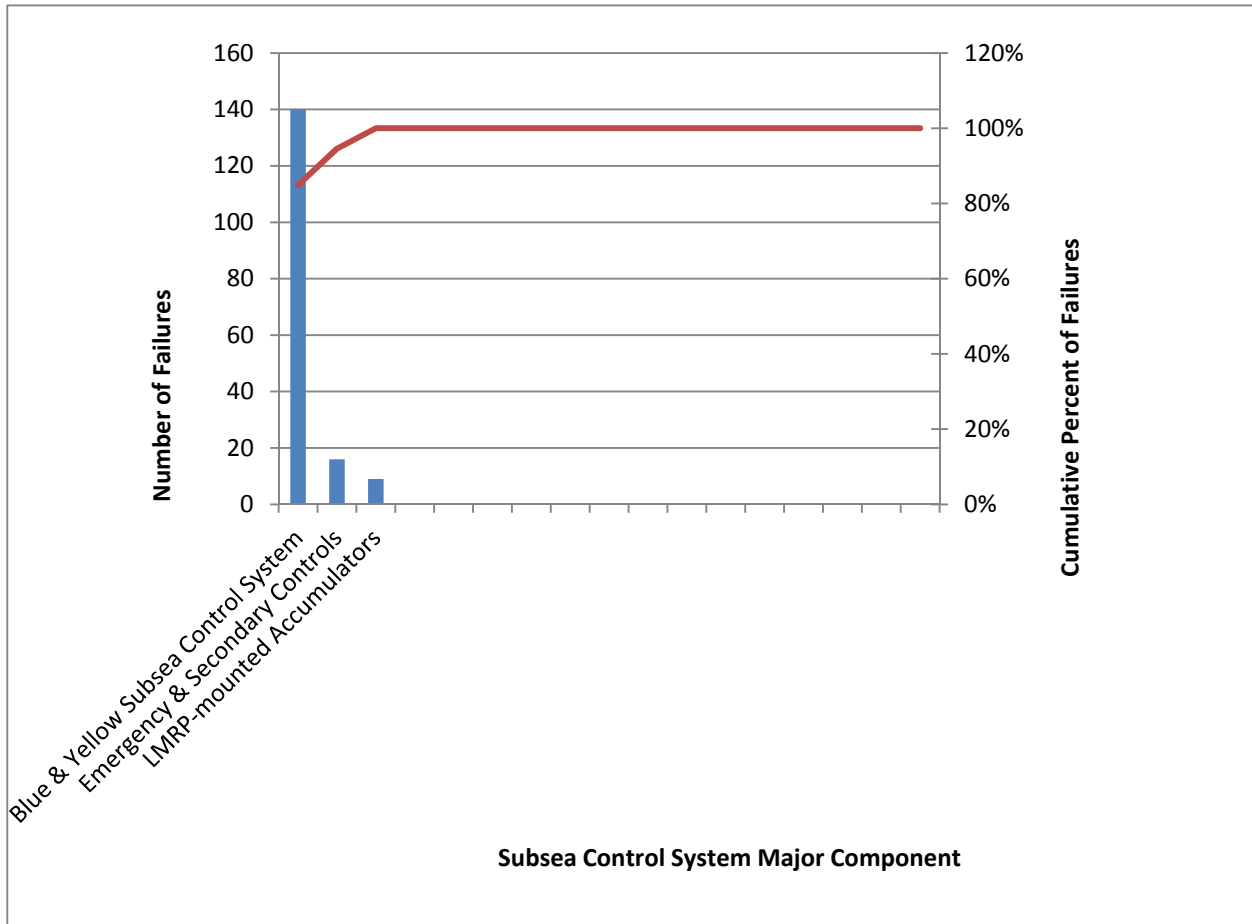


Figure 3-10. Subsea Control System Major Component Pareto Chart

Table 3-15 and Figure 3-11 indicate the dominant failure modes for the subsea control system failures (excluding unspecified failure modes) are external leakage, mechanical failure, substandard workmanship (i.e., human error), electrical short, and mechanical damage. These five failure modes account for more than 75% of the subsea control system failures.

Table 3-15: Subsea Control System Failure Mode Data Summary

Subsea Control System Failure Mode	No. of Failures	Percent of Failures, including Unspecified Failure Mode	Cumulative Percent of Failures, including Unspecified Failure Mode	Percent of Failures, excluding Unspecified Failure Mode	Cumulative Percent of Failures, excluding Unspecified Failure Mode
External Leakage	64	39%	39%	42%	42%
Mechanical Failure	18	11%	50%	12%	54%
Unspecified	14	8%	58%		
Substandard Workmanship	12	7%	65%	8%	62%
Electrical Short	12	7%	73%	8%	70%
Mechanical Damage	9	5%	78%	6%	76%
Hardware Failure	6	4%	82%	4%	80%
Erratic output	7	4%	86%	5%	85%
Component Out of Specification	5	3%	89%	3%	88%
Plugging	3	2%	91%	2%	90%
Fails with no communication	3	2%	93%	2%	92%
Communication problem	2	1%	94%	1%	93%
Instrument Error	2	1%	95%	1%	95%
Loss of communication	2	1%	96%	1%	96%
Loss of Power	2	1%	98%	1%	97%
Processing Error	1	1%	98%	1%	98%
Internal Leakage	1	1%	99%	1%	99%
Fails to respond to input	1	1%	99%	1%	99%
Loss of Pressure	1	1%	100%	1%	100%

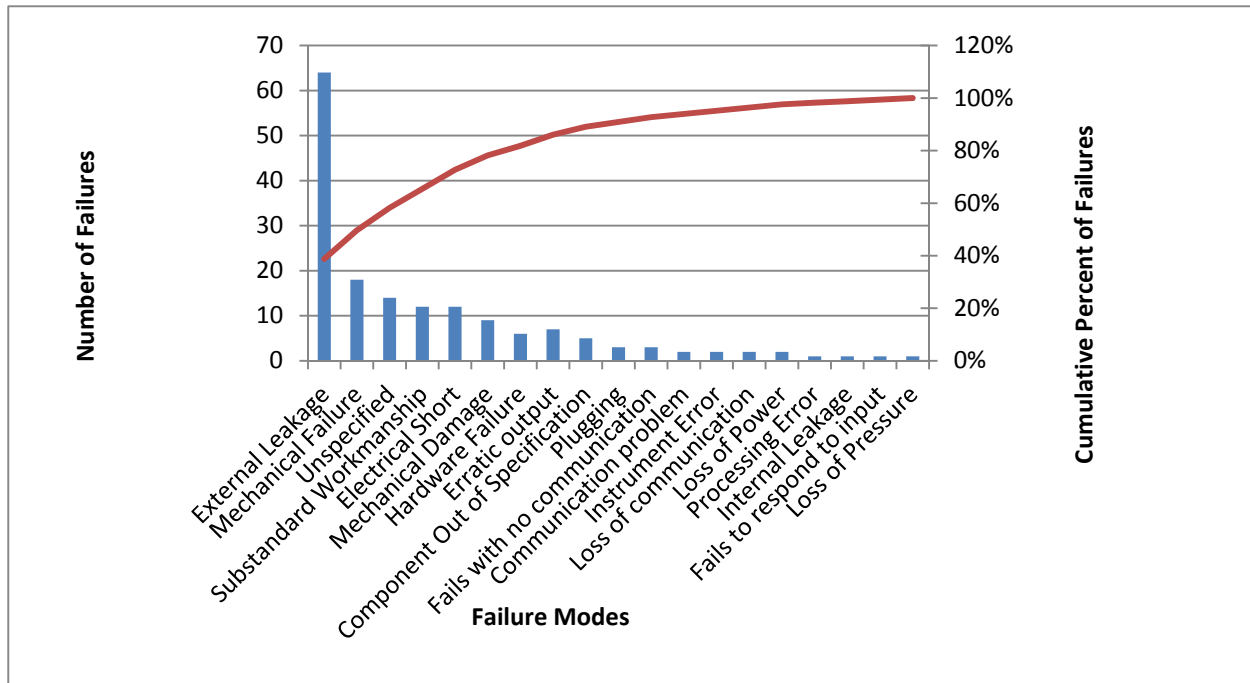


Figure 3-11. Subsea Control System Failure Mode Pareto Chart

To further analyze subsea control system failures, a Pareto charts of the Blue & Yellow Control System component failures and associated failure modes were generated and analyzed. Table 3-16 and Figure 3-12 provide the failure data summary and Pareto chart for the Blue & Yellow Control System components, respectively. These data indicate the dominant component failures are SPM valve & manifold, SEM, regulators, pod receptacles, MUX system-subsea, flowmeter, and shuttle valves, which account for more than 80% of the failures.

Table 3-16 Blue & Yellow Control System Component Failure Data Summary

Blue & Yellow Control System Component	No. of Failures	Percent of Failures Including Unspecified Failures	Cumulative Percent of Failures Including Unspecified Failures	Percent of Failures excluding Unspecified Failures	Cumulative Percent of Failures excluding Unspecified Failures
SPM Valve & Manifold	26	19%	19%	21%	21%
SEM	25	18%	36%	20%	42%
Unspecified	18	13%	49%		
Regulators	17	12%	61%	14%	56%
Pod Receptacles	10	7%	69%	8%	64%
MUX System - Subsea	8	6%	74%	7%	70%
Flowmeter	8	6%	80%	7%	77%
Shuttle valves	6	4%	84%	5%	82%
Tubing	6	4%	89%	5%	87%

Table 3-16 Blue & Yellow Control System Component Failure Data Summary

Blue & Yellow Control System Component	No. of Failures	Percent of Failures Including Unspecified Failures	Cumulative Percent of Failures Including Unspecified Failures	Percent of Failures excluding Unspecified Failures	Cumulative Percent of Failures excluding Unspecified Failures
POCV	5	4%	92%	4%	91%
Solenoids	4	3%	95%	3%	94%
Hoses	3	2%	97%	2%	97%
Accumulators - LMRP	1	1%	98%	1%	98%
Pilot & Supply Filters & Manifold	1	1%	99%	1%	98%
Piping	1	1%	99%	1%	99%
Check valve	1	1%	100%	1%	100%

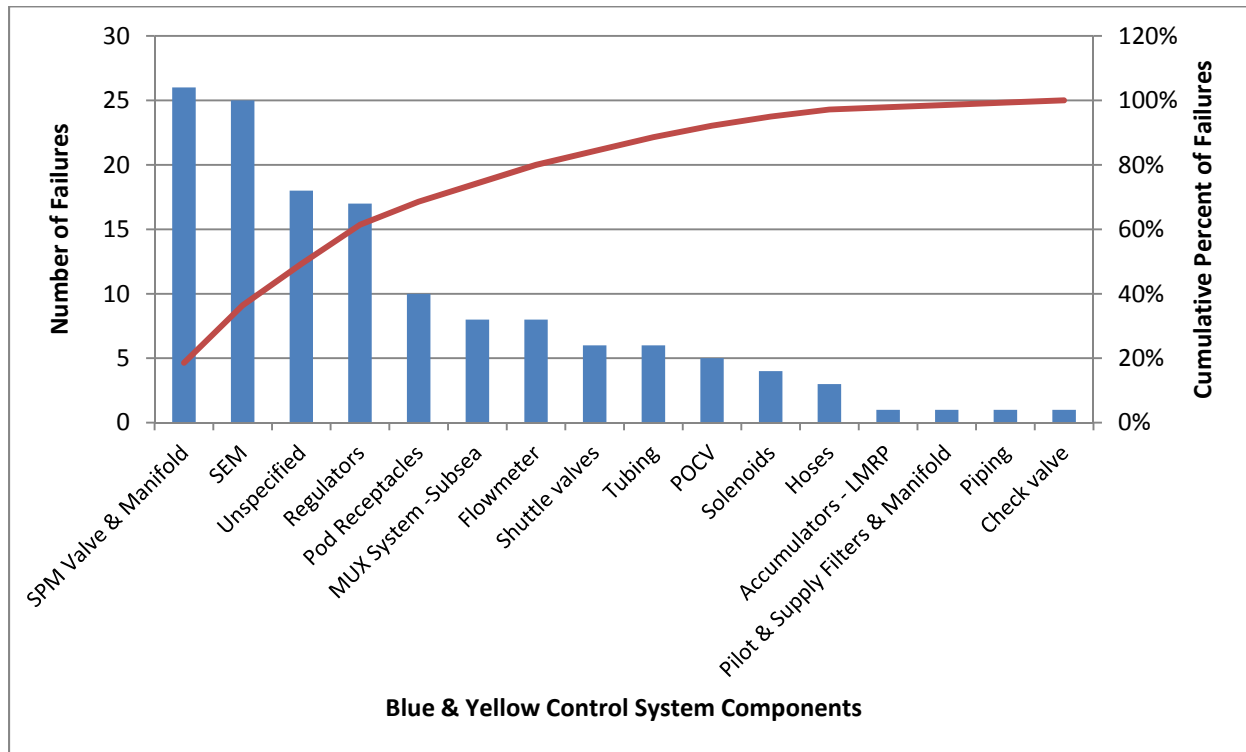


Figure 3-12. Blue & Yellow Control System Component Failure Pareto Chart

Table 3-17 and Figure 3-13 contain the data and Pareto chart for the Blue & Yellow Control system failure modes. These data indicate external leakage is the dominant failure mode and accounts for the 42% of the failures (excluding the unspecified failure mode). Mechanical failure, electrical short, substandard workmanship (i.e., human error) and mechanical damage cumulatively account for 32% of the failures.

Table 3-17: Blue & Yellow Control System Failure Mode Data Summary

Blue & Yellow Control System Failure Modes	No. of Failures	Percent of Failures, including Unspecified Failure Mode	Cumulative Percent of Failures, including Unspecified Failure Mode	Percent of Failures, excluding Unspecified Failure Mode	Cumulative Percent of Failures excluding Unspecified Failure Mode
External Leakage	53	38%	38%	42%	42%
Mechanical Failure	13	9%	47%	10%	52%
Unspecified	13	9%	56%		
Electrical Short	11	8%	64%	9%	61%
Substandard Workmanship	9	6%	71%	7%	68%
Mechanical Damage	8	6%	76%	6%	74%
Erratic output	7	5%	81%	6%	80%
Hardware Failure	6	4%	86%	5%	84%
Component Out of Specification	4	3%	89%	3%	87%
Fails with no communication	3	2%	91%	2%	90%
Plugging	3	2%	93%	2%	92%
Loss of communication	2	1%	94%	2%	94%
Loss of Power	2	1%	96%	2%	95%
Communication problem	2	1%	97%	2%	97%
Instrument Error	1	1%	98%	1%	98%
Internal Leakage	1	1%	99%	1%	98%
Fails to respond to input	1	1%	99%	1%	99%
Processing Error	1	1%	100%	1%	100%

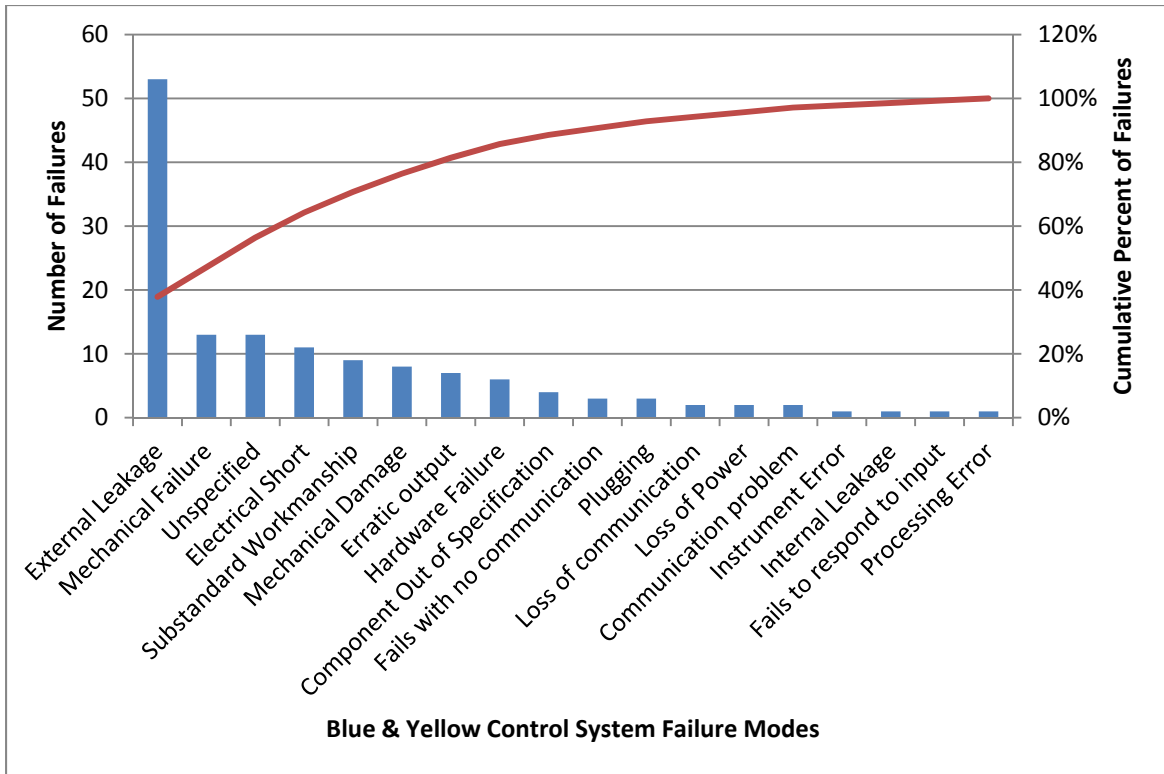


Figure 3-13. Blue & Yellow Control System Failure Mode Pareto Chart

3.1.5 BOP Stack Results

As with the other two BOP systems, Pareto analyses of the BOP Stack major components failures and failure modes were performed. Table 3-18 summarizes the BOP Stack failure data, and Figure 3-14 contains the Pareto chart for the BOP Stack failures. As shown in this table and figure, 75% of the BOP Stack failures (excluding unspecified failures) are due to pipe and test ram, C&K line/valves, and connectors. (Note: Given the recent industry interest in connectors, wellhead, LMRP, and riser connector data are provided in the following data tables. These data are contained in the parenthetical values in the data tables.)

Table 3-18: BOP Stack Failure Data Summary

BOP Stack Major Component	No. of Failures	Percent of Failures, including the Unspecified Failures	Cumulative Percent of Failures, including the Unspecified Failures	Percent of Failures, excluding the Unspecified Failures	Cumulative Percent of Failures, excluding the Unspecified Failures
Pipe & Test Rams	38	28%	28%	30%	30%
Connectors*	29	21%	49%	23%	53%
(Wellhead, LMRP & Riser Connectors)	(12)	(8.7%)		(9.4%)	

Table 3-18: BOP Stack Failure Data Summary

BOP Stack Major Component	No. of Failures	Percent of Failures, including the Unspecified Failures	Cumulative Percent of Failures, including the Unspecified Failures	Percent of Failures, excluding the Unspecified Failures	Cumulative Percent of Failures, excluding the Unspecified Failures
C&K Valves and Lines	28	20%	69%	22%	75%
Annulars	13	9%	78%	10%	85%
Unspecified	11	8%	86%		
Blind Shear Ram	9	7%	93%	7%	92%
Casing Shear Ram	7	5%	98%	6%	98%
Stack-mounted Accumulators (Autoshear)	3	2%	100%	2%	100%

*The “Connectors” category contains all subsea connectors including the wellhead and LMRP connectors, as well as other connectors such as stabs and wet mate connector. If the connectors are subdivided, the wellhead, LMRP, and riser connectors account for 8.7% and 9.4% of the BOP Stack failures, including and excluding unspecified failures, respectively.

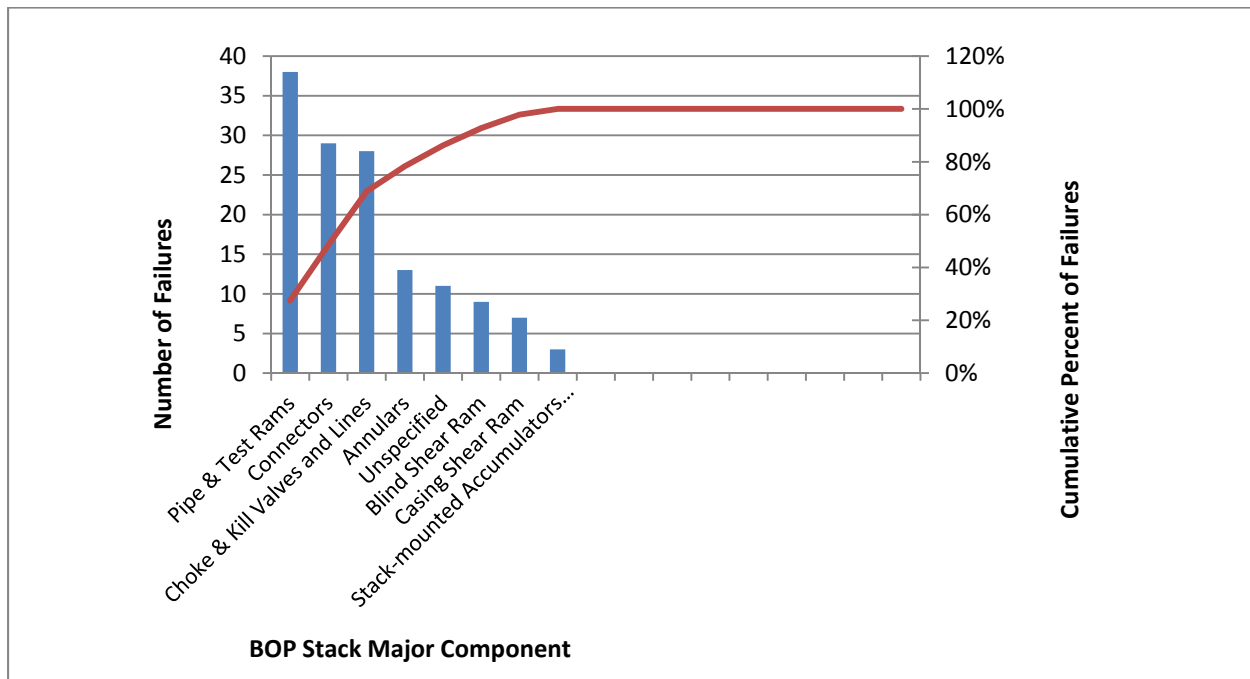


Figure 3-14. BOP Stack Major Component Pareto Chart

The BOP Stack failure modes were next analyzed, with the data summary and results provided in Table 3-19 and Figure 3-15. The dominant failure modes are mechanical damage, external leakage, mechanical failure, and substandard workmanship (i.e., human error). These failure modes account for more than 80% of the BOP Stack failures (excluding unspecified failure mode).

Table 3-19: BOP Stack Failure Mode Data Summary

BOP Stack Failure Modes	No. of Failures	Percent of Failures, including Unspecified Failure Mode	Cumulative Percent of Failures, including Unspecified Failure Mode	Percent of Failures, excluding Unspecified Failure Mode	Cumulative Percent of Failures, excluding Unspecified Failure Mode
Mechanical Damage	31	22%	22%	25%	25%
External Leakage	26	19%	41%	21%	46%
Mechanical Failure	26	19%	60%	21%	67%
Substandard Workmanship	23	17%	77%	19%	86%
Unspecified	15	11%	88%		
Component Out of Specification	8	6%	93%	7%	93%
Plugging	3	2%	96%	2%	95%
Design Issue	3	2%	98%	2%	98%
Internal Leakage	2	1%	99%	2%	99%
Hardware Failure	1	1%	100%	1%	100%

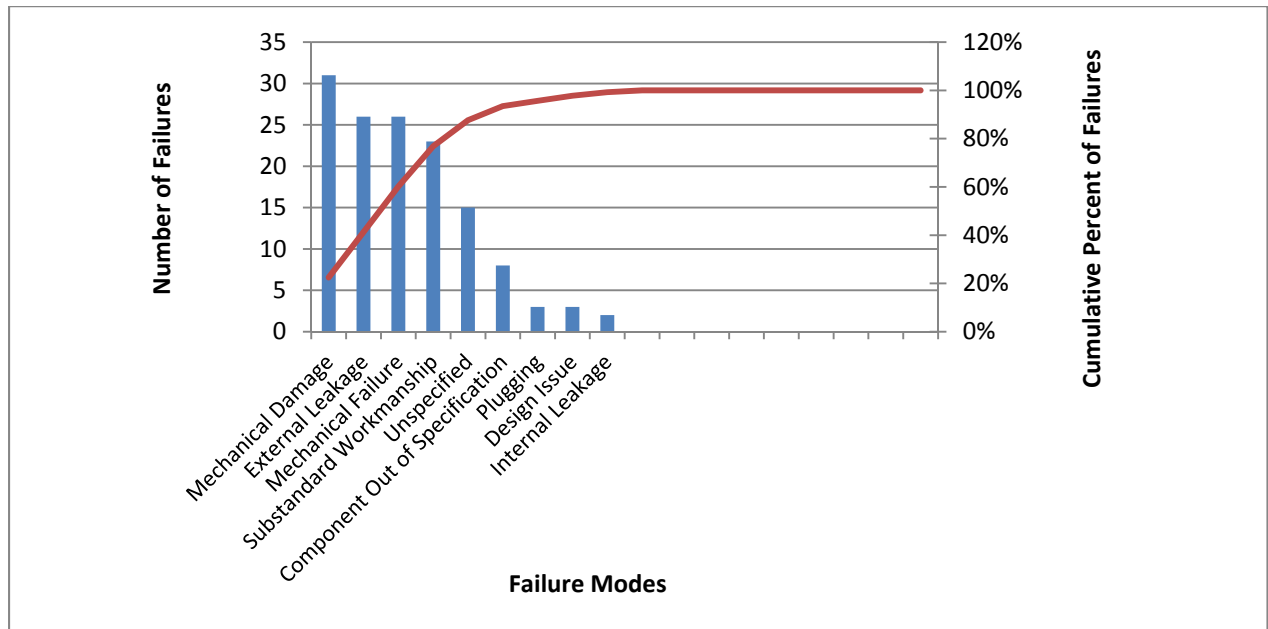


Figure 3-15. BOP Stack Failure Mode Pareto Chart

To further analyze BOP Stack failures, the specific component contributing to the pipe & test rams, connectors, and C&K valves and lines were identified. For pipe & test rams, the failure data did not include sufficient information to identify any component failure trends. However, sufficient data was available to identify component failure trends for connectors, and C&K valves and lines. The failure

data for connector components is summarized in Table 3-20, and the corresponding pareto chart is provided in Figure 3-16.

Table 3-20: Connector Component Failure Data Summary

BOP Connectors	No. of Failures	Percent of Failures	Cumulative Percent of Failures
Riser Connector	9	31%	31%
C&K Stabs	7	24%	55%
Hydraulic Stabs	5	17%	72%
POD Connector	4	14%	86%
Wellhead Connector	3	10%	97%
Wet mate Connector	1	3%	100%

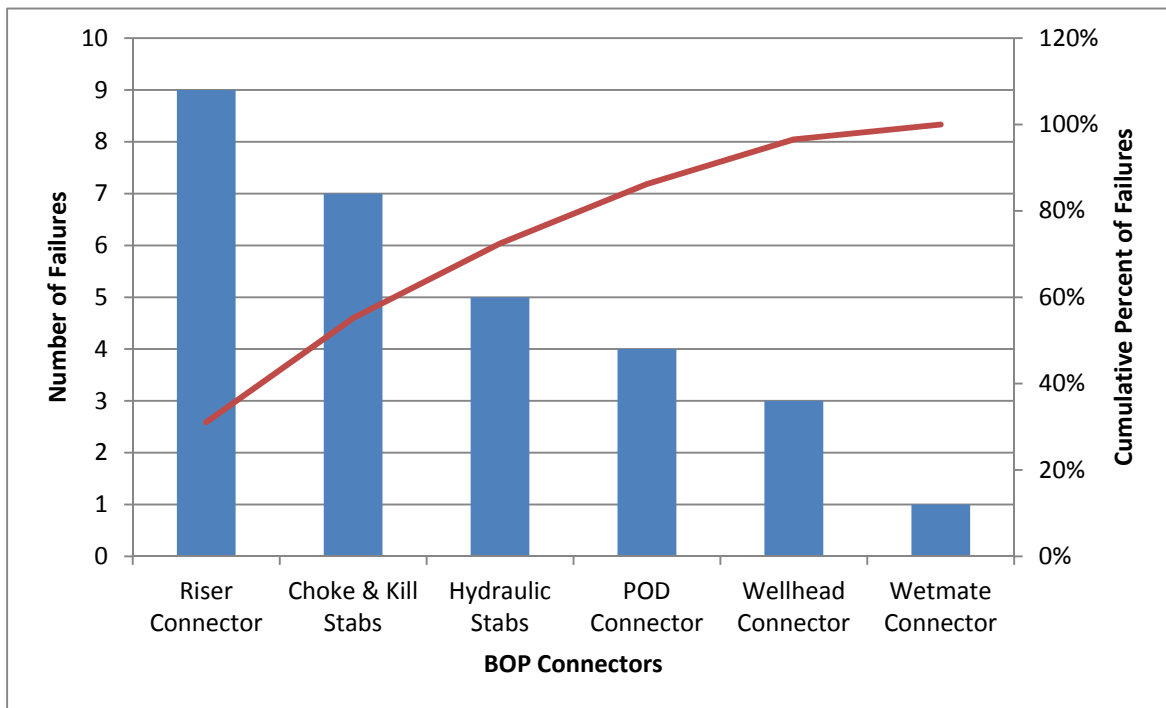


Figure 3-16. Connector Component Failure Pareto Chart

Table 3-21 and Figure 3-17 contain the corresponding information for the C&K valves and lines. The connector data indicate the riser connector, C&K stabs, and hydraulic stabs account for a majority of the connector failures. For the C&K valves and lines, the dominant failures are connections and spools, C&K lines, and C&K valves.

Table 3-21: C&K Valves and Lines Failure Data Summary

C&K Valves and Lines Component	No. of Failures	Percent of Failures, Including Unspecified	Cumulative Percent of Failures, Including Unspecified	Percent of Failures, excluding Unspecified Failures	Cumulative Percent of Failures, excluding Unspecified Failures
Connection & Spool Pieces	9	32%	32%	36%	36%
C&K Lines	6	21%	54%	24%	60%
C&K Valves	5	18%	71%	20%	80%
Jumper Hose or Flex Loop	3	11%	82%	12%	92%
Unspecified	3	11%	93%		
Bleed Valves	2	7%	100%	8%	100%

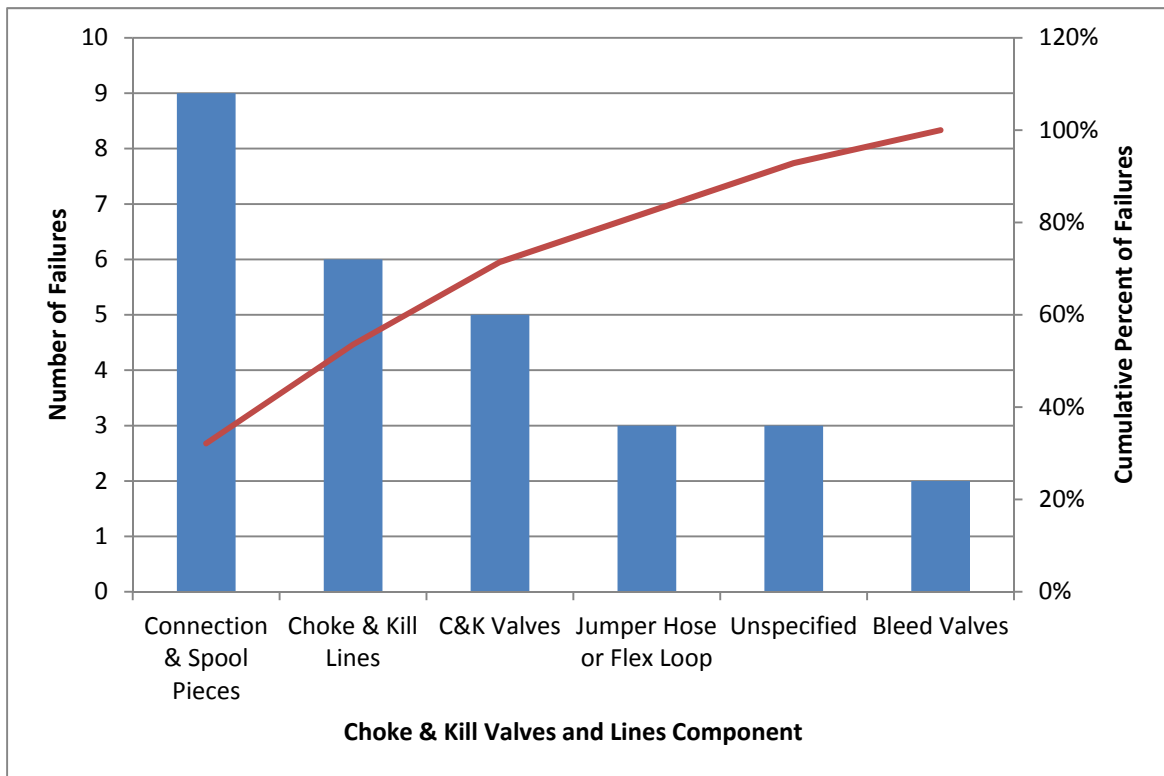


Figure 3-17. C&K Valves and Lines Component Failure Pareto Chart

To complete the analysis of the BOP Stack failures, the failure modes associated with the pipe & test rams, connectors, and C&K valves and lines were identified and analyzed. Table 3-22 and Figure 3-18 provide the failure mode data for the pipe & test rams. The dominant failure modes for pipe & test rams are mechanical failure, substandard workmanship (i.e., human error) and mechanical damage.

Table 3-22 Pipe & Test Rams Failure Mode Data Summary

Pipe & Test Rams Failure Mode	No. of Failures	Percent of Failures, Including Unspecified Failure Mode	Cumulative Percent of Failures, Including Unspecified Failure Mode	Percent of Failures, excluding Unspecified Failure Mode	Cumulative Percent of Failures, excluding Unspecified Failure Mode
Mechanical Failure	9	24%	24%	26%	26%
Substandard Workmanship	9	24%	47%	26%	53%
Mechanical Damage	8	21%	68%	24%	76%
Unspecified	4	11%	79%		
External Leakage	3	8%	87%	9%	85%
Component Out of Specification	2	5%	92%	6%	91%
Plugging	2	5%	97%	6%	97%
Internal Leakage	1	3%	100%	3%	100%

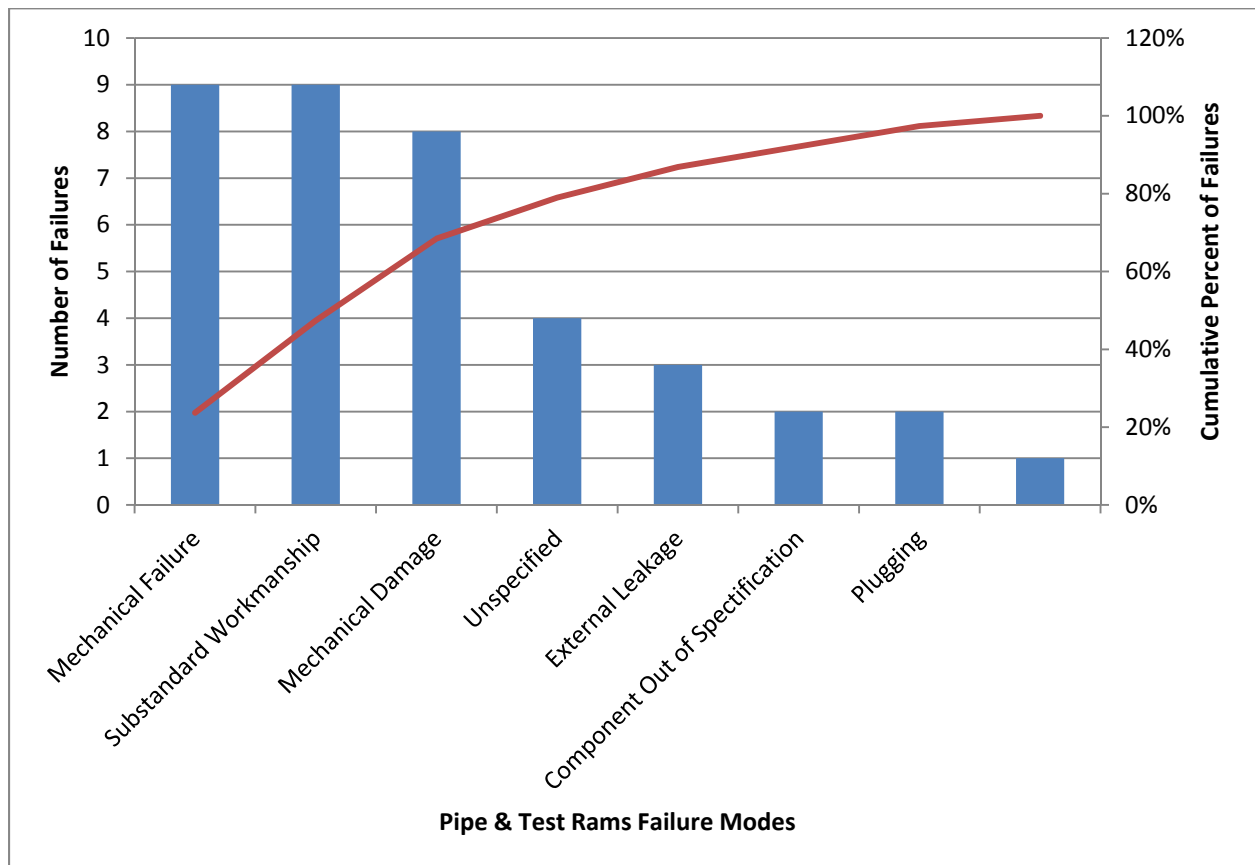


Figure 3-18. Pipe and Test Ram Failure Mode Pareto Chart

Similarly, Table 3-23 and Figure 3-19, and Table 3-24 and Figure 3-20, provide the failure mode data for the connector and C&K valves and lines. For both of these major components, external leakage

and substandard workmanship (i.e., human error) were dominant failures. Additionally for connectors, mechanical damage is a dominant failure mode.

Table 3-23 Connector Failure Mode Data Summary

BOP Connectors Failure Modes	No. of Failures	Percent of Failures, including Unspecified Failure Mode	Cumulative Percent of Failures, including Unspecified Failure Mode	Percent of Failures, excluding Unspecified Failure Mode	Cumulative Percent of Failures, excluding Unspecified Failure Mode
External Leakage	8	28%	28%	31%	31%
Mechanical Damage	8	28%	55%	31%	62%
Substandard Workmanship	5	17%	72%	19%	81%
Mechanical Failure	3	10%	83%	12%	92%
Unspecified	3	10%	93%		
Component Out of Specification	2	7%	100%	8%	100%

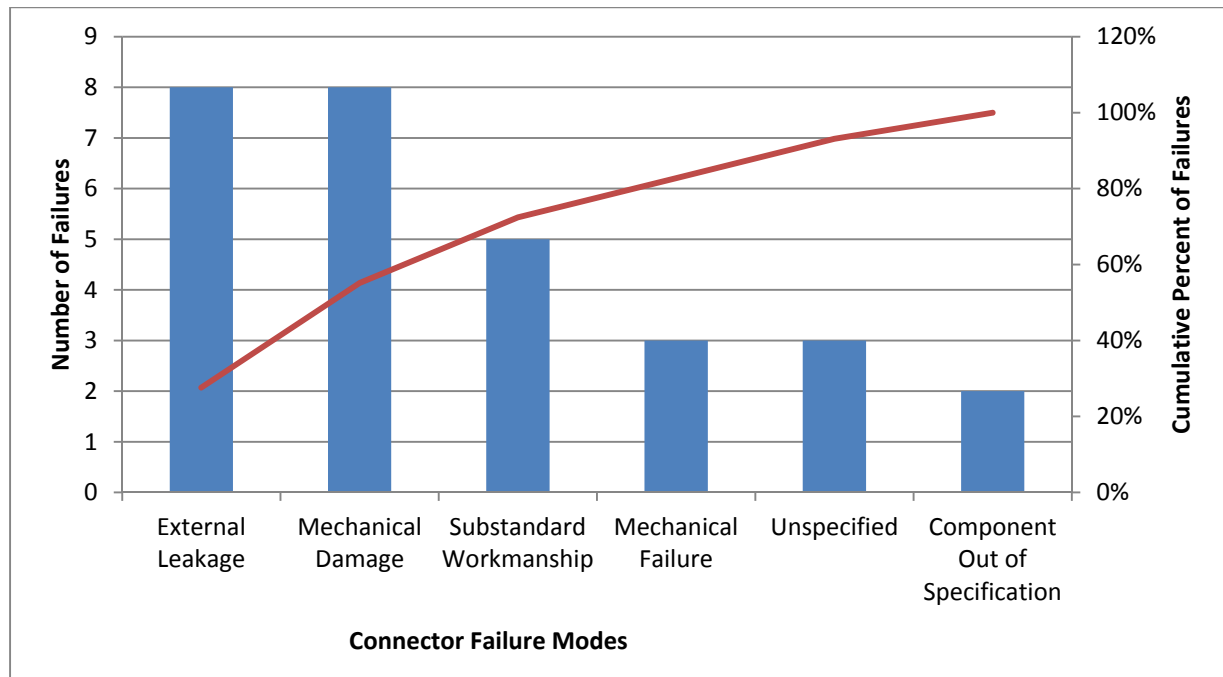


Figure 3-19. Connector Failure Mode Pareto Chart

Table 3-24: Choke & Kill Valves and Lines Failure Mode Data Summary

C&K Valves/Lines Failure Mode	No. of Failures	Percent of Failures, Including Unspecified Failure Mode	Cumulative Percent of Failures, Including Unspecified Failure Mode	Percent of Failures, excluding Unspecified Failure Mode	Cumulative Percent of Failures, excluding Unspecified Failure Mode
External Leakage	12	43%	43%	55%	55%
Unspecified	6	21%	64%		
Substandard Workmanship	5	18%	82%	23%	77%
Mechanical Failure	2	7%	89%	9%	86%
Plugging	1	4%	93%	5%	91%
Component Out of Specification	1	4%	96%	5%	95%
Mechanical Damage	1	4%	100%	5%	100%

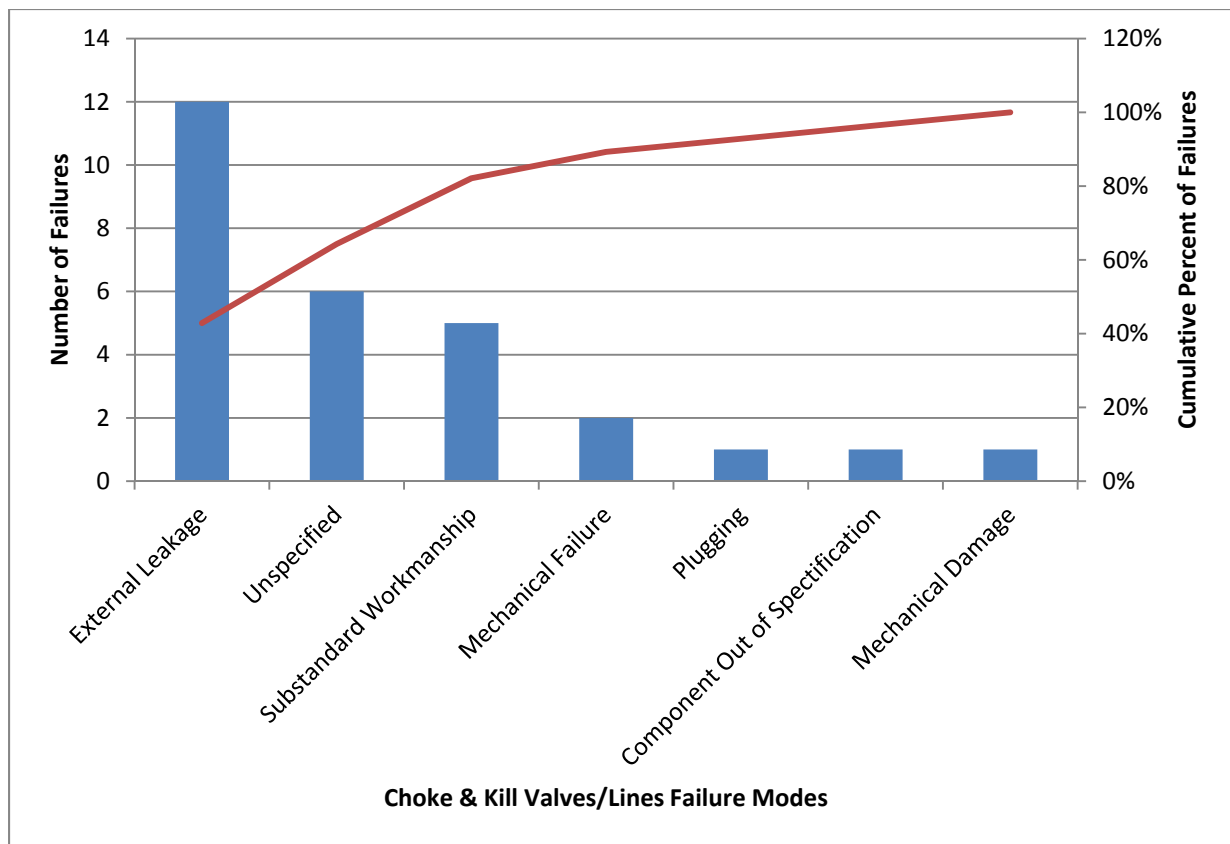


Figure 3-20. C&K Valves and Lines Pareto Chart

3.1.6 Overall BOP and BOP MTTF Estimation

The final data analysis activity involved the calculation of MTTFs for the three BOP systems and then the entire BOP. Table 3-25 summaries the MTTF calculations. Specifically, this table provides the following raw failure event data:

- Total number of failures events in which BOP operating days data were available
- Estimated total BOP operating days associated the failure events

In addition, this table includes the estimated MTTFs (as BOP operating days) and the failure rate (λ) as failures per BOP operating day. Equations 1 and 2 in Section 2.3 are used to calculate these values.

Table 3-25: BOP System Data and MTTFs

	Surface Control System	Subsea Control System	BOP Stack
Number of Failure Events	72	108	86
Total Number of BOP Operating Days	12,783	12,783	12,783
Calculated MTTF, BOP Operating Days	177.5	118.4	148.6
λ (Failures per BOP Day)	0.00563	0.00845	0.00673

Next, the failure rate (λ) for the entire BOP system and MTTF were calculated using equations 3 and 4 provided in Section 2.3. The failure rate for the entire BOP system estimated to be 0.0208 failures per BOP operating day. This results in a MTTF for the entire BOP system of 48.1 BOP operating days. (Note: Because of the level of BOP redundancy, these MTTF estimates are not reflective of MTTF for failures resulting in a BOP system failure, but rather the numbers are reflective of MTTF for failures requiring a repair action.) As a comparison, the Sintef reports Phase I DW and Phase II DW calculated an overall MTTFs of 23.1 and 34.3 BOP days, respectively.

These results support that subsea control system fails more often than the BOP Stack (i.e., as evident by the lower MTTF) and is the most frequent contributor to the overall BOP failures. In addition, all systems have a large spread in the minimum and maximum BOP operating days. When reviewing these analysis results, it should be noted these results are based on the 266 failure events, which included BOP operating day information (i.e., BOP operating day information or estimates were not available for all 430 failure events).

3.2 MAINTENANCE TASK DATA ANALYSIS

Maintenance task data analysis involved the evaluation of more than 88,000 maintenance task records. The objectives of this analysis effort were to (1) assess the ratio of corrective maintenance to proactive maintenance and (2) evaluate the effectiveness of maintenance tasks in detecting failures.

As described in Section 2 of this report, the initial analysis activities involved reviewing the maintenance task records to identify and remove records that (1) were duplicated, (2) were not

directly related to the task execution (e.g., ordering of parts, adjusting store inventory), and/or (3) merely documented information regarding equipment or a maintenance-related activity. This reduced the number of maintenance task records to just over 61,000 records. The maintenance task classification provided by IPs were reviewed and as appropriate the tasks were reclassified in accordance the maintenance task categories defined in this report. This information was then used to analyze and trend maintenance tasks. The maintenance task data analysis results are presented in the following sections:

- Maintenance Task Data Summary
- Maintenance Task Data Comparison
- Maintenance Task Type Analysis and Results
- Maintenance Task Effectiveness Analysis and Results

3.2.1 Maintenance Task Data Summary

The maintenance task data indicates a high percentage of proactive maintenance (more than 95% of all maintenance tasks) being performed on BOP system and correspondingly there is a low percentage of the maintenance tasks (less than 5%) which are related to correcting failed or failing BOP components.

In terms of the proactive maintenance being performed, a high percentage of scheduled tests and scheduled inspections are performed on BOP components, 59% and 28% respectively. The level of planned maintenance (i.e., time-based intrusive maintenance) overall is low (about 6.6%). However, the percentage of PdM performed is low at about 1.2%.

While the overall percentage of planned maintenance is low, there are several BOP major components in which the percentage of planned maintenance appears to be high. In addition, there are indications that increasing the percentage of planned maintenance correlates to an increased percentage of corrective maintenance and increased number of failures for these major BOP components.

In addition to the correlation of planned maintenance to corrective maintenance and number of failures, the study investigated task effectiveness by evaluating how failures were detected (i.e., detected via proactive maintenance or detected via operations) The result of this evaluation is that a significant number of BOP system failures are detected during operations. However, the scheduled tests and scheduled inspections combined did detect as many failures as being detected during operation. This is a good indication that scheduled tests and inspections are being effective. However, the failure event analysis indicate that significant number of failures are due to substandard workmanship, out of specification component, and processing errors and these failures are typically detected via operations.

3.2.2 Maintenance Task Data Comparison

This section provides comparison of the maintenance task data to evaluate the potential impact of the maintenance task re-categorizations and to assess the impact of analyzing the maintenance tasks by

number of tasks versus labor hours. Because the IPs classify maintenance tasks using different categories and task definitions, this study wanted to evaluate the BOP maintenance task using the following commonly used maintenance task categories.

- **Corrective Maintenance** – A maintenance event to repair, restore or replace a failing or failed component
- **Proactive Maintenance** – A scheduled maintenance event, performed to detect or prevent a component from failing, and is divided into the following four subcategories:
 - Planned Maintenance – A time-based activity designed to prevent component failure by maintaining/restoring the component’s reliability through servicing and/or repairing or replacing specific components
 - Predictive Maintenance (PdM) – An activity designed to detect the onset of failure by measuring and analyzing of key component operating or performance parameters related to the failure mode of interest
 - Scheduled Inspection – A scheduled activity design to check or verify the condition of a component, usually taken to be a visual inspection or some type of non-destructive testing
 - Scheduled Test – A scheduled activity designed to detect the condition related to the onset of failure or hidden failure of a BOP component, usually via a functional or performance test

To help ensure the re-categorization process did not introduce a significant bias in the study results, the number of maintenance tasks, based on the IP task classification, was compared to the number of re-categorized tasks maintenance tasks. Figure 3-21 provides a pie chart based on the IP original task classifications, which shows almost 6% the tasks were classified as corrective maintenance and about 94% of the tasks as proactive maintenance.

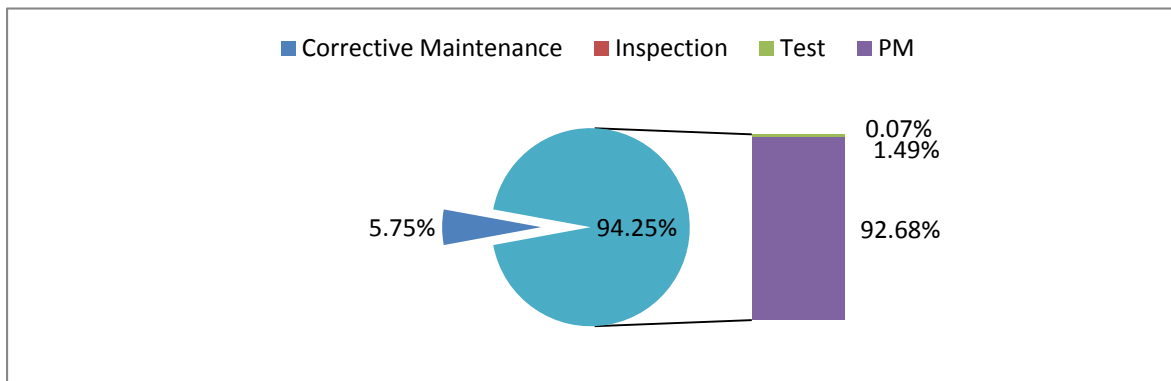


Figure 3-21. Maintenance Task Classification by IPs

Figure 3-22 provides a pie chart of maintenance tasks after re-categorization, which shows 4.5% of the tasks were classified as corrective maintenance and 95.5% of the tasks were classified as proactive maintenance. In comparing the two pie charts, there is good agreement between the IP task classifications and re-categorization of the maintenance tasks. However, the deviations in the task

classifications seem to only be significant when comparing the classifications of the proactive subcategories (i.e., planned maintenance, PdM, scheduled inspection, or scheduled test). This primarily results because one IP only uses one maintenance task classification (i.e., preventive maintenance [PM]) for all proactive tasks; even though, when the records are reviewed, the tasks could be categorized as outlined in this study. The result is the task re-categorization, which was done to allow more detailed data analysis, appears to be appropriate for use in this study.

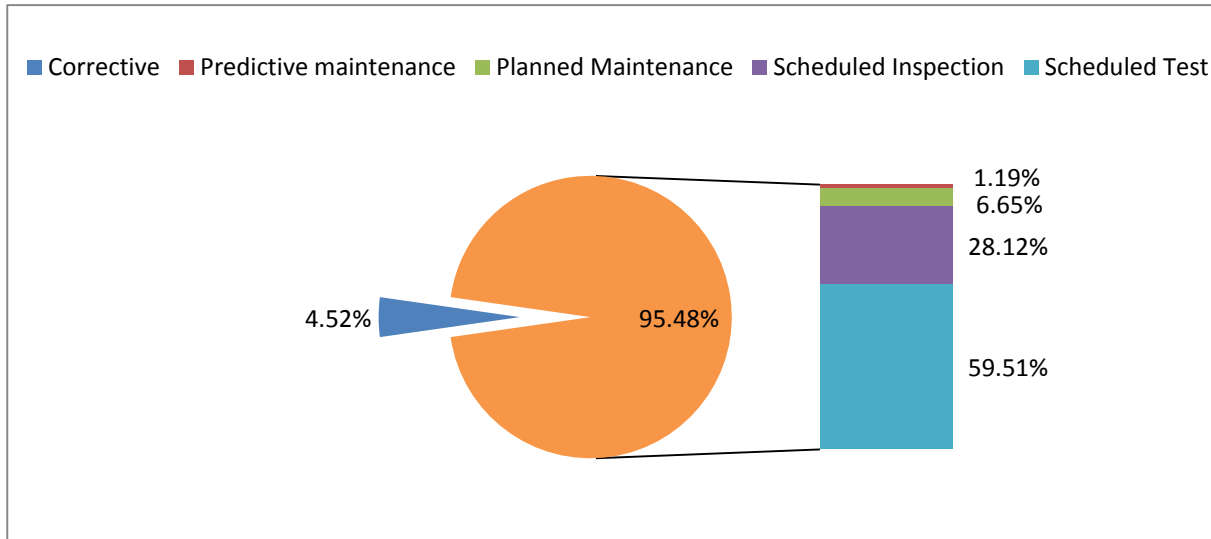


Figure 3-22. Maintenance Task Classification after Re-categorization

Next, a comparison of the maintenance tasks by number of completed tasks and labor hours was performed. This comparison is needed because not all maintenance task data included labor which would have reduced the number of data points if the analyses were based solely on labor hours. In performing this comparison, the amount of proactive maintenance and corrective maintenance performed based on number of completed tasks and recorded maintenance hours were compared by BOP major component. Figures 3-23 and 3-24 provide the proactive and corrective maintenance performed on each major component by number of tasks and recorded maintenance hours, respectively. (Note: The component order in Figure 3-24 was not changed to allow direct comparison with Figure 3-23.) These two figures indicate four of the five same major components as those receiving the most maintenance on an evaluation of either the number of maintenance tasks or the number of maintenance hours. In addition, the relative ratios of two tasks (either by number of tasks or maintenance hours) are nearly the same for most component comparisons. Based on this comparison, it was decided the maintenance task analysis would be based on the number of maintenance tasks to accommodate a larger data population.

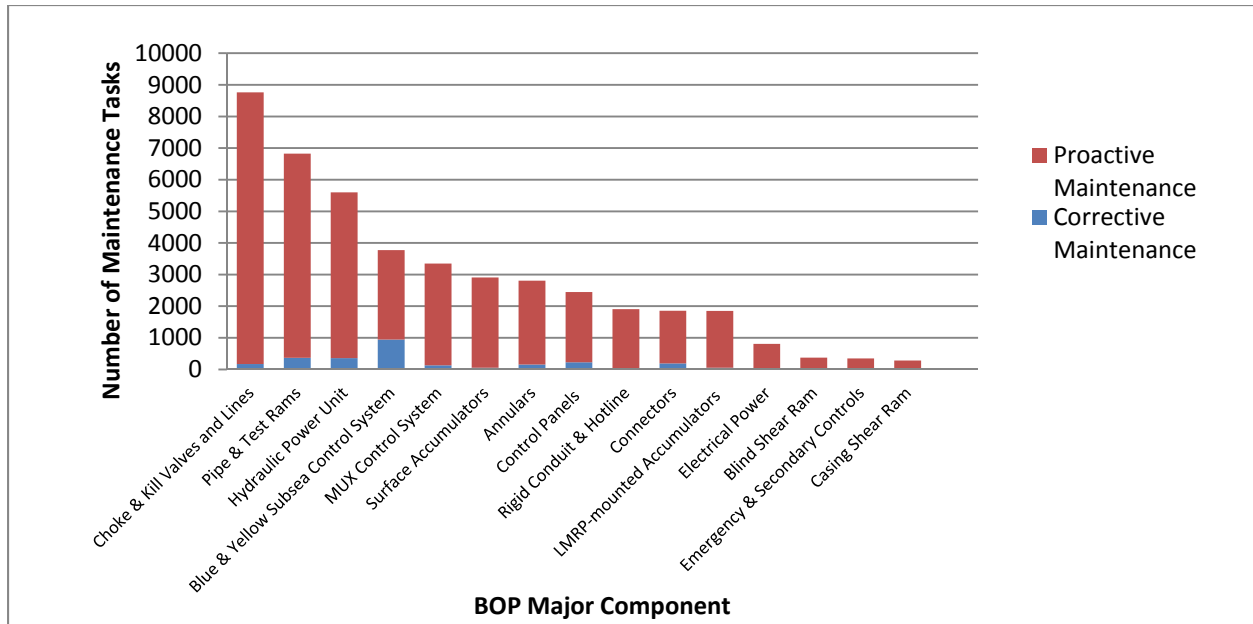


Figure 3-23. Number of Completed Maintenance Tasks by Major Component

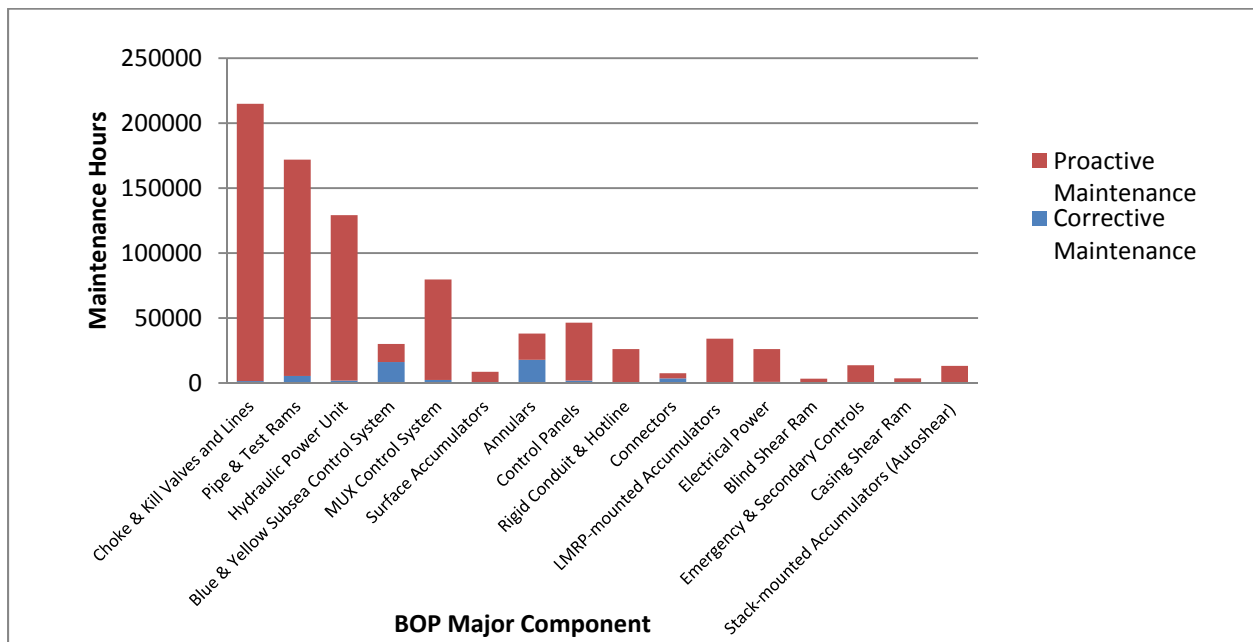


Figure 3-24. Maintenance Hours for Completed Maintenance Tasks by Major Component

3.2.3 Maintenance Task Type Analysis and Results Summary

The initial analysis of the maintenance task data included an evaluation of the corrective maintenance and proactive maintenance, including the types of the proactive maintenance performed beginning with overall BOP and then each major BOP component. As shown in Figure 3-25 (and repeated as Figure 3-22), 4.5% of the BOP system maintenance tasks performed are related to correcting failed or failing components (i.e., corrective maintenance) and more than 95% of the BOP maintenance

tasks performed are related to detecting or preventing failures. In general, this is a good ratio of the proactive or corrective maintenance.

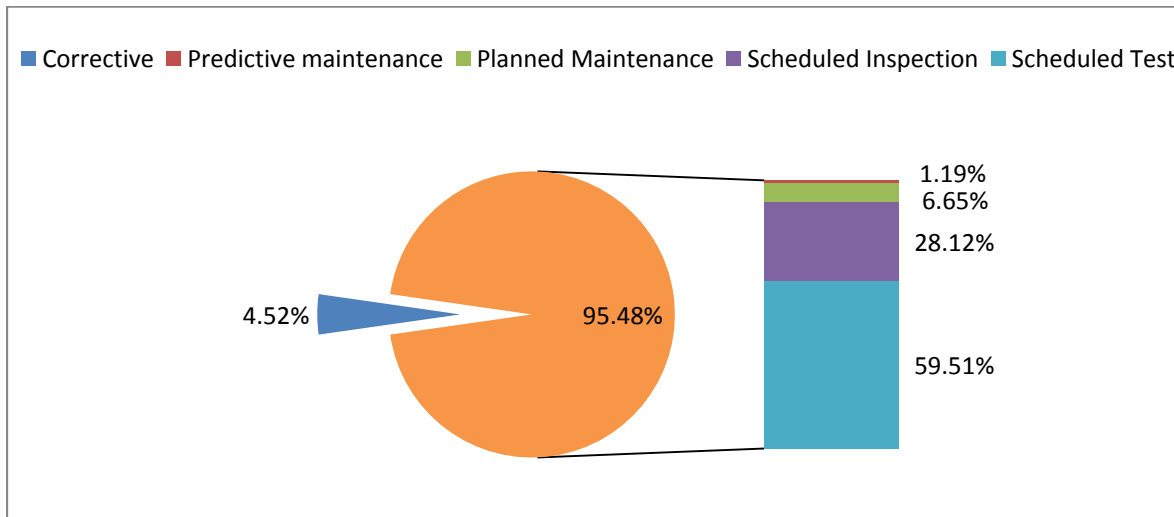


Figure 3-25. Overall BOP Maintenance Task Type

In analyzing the proactive maintenance tasks, it is seen that nearly 60% of the BOP system maintenance tasks are scheduled tests, another 28% are scheduled inspections, more than 6 % are planned maintenance (e.g., intrusive rebuilding tasks), and just over 1% are PdM. These overall results show a high percentage of scheduled testing and inspections and reasonably low percentage of planned maintenance, which are good trends. However, the percentage of PdM is a lower percentage than commonly, accepted as a good maintenance practice.

Next, the amount of corrective and proactive maintenance performed on each major component was evaluated, with the results provided in Figure 3-26. The results indicate multi-component category as having the highest number of tasks, which is due the high number of required scheduled tests involving multiple BOP components (e.g., functional testing involving most all BOP systems, pressure tests). These results indicate the BOP major component with the highest number of maintenance tasks is the C&K valves and lines. This result may occur because some of the IPs identify each C&K valve as separate maintainable asset in their CMMS, which means the number of proactive tasks may be higher because of the number of C&K valves installed.

However, these results show that four of the top five most frequently failed major components (i.e., Blue & Yellow Subsea Control system, Mux Control System, Pipe & Test Rams, and C&K Valves and Lines) are in the top five of the highest maintained BOP major components (excluding Multiple Components), indicating a higher level of maintenance on these components. The other most frequently failed major component (i.e., Connectors) still receives significant degree of maintenance, but not as high as the other four major components. However, the major components with the highest number of failures do not necessarily correlate to the highest number of maintenance tasks performed. The significance of this trend (if any at all) is not readily apparent in that

components receiving higher levels of maintenance have a higher number of failures than components with lower levels of maintenance. In addition, the two components with highest number of failures receive relatively high levels of maintenance, but not as high of levels as some components.

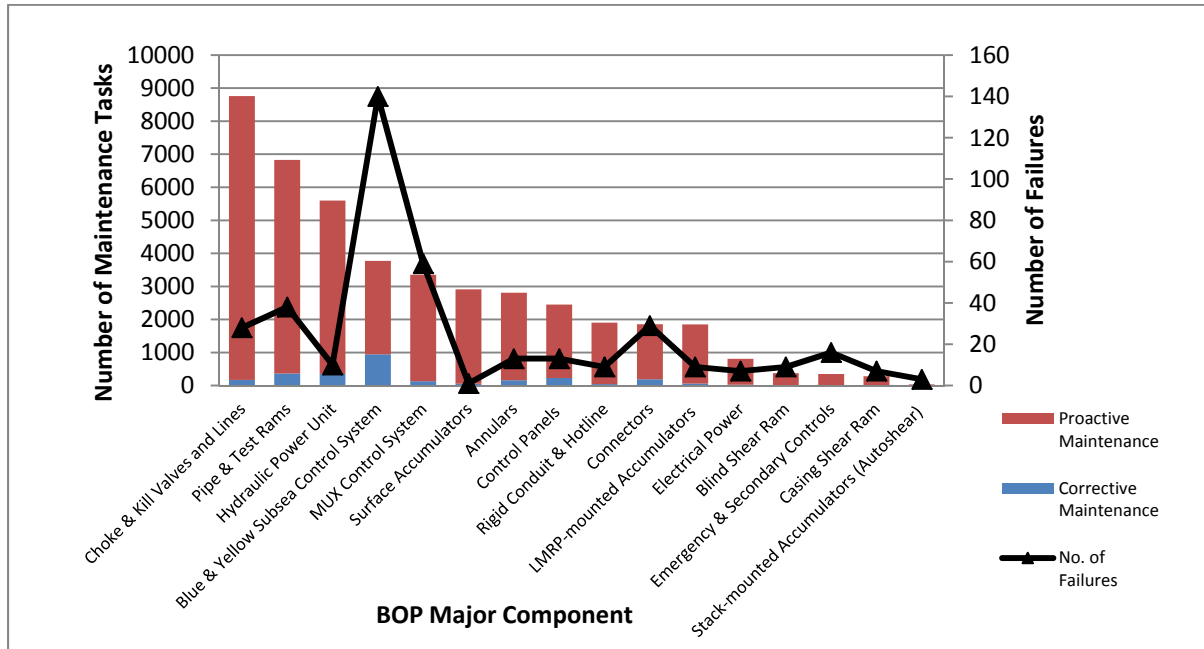


Figure 3-26. Number of Maintenance Tasks Completed by BOP Major Component

The next level of analysis involved an evaluation of the percentage of corrective maintenance and proactive (by proactive maintenance task type) for each major component. Figure 3-27 provides these results on a normalized basis (i.e., 100% task scale). These results show the relative percentage of the corrective maintenance and the four proactive maintenance task types.

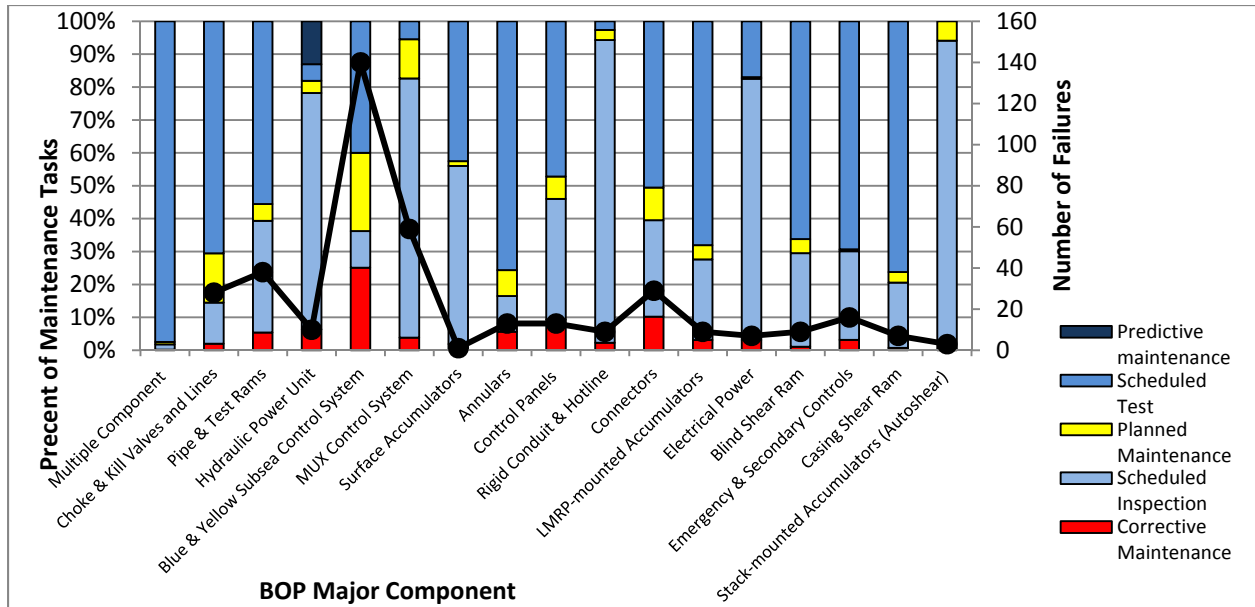


Figure 3-27. Percent of Maintenance Tasks by BOP Major Component

In reviewing these results, it is noted that PdM is only applied to Hydraulic Power unit. Also, the results indicate the Blue & Yellow Subsea Control system, Control Panels, and Connectors require more than 10% corrective maintenance, which is twice the corrective maintenance average for the overall BOP. In addition, Pipe & Test Rams, HPU, and Annulars corrective maintenance percentage is greater than 5%, which is the near the corrective maintenance average for the BOP. In addition, the number of failures for these major components are, in general, higher (only MUX control system and Emergency & Secondary Controls have equivalent number of failures) than most other major BOP components. Another trend in the data shows that as the percentage of planned maintenance for a component increases the percentages of corrective maintenance and the numbers of failures seem to increase. This trend will be discussed more in the next report section.

3.2.4 Maintenance Task Effectiveness Analysis and Results

To evaluate maintenance task effectiveness, the analysis involved evaluation of (1) any correlation between proactive maintenance tasks and corrective maintenance and the number of failures and (2) the means in which reported failures are discovered (i.e., either during operation or performance of a proactive maintenance task). To evaluate any correlation between proactive maintenance tasks, corrective maintenance and number of failures, a series of scatter plots were generated to test a relationship between the following data:

- Percent of Corrective Maintenance Performed to Percent of Planned Maintenance
- Percent of Corrective Maintenance Performed to Percent of Predictive Maintenance
- Percent of Corrective Maintenance Performed to Percent of Scheduled Inspections
- Percent of Corrective Maintenance Performed to Percent of Scheduled Tests
- Number of Failures to Percent of Planned Maintenance
- Number of Failures to Percent of Predictive Maintenance

- Number of Failures to Percent of Scheduled Inspections
- Number of Failures to Percent of Scheduled Tests

These plots were generated based on Major Component and rig maintenance task and failure data. A linear trend line was fitted to each scatter plot and a corresponding correlation coefficient (i.e., R^2) was calculated. The only scatter plots showing strong correlations were the percentage corrective and number of failures relative to percentage of planned maintenance for the major components. Figures 3-28 and 3-29 provide these results and Table 3-26 provides the data and symbol for these plots. Both of these plots indicate a strong correlation between increased percentages of planned maintenance on major components with increased (1) percentages of corrective maintenance (on the respective major components) and (2) number of failures (of the respective major component). While these figures appear to imply increased planned maintenance results in increased corrective maintenance and number of failures, it is possible that the planned maintenance currently performed has reduced the percentages of corrective maintenance and number of failures when compared to the percentages and numbers prior to implementation of planned maintenance. To confirm any conclusion on this issue, it is recommended that further investigation and analysis be performed. (Note: During the generation of these scatter diagrams it was found that the correlation coefficient was significantly reduced by removing the one data point with the highest percentage of planned maintenance. However, the analysis team did not uncover technical justification to indicate this point is an outlier.)

Table 3-26: Scatter Plot Data and Symbol Legend













BOP Major Component	Figures 3-28 & 3-29 Symbol Legend	Percent Corrective Maintenance	Number of Failures	Percent Planned Maintenance
Choke & Kill Valves and Lines		2.00%	28	15.26%
Pipe & Test Rams		5.67%	38	5.40%
Hydraulic Power Unit		6.79%	10	3.95%
Blue & Yellow Subsea Control System		33.62%	140	31.91%
MUX Control System		4.02%	59	12.44%
Surface Accumulators		1.93%	1	1.51%
Annulars		5.96%	13	8.34%
Control Panels		10.35%	13	7.55%
Rigid Conduit & Hotline		2.31%	9	3.17%
Connectors		11.37%	29	11.06%
LMRP-mounted Accumulators		3.18%	9	4.51%
Electrical Power		3.20%	7	0.51%

Table 3-26: Scatter Plot Data and Symbol Legend

BOP Major Component	Figures 3-28 & 3-29 Symbol Legend	Percent Corrective Maintenance	Number of Failures	Percent Planned Maintenance
Blind Shear Ram	×	1.08%	9	4.34%
Emergency & Secondary Controls	✕	3.25%	16	0.59%
Casing Shear Ram	●	0.71%	7	3.21%
Stack-mounted Accumulators (Autoshear)	+	0.00%	3	5.88%

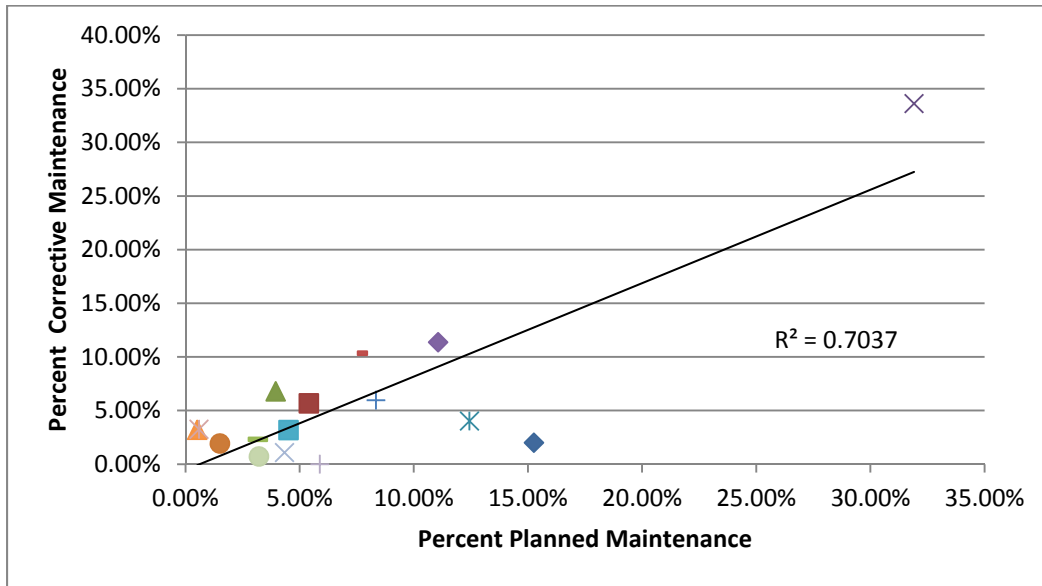


Figure 3-28. Scatter Plot of Percent Corrective Maintenance versus Percent Planned Maintenance for BOP Major Components

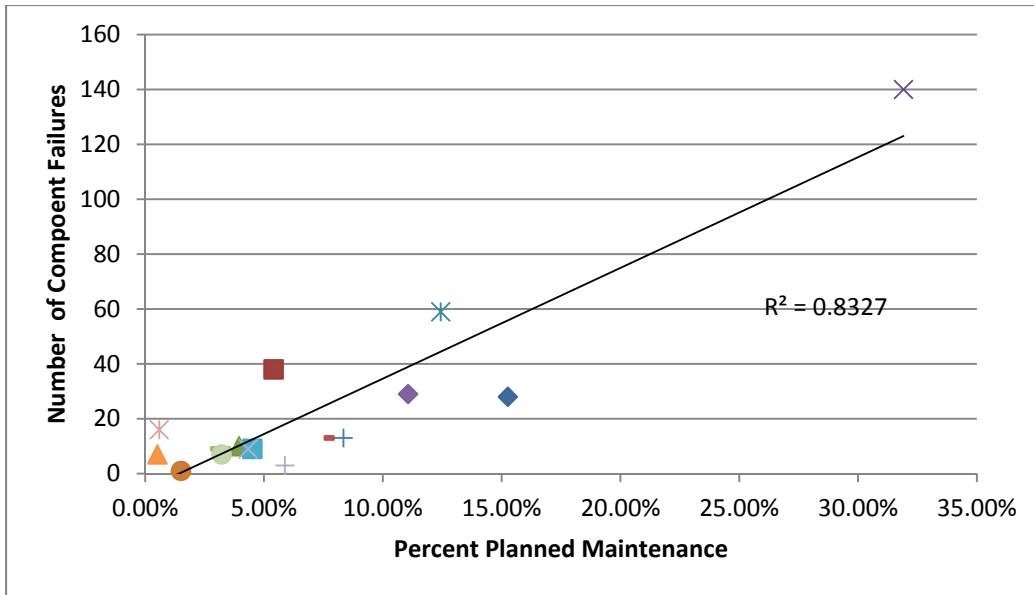


Figure 3-29. Scatter Plot of Number of Component Failures versus Percent Planned Maintenance for BOP Major Components

The second part of the maintenance task effectiveness analysis was to determine whether failures are being detected during maintenance tasks or during operations. (Note: Failures detected during operations is used to indicate failures discovered while the BOP is latched on the well and not detected by test, inspection, or other type of proactive maintenance activity. This terminology is not meant to exclusively indicate failures detected during active operation of a BOP system function.) For this evaluation, the failure event data was used. Specifically, this evaluation involved determining how the failures for the top seven BOP system failure modes were discovered. The evaluation consisted of determining the percentage of failures discovered via proactive maintenance tasks (i.e., planned maintenance, predictive maintenance, scheduled inspection or scheduled test) and the percentage of failures discovered during operation for the most frequent failure modes for the overall BOP system: External Leakage, Mechanical Damage, Substandard Workmanship, Hardware Failure, Out of Specification Component, and Processing Error. Figure 3-30 contains a series of pie charts with the respective percentages.

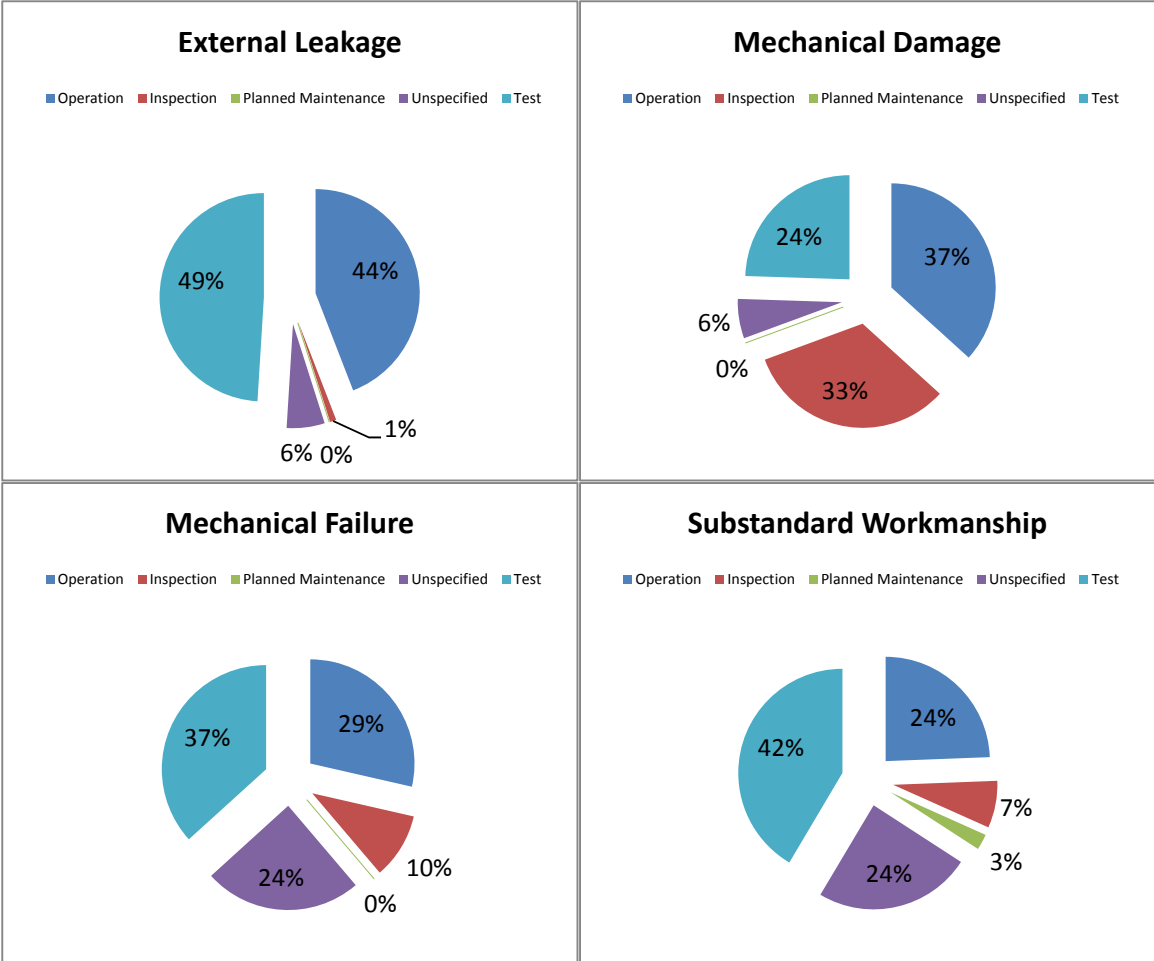


Figure 3-30. Percent of BOP Events Detected By Operations and Maintenance Tasks for the Top BOP Failure Modes (continued on next page)

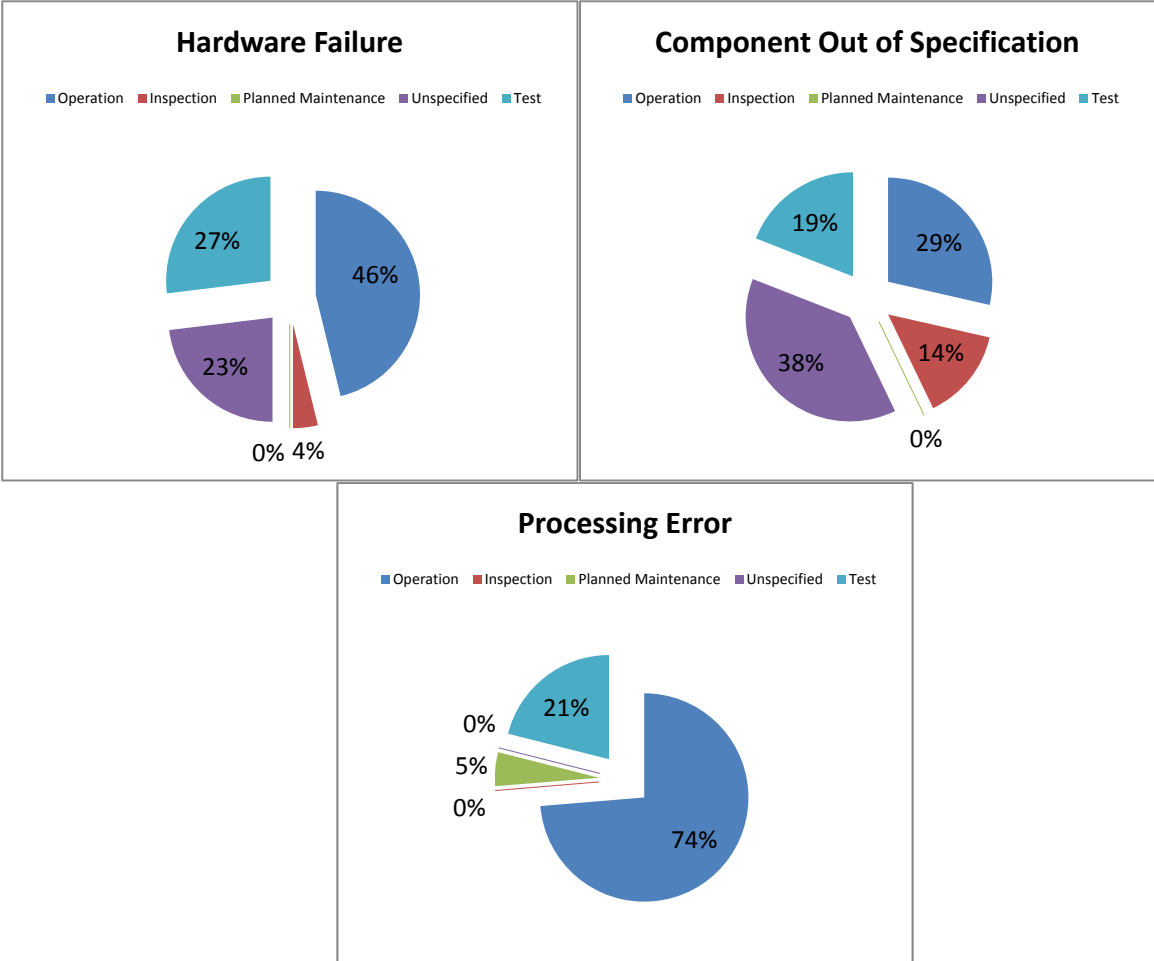


Figure 3-30 (continuation). Percent of BOP Events Detected By Operations and Maintenance Tasks for the Top BOP Failure Modes

These results appear to indicate a significant number of failures are being discovered via operation versus during maintenance tasks. Specifically, operations is a most frequent method in which failures due to mechanical damage, mechanical failure, and hardware failures are discovered. Likewise, external leakage failures are discovered 44% of the time during operations. However for all four of these failure modes, a large percentage of failures are discovered via the scheduled inspection and tests, which is a positive indication that the scheduled inspections and tests are identifying a significant number of failures resulting from these failure modes.

The failure mode data for substandard workmanship (i.e., human error) and out of specification component both include a significant percentage of failures in which the means of failure detection was not identifiable in the failure data. However, these two failure modes are typically best addressed by quality assurance during the performance of other maintenance tasks (e.g., corrective maintenance, planned maintenance) If there is a lack of maintenance quality assurance, this could result in a high percentage of failures being discovered during operations because the failure may occur prior to the performance of a proactive maintenance task. Similarly, 74% of processing error failures are discovered during operations. This is somewhat explainable since it is expected that

these errors would be most likely be introduced during computer system software or hardware changes. Thus resulting in the failure being discovered before a proactive task is performed. These three failure modes appear to be an indication of a need for increased quality assurance during the performance of certain maintenance tasks.

3.3 OBSERVATIONS AND COMMENTS REGARDING THE DATA

In compiling and analyzing the failure and maintenance event data, the report authors observed certain trends and aspects of the data, which need to be considered when evaluating this report's results. The following are the observations with comments regarding the potential impact on this report's results and conclusions.

Other than as noted below, the failure and maintenance data provided by the IPs are assumed to be accurate and complete within common industry practices. However, a reader of this report must recognize it is likely that some details of the provided events, included in the data set, may contain inaccuracies.

The maintenance event data for one drilling contractor was extracted from the contractor's downtime reports. The concern is corrective maintenance events and proactive tasks performed that did not result in downtime are not likely included in the data set. However, this is believed to have minimal impact since this drilling contractor's maintenance event data comprised less than 2% of the maintenance event data.

The type and quality of the data recorded is very inconsistent from drilling contractor to drilling contractor and from OEM to OEM. The concern is that sufficient quality data needed to trend equipment failures and maintenance events may not have been obtainable.

There are no industry accepted equipment hierarchy and/or failure modes/codes to record BOP-related failure and maintenance data. The concern is the equipment and maintenance categorization performed during this analysis are subject to the analyst interpretation of the available data.

Even though the analysts recognize that maintenance events can be associated with multiple BOP components or involve more than one type of proactive maintenance activity, when possible a single maintenance event was assigned to specific BOP major component and one type of proactive maintenance tasks. To minimize this impact on the results, these assignments have been consistently applied across the data set. The concern is some maintenance event data may be associated with different components and other types of maintenance tasks than applied by some IPs.

4.0 CONCLUDING REMARKS

The analysis of 430 failure events and more than 61,000 performed maintenance tasks provides valuable insight and information for both the FMECAs and RAM studies. Specifically, these results have identified the following major components as the dominant BOP failures, which account for more than 75% of the BOP system failures:

1. Blue & Yellow Subsea Control System (Subsea Control System) – 36%
2. MUX Control System (Surface Control Systems) – 15%
3. Pipe & Test Rams (BOP Stack) – 10%
4. Connectors* (BOP Stack) – 7%
5. C&K Valves and Lines (BOP Stack) – 7%

*This “Connectors” category contains all subsea connector including the wellhead and LMRP connectors, as well as other connectors such as stabs and wet mate connector. If the connectors are subdivided, the wellhead, LMRP, and riser connector account for 3% of the BOP failures (excluding unspecified failures).

Similarly, the following are the dominant failure modes and they account for more than 80% of the BOP system failures. Interestingly, this list of top failure modes include substandard workmanship and component out of specification, which are typically not detected or prevented by common proactive activities and may be the result of the performance of other maintenance activities (e.g., corrective maintenance, planned maintenance)

1. External Leakage
2. Mechanical Damage
3. Mechanical Failure
4. Substandard Workmanship (i.e., human error)
5. Hardware Failure (electrical/electronic component)
6. Component Out of Specification
7. Processing Error

Since these major components and failure modes account for 75% and 80% of the BOP system failures respectively, this will allow the project teams to focus on evaluating the MIT activities associated with these items.

The last failure event analysis estimated the MTTF for the overall BOP system and the three BOP systems, based on the provided failure data. Specifically, this analysis estimated the MTTF values to be the following:

- Surface Control System – 177.5 BOP operating days
- Subsea Control System – 118.4 BOP operating days
- BOP Stack – 148.6 BOP operating days
- Overall BOP – 48.1 BOP operating days

These overall BOP MTTF result compares favorably with Sintef Phase I DW and Phase II DW report results. These values and other component-level MTTF values will be used in the RAM models, which will provide updated MTTF values based on statistical modeling.

In terms of the maintenance task analyses, the analysis results indicate a high level of proactive maintenance being performed on BOP system and less than 5% of maintenance activities related to correcting failed or failing components (i.e., corrective maintenance). However, a lower percentage of PdM activities are being performed than would be anticipated. This is likely due to limitation of common PdM techniques, but further investigation into expanded use of PdM is recommended.

In addition, the maintenance task analyses indicated a strong correlation between increased corrective maintenance and number of component failures with increased percentages of planned maintenance. This type of trend has been noted in maintenance studies in other industries (e.g., aviation, maritime). However, while this trend appears to imply increasing planned maintenance increases failures, it is also possible that the implementation of planned maintenance has actually reduced the number of failures (as compared to the number of failures with less planned maintenance). Therefore, further investigation to this potential correlation is recommended.

Finally, a significant percentage (more than 25%) of the most frequently occurring failure mode failures are being discovered during operation (versus during proactive maintenance). This may be an indication of a need to change or improve current proactive maintenance tasks designed to detect or prevent these specific failure modes. As seen in other industries (e.g., aviation), the application of more advanced reliability engineering analyses, such as reliability-centered maintenance, have provided technically robust means to evaluate and determine improved failure management strategies for these situations. This topic may also warrant further investigation and studies.

APPENDIX A – OVERVIEW OF TRIMM

To efficiently analyze the volume of failure and maintenance data collected from the industry partners, ABS Consulting developed an integrated database management software system. The software is now in a first release phase. Tool for Reliability, Inspection and Maintenance Management (TRIMM) is an ongoing software development effort.

The three major functional areas in TRIMM are:

1. Failure reporting,
2. Maintenance task reporting, and
3. Data analysis.

The primary objectives of TRIMM are to provide:

- State of the art failure and maintenance data analysis capability for this project to better organize the failure and maintenance history of BOP equipment, and
- A model to demonstrate how Blowout Preventers (BOP) failure and maintenance data could be captured and used for future analysis and reliability improvement.

The current version of TRIMM was developed and tested successfully on a localized database. The software is designed to support easy data entry. One design feature is that each rig will have a lock on only records that belong to that rig. Another feature that was implemented with regards to data retention is an automated or command driven backup option, such that the database is regularly backed up. In case of any failure or crash the system can be restored with minimal data loss.

Analysis and Reports:

TRIMM is currently capable of generating reports related to failure and maintenance analysis. Work is in progress to include the analysis related to MTTF and mean time to repair calculations. It is possible to include another type of data analysis as per the future requirements. Another feature that will be included will be a search feature and downtime report generation based on specific rig, subsea system or subsystem level.

***SURVEY OF BLOWOUT PREVENTER (BOP)
 MAINTENANCE, INSPECTION, AND TEST (MIT) ACTIVITIES AND
 MIT MANAGEMENT SYSTEMS FOR
 THE BUREAU OF SAFETY AND ENVIRONMENTAL ENFORCEMENT***

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Report No.	Revision	Purpose of Revision	Date

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Original Equipment Manufacturer (2)

Industry Participants (IP)

DC-1, DC-2, DC-3
OEM-1, OEM-2

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SUMMARY

At the operational stage of an asset's life cycle, asset maintenance and reliability practices are mostly comprised of (1) maintenance, inspection, and test (MIT) activities (i.e., proactive maintenance) and (2) maintenance and reliability management systems. In regards to this project, this report contains a study of these activities and represents one portion of deliverable F associated with Tasks 6.1.1, 6.1.2 and 6.1.3, as outlined in the contract.

The objectives of this report are to identify (1) key MIT activities and (2) some of the key maintenance and reliability management system practices impacting Blowout Preventer (BOP) reliability performance.

This report summarizes the MIT activities (and their associated frequencies) (1) contained in applicable, worldwide regulations, and industry standards and recommended practices and (2) included in Industry Participant (IP) MIT plans for BOPs operating in the Gulf of Mexico (GoM). In addition, the report provides the results from reliability and maintenance management system survey. Finally, the report provides a comparison of the MIT activities and practices and BOP performance.

Section 2 outlines and compares the MIT activities identified in applicable BOP regulations and industry standards and recommended practices. This section identifies the MIT activities and associated frequencies included in the reviewed regulations and industry standards and recommended practices. This effort included a review of the following regulations and industry standards and recommended practices:

- *Blowout Prevention in California: Equipment Selection and Testing, Tenth Edition*, California Department of Conservation, Division of Oil, Gas, and Geothermal Resources
- *Consolidated Newfoundland and Labrador Regulation 1150/96, Petroleum Drilling Regulations under the Petroleum and Natural Gas Act*, St. John's, Newfoundland, and Labrador, Canada.
- *Drilling Blowout Prevention Requirements and Procedures*, Directive 36, Alberta Energy and Utilities Board.
- *Guideline for Certification of Blow-Out Preventers*, Edition 2011, GL Noble Denton.
- *Guidelines Regarding the Facilities Regulation*, Petroleum Safety Authority Norway, 20.12.2007
- *Oil and Gas and Sulphur Operations in the Outer Continental Shelf*, Code of Federal Regulations (CFR), Part 250.

- *Recommended Practices for Blowout Prevention Equipment Systems for Drilling Wells*, Third Edition, American Petroleum Institute (API) Recommended Practice (RP) 53. *Recommended Practices for Blowout Prevention Equipment Systems for Drilling Wells*, Fourth Edition, API RP 53.
- *Recommended Practice for Well Control Operations*, Second Edition, API RP 59.
- *Well Integrity in Drilling and Well Operations*, Rev.3, Norsok Standard D-10.
- *Specification for Choke and Kill Systems*, First Edition, API Specification 16C.
- *Specification for Drilling Well Control Equipment and Control Systems for Diverter Equipment*, API Specification 16D.
- *Specification for Drill-through Equipment*, Third Edition, API Specification 16A.
- *Specification for Wellhead and Christmas Tree Equipment*, Nineteenth Edition, ANSI/API Specification 6A.

Section 3 outlines the survey of the current MIT activities included in drilling contractors' MIT plans and original equipment manufacturers' (OEMs) installation, operations, and maintenance (IOM) manuals. The effort resulted in the compilation of typical MIT activities and associated frequencies employed to maintain BOPs operating in the GoM. This survey lists more than 300 BOP MIT activities. Appendix B of this report contains the complete survey results.

Section 4 of this report outlines the MIT reliability and maintenance management system survey approach and summarizes its results. The survey inquired about MIT management system practices in six key areas: Failure Elimination, Computerized Maintenance Management System, Maintenance Management Practices, Preventive Maintenance (PM) Program, Written Instructions, and Training. The results indicated many good practices are in place and noted some improvement areas for each area reviewed. The survey respondents consisted of 21 individuals – 16 from drilling contracting companies and 5 from BOP OEM companies. The detailed results are provided in Section 4 and Appendix C contains the survey questions.

Section 5 provides a comparison of the MIT activities required by regulations and industry practices and recommended practices to MIT activities currently implemented for BOPs operating in the GoM. This effort identified that the MIT requirements contained in API 53 are referenced or incorporated in most all regulations and industry standards related to BOPs. The comparison of the API 53 activities to the drilling contractors' MIT plans indicated that the API-required tasks comprise about 10% of the maintenance activities performed. The MIT plans include significantly more maintenance activities than required by API 53 and regulations.

Section 6 contains concluding remarks resulting for the MIT activities and MIT management system results. In addition, this section lists 14 potential areas in which improvements could be made.

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LIST OF ACRONYMS

ABS	—	American Bureau of Shipping
API	—	American Petroleum Institute
BOP	—	Blowout Preventer
BSEE	—	Bureau of Safety and Environmental Enforcement
C&K	—	Choke and Kill
CCSV	—	Compensated Chamber Solenoid Valve
CMMS	—	Computerized Maintenance Management System
DDV	—	Direct Drive Valve (solenoid valve)
EDS	—	Emergency Disconnect System
EH	—	Electronic – Hydraulic
ERA	—	Electronic Riser Angle
GoM	—	Gulf of Mexico
HKR	—	Remote Hydraulic Regulator
HPHT	—	High Pressure High Temperature
HPU	—	Hydraulic Power Unit
ID	—	Inside Diameter
IOM	—	Installation, Operations, and Maintenance
IP	—	Industry Participant
LED	—	Light Emitting Diode
LMRP	—	Lower Marine Riser Package
MIT	—	Maintenance, Inspection and Test
MKR	—	Manual Hydraulic Regulator
MUX	—	Multiplex
NDE/T	—	Non-destructive Examination/Testing
OD	—	Outside Diameter
OEM	—	Original Equipment Manufacturer
PBOF	—	Pressure Balanced Oil Filled
PM	—	Preventive Maintenance
ROV	—	Remote Operated Vehicle
RP	—	Recommended Practice
SEM	—	Subsea Electronic Module
SPM	—	Subsea Plate-mounted (valve)
UPS	—	Uninterrupted Power Source

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1.0 INTRODUCTION

At the operational stage of an asset's life cycle, asset maintenance and reliability practices for assets are mostly comprised of (1) maintenance, inspection, and test (MIT) activities (i.e., proactive maintenance) and (2) maintenance and reliability management systems. In regards to this project, this report contains a study of these activities and represents one portion of deliverable F associated with Tasks 6.1.1, 6.1. 2 and 6.1.3, as outlined in the contract

MIT activities are conducted to help detect and/or prevent Blowout Preventer (BOP) equipment failures before occurrence and are typically performed on a time and/or event-based schedule. Event-based activities are performed in conjunction with an operation activity such as: running the BOP Stack, upon latching on the wellhead, scheduling a test during drilling operation, prior to drilling out of cased hole, prior to drilling into a known high pressure zone or unplanned retrieval of the BOP. The activities are often based on input from several sources including:

- Statutory regulations (regulations)
- Operator requirements
- Drilling contractor preventive maintenance (PM) programs, including site- or rig-specific programs
- Original Equipment Manufacturer (OEM) recommendations

The maintenance and reliability management systems provide the policies and procedures related to these BOP maintenance and reliability activities:

- MIT program design, implementation, and execution
- Equipment failure elimination and performance improvement
- Equipping personnel to perform MIT maintenance activities

This report provides information related to MIT activities and maintenance and reliability management system practices.

1.1 OBJECTIVES

The objectives of this report are to identify (1) key MIT activities and (2) some of the key maintenance and reliability management system practices impacting BOP reliability performance.

1.2 REPORT ORGANIZATION

This report summarizes the MIT activities (and their associated frequencies) that are: (1) contained in applicable, worldwide regulations, and industry standards and recommended practices and (2) included in industry participants (IP) MIT plans for BOPs operating in the Gulf of Mexico (GoM). In addition, the report provides the results from a reliability and maintenance management system survey. Finally, the report provides a comparison of the MIT activities and practices, and BOP performance.

Section 2 outlines and compares the MIT activities identified in applicable BOP regulations and industry standards and recommended practices. This section identifies the MIT activities and associated frequencies included in the regulations, and in selected industry standards and recommended practices. Section 3 outlines the survey of the current MIT activities included in drilling contractor MIT plans and OEM installation, operations, and maintenance (IOM) manuals. Specifically, Section 3 describes the scope and approach used for this survey and outlines the survey results. Appendix B of this report contains the complete survey results.

Section 4 of this report outlines the reliability and maintenance management system survey approach and summarizes its results. Appendix C contains the survey questions. Section 5 provides a comparison of the MIT activities required by regulations and industry practices and recommended practices to MIT activities currently implemented for BOPs operating in the GoM. Finally, Section 6 contains concluding remarks resulting for the MIT activities and MIT management system results.

2.0 MIT ACTIVITIES - REGULATIONS AND INDUSTRY STANDARDS AND RECOMMENDED PRACTICES

This section contains MIT activities identified in the reviewed regulations, and industry standards and recommended practices. Specifically, this section provides a comparison of the MIT activities included in US regulations, other prominent worldwide regulations, and selected, applicable industry standards and recommended practices. This tabular comparison allows easy identification of common MIT activities, as well as highlights differences in activities and the associated frequencies.

The following subsections identify the scope of this effort and provide a tabular comparison of the MIT activities.

2.1 SCOPE

The scope of this effort involved a review of the regulations and industry standards and recommended practices identified in Table 2-1. Each of these documents were reviewed to identify the MIT activities and associated MIT program requirements related to the BOP equipment listed in Table 2-2. Appendix A provides a more detailed list of items included in each equipment category.

Table 2-1: Regulations and Industry Standards and Recommended Practices

Regulations	Industry Standards and Recommended Practices
<i>Part 250—Oil And Gas And Sulphur Operations In The Outer Continental Shelf, 30 Code of Federal Regulations 250, Washington, District of Columbia.</i>	<i>Blowout Prevention Equipment Systems for Drilling Wells, American Petroleum Institute (API) Standard 53, Fourth Edition, American Petroleum Institute Washington, District of Columbia, November 2012.</i>
<i>BOP Classification System For Onshore Newfoundland And Labrador, Interpretation Note Issued Under The Petroleum Drilling Regulations (Cnr 1150/96), Government Of Newfoundland And Labrador, Department Of Natural Resources, Petroleum Resource Development Division, Newfoundland And Labrador, Canada, December 2004.</i>	<i>Recommended Practice for Well Control Operations, API Recommended Practice 59, Second Edition, American Petroleum Institute Washington, District of Columbia, May 2006.</i>
<i>Directive 036: Drilling Blowout Prevention Requirements and Procedures, Energy Resources Conservation Board, Calgary, Alberta, Canada, February 2006.</i>	<i>Specification for Control Systems for Drilling Well Control Equipment and Control Systems for Diverter Equipment, API Specification 16D (Spec 16D), American Petroleum Institute Washington, District of Columbia, Second Edition, July 2004, Effective Date, January 2005.</i>

Table 2-1: Regulations and Industry Standards and Recommended Practices (cont'd)

Regulations	Industry Standards and Recommended Practices
<i>Blowout Prevention in California: Equipment Selection and Testing</i> , California Department of Conservation, Division of Oil, Gas, and Geothermal Resource, Sacramento, Tenth Edition, 2006.	<i>Specification for Choke and Kill Systems</i> , API Specification 16c (Spec WC), American Petroleum Institute Washington, District of Columbia, First Edition, January 1993.
	<i>Specification for Wellhead and Christmas Tree Equipment</i> , ANSI/API Specification 6A, Nineteenth Edition, ISO 10423:2003, (Modified) Petroleum and natural gas industries—Drilling and production equipment—Wellhead and Christmas tree equipment, American Petroleum Institute Washington, District of Columbia, July 2004.
	<i>Guide For The Classification Of Drilling Systems</i> , American Bureau of Shipping, Houston, Texas, March 2011.
	<i>Guideline for the Certification of Blow-Out Preventers</i> , Germanischer Lloyd SE, GL Noble Denton, Hamburg, Germany, May 2011.

Table 2-2: BOP Equipment Scope

BOP Control Systems	BOP Stack Equipment
<i>Surface Control System</i>	
<ul style="list-style-type: none"> • Electrical Power • Multiplex (MUX) Control System • Hydraulic Power Unit (HPU) • Rigid Conduit & Hotline • Surface Accumulators 	<ul style="list-style-type: none"> • Annulars • Blind Shear Ram • Casing Shear Ram • Pipe & Test Rams • Choke & Kill (C&K) Valves and Lines • Connectors
<i>Subsea Control System</i>	<ul style="list-style-type: none"> • Stack-mounted Accumulators
<ul style="list-style-type: none"> • Blue & Yellow Subsea Control Systems 	
<ul style="list-style-type: none"> • Lower Marine Riser Package (LMRP)-mounted Accumulators 	
<ul style="list-style-type: none"> • Emergency & Secondary Controls 	

2.2 MIT ACTIVITY COMPARISON

This section provides the results of MIT activities and practices included the documents listed in Table 2-1. The identified MIT activity requirements are provided in a tabular format to allow comparison of the activities. Table 2-3 summarizes the identified requirements and contains the following information:

- **MIT Activity** - This column identifies a specific requirement included in one or more of the documents reviewed.
- **Industry Standards and Recommended Practices** – The rows in this section of the table provide an indication of whether an industry standard or recommended practice contains a requirement to perform a specific MIT activity. In addition if the industry standard or recommended practice listing the MIT activity includes a specified interval, the interval is included in the table. A blank row indicates that no requirements were identified.
- **Regulations** – The rows in this section of the table provide an indication of whether the regulation contains a requirement to perform a specific MIT activity. In addition if the regulation listing the MIT activity includes a specified interval, the interval is included in the table. A blank row indicates that no requirements were identified.

In addition to the information contained in Table 2-3, the following information regarding other MIT activities and practices were identified:

- American Petroleum Institute (API) Recommended Practice (RP) 53 includes a requirement to develop and implement a planned maintenance program for each rig.
- API RP 59 references sections of API RP 53 containing maintenance requirements.

Also, this review included the following documents which contain equipment related inspection and testing activities, but these activities are intended for application during the fabrication and/or manufacturing of the BOP components or systems.

- *Specification for Choke and Kill Systems*, First Edition, API Specification 16C.
- *Specification for Drilling Well Control Equipment and Control Systems for Diverter Equipment*, API Specification 16D.
- *Specification for Drill-through Equipment*, Third Edition, API Specification 16A.
- *Specification for Wellhead and Christmas Tree Equipment*, Nineteenth Edition, ANSI/API Specification 6A.

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Table 2-3: Regulations and Industry Standards and Recommended Practices MIT Activities

MIT Activity	Industry Standards and Recommended Practices	API RP 53, 3 rd Ed.	❖ At least once per week	
<i>Operational Components Function Test</i>		Industry Standards and Recommended Practices	API 53 4th Ed., Nov 2012	❖ At least once per week
			ABS Guide for Classification of Drilling Systems	
			CNLR 1150/96	
			GL Noble Guideline for Certification of Blow-Out Preventers	
	Regulations		30 CFR 250	<ul style="list-style-type: none"> ❖ BOP Systems tested when installed ❖ BOP Systems tested at least every 7 days ❖ BOP systems tested following repairs that require disconnecting a pressure seal in the assembly ❖ Function test annular and RAM BOPs every 7 days between pressure tests¹²
		Blowout Prevention in California	<ul style="list-style-type: none"> ❖ 24-hrs, function test of pipe rams, blind rams, kelly cocks, drill pipe safety valve, adjustable chokes, hydraulic valves ❖ At least once every seven days, function test of annular preventer, all gate valves in choke and kill system, and manually operated BOP 	
		ERCB Directive 36	<ul style="list-style-type: none"> ❖ Daily function test of annulars(s) and pipe rams ❖ Daily function of blind rams when drill string is out of the hole ❖ Weekly function test of HCR ❖ Function test of annular and HCR prior to drilling, for wells with a diverter system 	
		Norsok Standard D-010, Rev. 3	❖ Set performance criteria for components	

Table 2-3: Regulations and Industry Standards and Recommended Practices MIT Activities (cont'd)

MIT Activity <i>BOP Pressure Gauges calibration</i>	Industry Standards and Recommended Practices	API RP 53, 3rd Ed.	❖ At least every 3 years (to 1% accuracy)
		API 53 4th Ed., Nov 2012	❖ Annual calibration in accordance with OEM procedures
		ABS Guide for Classification of Drilling Systems	
		CNLR 1150/96	
		GL Noble Guideline for Certification of Blow-Out Preventers	
	Regulations	30 CFR 250	
		Blowout Prevention in California	
ERCB Directive 36			
Norsok Standard D-010, Rev. 3		❖ Set performance criteria for components	
MIT Activity <i>Electronic Pressure Measurement Devices Calibration</i>	Industry Standards and Recommended Practices	API RP 53, 3rd Ed.	
		API 53 4th Ed., Nov 2012	❖ No timing specified but devices must be calibrated within 1% and utilize the manufacturer's specified range
		ABS Guide for Classification of Drilling Systems	
		CNLR 1150/96	
		GL Noble Guideline for Certification of Blow-Out Preventers	
	Regulations	30 CFR 250	
		Blowout Prevention in California	
ERCB Directive 36			
Norsok Standard D-010, Rev. 3		❖ Set performance criteria for components	

Table 2-3: Regulations and Industry Standards and Recommended Practices MIT Activities (cont'd)

MIT Activity	Industry Standards and Recommended Practices	API RP 53, 3rd Ed.	<ul style="list-style-type: none"> ❖ BOP stack initially installed on wellhead^{1,4,7} ❖ While on wellhead, Not to exceed 21 days^{1,4} ❖ After the disconnection or repair of any pressure containment seal but limited to the affected component¹⁶
<i>Low Pressure Test¹⁰</i>		API 53 4th Ed., Nov 2012	<ul style="list-style-type: none"> ❖ Predeployment of the BOP subsea and upon installation ❖ after the disconnection or repair of any pressure containment seal in the BOP stack, choke line, kill line, choke manifold, or wellhead assembly but limited to the affected component; ❖ In accordance with equipment owner's PM program or site-specific requirements; ❖ Not to exceed intervals of 21 days
		ABS Guide for Classification of Drilling Systems	<ul style="list-style-type: none"> ❖ Annual survey includes low pressure test of BOP in accordance with API RP 53
		CNLR 1150/96	<ul style="list-style-type: none"> ❖ After installation ❖ Before drilling out a string of casings installed in a well ❖ Before connecting a formation flow test or a series of test ❖ Following repairs that require disconnecting a pressure seal in the wellhead assembly ❖ Not less than once every 15 days
		GL Noble Guideline for Certification of Blow-Out Preventers	
	Regulations	30 CFR 250	<ul style="list-style-type: none"> ❖ When BOP stack initially installed on wellhead⁷ ❖ Before 14 days elapse since last BOP pressure test ❖ Before drilling out each string of casing or liner ❖ Before the high pressure test ❖ Interval for blind or blind-shear pressure tests may not exceed 30 days
		Blowout Prevention in California	
		ERCB Directive 36	<ul style="list-style-type: none"> ❖ Prior to drilling out the surface, intermediate, and production casing⁹
		Norsok Standard D-010, Rev. 3	<ul style="list-style-type: none"> ❖ Set performance criteria for components

Table 2-3: Regulations and Industry Standards and Recommended Practices MIT Activities (cont'd)

MIT Activity	Industry Standards and Recommended Practices	API RP 53, 3rd Ed.	<ul style="list-style-type: none"> ❖ BOP stack initially installed on wellhead^{1,4,5,7} ❖ While on wellhead, not to exceed 21 days^{1,4,5} ❖ After the disconnection or repair of any pressure containment seal but limited to the affected component¹⁶
<i>High Pressure Test¹⁰</i>		API 53 4th Ed., Nov 2012	<ul style="list-style-type: none"> ❖ Predeployment of the BOP subsea and upon installation; ❖ After the disconnection or repair of any pressure containment seal in the BOP stack, choke line, kill line, choke manifold, or wellhead assembly but limited to the affected component; ❖ In accordance with equipment owner's PM program or site-specific requirements; ❖ Not to exceed intervals of 21 days
		ABS Guide for Classification of Drilling Systems	<ul style="list-style-type: none"> ❖ Annual survey includes high pressure test of BOP in accordance with API RP 53
		CNLR 1150/96	<ul style="list-style-type: none"> ❖ After installation ❖ Before drilling out a string of casings installed in a well ❖ Before connecting a formation flow test or a series of test ❖ Following repairs that require disconnecting a pressure seal in the wellhead assembly ❖ Not less than once every 15 days
		GL Noble Guideline for Certification of Blow-Out Preventers	
	Regulations	30 CFR 250	<ul style="list-style-type: none"> ❖ BOP stack initially installed on wellhead⁷ ❖ Before 14 days elapse since last BOP pressure test ❖ Before drilling out each string of casing or liner ❖ After the low pressure test ❖ Interval for blind or blind-shear pressure tests may not exceed 30 days
		Blowout Prevention in California	<ul style="list-style-type: none"> ❖ High pressure testing after each subsequent casing string is set
		ERCB Directive 36	<ul style="list-style-type: none"> ❖ Prior to drilling out the surface, intermediate, and production casing^{10,11}
		Norsok Standard D-010, Rev. 3	<ul style="list-style-type: none"> ❖ Set performance criteria for components

Table 2-3: Regulations and Industry Standards and Recommended Practices MIT Activities (cont'd)

MIT Activity			
<i>BOP Control System Function Test³</i>	Industry Standards and Recommended Practices	API RP 53, 3rd Ed.	<ul style="list-style-type: none"> ❖ BOP stack initially installed on the wellhead¹ ❖ While on wellhead, not to exceed 21 days¹⁷
		API 53 4th Ed., Nov 2012	❖ See Operational Components Function Test category
		ABS Guide for Classification of Drilling Systems	
		CNLR 1150/96	<ul style="list-style-type: none"> ❖ All major components of the BOP system, except the blind rams, are actuated once each day that drilling operations are carried out if the drill string is out of the hole or the drill bit is in the casing ❖ All major components of the BOP system, except the blind rams, are actuated at least once every 3 days ❖ The blind rams are actuated at least once each time that the drill string is out of the hole
		GL Noble Guideline for Certification of Blow-Out Preventers	
	Regulations	30 CFR 250	❖ Function test annular and RAM BOPs every 7 days between pressure tests
		Blowout Prevention in California	<ul style="list-style-type: none"> ❖ At least once during an 8-hour tour actuate all audible and visual indicators ❖ At least every 24-hrs, function test of pipe rams, blind rams, kelly cocks, drill pipe safety valve, adjustable chokes, hydraulic valves ❖ At least once every seven days, function test of annular preventer, all gate valves in choke and kill system, and manually operated BOP valves
		ERCB Directive 36	
		Norsok Standard D-010, Rev. 3	❖ Set performance criteria for components

Table 2-3: Regulations and Industry Standards and Recommended Practices MIT Activities (cont'd)

<p>MIT Activity</p>	<p>Industry Standards and Recommended Practices</p>	<p>API RP 53, 3rd Ed.</p>	<ul style="list-style-type: none"> ❖ The precharge pressure on each accumulator bottle should be measured prior to each BOP stack installation on each well and adjusted if necessary 	
<p><i>Accumulator Pressure Precharge Verification</i></p>		<p>API 53 4th Ed., Nov 2012</p>	<ul style="list-style-type: none"> ❖ After installation ❖ Every 6 months after each pressure test ❖ After any repair that required isolation/partial isolation of the system 	
		<p>ABS Guide for Classification of Drilling Systems</p>		
		<p>CNLR 1150/96</p>		
		<p>GL Noble Guideline for Certification of Blow-Out Preventers</p>		
		<p>30 CFR 250</p>		
		<p>Regulations</p>	<p>Blowout Prevention in California</p>	<ul style="list-style-type: none"> ❖ At least once during 8-hour tour
	<p>ERCB Directive 36</p>			
<p>Norsok Standard D-010, Rev. 3</p>	<ul style="list-style-type: none"> ❖ Set performance criteria for components 			
<p>MIT Activity</p>	<p>Industry Standards and Recommended Practices</p>	<p>API RP 53, 3rd Ed.</p>	<ul style="list-style-type: none"> ❖ Change out as soon as possible after exposure to hydrogen sulfide ❖ When well control equipment has been out of service for 6 months or longer 	
<p><i>Critical BOP Elastomeric Components Replacement (suggested activity)</i></p>		<p>API 53 4th Ed., Nov 2012</p>	<ul style="list-style-type: none"> ❖ Consider replacing BOP elastomeric components on wellhead equipment that has been out of service for 6 months and not preserved according to equipment owner's guide ❖ After exposure to hydrogen sulfide (H₂S) and/or CO₂, under pressure, in accordance with the original equipment manufacturer (OEM) or equipment owner's requirements 	
		<p>ABS Guide for Classification of Drilling Systems</p>		
		<p>CNLR 1150/96</p>		
		<p>GL Noble Guideline for Certification of Blow-Out Preventers</p>		
		<p>30 CFR 250</p>		
		<p>Regulations</p>	<p>Blowout Prevention in California</p>	
			<p>ERCB Directive 36</p>	
			<p>Norsok Standard D-010, Rev. 3</p>	<ul style="list-style-type: none"> ❖ Set performance criteria for components

Table 2-3: Regulations and Industry Standards and Recommended Practices MIT Activities (cont'd)

MIT Activity	Industry Standards and Recommended Practices	API RP 53, 3rd Ed.	❖ After each well is drilled, the well control equipment should be cleaned, visually inspected, preventive maintenance performed, and pressure tested before installation on the next well
<i>Well Control Equipment Cleaning, Visual Inspection, Preventive Maintenance, and Pressure Test</i>			API 53 4th Ed., Nov 2012
		ABS Guide for Classification of Drilling Systems	❖ Special periodical survey every 5 yr. including examination of the equipment associated with the well control system and their maintenance records ¹⁵
		CNLR 1150/96	
		GL Noble Guideline for Certification of Blow-Out Preventers	<ul style="list-style-type: none"> ❖ Annual inspection, described in Section 4 ❖ Every five years, an Inspection for Re-Certification shall be carried out, described in Section 5
	Regulations	30 CFR 250	<ul style="list-style-type: none"> ❖ BOP stack initially installed on wellhead⁷ ❖ Following repairs that require disconnect of a pressure seal
		Blowout Prevention in California	❖ At least once during an 8-hour tour actuate all audible and visual indicators
		ERCB Directive 36	
		Norsok Standard D-010, Rev. 3	

Table 2-3: Regulations and Industry Standards and Recommended Practices MIT Activities (cont'd)

MIT Activity <i>Flexible Choke and Kill line Visual External Inspection</i>	Industry Standards and Recommended Practices	API RP 53, 3 rd Ed.	❖ A full internal and external inspection of the flexible choke and kill lines should be performed in accordance with the equipment manufacturer's guidelines.
		API 53 4th Ed., Nov 2012	❖ The external inspection programs shall be performed as specified by the equipment owner's PM program in accordance with equipment manufacturer's recommendations.
		ABS Guide for Classification of Drilling Systems	❖ Annual survey specified in detail in Section 5.3
		CNLR 1150/96	❖
		GL Noble Guideline for Certification of Blow-Out Preventers	❖ Annual inspection, described in Section 4 ❖ Every five years, an inspection for Re-Certification shall be carried out, described in Section 5 ❖ Extraordinary inspection after BOP or its components suffer damage
	Regulations	30 CFR 250	
		Blowout Prevention in California	
		ERCB Directive 36	
Norsok Standard D-010, Rev. 3			
MIT Activity <i>BOP Stack and Choke Manifold Disassembly and Inspection⁶</i>	Industry Standards and Recommended Practices	API RP 53, 3 rd Ed.	❖ Every 3-5 years of service
		API 53 4th Ed., Nov 2012	❖ At least every 5 years
		ABS Guide for Classification of Drilling Systems	
		CNLR 1150/96	
		GL Noble Guideline for Certification of Blow-Out Preventers	❖ Annual inspection ❖ Inspection for recertification after 5 years ❖ Extraordinary inspection after BOP or its components suffer damage
	Regulations	30 CFR 250	
		Blowout Prevention in California	
		ERCB Directive 36	
		Norsok Standard D-010, Rev. 3	

Table 2-3: Regulations and Industry Standards and Recommended Practices MIT Activities (cont'd)

MIT Activity		API RP 53, 3rd Ed.	
<i>BOP Visual Inspection</i>	Industry Standards and Recommended Practices	API 53 4th Ed., Nov 2012	
		ABS Guide for Classification of Drilling Systems	
		CNLR 1150/96	
		GL Noble Guideline for Certification of Blow-Out Preventers	
	Regulations	30 CFR 250	<ul style="list-style-type: none"> ❖ Daily (for surface BOP systems) ❖ Visual inspection every 3 days, weather and sea conditions permitting (for subsea BOP and marine riser)
		Blowout Prevention in California	
		ERCB Directive 36	
		Norsok Standard D-010, Rev. 3	❖ Set performance criteria for components
MIT Activity		API RP 53, 3rd Ed.	
<i>BOP Stump Test</i>	Industry Standards and Recommended Practices	API 53 4th Ed., Nov 2012	
		ABS Guide for Classification of Drilling Systems	
		CNLR 1150/96	
		GL Noble Guideline for Certification of Blow-Out Preventers	
	Regulations	30 CFR 250	❖ Before installation
		Blowout Prevention in California	
		ERCB Directive 36	
		Norsok Standard D-010, Rev. 3	❖ Set performance criteria for components

Table 2-3: Regulations and Industry Standards and Recommended Practices MIT Activities (cont'd)

MIT Activity <i>BOP Inspections</i>	Industry Standards and Recommended Practices	API RP 53, 3 rd Ed.	
		API 53 4th Ed., Nov 2012	
		ABS Guide for Classification of Drilling Systems	
		CNLR 1150/96	
		GL Noble Guideline for Certification of Blow-Out Preventers	
	Regulations	30 CFR 250	❖ Must meet or exceed provisions in Section 18.10 in API RP 53 ¹⁴
		Blowout Prevention in California	
		ERCB Directive 36	
Norsok Standard D-010, Rev. 3		❖ Set performance criteria for components	
MIT Activity <i>BOP Maintenance</i>	Industry Standards and Recommended Practices	API RP 53, 3 rd Ed.	
		API 53 4th Ed., Nov 2012	
		ABS Guide for Classification of Drilling Systems	
		CNLR 1150/96	
		GL Noble Guideline for Certification of Blow-Out Preventers	
	Regulations	30 CFR 250	❖ BOP maintenance must meet or exceed provisions in Sections 18.11 and 18.12 in API RP 53 ¹⁴
		Blowout Prevention in California	
		ERCB Directive 36	
Norsok Standard D-010, Rev. 3			

Table 2-3: Regulations and Industry Standards and Recommended Practices MIT Activities (cont'd)

MIT Activity		API RP 53, 3rd Ed.	
<i>Audible and Visual Indicator Actuation Test</i>	Industry Standards and Recommended Practices	API 53 4th Ed., Nov 2012	
		ABS Guide for Classification of Drilling Systems	
		CNLR 1150/96	
		GL Noble Guideline for Certification of Blow-Out Preventers	
	Regulations	30 CFR 250	
		Blowout Prevention in California	❖ At least once during an 8-hour tour
		ERCB Directive 36	
	Norsok Standard D-010, Rev. 3	❖ Set performance criteria for components	
MIT Activity		API RP 53, 3rd Ed.	
<i>Subsea Systems Visual Inspection</i>	Industry Standards and Recommended Practices	API 53 4th Ed., Nov 2012	
		ABS Guide for Classification of Drilling Systems	
		CNLR 1150/96	
		GL Noble Guideline for Certification of Blow-Out Preventers	
	Regulations	30 CFR 250	
		Blowout Prevention in California	❖ At least once each day, weather and sea conditions permitting
		ERCB Directive 36	
	Norsok Standard D-010, Rev. 3	❖ Set performance criteria for components	

Table 2-3: Regulations and Industry Standards and Recommended Practices MIT Activities (cont'd)

MIT Activity		API RP 53, 3rd Ed.	
<i>Subsea Equipment Inspection and Maintenance</i>	Industry Standards and Recommended Practices	API 53 4th Ed., Nov 2012	
		ABS Guide for Classification of Drilling Systems	
		CNLR 1150/96	
		GL Noble Guideline for Certification of Blow-Out Preventers	
	Regulations	30 CFR 250	
		Blowout Prevention in California	❖ No timing specified other than inspect and maintain in accordance with manufacturer's recommended procedures
		ERCB Directive 36	
	Norsok Standard D-010, Rev. 3	❖ Set performance criteria for components	
MIT Activity		API RP 53, 3rd Ed.	
<i>Surface BOP System Testing and Maintenance</i>	Industry Standards and Recommended Practices	API 53 4th Ed., Nov 2012	❖ Table 6 specifies frequency for surface testing ¹⁸
		ABS Guide for Classification of Drilling Systems	
		CNLR 1150/96	
		GL Noble Guideline for Certification of Blow-Out Preventers	<ul style="list-style-type: none"> ❖ Annual inspection ❖ Inspection for recertification after 5 years ❖ Extraordinary inspection after BOP or its components suffer damage
	Regulations	30 CFR 250	<ul style="list-style-type: none"> ❖ Daily visual inspection ❖ BOP inspections must meet or exceed provisions in Section 18.10 in API RP 53¹³ ❖ BOP maintenance must meet or exceed provisions in Sections 18.11 and 18.12 in API RP 53¹⁴
		Blowout Prevention in California	
		ERCB Directive 36	
	Norsok Standard D-010, Rev. 3		

Table 2-3: Regulations and Industry Standards and Recommended Practices MIT Activities (cont'd)

MIT Activity		API RP 53, 3 rd Ed.	
<i>Subsea BOP System and Marine Riser Inspection and Recertification</i>	Industry Standards and Recommended Practices	API 53 4th Ed., Nov 2012	<ul style="list-style-type: none"> ❖ Table 7 specifies Subsea testing¹⁹ ❖ Table 8 specifies other system tests ❖ Table 9 specifies pre-deployment pressure tests for Floating Rigs with Subsea BOP stacks ❖ Table 10 specifies subsea pressure tests for Floating Rigs with Subsea BOP stacks
		ABS Guide for Classification of Drilling Systems	
		CNLR 1150/96	
		GL Noble Guideline for Certification of Blow-Out Preventers	<ul style="list-style-type: none"> ❖ Annual inspection ❖ Inspection for recertification after 5 years ❖ Extraordinary inspection after BOP or its components suffer damage
	Regulations	30 CFR 250	<ul style="list-style-type: none"> ❖ Visual inspection every 3 days, weather and sea conditions permitting ❖ Stump test Subsea BOP system before installation ❖ BOP inspections must meet or exceed provisions in Section 18.10 in API RP 53 ❖ BOP maintenance must meet or exceed provisions in Section 18.120 in API RP 53
		Blowout Prevention in California	<ul style="list-style-type: none"> ❖ All subsea equipment must be inspected and maintained in accordance with manufacturer's recommended procedures ❖ All subsea systems must be visually inspected at least once each day, weather and sea conditions permitting
		ERCB Directive 36	
		Norsok Standard D-010, Rev. 3	

- 1 Includes testing of annular, ram preventers, BOP-to WHD connector, choke & kill lines & valves, and choke & kill manifold
- 2 Includes testing of BOP control system manifold(s)
- 3 Function test includes close time, pump capability, and control station tests
- 4 Includes testing of casing seals and BOP choke manifold
- 5 Includes optional testing of control system manifold and BOP lines
- 6 Includes change out of elastomeric components, examination of surface finishes for corrosion and wear, check of dimensional parameters, and internal and external inspection of flexible choke and kill lines
- 7 Includes choke manifold, Kelly valves, inside BOP, and drill-string safety valve
- 8 Includes ram blowout preventers, ram blocks and packers and top seals, annular blowout preventers, annular packing units, hydraulic connectors, drilling spools, adapters, loose connections, clamps
- 9 Includes testing of annular, rams, bleed-off line and valves, manifold valves, kill line and valves, stabbing valve, inside BOP, lower Kelly cock, and surface/intermediate/production casing at 1400 kPa for 10 minutes
- 10 Prior to drilling out surface case; includes testing of annular, rams, bleed-off line and valves, manifold valves, kill line and valves, stabbing valve, inside BOP, lower Kelly cock, and surface casing at the lesser of 7000kPa or 50 times setting depth in meters of the surface casing for 10 minutes
- 11 Prior to drilling out intermediate or production casing; annular must be tested at 50% of the working pressure of the required BOP system for the well class for 10 minutes; rams, bleed-off line and valves, manifold valves, kill line and valves, stabbing valves, inside BOP, and lower Kelly cock must be tested to the minimum of the required BOP system based on well class for 10 minutes; intermediate or production casing must be tested at a pressure equal to 67% of the BHP at the casing setting depth
- 12 Includes test of annular and ram BOPS

Table 2-3: Regulations and Industry Standards and Recommended Practices MIT Activities (cont'd)

- 13 After each well, well control equipment should be inspected per the manufacturer's recommendation. Test recommendations are provided in Table 3. Specifies visual inspection of choke & kill lines. Specifies major inspection every 3 to 5 years (disassembly and inspection of BOP stack, choke manifold, and diverter components, change out elastomeric components, full internal and external inspection of flexible choke & kill lines)
- 14 OEM manuals should be available for all BOP equipment on the rig, planned maintenance system should identify equipment, maintenance tasks specified and time interval, the rig maintenance and inspection schedule should provide for periodic nondestructive examination of the mudgas separator to verify pressure integrity. This examination may be performed by hydrostatic, ultrasonic, or other examination methods
- 15 Special periodical survey includes all items listed under Annual Survey and review of OEM maintenance records to verify: 1) periodical testing requirement reconditioning, 2) reconditioning of well control equipment, BOP controls, riser system, pressure vessels, electrical systems/equipment drilling hoisting system; internal examination of pressure vessels, testing of relief valves and pressure piping systems,; hydrostatic testing of drilling piping systems, pressure vessel, and hydraulic hoses
- 16 Any pressure containment seal in the BOP stack, choke line, choke manifold, or wellhead assembly.
- 17 The elements of the BOP control system normally include: a. Storage (reservoir) equipment for supplying ample control fluid to the pumping system, b. Pumping systems for pressurizing the control fluid, c. Accumulator bottles for storing pressurized control fluid (some accumulator bottles may be located subsea on the BOP stack assembly), d. Hydraulic control manifold for regulating the control fluid pressure and directing the power fluid flow to operate the system functions (BOPS and choke and kill valves), e. Remote control panels for operating the hydraulic control, manifold from remote locations, f. Hydraulic control fluid, g. Umbilical control hose bundle(s) and reel(s), and h. Control pod(s) located on the BOP
- 18 Secondary, emergency, and other systems including Emergency Disconnect System/Sequence, Autoshear System Deadman System, remote operated vehicle (ROV) Intervention, Acoustic Control System
- 19 Secondary, emergency, and other systems including Emergency Disconnect System/Sequence, Autoshear System Deadman System, ROV Intervention, Acoustic Control System, Dedicated Emergency Accumulators

3.0 MIT ACTIVITIES – IP MIT PLANS AND OEM IOM MANUALS

This section summarizes the current MIT activities applied to BOPs operating in the GoM. Specifically, this section includes a survey of MIT activities based on the following information:

- Drilling contractor MIT plans which include statutory regulation requirements, operator requirements, the drilling contractor’s own PM programs, and site- or rig-specific programs
- BOP OEM defined MIT plans intended to preserve warranty and maintain equipment integrity, over and above the regulatory activities

The survey of these plans provides information related to the MIT activities performed during drilling operations. The following subsections identify the scope of this effort, describe the approach used to collect the information and provide the tabular results of the MIT activities.

3.1 SCOPE

The scope of this effort included identifying MIT activities contained in drilling contractors’ MIT plans and OEM IOM manuals. In total, more than 200 documents (i.e., MIT plans, well control manuals, and OEM IOM manuals) were included in this scope. In addition, this effort focused on identifying MIT activities for the following phases of BOP operation:

- **Between Well** – When the drilling program is completed and the well is secured, the BOP Stack is brought to the surface and prepared for the next well. The extent of MIT between wells is governed by the drilling contractor and/or operator and/or site-/rig-specific procedures and programs. MIT activities typically include limited disassembly of components, replacement of some consumables and resolution of any deferred maintenance.
- **Pre-drilling**: This describes activities performed to ensure the BOP System is operating in accordance with design parameters, statutory regulations and individual drilling contractor and/or operator requirements. Pre-drilling is composed of two event-based activities.
 - i. **Prior to Deployment**: The final MIT performed on the surface prior to running the BOP. Unlike subsea tests, the pre-deployment test typically tests all functions.
 - ii. **Upon Latching/Initial test upon latching**: Performed when the BOP is latched on the well head and before drilling operations begin. In the event that the BOP has been retrieved and re-run to facilitate repairs, weather or other operations, MIT criteria will vary between individual drilling contractors and operators.
- **Drilling**: Inspections and tests during drilling operations while the BOP Stack is latched on a wellhead and during the course of the drilling program. MIT activities

are either calendar or event-based. MIT events during a drilling program are sometimes limited by operational limitations and concerns.

Scheduled Major Overhauls – These are procedures to recertify equipment and require disassembly to the module level with parent material identification/parent material analysis, non-destructive evaluation and testing (NDE/T), and dimensional inspection and can include remanufacture of components. The frequency of recertification is prescribed by statutory regulations and/or drilling contractor PM program. The scope of inspection and verification to achieve recertification is determined by the OEM or owner of the design. In the event that an overhaul procedure involves multiple components, some drilling contractors choose to overhaul or replace a percentage of the components on an annual basis.

3.2 INFORMATION COLLECTION AND COMPILATION

This section outlines the approach used to collect MIT activities and compile the information into a tabular format. The information collection started by developing a list of information to be requested from the IPs. Specifically, the list requested that the IPs provide BOP IOM manuals and/or MIT plans containing this information:

- MIT activities performed, including planned maintenance, predictive maintenance, scheduled inspections, and scheduled tests performed to detect or prevent failures (i.e., proactive maintenance activities versus corrective maintenance activities)
- Indication of the operating/maintenance regime (i.e., pre-drilling, drilling, in-between wells, scheduled overhauls) when each MIT activity is to be performed
- Frequency that each MIT activity is to be performed
- BOP equipment included in the MIT activity

(Note: Some MIT activities are event-based such as activities performed during pre-drilling and in-between wells. Other MIT activities are time-based, such as those performed during drilling, between wells and scheduled overhauls.)

The MIT activities were to reflect the tasks performed to comply with regulatory requirements and industry practices (e.g., MIT activities included in API 53), as well as other tasks performed to ensure the safe operation and reliability of BOP systems.

Once the requested information was collected, the information provided was reviewed for use in this deliverable. The relevant information was then extracted and compiled. In compiling the information, the following activities were performed:

- Review of all the collected information and manuals for MIT information
- Extraction of relevant MIT information from the information and manuals
- Transfer of the MIT information into a tabular format

- Review of the respective information by industry participants and American Bureau of Shipping (ABS) personnel
- Compilation of the information into a series of tables by OEM and drilling contractor provided information

In general, the information was transferred “as-found” in the respective IP’s information. However, the information was reviewed to identify any details which would indicate the source of the information (e.g., reference to a specific procedure, reference to a specific OEM manual). As these instances were identified, the MIT information was altered, usually by simply removing the source reference, in a manner not to alter the intent of the content. Also, each MIT activity was classified into one of the following proactive maintenance categories:

- Planned Maintenance – A time-based activity designed to prevent a BOP component failure by maintaining/restoring the component’s reliability through servicing and/or repairing or replacing specific BOP components.
- Predictive Maintenance – An activity designed to detect the onset of failure by measuring and analyzing of key component operating or performance parameters related to the failure mode of interest.
- Scheduled Inspection – A scheduled activity designed to check or verify the condition of a BOP component, usually taken to be a visual inspection or some type of non-destructive testing.
- Scheduled Test – A scheduled activity designed to detect the condition related to the onset of failure or hidden failure of a BOP component, usually via a functional or performance test.

Because the IOM manuals, MIT plans, and well control manuals did not always clearly identify the operating/maintenance regime when the MIT activity was to be performed, the following conventions were used:

- Event-based MIT activities identified as between well were also assigned as pre-drill MIT activities
- Time-based MIT activities involving testing or inspections with 30 days or less frequency were assigned as drilling MIT activities
- Some MIT activities which could not be associated with a specific operating/maintenance regime were included as Miscellaneous (activities).

3.3 IP MIT ACTIVITY SURVEY RESULTS

The results of the survey of current MIT activities are summarized in tables which outline the BOP MIT activities included in the IOM manuals, MIT plans, and well control manuals. Specifically, the compiled MIT activities are presented in tabular format with the MIT activities included in the BOP IOM manuals and MIT plans being provided as a series of

tables in Appendix B. These tables contain the following columns and associated information:

- BOP System and Subsystem Columns – These columns identify the BOP system and subsystem in which the MIT activities are associated with either in IOM manual or the first level of indenture in the drilling contractor’s Computerized Maintenance Management System (CMMS) equipment hierarchy.
- Component Column – This column identifies the specific component(s) associated with the MIT activity, as applicable. (Note: Some component table cells are blank because the MIT activity is applicable to multiple components.)
- MIT Activity – This column provides a description of the specific MIT activities planned for the component group. These descriptions include a brief description of the MIT activity and usually the BOP component(s) involved. Please note these descriptions were transferred directly from the provided information with the only alteration being removal of references which would identify the information’s source.
- Maintenance Activity Type – This column provides ABS Consulting’s classification of the type of MIT activity as follows based on the following conventions:
 - Planned Maintenance
 - Predictive Maintenance
 - Scheduled Inspection
 - Scheduled Test
- MIT Activity Interval – This series of columns indicates the operating/maintenance regime in which each specific MIT activity is planned to be performed, as well as, provides the specific time-based interval or event for each MIT activity.

Appendix B contains MIT activities in the following four tables:

- Overall BOP MIT Activities
- Surface Control System MIT Activities
- Subsea Control System MIT Activities
- BOP Stack MIT Activities

4.0 MIT MANAGEMENT SYSTEM SURVEY

In addition to MIT activities, other key components of BOP reliability performance are the maintenance- and reliability-related management systems. These management systems are important because they define policies and procedures related to the key activities such as, (but not limited to):

- Defining MIT activities to be executed, including statutory requirements
- Scheduling , executing, and documenting MIT activities
- Identifying equipment failures and implementing appropriate corrective actions
- Trending and eliminating equipment failures
- Ensuring proper information and instructions are provided to personnel who perform BOP maintenance
- Providing personnel who perform BOP maintenance appropriate training

The survey's objective was to identify maintenance and reliability management system practices currently implemented by drilling contractors and OEMs relative to maintaining BOPs. The following sections identify the scope of this effort, describe the approach used to perform the survey, and provide the survey results.

4.1 SCOPE

The survey focused on evaluating the presence and implementation of management systems related to the following BOP maintenance and reliability activities:

- Identification and elimination of BOP failures
- Use of CMMS or other computer tools
- Implementation of generally accepted maintenance management practices, such as scheduling and planning
- PM program
- Operation and optimization of the PM program
- Use and quality of written instructions for BOP maintenance
- Training of personnel who perform BOP maintenance

Specifically, the survey was provided to both drilling contractors and BOP OEMs for distribution within their respective organizations. The targeted positions for the survey within these organizations were:

- BOP Maintainers
- BOP Maintenance Supervisors
- Maintenance Planners
- Maintenance Schedulers
- Other Maintenance and Engineering Support Personnel

- Rig Operation Leaders
- Rig Operations Supervisors
- Reliability and Maintenance Engineers

4.2 MANAGEMENT SYSTEM SURVEY APPROACH

Based on similar maintenance and reliability surveys and management system assessments, ABS Consulting developed a series of survey questions related to 1) the participant demographics, and 2) the focal management systems listed above. In general, the management system survey questions inquired about the existence of a management system, the formality of the management system implementation (e.g., undocumented, documented), and the consistency and degree of implementation. In addition, the survey questions were designed to solicit input from both field personnel, and office and management personnel. This approach provides the capability to compare designed/planned implementation to actual implementation. The following provides an overview of the survey questions for each category:

- Demographics – Six questions related to each participant’s experience level, job position and role, and BOP manufacturer experience
- Failure Elimination – Nine questions related to the identification and reporting of BOP failures, the analysis of failures, and the implementation of corrective actions
- CMMS – Four questions related to the existence of a CMMS or a similar computer system, field personnel’s use of the CMMS, and management personnel’s use of the CMMS.
- Maintenance management practices – Seven questions related to the existence and implementation of a formal maintenance work control process and procedures, including use of work orders, assignment of work, and planning and scheduling of work.
- PM program – Five questions related to the development of PMs, the basis for PM frequencies, and optimization of PM activities.
- Written Instructions – Seven questions related to the existence of written instructions for BOP repairs and PMs, the field use of written instructions, the content of the written instructions, and the quality of the instructions.
- Training - Three questions related to training of personnel who perform BOP maintenance, including timing and content of initial and refreshing training.

The specific survey questions are provided in Appendix C. These survey questions were configured in a web-based survey tool and then the survey link was provided to drilling contractors and OEM project leads for distribution within their respective organizations.

The survey results were collected electronically over a 2 ½-week period. The results were then compiled and analyzed for trends.

4.3 MANAGEMENT SYSTEM SURVEY RESULTS

The survey results consist of a summary of the number of respondents and their demographics, and evaluation and comparison of the management systems employed by drilling contractors to those employed by BOP OEM. *(Note: The survey responses were provided by individuals, and therefore, the response reflect individual’s opinions rather than any specific organization’s policy or operation. In addition due the small number of respondents, readers are caution not to develop firm conclusions about the respective management system performance based solely on these results.)*

4.3.1 Demographic Results

The survey included responses from 21 participants – 16 drilling contractor participants and 5 BOP OEM participants. The survey included responses from personnel in operations, maintenance, rig management and technical support job roles. All of the respondents completed the manager version section of the survey questions provided in Appendix C. In addition, the respondents averaged more than 10 years of offshore experience and nearly 50% of the respondents have been in their current position for 5 or more years. Figures 4-1 through 4-4 provide the specific demographics of the survey participants.

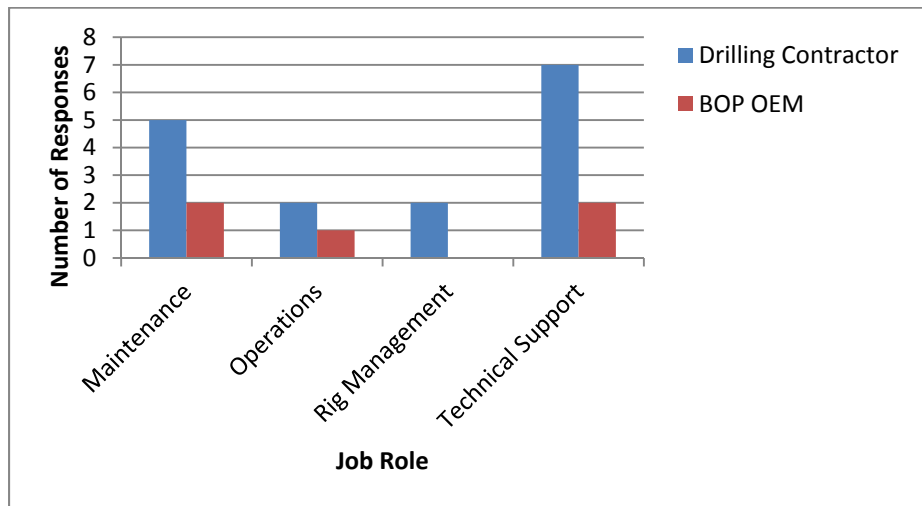


Figure 4-1. Respondent Job Roles

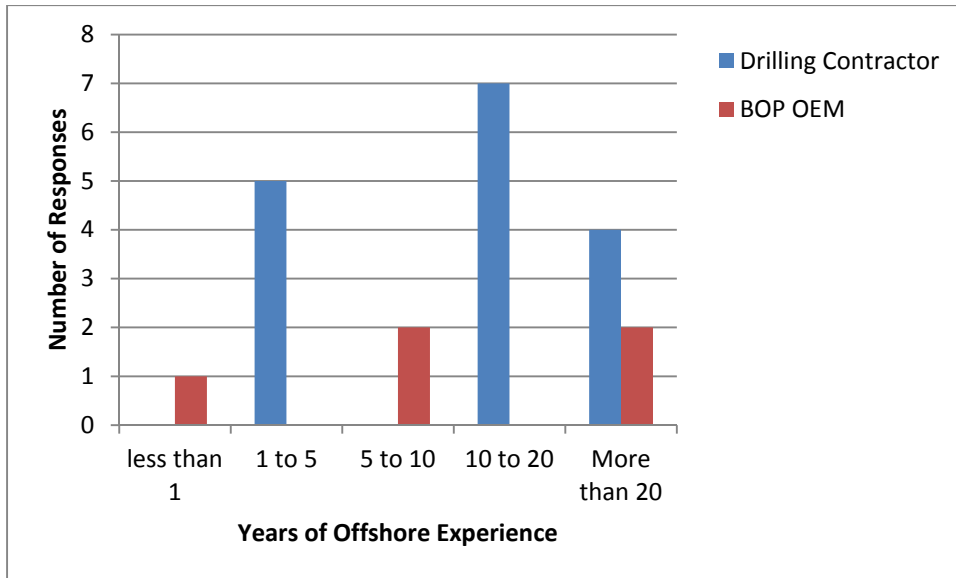


Figure 4-2. Respondent Offshore Experience

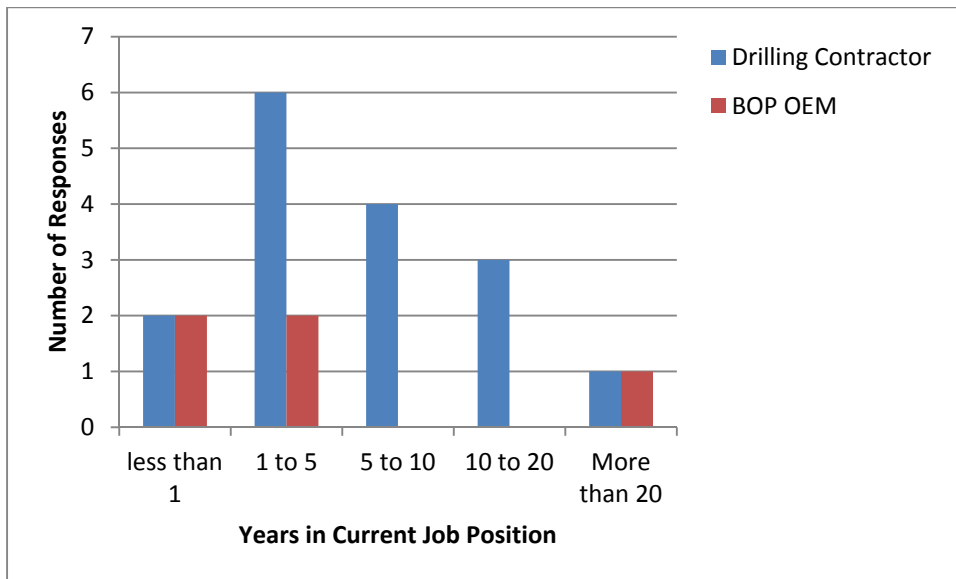


Figure 4-3. Respondent Current Job Experience

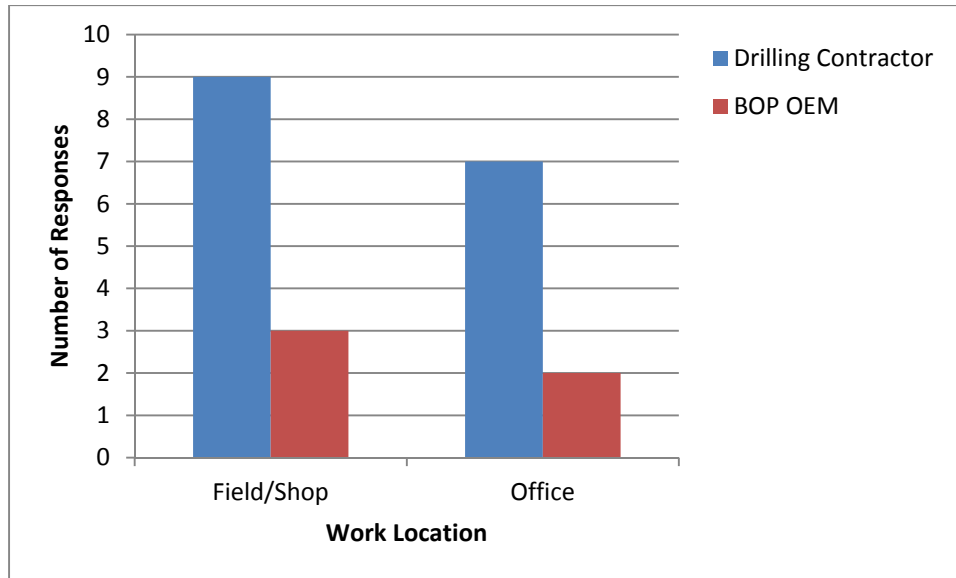


Figure 4-4. Respondent Work Location

4.3.2. Failure Elimination Results

The survey focused on 3 portions of the failure elimination process – identification and documentation, investigation, and corrective actions. Figures 4-5 to 4-8 provide the results related to identification and documentation of failures. Figure 4-5 indicates drilling contractors are identifying and documenting BOP failures having lesser impact, in addition to the larger impact failures. BOP OEM response seems appropriate given they are most likely only involved when more significant BOP failures occur.

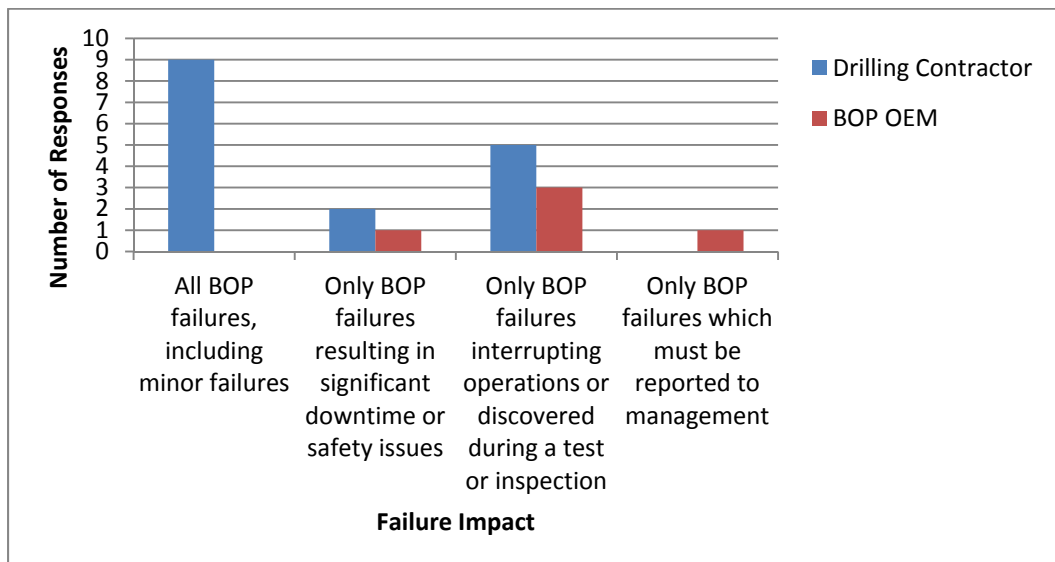


Figure 4-5. BOP Failure Identification and Documentation

Figure 4-6 indicates work order is most common approach used by drilling contractors for documenting BOP failures. In addition, some drilling contractors and OEMs appear to have established dedicated failure tracking systems. Based on performance in other industries, dedicated failure tracking systems are proven effective for identifying failure trends, driving continuous improvement, and ensuring organizational awareness of critical equipment failures.

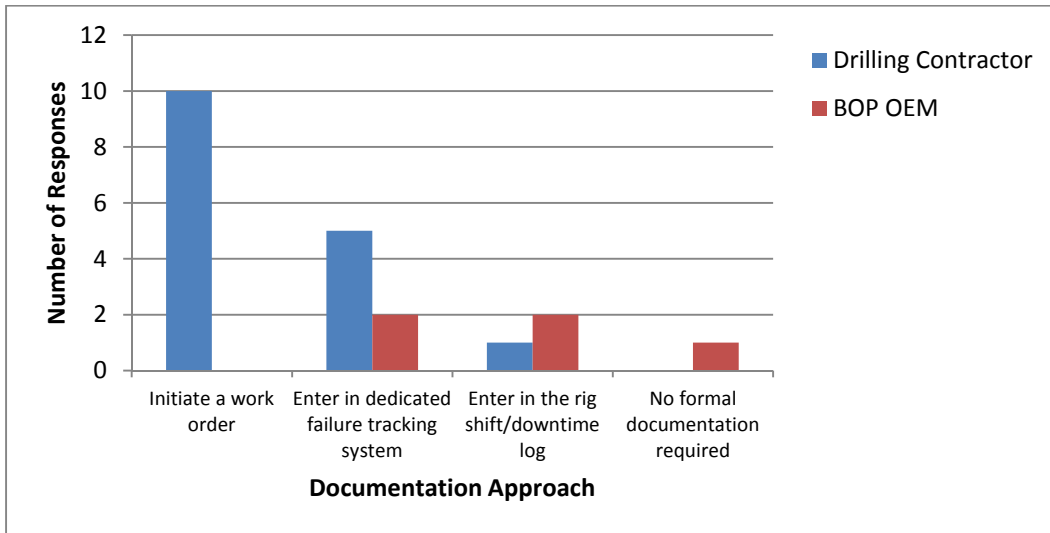


Figure 4-6. BOP Failure Documentation Approach

The final result relates to existence (or knowledge of existence) of a written procedure for identifying and documenting BOP equipment failures. This question provides indication about the sustainability and consistency of the management system related to BOP failure identification and documentation. Figure 4-7 contains the survey results, which indicate about 60% of the participants, indicated a written procedure was in place.

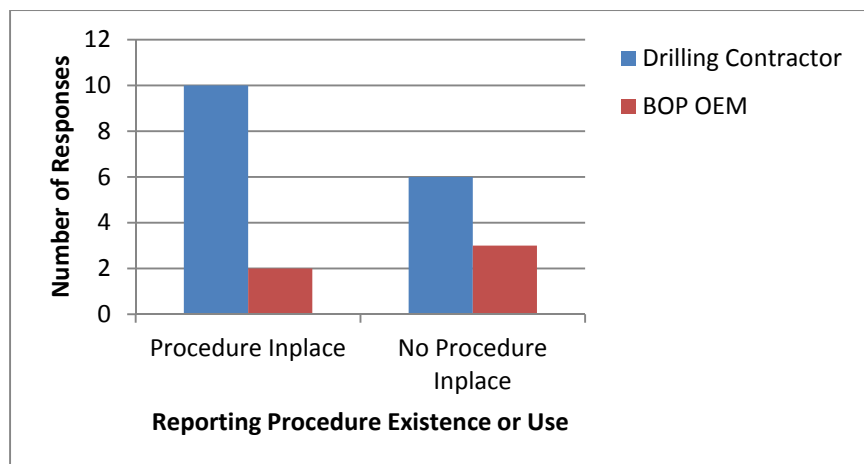


Figure 4-7. BOP Equipment Failure and Condition Reporting Procedure

Next, the survey inquired about the investigation of BOP failures. Specifically, the survey investigated which BOP failures were formally investigated and what the formal investigation process involves. Figure 4-8 shows which BOP failures are formally investigated. Two thirds of the survey participants indicated BOP failures were investigated if the failure impact results in a safety issue or significant downtime. Also based on these results, trending of repeat failures does not appear to be a common trigger for a formal investigation.

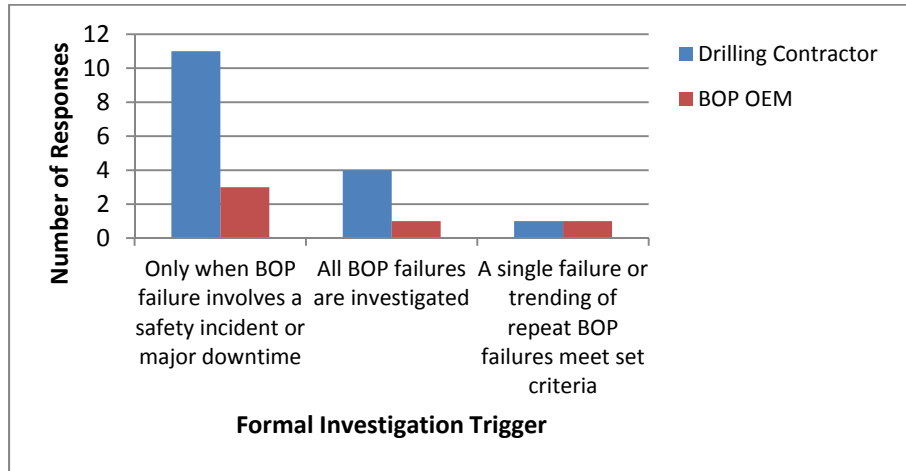


Figure 4-8. BOP Failures Resulting in Formal Investigation

The survey inquired about the types of tools used in the formal investigations, and the organizations participating in the formal investigation. Figure 4-9 provides the survey results related to the investigation tools used. These results indicate forensic-type failure analysis, structured root cause analysis, and data gathering are used by both the drilling contractors and BOP OEMs. These are all good practices. In addition, the drilling contractors use a multi-discipline investigation teams.

Figure 4-10 provides the results related to the differing organizations typically participating in formal investigations. A high percentage of the drilling contractor respondents indicate involvement from multiple organizations in formal investigations. While the BOP OEM participants did not indicate the use of multiple-discipline teams (see Figure 4-9), these results seem to indicate investigations might include personnel from more than one part of their organization.

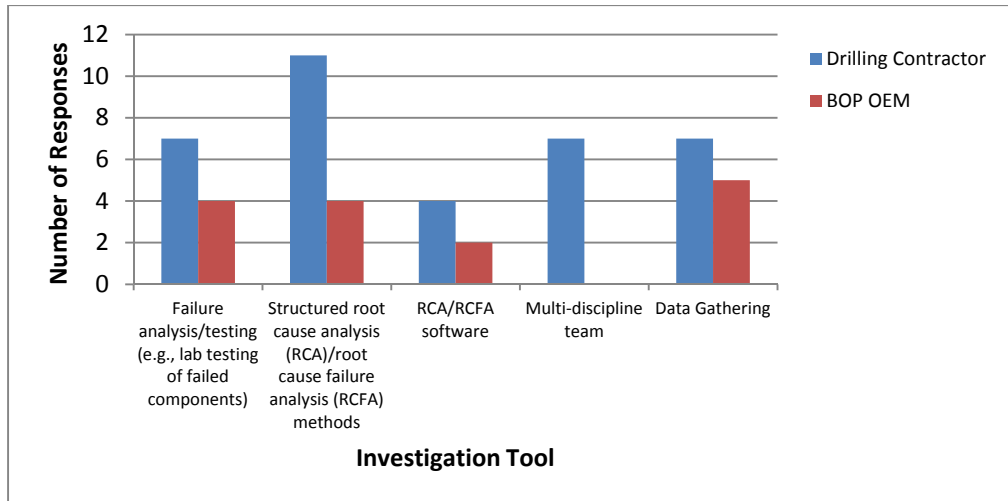


Figure 4-9. Tools Used in Formal Investigations

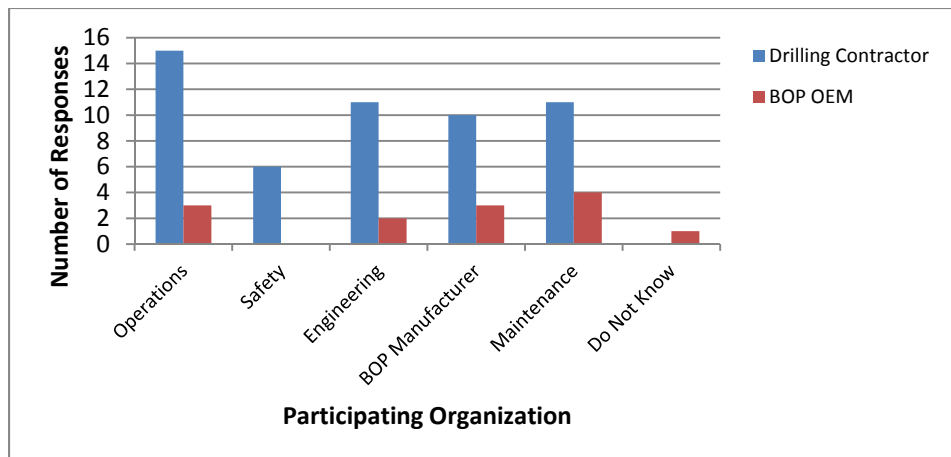


Figure 4-10. Formal Investigation Participants

The last failure elimination survey questions related to the corrective actions developed by the formal investigation. Specifically, the survey inquired about the type (or level) of corrective actions typically resulting from the investigation and then the tracking mechanisms used to ensure corrective actions were implemented. Figure 4-11 provides the results related to the type (or level) of corrective actions resulting from investigations. These results indicate a tendency by both the drilling contractors and BOP OEMs to develop a spectrum of corrective actions which address the basic causes of the specific failure, specific equipment improvements for the failed equipment item and similar equipment items, personnel performance issues, and finally management systems changes/improvements. This is a good trend, especially, with many of the respondents indicating management system corrective actions typically result from formal investigations.

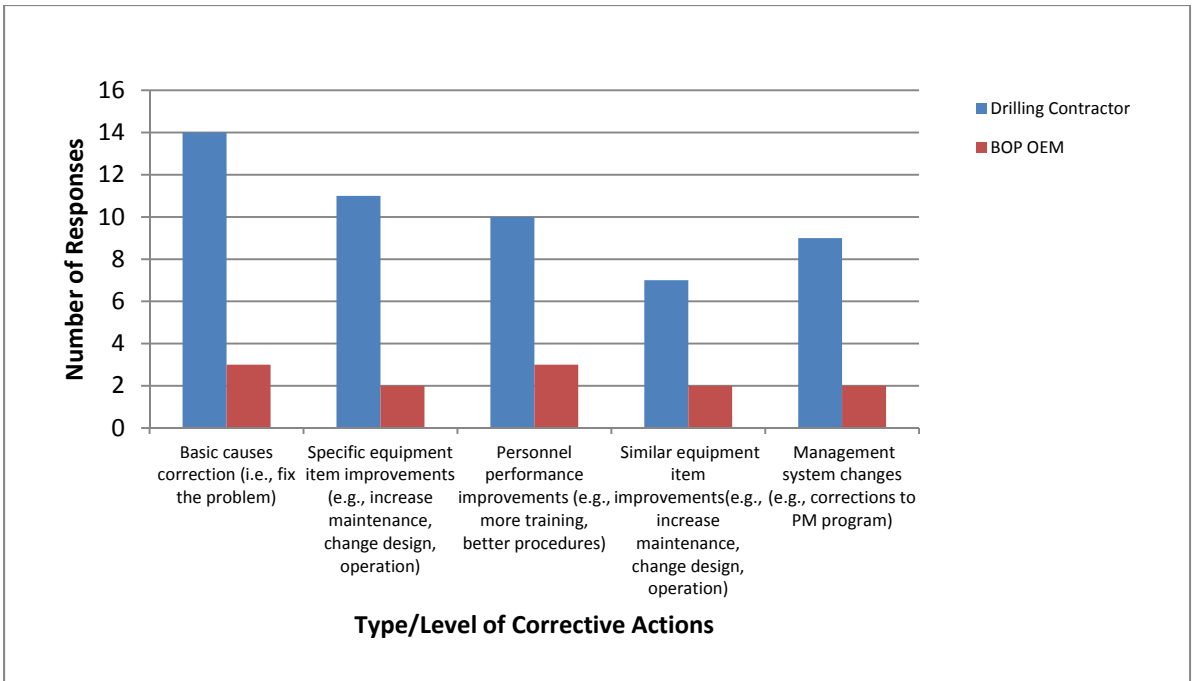


Figure 4-11. Formal Investigation Corrective Actions

Finally, Figure 4-12 provides the survey results related to corrective action tracking mechanisms used. While 60% of the respondents indicated some form of corrective action tracking was in place, the number indicating there was no formal tracking process is an indication that some IPs may not have a tracking system or their personnel are not aware of corrective action tracking. In either case, this is indication that improvement in this area may be warranted.

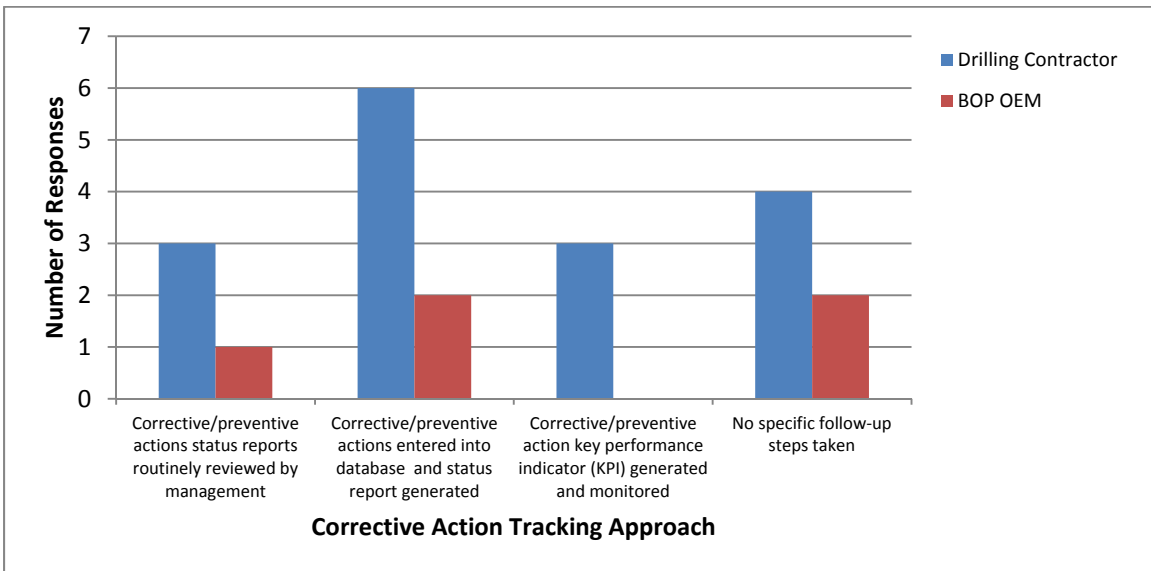


Figure 4-12. Corrective Action Tracking

4.3.3 CMMS Results

Another area surveyed related to the use of a CMMS (or similar computer system), and the system's use in BOP maintenance. The first area of inquiry related to use of CMMS (or similar system) to manage BOP maintenance and length of time in the CMMS had been in use. These results are provided in Figures 4-13 and 4-14 respectively. Figure 4-13 show 81% of drilling contractor and 60% of BOP OEM respondents indicate a CMMS or similar computer system is used to manage BOP maintenance. The results in Figure 4-14 indicate that these systems are past the initial implementation, but may be relatively new as compared to some industries.

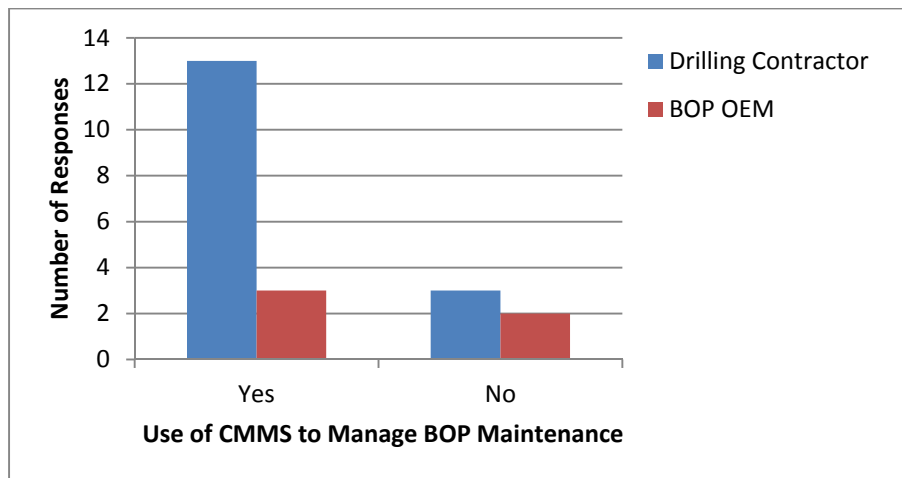


Figure 4-13. CMMS Used in BOP Maintenance

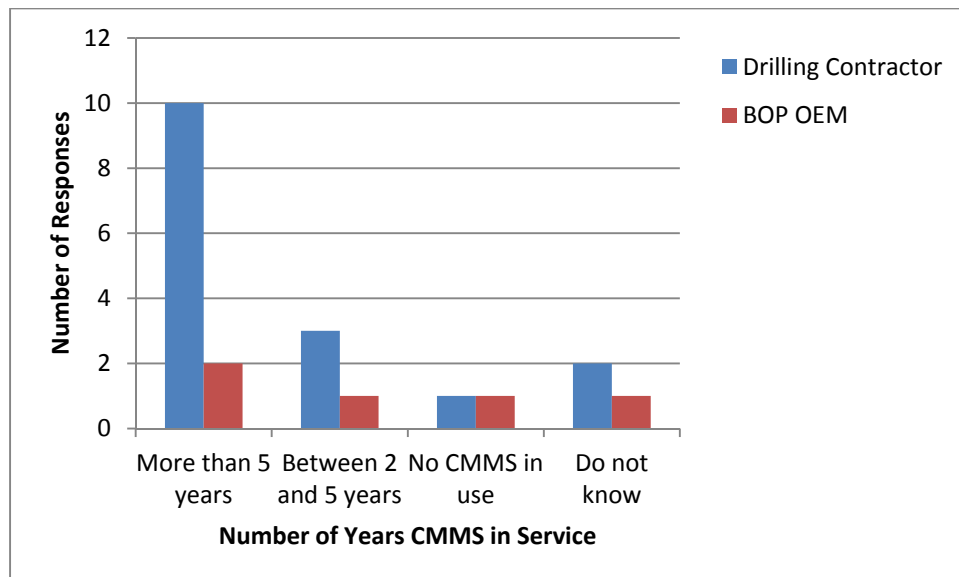


Figure 4-14. CMMS In-Service Time

The next inquiry involved the CMMS functionality employed in the management of BOP maintenance and types of overall management activities in which the CMMS is used. Figure 4-15 shows the CMMS functionality in use, and these results indicate core CMMS functionalities related to asset register, asset criticality, and maintenance work process activities (e.g., work order management, PM) are in use by both drilling contractors and BOP OEMs. To lesser extent, the CMMS appears to be used for procurement, stores inventory and document management activities. The notable areas in which the CMMS use could improve are related to continuous improvement type of activities, such as PM optimization, failure tracking, and reliability analyses.

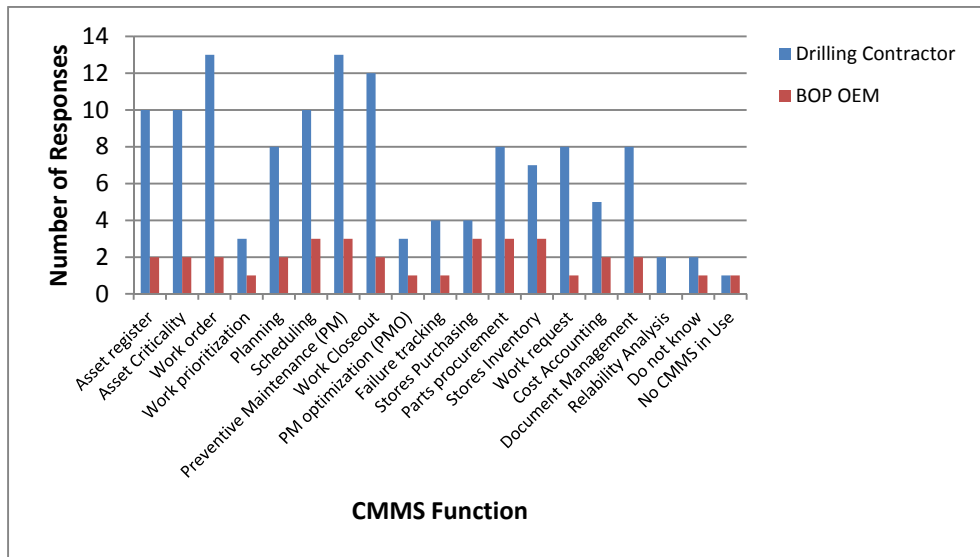


Figure 4-15. CMMS Functionality Employed

From the management activity perspective, the results in Figure 4-16 indicate the drilling contractors use the CMMS for cost and regulatory management activities. From a reliability improvement perspective, increase in the apparent CMMS use of stores inventory management, reliability analysis and key performance indicator generation and monitoring would likely aided in ensuring and improving BOP reliability performance.

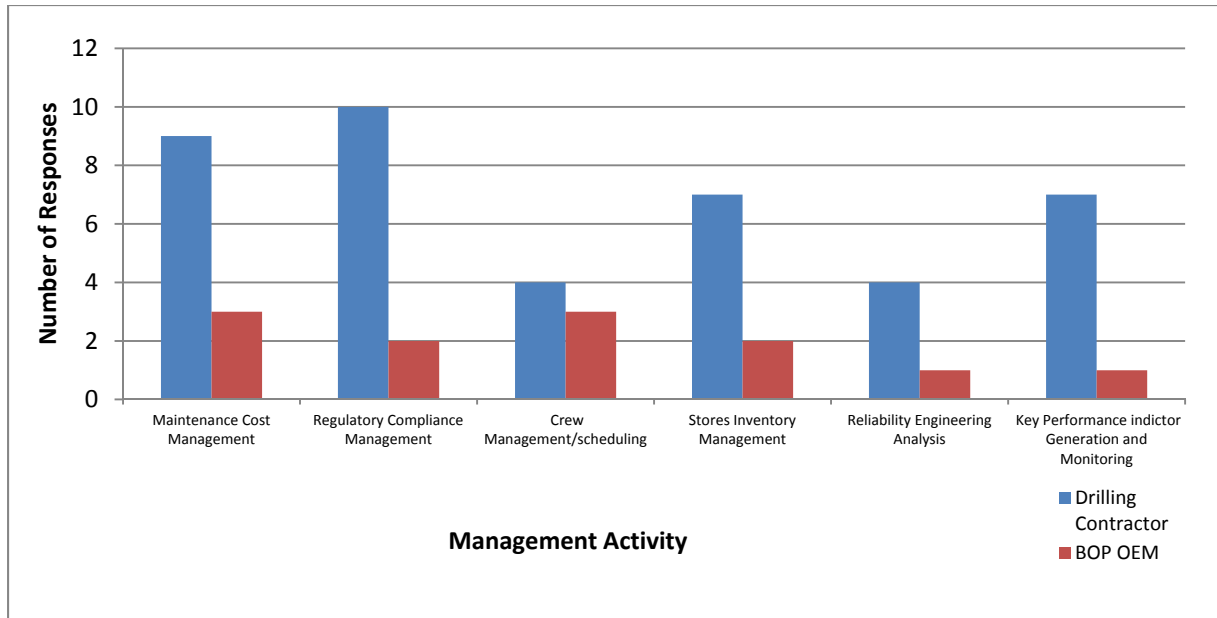


Figure 4-16. CMMS Management Activities

4.3.4 Maintenance Management Practice Results

Somewhat related to CMMS use, the next area surveyed related to the maintenance management practices in place. Specifically, the survey inquired about the formality of the maintenance management work process and adherence to the process, the work process elements included, the performance of key work process elements, and the monitoring of the work process. Figure 4-17 provides the results related to the formality and adherence to the work process. This figure indicates the drilling contractors have a formal process. However, BOP OEM respondents did not provide as strong of an indication of a formal process. In terms of adherence to the formal process (i.e., following the maintenance work process), fifty percent of the drilling contractors indicate formal process is not followed. This is not unusual in the maintenance practice surveys, and it is usually an indication that re-engineering of maintenance work processes may be needed. This is especially important because the maintenance work process is one of the most important management systems for ensuring proactive MIT activities are executed as planned and corrective maintenance is properly performed in a timely manner.

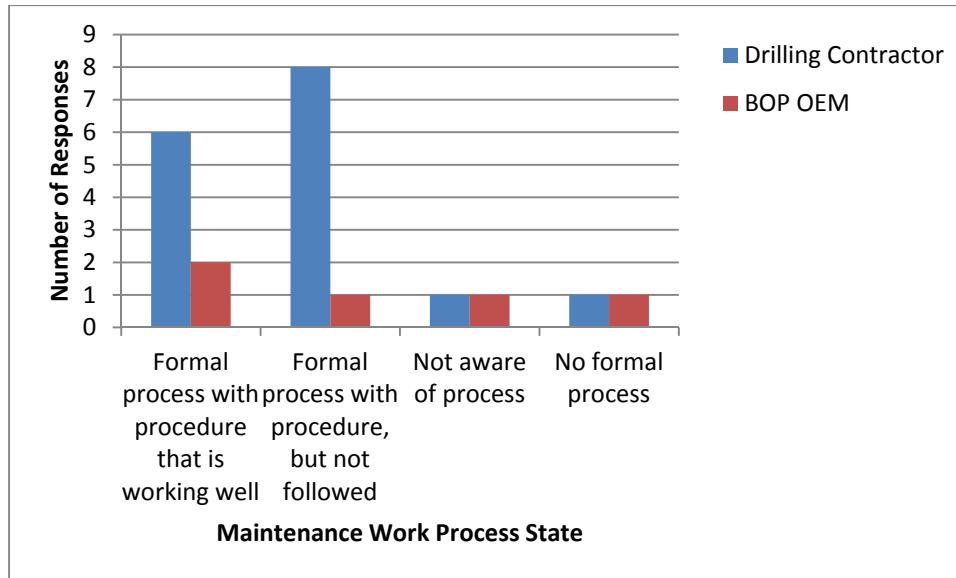


Figure 4-17. Maintenance Work Process

Next the elements included in the maintenance work process procedure were surveyed, and these results are presented in Figure 4-18. As with the CMMS, these results indicate the basic maintenance work control elements are included in the procedure.

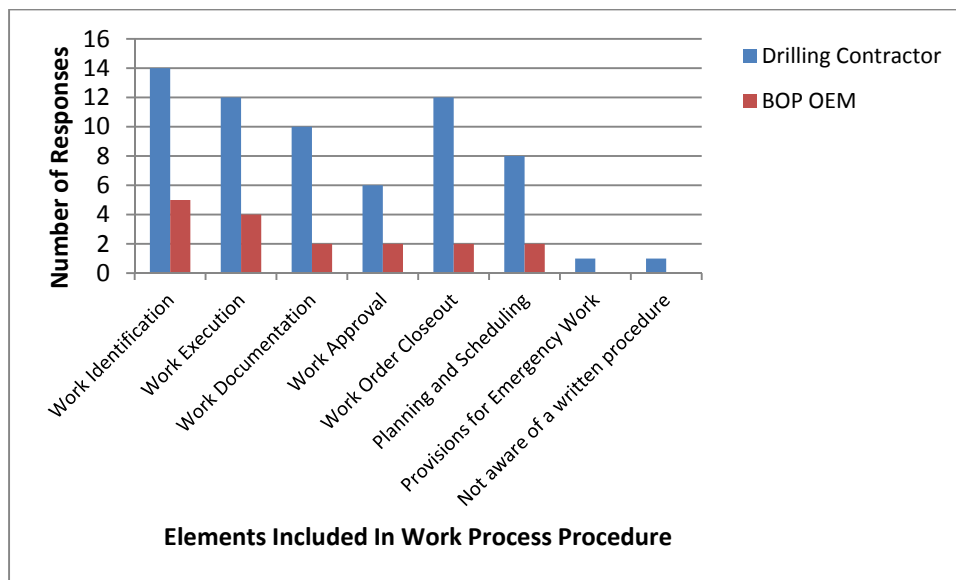


Figure 4-18. Work Process Elements

The next areas surveyed related to key work process elements – work order use, work prioritization, and work planning. Figure 4-19 provides the work order usage results, which indicates a high percentage of maintenance work performed is managed by work orders. However, the most frequent response was frequently, 75% to 95%, which is good

performance, but is below what many industries consider best practice, >95%. In terms of work prioritization, the responses provide in Figure 4-20 indicate the priorities are jointly set by operations and maintenance personnel during work scheduling. This is seen as a good practice in many industries.

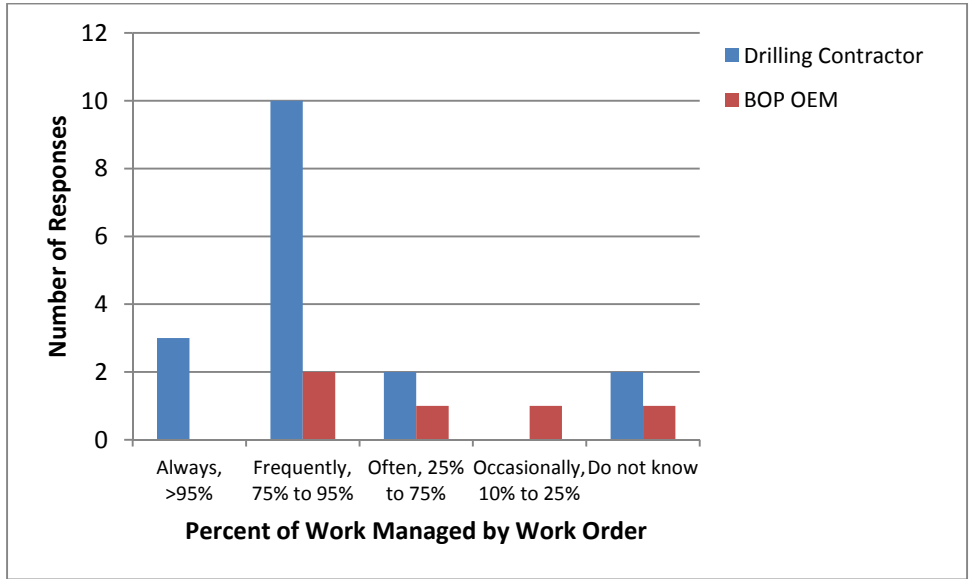


Figure 4-19. Work Order Use

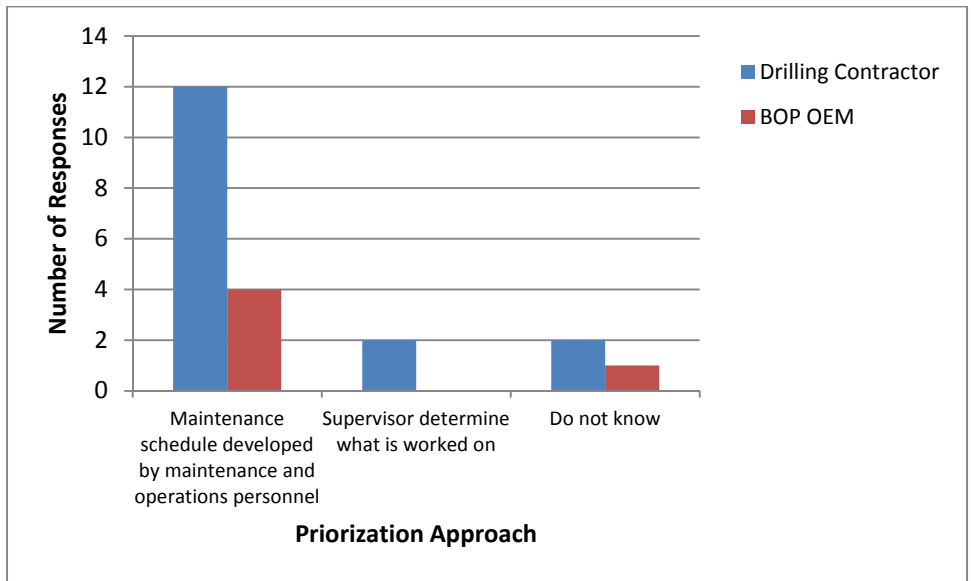


Figure 4-20. Work Prioritization

Figure 4-21 provides the responses related to work planning, and it shows that for drilling contractors a high percentage of time BOP maintenance work is planned. The BOP OEM respondents indicate less work planning is employed.

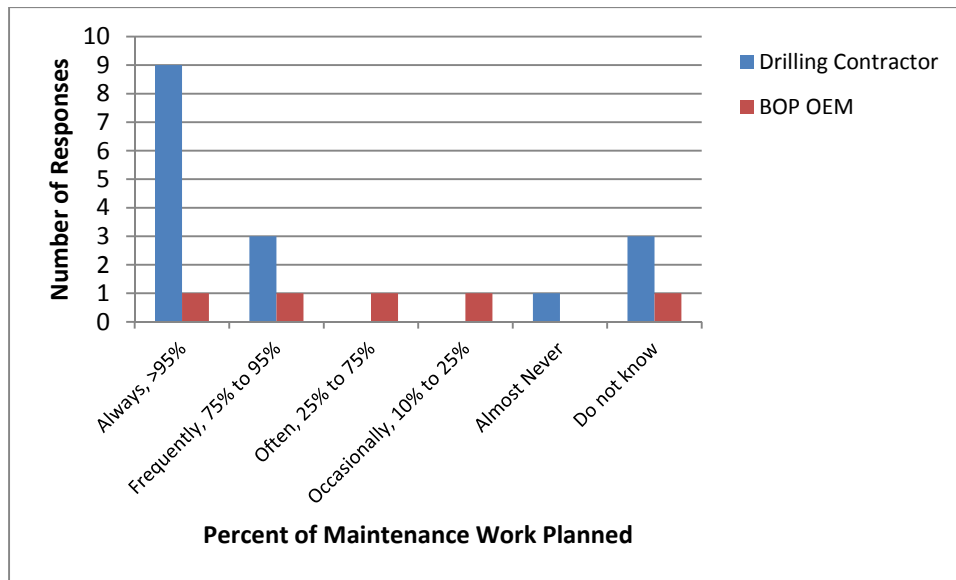


Figure 4-21. Maintenance Planning

The last work process element surveyed related to work results documentation. Figure 4-22 provides these results. These results indicate that drilling contractor documentation practices may not ensure proper recording of information, as 7 of the 16 responses indicate results are documented by indicating work order complete or recording equipment is okay (for PM results). In general, a good maintenance practice involves the recording more information about the work performed and equipment condition (for PMs). Eighty percent of the BOP OEM respondents indicate good documentation practices.

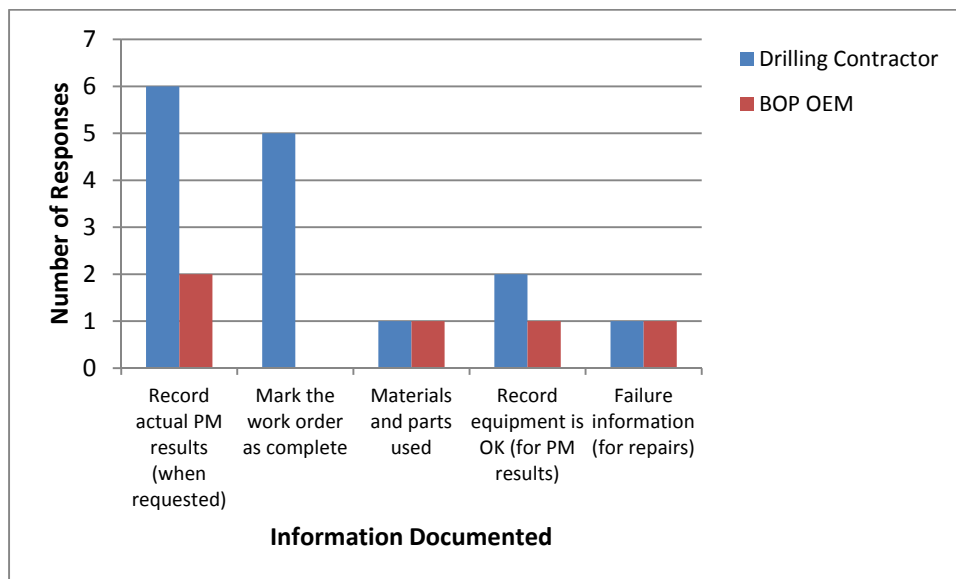


Figure 4-22. Work Results Documentation

The final area of inquiry related to monitoring of the maintenance work process performance, and Figure 4-23 contains these results. These results indicate the most common practice is routine work backlog review, which is the common practice in most industries. However, some respondents indicated audits and work management key performance indicators as approaches used. The use of work process key performance indicators is viewed as good practice in many industries, and the expanded use of this type of tool would likely help ensure and improve BOP reliability performance.

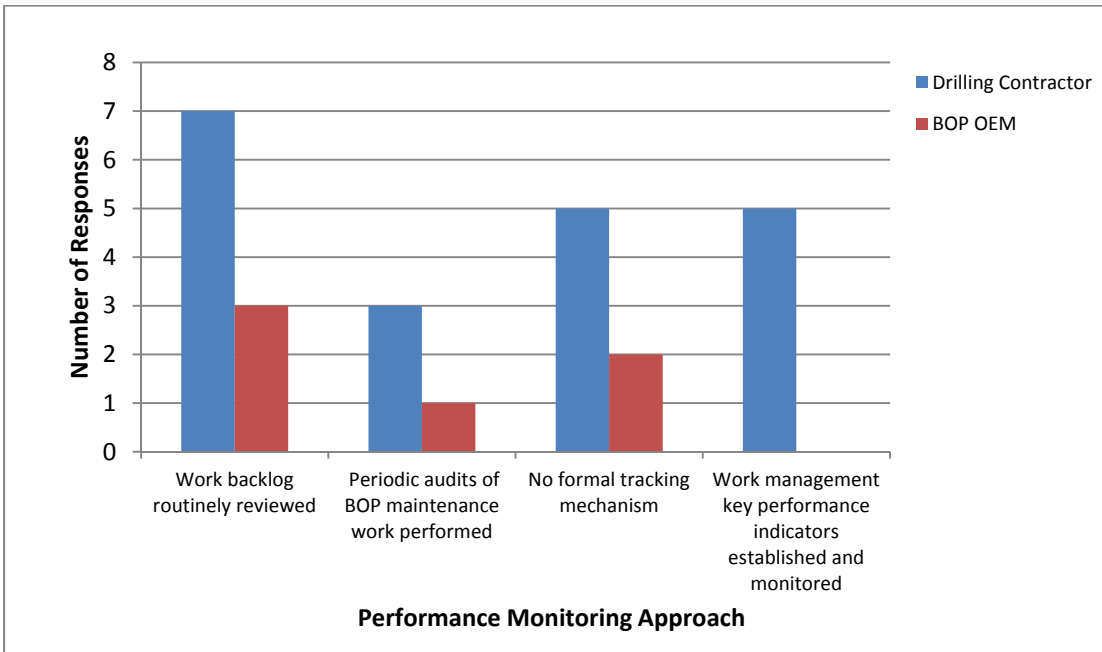


Figure 4-23. Maintenance Work Process Monitoring

4.3.5 PM Program Results

The next area surveyed involved attributes of the PM program. Specifically, the survey inquired about two areas of the PM program: (1) the approach for PM task periodicity and (2) the part replacement philosophy for BOP equipment. Figure 4-24 provides the survey results related to the basis for PM task periodicity (i.e., task intervals). These results show, as expected from the planned MIT task review presented in this report, a high dependence on BOP OEM recommendations. These results also seem to indicate BOP OEMs rely on their equipment vendors for PM task intervals.

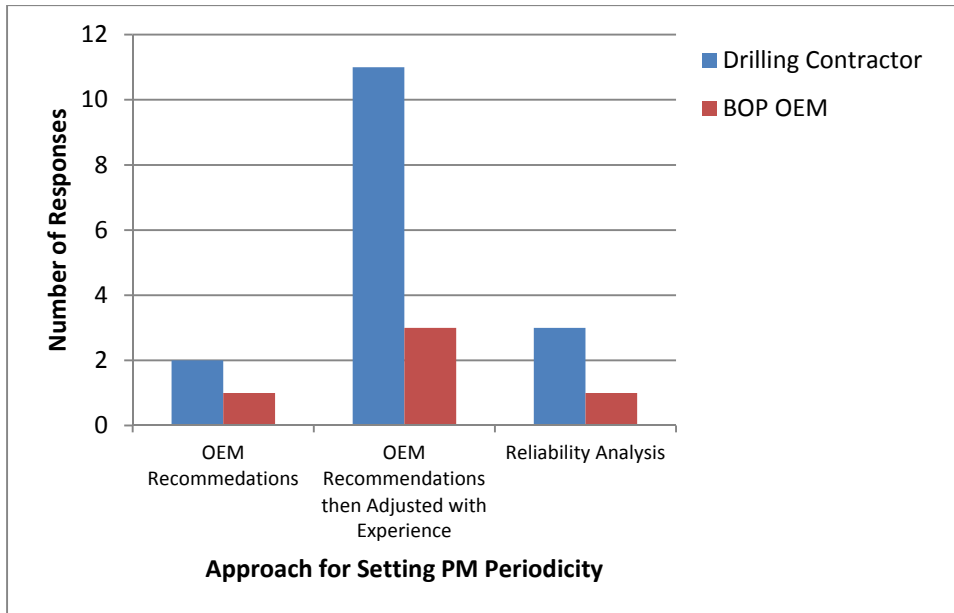


Figure 4-24. PM Task Periodicity Bases

The type of PM task intervals used by drilling contractors were surveyed, see Figure 4-25, and these results indicate calendar-based PM intervals are most frequently used while the BOP OEMs appear to set PM task intervals by a variety techniques. The final PM task interval question related to the review of PM task intervals. These results are provided in Figure 4-26 and indicate the most frequent response is that PM task intervals are regularly reviewed, which is a good practice for helping to improve maintenance effectiveness and BOP reliability performance.

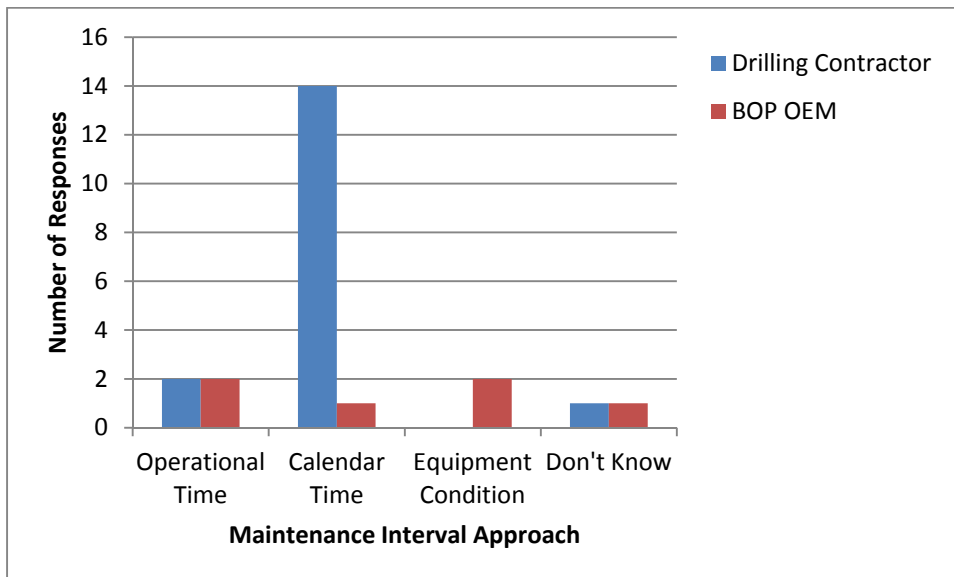


Figure 4-25. Type of PM Task Intervals

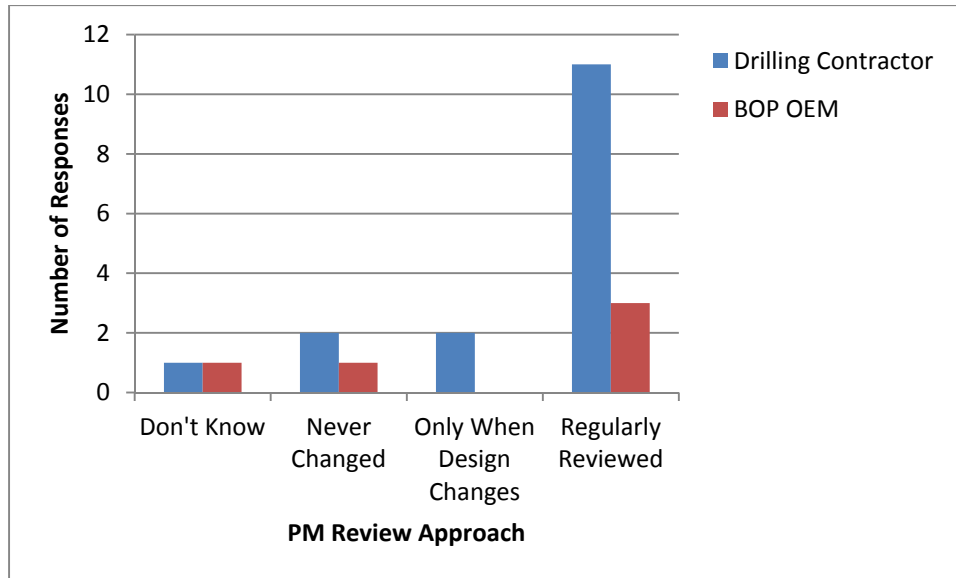


Figure 4-26. PM Review

The last area surveyed related to the part replacement philosophy for surface and subsea BOP equipment. This question relates which of the following philosophies are being used: run-to-failure, time-based, or condition-based. Figures 4-27 and 4-28 contain the results for parts replacement philosophy for subsea equipment and surface equipment respectively. Both results indicate a time-based approach (i.e., schedule calendar intervals) is used by the drilling contractors and BOP OEMs. However, condition-based approach appears to have some use for surface equipment. More use of a condition-based approach could improve BOP reliability performance if an effective approach can be designed, based on history in other industries.

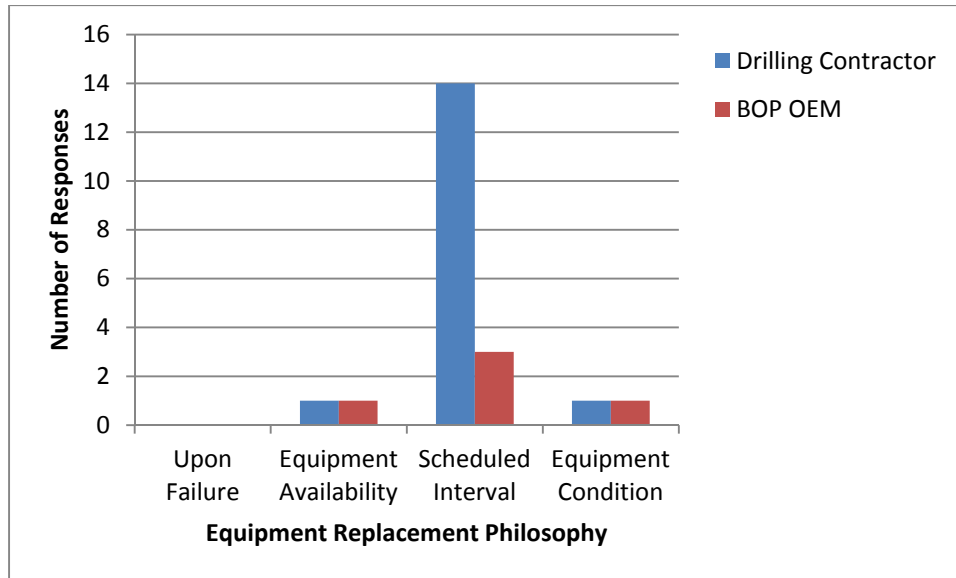


Figure 4-27. Subsea BOP Equipment Replacement Philosophy

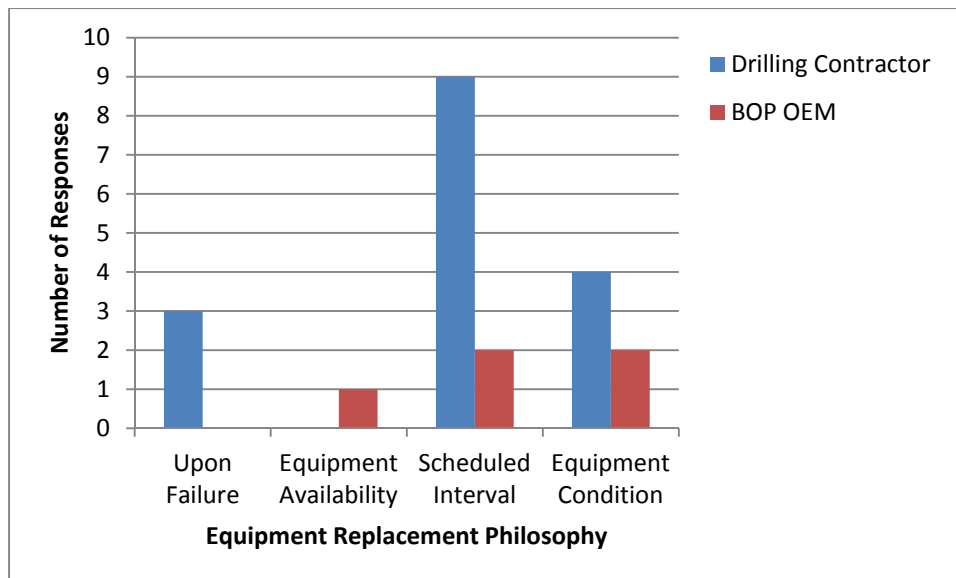


Figure 4-28. Surface BOP Equipment Replacement Philosophy

4.3.6 Written Instructions Results

This area of survey inquired about the written instructions and information provided to personnel who maintain the BOPs (BOP maintainers). The survey inquired about the type of instructions and information provided, its accessibility, the expected and actual use of the instructions, the content of written instructions, and the measures used to ensure and maintain accurate written instructions and information. The first area of inquiry involved the type of written instructions and how the BOP maintainers access the written instructions/information. These results are provided in Figures 4-29 and 4-30. Figure 4-29 indicates the high dependence on BOP OEM manuals and work order descriptions (vs. site/unit specific step-by-step instructions). Based on the results in presented in Figure 4-30, electronic access or transmission with the work order are used to provide BOP maintainers access to the written instructions/information. These accessible approaches have advantages in that they are electronic based which provides a better means for ensuring the most up-to-date information is provided BOP maintainers.

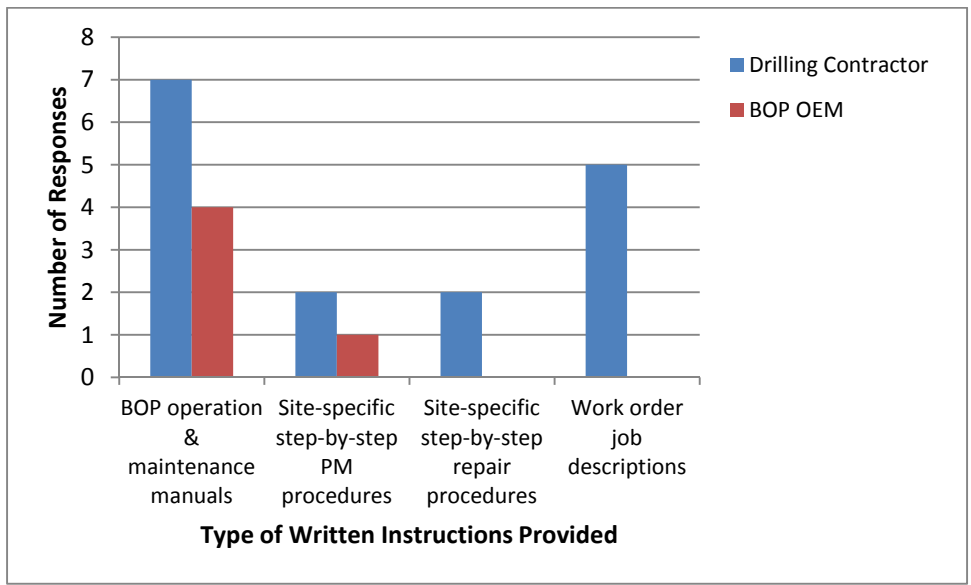


Figure 4-29. Type of Written Instructions/Information

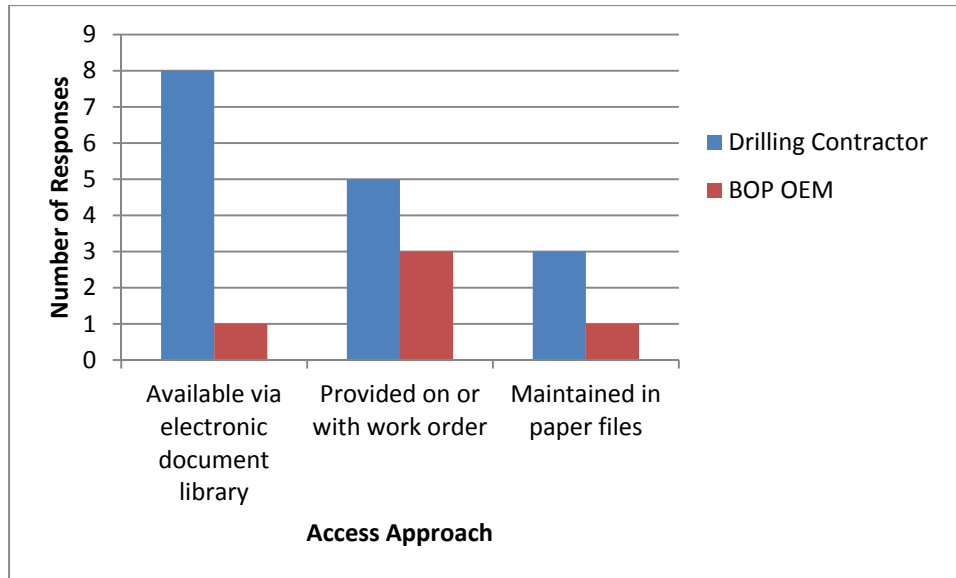


Figure 4-30. Written Instruction/Information Accessibility

The survey inquired by the content of typical written instructions. Specifically, this inquiry involved the content of repair instructions. (Note: Routine PM tasks are often detailed in OEM manuals and/or work order information; therefore, the inquiry regarding repair procedure instruction was selected.) Figure 4-31 contains the survey results regarding repair instruction content, and it shows nearly half of the drilling contractors indicated step-by-step instructions are provided, which is a good practice. However, slightly more than half of the drilling contractor respondents and majority of BOP OEM respondents indicated limited information is directly provided in the written repair instructions.

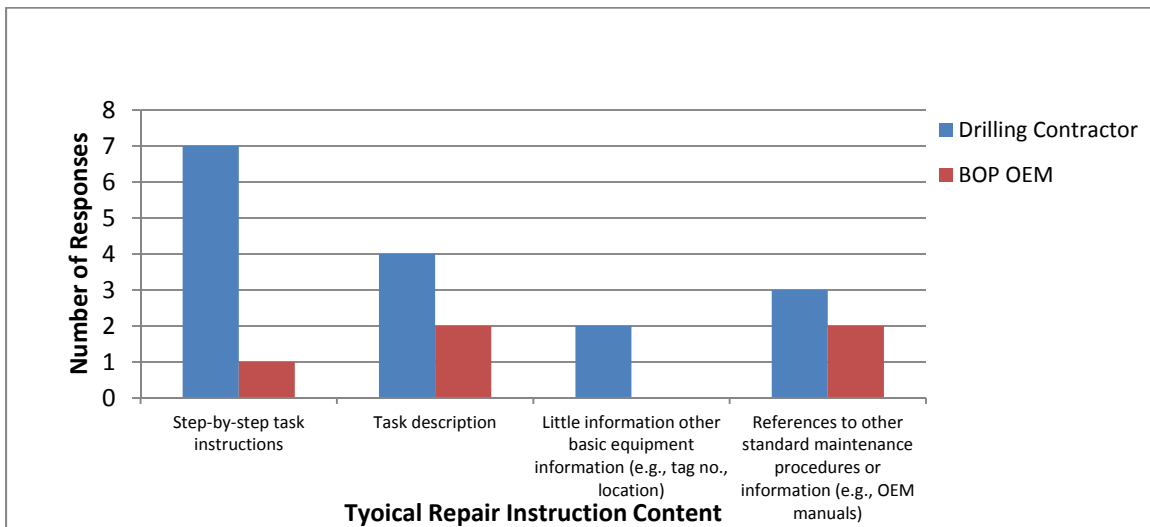


Figure 4-31. Typical Repair Instruction Content

There can be differing expectations on use of the written instructions, such as written instructions are primarily used as (1) a training tool,(2) a reference/guideline for performing a task, or (3) the expected means for performing a task. Figure 4-32 provides the data related to expected use of written instructions, and indicates mixed results in that some respondents view the written instructions as providing the expected way to perform tasks and other respondents view the written instructions as a guideline. While this is not usual, the most effective use of written instructions involves establishing procedures and clear expectations that the written instructions provide the expected steps for performing a task.

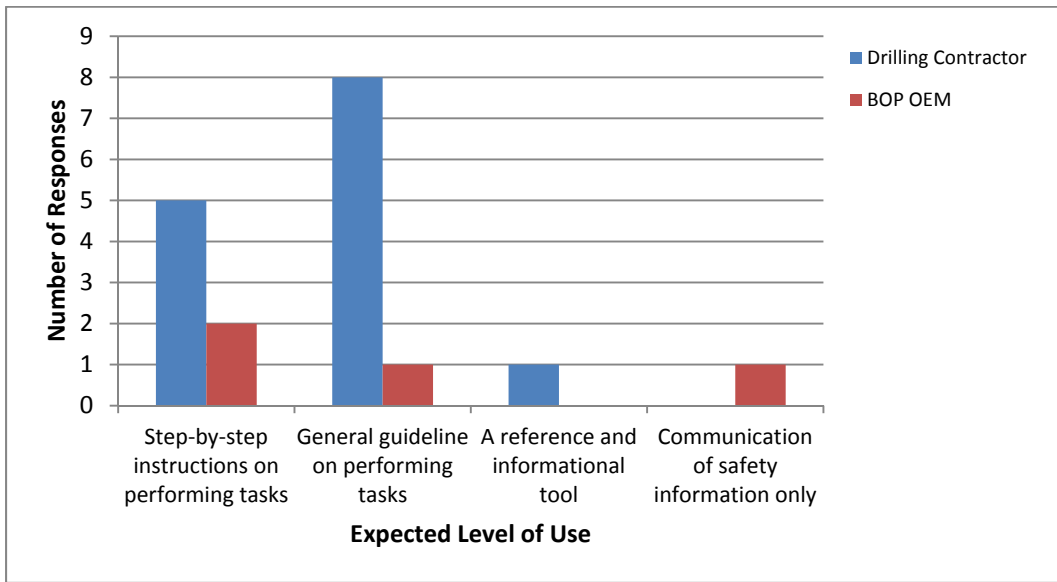


Figure 4-32. Expected Level of Use of Written Instructions

The next survey question inquired about the field use of the written instructions. Specifically, the question inquired how often the written procedures are typically used and when they are used during task performance. The results in Figure 4-33 indicate that the majority of drilling contractor and BOP OEM respondents indicate written instructions are usually reviewed/read either before or during the performance of a task. In addition, more than 50% of drilling contractor respondents indicated procedures are used during the performance of a task.

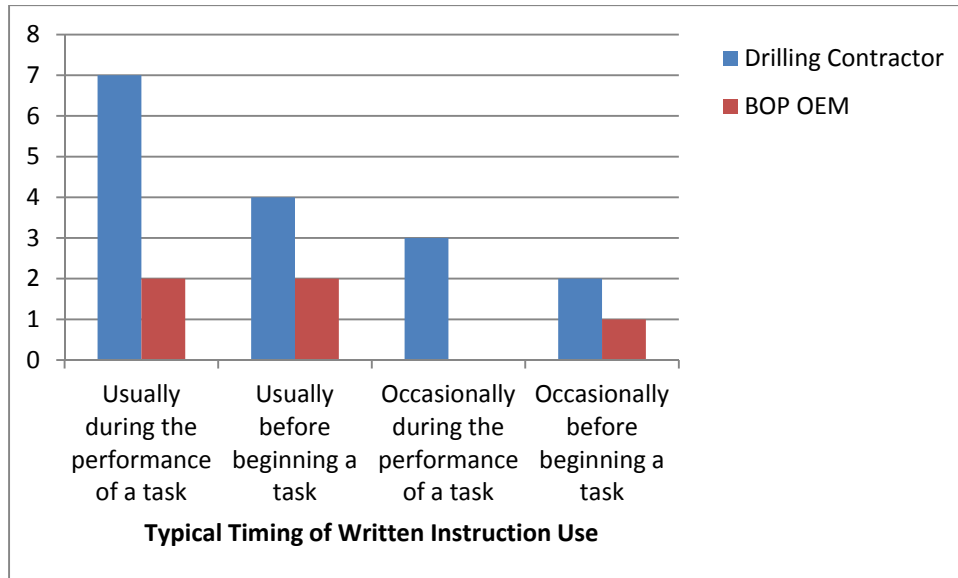


Figure 4-33. Written Instruction Use

The last two written instruction survey questions address systems in place to help ensure and maintain the accuracy of the written instructions. Figure 4-34 shows that a formal procedure review and approval with field validation is the most frequent approach used by drilling contractors. In addition, there were two responses by both drilling contractor and BOP OEM respondents indicating a formal procedure review and approval process is used. So nearly half of the respondents indicate a formal procedure review and approval process (with or without field validation) is used. However, nearly half of the other respondents indicated that there was no formal procedure review and approval process or relied on knowledge personnel to develop the written instructions. An improved practice would be to ensure all written instructions are reviewed and approved via a formal process, with the process including field validation when possible.

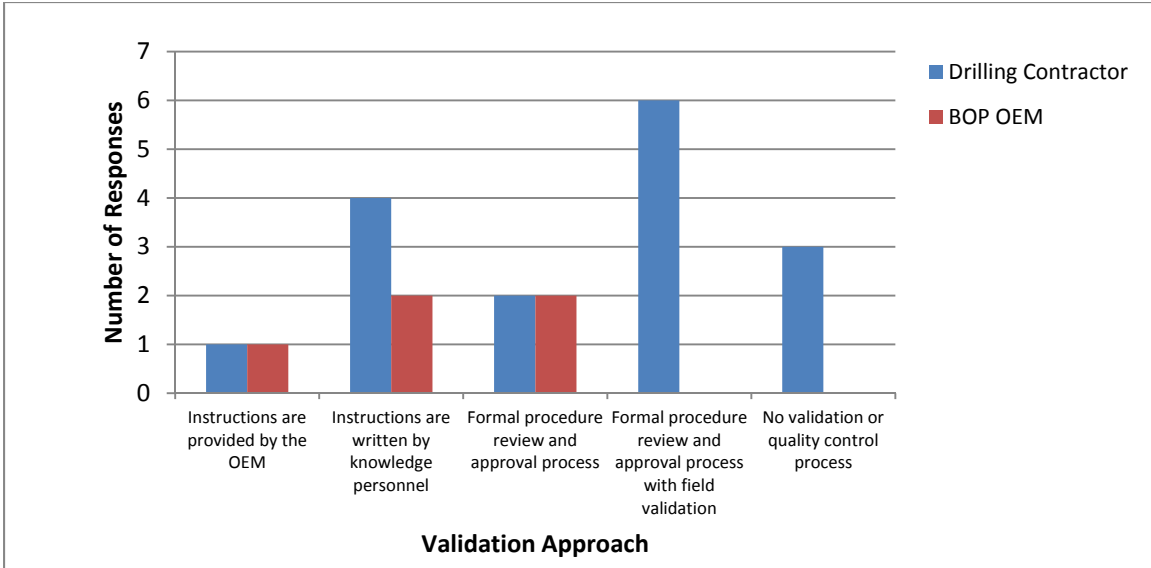


Figure 4-34. Written Instruction Validation

Figure 4-35 provides the results related to process used for controlling and maintaining written instructions. These results indicate BOP OEMs have some form of a document control standard and system in place. Also, a little more than one half of the drilling contractor respondents indicated an existence and use of some form of a document control standard and system.

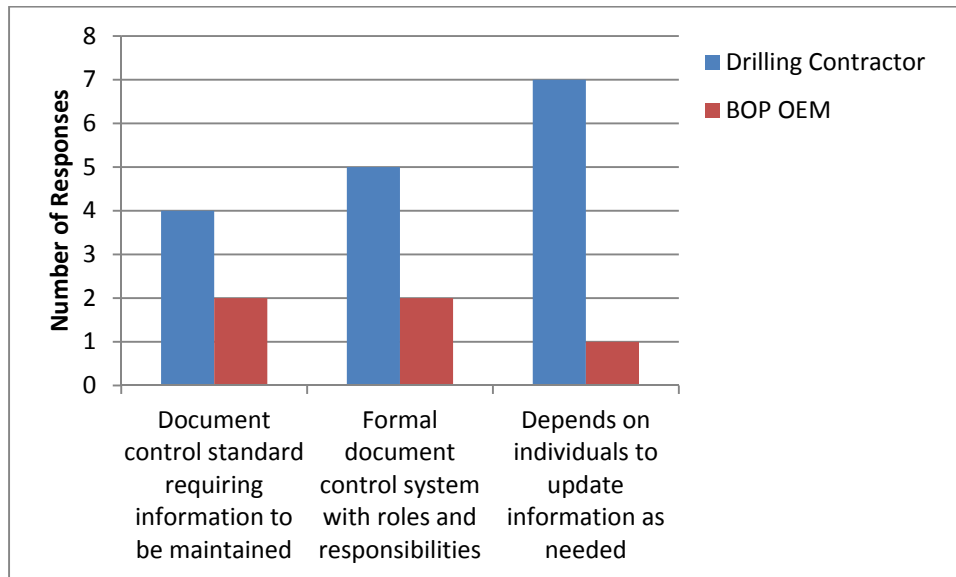


Figure 4-35. Written Instructions Control

4.3.7 Training Results

The last survey area involved the training programs in place for personnel who maintain BOPs (i.e., BOP maintainers). The survey addressed the type of training techniques used, the timing of training, and the general content of training. Figure 4-36 indicates both drilling contractors and BOP OEMs rely on previous work experience and also provide informal, on-the-job training, and formal training (e.g., classroom training).

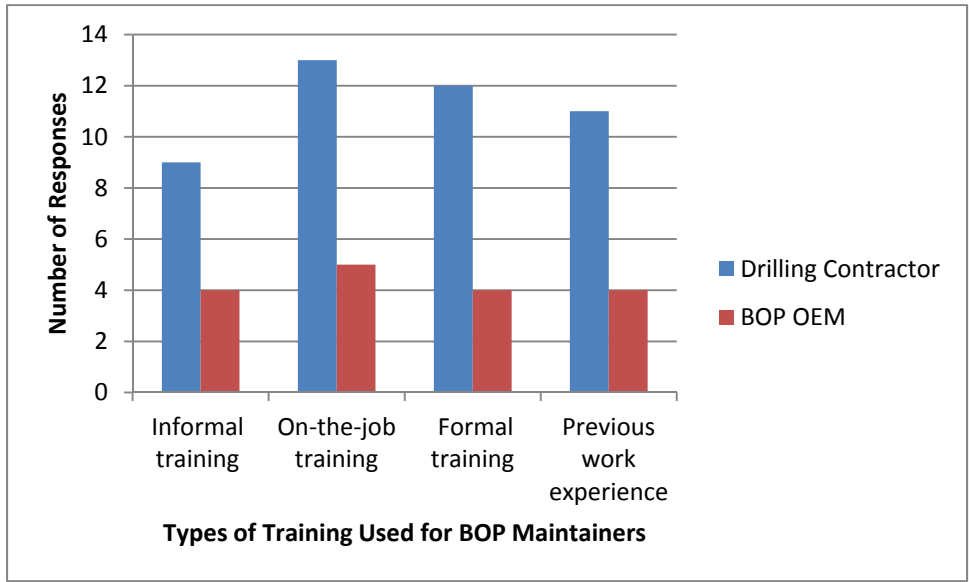


Figure 4-36. BOP Training Approaches

Figures 4-37 and 4-38 provide the survey results related to when training is provided and the content of the training. As seen in Figure 4-37, nearly all of the respondents indicate BOP maintainers receive training when they are assigned to their position. However, these results appear to indicate that a limited amount of refresher and periodic training is provided. Most of the drilling contractor and BOP OEM responses in Figure 4-38 indicate basic craft skill training, general BOP operations and maintenance training, and safety type training are provided. However, the responses seem to indicate training on BOP PM and repair procedures and maintenance policies and procedures may be less common.

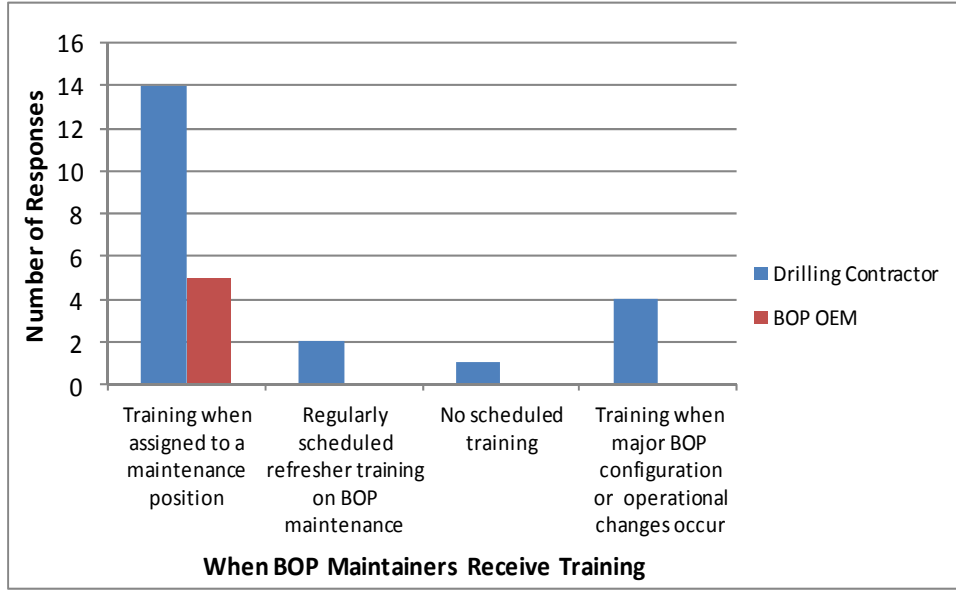


Figure 4-37. BOP Training Timing

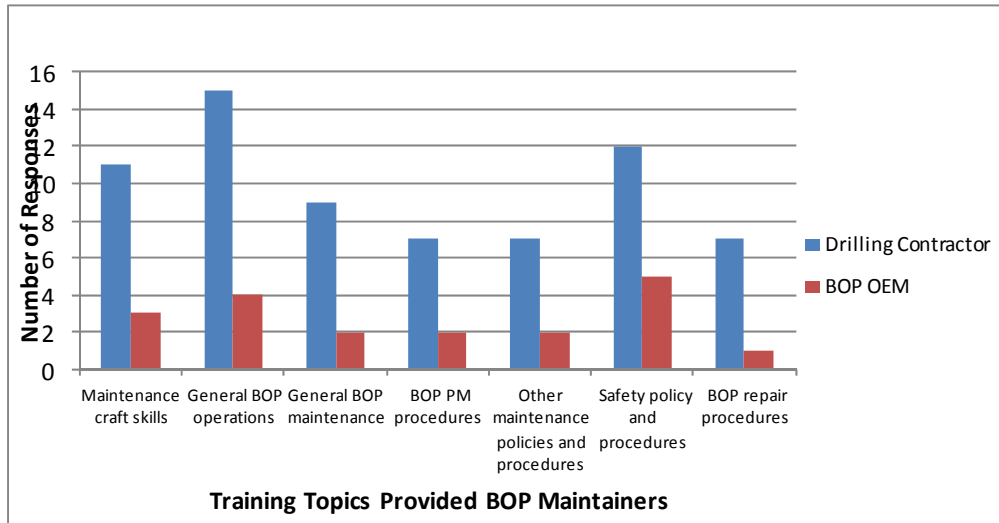


Figure 4-38. BOP Training Content

5.0 MIT ACTIVITIES COMPARISON

The section provides a comparison of the MIT activities collected from the various sources included in this project (e.g., regulations, industry standards and recommended practices, IP MIT plans). The initial comparison focuses on comparing API 53 and 30 CFR 250 with the other regulations reviewed. In addition, this section compares (at a high-level) the MIT activities identified in the regulations and industry standards and recommended practices to the MIT activities currently employed by IPs operating BOPs in the GoM.

5.1 REGULATORY AND INDUSTRY STANDARD AND RECOMMENDED PRACTICE COMPARISON

Section 2 of this report provides a tabular summary and comparison of the API 53 and 30 CFR 250 MIT requirements to the MIT requirements included in selected industry standards and recommended practices, and international regulations. In general, 30 CFR 250 and most of the other international regulations incorporate and reference MIT requirements included in API 53. The following are the exceptions/differences found when comparing MIT requirements:

- Higher frequency of Operational Components Function Test (Blowout Prevention in California)
- Higher frequency of BOP Control System Function Test (Blowout Prevention in California)
- Higher frequency of Accumulator Pressure Precharge Verification (Blowout Prevention in California)
- Higher frequency of BOP Visual Inspection (30 CFR 250)
- Higher frequency of visual inspection of Subsea BOP System and Marine Riser (Blowout Prevention in California)

One other notable difference is some international regulations (e.g., Norsok D-010 specifies that that the well testing activity starts after having drilled the last open hole section) allow or require MIT requirements to be more based on performance or risk-based approaches rather than the mostly perspective approach seen in API 53 and 30 CFR 250.

5.2 IP MIT PLAN AND API 53 COMPARISON

As indicated in the above section, API 53 MIT requirements are incorporated in most all regulations and other industry standard; therefore, the IP MIT plans (i.e., tables included in Appendix B) were compared to the specific MIT requirements in API 53. (Note: API 53 includes a requirement to implement a PM program based on OEM requirements. This recommendations was not included in this comparison).

This comparison indicated that all of the prescriptive API 53 requirements are included in the IP MIT plans included Appendix B at the API 53-indicated interval. In addition, the analysis included a comparison of the percent of API 53 tasks to the overall planned MIT tasks. This included a comparison to the number of specified tasks (i.e., simple count of MIT tasks by task type), and these results are provided in Figure 5-1. This figure indicates API 53 tasks comprise between 10 to 18% of planned maintenance, scheduled inspection, and scheduled test tasks included IPs MIT plans (based on simple count of number of tasks). This comparison shows the planned MIT tasks include an appreciable more number of MIT tasks than required by API 53.

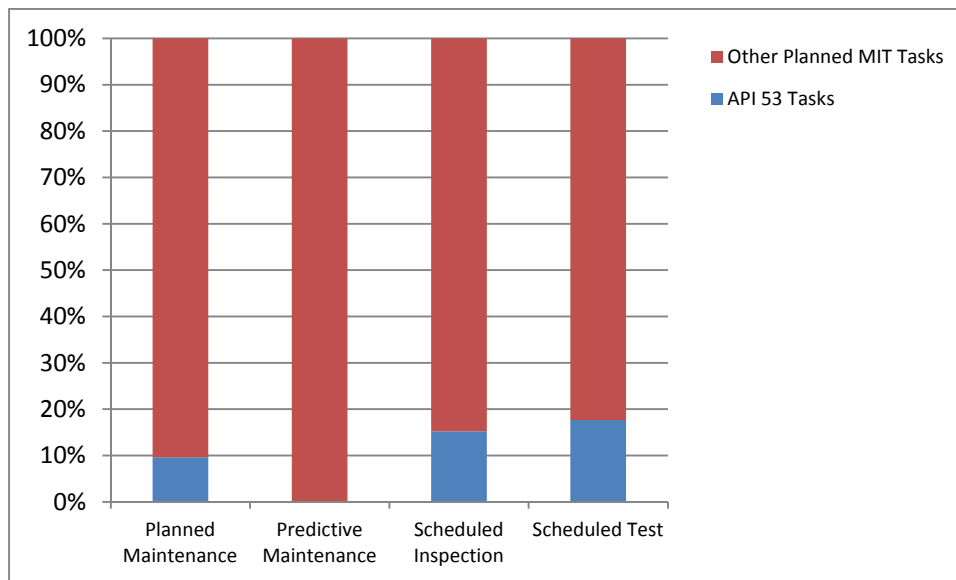


Figure 5-1. Percent of API 53 Tasks Specified of Total Count of Planned MIT Tasks

To compare the percentage to performed tasks, the analysis included an estimation of the number of MIT tasks executed during a one year time period based on a six 8-week drilling programs over one year. Figure 5-2 contains an estimation of percent of API 53 required tasks performed as compared to the performance of all of the planned MIT tasks during the year. This figure shows a similar trend as Figure 5-1 except the percentages are even lower. Again, an indication IPs MIT plans include MIT tasks significantly beyond what is required by API 53.

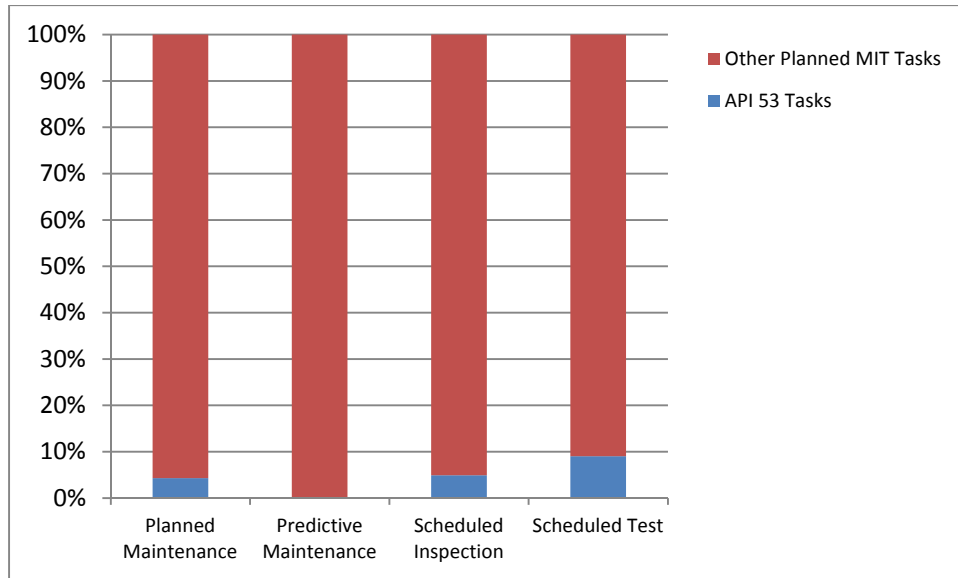


Figure 5-2. Estimated Percent of API 53 Tasks Performed of Total Number of Planned MIT Tasks Performed

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6.0 CONCLUDING REMARKS

This report summarizes three aspects of the BOP MIT practices: (1) the MIT requirements included in regulations and industry standards, (2) the typical planned MIT tasks employed by the IPs participating in this project, and (3) the results of maintenance and reliability management practices survey. Each aspect provides unique information regarding BOP MIT practices and insights into some potential MIT improvement opportunities. This section summarizes each report section and any related findings.

6.1 MIT ACTIVITIES – REGULATIONS AND INDUSTRY STANDARDS AND RECOMMENDED PRACTICES

As expected, this effort clearly indicates API 53 is the key document for defining the BOP MIT requirements. API 53 provides a rather comprehensive approach and includes references to OEM PM program requirements. One observation from this review is:

- The application of performance- and/or risk-based maintenance approaches (versus adoption of OEM PM requirements) may result in improved BOP reliability performance with less maintenance. This trend is been seen in other industries.

6.2 MIT ACTIVITIES – IP MIT PLANS AND OEM IOM MANUALS

These results indicate an extensive set of MIT activities are included in IP MIT plans and the OEM IOM manuals. In addition, these planned MIT activities include many more activities than required by API 53 MIT requirements. As discussed in Section 5 of this report, the planned MIT activities involve approximately nine fold increase over the API 53 required MIT. In addition, many of these requirements appear to be based on information in OEM IOM manuals. Two observations from this effort are:

- The use of predictive maintenance techniques to maintain BOP equipment is very limited.
- Much of the planned MIT activities are prescriptive time- based activities included in OEM IOM manuals rather than tasks based on a performance, or a risk or reliability analysis.

6.3 MIT MANAGEMENT SYSTEM SURVEY

The MIT management system survey indicated the presence of good maintenance management practices in many of areas surveyed. All management system areas surveyed indicated some good practices were in place. In addition, the survey results generated the following observations:

Failure Elimination

- BOP failure identification and documentation and formal investigation processes appear to be in place and functioning.
- Based on the limited number of responses related to trending of repeat failures, there does not appear to be a practice of trending of failures and reviewing the trend for repeat failures and thus the potential need for investigation and corrective action.
- Several survey respondents indicated there was no formal corrective action tracking system, which is a key system to ensuring corrective actions are implemented in a timely manner.

CMMS

- In general, it appears that the core CMMS elements are being used by most IPs to manage BOP maintenance.
- CMMS functionality, such as PM optimization, failure tracking, and reliability analyses appear to be in less use. These functionalities can be used to help improve BOP reliability performance once implemented.
- Similarly, as for management activities, CMMS appears to be used less for stores inventory management, reliability analysis, and key performance indicator generation and monitoring. Further implementation of these activities may also help improve and sustain BOP reliability performance.

Maintenance Management Systems

- The survey responses indicate a good number of the maintenance management systems, relative to the core maintenance work process (e.g., work order use, work prioritization), are in place and functioning.
- The survey responses seem to indicate that the results from maintenance work activities (e.g., PM results, repair actions) may not be consistently recorded. Complete documentation of work activities provides the information needed for continuous improvement efforts, such as PM optimization and reliability analyses.
- Key performance indicators do not appear to be widely used to monitor and improve maintenance activities and maintenance management performance.

PM Program

- As stated above, extensive PM programs have been established for BOP and most of the PM intervals based on calendar time, which results from API 53 requirements and/or maintenance practices in OEM IOM manuals.

- There is a high dependence on OEM IOM manual recommendations for PM task intervals versus more performance and analytical approaches, such as reliability-centered maintenance analyses.
- The PM intervals are almost all based on calendar time rather than equipment condition.

Written Instructions

- The survey indicates written instructions of varying types are provided and are readily available to BOP maintainers. In addition, most respondents indicated some form of a document control system was in place to help ensure written instructions are maintained.
- The survey provided mixed feedback on the expected use of written instructions. About half respondents indicated written instructions should be used as step-by-step instructions for performing a task and about an equal number of respondents viewed written instructions as a general guideline for performing a task.
- Slightly more than of the survey responses indicated repair procedures tend to contain limited information (i.e., step-by-step instruction were not provided).

Training

- The survey responses indicated training programs are in place for BOP maintainers, and the training is provided when personnel are assigned to a job involving BOP maintenance.
- The survey results indicated that a limited amount of refresher and periodic training is provided to BOP maintainers.
- The training provided BOP maintainers appears to not always include training on BOP PM and repair procedures.

In closing, this report's results show that BOP MIT activities are important to drilling industry and regulators, and the drilling contractors and BOP OEMs have established MIT programs and management systems intended to proactively maintain BOPs.

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APPENDIX A – BOP SYSTEM HIERARCHY AND DEFINITIONS

Table A-1: BOP System Hierarchy and Definitions

<p>Surface Control System: The purpose of the BOP control system is to provide a means to individually actuate components in the BOP stack by providing pressurized hydraulic fluid to the selected stack components.</p> <p>Consists of Electric Power Supply, Uninterrupted Power Source (UPS), Hydraulic Power Unit (HPU), Human to Machine Interface (HMI), MCC and I/O modules to process, communicate and display command and status data.</p>	
<p>HPU</p>	<p>Monitors, mixes, store hydraulic fluid and generate pressurized hydraulic fluid for BOP system control usage. Directs the hydraulic fluid via regulators and manifolds to various BOP functions and surface accumulators.</p> <p>Mixing system Storage tanks, pumps and associated pipes & manifolds to mix storage tank contents with a fresh water supply and store in a mixing tank with level indicators and mixing pump.</p> <p>HPU Creates and monitors hydraulic operating pressure inclusive of distribution piping, hydraulic pumps with associated electric motors, suction strainers, high pressure discharge filters, check and isolation valves in discharge manifold, hydraulic manifolds supplying to accumulator banks, rigid conduit and hose reels inclusive of isolation & relief valves.</p>
<p>Electrical Power</p>	<p>Uninterruptible power supply, blue & yellow UPS, inclusive of independent control and distribution, battery - charged from primary generators or emergency generator, power distribution panels, power isolation junction box (J-box) providing isolation and/or cross-feed of UPS output, distribution panel distributing power to the various MUX control system, umbilical J-box providing control voltage to subsea functions.</p>
<p>MUX Control System</p>	<p>Subsea multiplex system (MUX) BOP control systems provide electrical power, control signal, hydraulic power and communication to various BOP function.</p> <p>Central Command Center/Unit (CCC/CCU) The primary processor to interpret and communicate control functions to and from subsea control pods by means of:</p> <ul style="list-style-type: none"> – Processing array's for communication and distribution – Power distribution and communication to associated equipment – Flash drives: pre-programmed hard disk drives with processing software programmed by the OEM – Climate-controlled purged cabinets. <p>MUX Reels Spools for mux cable inclusive of; drive motors, level winds, brakes and control panels. The MUX electrical cable supplies power and communications for control of the subsea control pods. The MUX cable is run, retrieved, and stored on a cable reel.</p> <p>Slip Rings fiber optic and electrical to provide communication during rotation.</p>

Table A-1: BOP System Hierarchy and Definitions (cont'd)

<p>Rigid Conduit & Hotline</p>	<p>Providing path for transfer of hydraulic fluid for subsea operations.</p> <p>Pipes, tubes and/or flexible hoses (hotline, hydraulic hose, rigid piping and tubing) The hotline hose supplies power fluid from the surface to the subsea control pods mounted on the LMRP. The hotline is run, retrieved, and stored on the hose reel.</p> <p>Hydraulic Supply Line (Hard/Rigid Conduit) An auxiliary hydraulic supply line, referred to as a hard or rigid conduit, is a line attached to riser joints. The purpose of this auxiliary line is to supply control fluid from the surface accumulator system to the control pods and subsea accumulators mounted on the BOP and/or LMRP assemblies.</p> <p>Reels: spools for hydraulic hoses inclusive of; drive motors, level winds, brakes and control panels. Swivel: providing hydraulic communication between supply and hose on the reel during rotation.</p>
<p>Surface Accumulators</p>	<p>Pressure vessel to store hydraulic energy with internal pressurized bladder (bag), charging valve, manifold and racks to mount and segregate multiple bottles, isolation valves, relief valves and check valves.</p>
<p>Control Panels</p>	<p>3.1.24 control station/panel, remote A panel containing a series of controls that will operate the BOP functions from a location that is remote from the hydraulic control manifold or central processor in the case of a MUX or multiplex control system. Remote panels sending and receiving command and status signals to/from the CCC/CCU, inclusive of:</p> <ul style="list-style-type: none"> – HMI: to input command signals (button or touch-screen) – Monitors – Indicator to display data – Processor nodes and/or cards – Flash drives (software programmed by OEM) – Sensors and alarms for control system & BOP status – Cabinet purge system with sensors and alarms – Includes TCP, DCP, Hydraulic control panel and local panels.

Table A-1: BOP System Hierarchy and Definitions (cont'd)

<p><u>Subsea Control System</u></p> <p>Primarily located subsea on the LMRP, it receives hydraulic fluid and command signals from the HPU and CCC/CCU respectively to regulate and direct hydraulic fluid to designated control and function-operators. Provide interface with Emergency and Secondary Control System commands.</p>	
<p>Blue & Yellow Subsea Control System</p>	<p>Control pod</p> <p>An assembly of valves and regulators (either hydraulically or electrically operated) that when activated will direct hydraulic fluid through special apertures to operate the BOP equipment. Each control pod contains Subsea Electronic Module (SEM) Module, all necessary valves and regulators to operate the BOP stack and LMRP functions. Blue & Yellow pods, located on the Lower Marine Riser Pack (LMRP) to receive command signals and hydraulic fluid and convert it to regulated hydraulic signal. Also communicates status signals to and from CCC/CCU. The system includes the following components:</p> <ul style="list-style-type: none"> • SEM: electronic modules to convert fiber-optic signal for input to solenoid valves and provide power distribution • Compensated Chamber: sealed di-electric fluid filled chamber containing electronic components compensated to outside hydrostatic pressure • Solenoid valves: receive electrical signal to operate Subsea Plate-mounted (SPM) valves. (Direct Drive Valves [DDVs] and Compensated Chamber Solenoid Valves [CCSVs]) • SPM Valves: three (3) way spool valves operated by a hydraulic pilot signal • Hydraulic Manifold: manifold block in which SPM valves are mounted. Provides supply pressure as well as, ambient vent and operate port for each valve • Pilot Operated Valves (POCV and SSV) : Pilot-operated directional valves • Manual Pressure Regulator: a component that permits attenuation of control system supply pressure to a satisfactory pressure level to operate components downstream and adjustable manually • Remote Pressure Regulator: a component that permits attenuation of control system supply pressure to a satisfactory pressure level to operate components downstream and adjustable remotely using pilot hydraulic supply • Pilot and Supply Manifold Filters A device to entrap physical contaminate of particular size in hydraulic fluid before it goes into system downstream • Tubing: pipes, tubes to direct hydraulic fluid to its designated operator function • Shuttle Valves: Two-position three-way valves installed on operating ports of Stack components. They provide communication between Yellow or Blue Control Pods and the associated • Flexible hoses: steel braided rubber hose between pods and shuttle valves, end device • Pod Receptacles: pod interface to LMRP and BOP receiver inclusive of packer seals seal subs and locks • Pod Flow meters: A device/component to measure fluid volume on blue & yellow pods • MUX subsea

Table A-1: BOP System Hierarchy and Definitions (cont'd)

LMRP-mounted Accumulators	LMRP-mounted, accumulators associated with specific functions
Emergency & Secondary Controls	<p>Emergency control systems operated either automatically or by surface command; and Secondary control systems such as acoustic signal or via ROV intervention.</p> <ul style="list-style-type: none"> • Emergency Disconnect System (EDS): The EDS is a programmed sequence of events that operates the functions to leave the stack and controls in a desired state and disconnect the LMRP from the lower stack. The number of sequences, timing, and functions of the EDS are specific to the rig, equipment, and location. • Autoshear: Autoshear is a safety system that is designed to automatically shut-in the wellbore in the event of a disconnect of the LMRP • Deadman: The deadman system is designed to automatically shut in the wellbore in the event of a simultaneous absence of hydraulic supply and control from both subsea control pods. • Acoustic Control: The acoustic control system is an optional secondary control system designed to operate designated BOP stack and LMRP functions and may be used when the primary control system is inoperable. • ROV Operation: the provision for ROV intervention to operate critical functions on subsea BOP stack. ROV intervention equipment that at a minimum allows the operation of the critical functions (each shear ram, one pipe ram, ram locks, and unlatching of the LMRP connector).
<p><u>Subsea BOP Stack</u></p> <p>The complete assembly of subsea well control equipment, including various preventers, spools, valves, connectors and nipples connected to the top of the wellhead or wellhead assemblies. BOP Stack is to contain wellbore fluids either in the annular space between the casing and the tubulars or in an open hole during well drilling, completion, and testing operations.</p>	
Annulars	A blowout preventer that uses a shaped elastomeric sealing element to seal the space between the tubular and the wellbore or an open hole.
Blind Shear Ram	Ram BOP whose ram blocks incorporate a cutting blade to shear the pipe and sealing elements to contain well bore pressure upon shearing of the pipe. A closing and sealing component in a ram blowout preventer that first shears certain tubulars in the wellbore and then seals off the bore or acts as a blind ram if there is no tubular in the wellbore.
Casing Shear Ram	Ram BOP whose ram blocks incorporate a cutting blade to cut casing and/or heavier grade tubulars within a specific range. They do not seal the well bore. A closing component in a ram blowout preventer that is capable of shearing or cutting certain tubulars.

Table A-1: BOP System Hierarchy and Definitions (cont'd)

<p>Pipe & Test Rams</p>	<ul style="list-style-type: none"> ● Pipe ram: A closing and sealing component in a ram blowout preventer that seals around the outside diameter of a tubular in the wellbore ● Ram blowout preventer: a blowout preventer that uses metal blocks with integral elastomer seals to seal off pressure on a wellbore with or without tubulars in the bore ● Fixed Pipe Ram: closing and sealing component in a ram blowout preventer that is capable of sealing on a fixed tubular sizes ● Variable Pipe Ram: closing and sealing component in a ram blowout preventer that is capable of sealing on a range of tubular sizes ● Test Ram: A Variable Bore Ram located in the lower most ram cavity with ram block installed in inverted position to seal pressure from the top and enable testing of the BOP Stack without running a test tool.
<p>C&K Valves and Lines</p>	<p>Valves and pipes assembly enabling communication to or from the well bore to the surface C&K manifold to circulate well, control kicks or kill a well.</p> <ul style="list-style-type: none"> ● C&K Line: a high-pressure line that allows fluids to be pumped into or removed from the well with the BOPs closed ● Subsea C&K Valves: fail-safe gate valves enabling communication with the well bore. ● Bleed Valves: fail-safe Valves located under the Upper most Annular to relieve trapped pressure/gas from the BOP stack upon completion of well control operations. ● C&K Line Test Valves: fail-safe valves enabling test of the Choke and Kill Lines while running the BOP stack or LMRP ● Flanges and Spools: devices incorporated in the C&K piping system, consists of spools (pipe with flanged connections), T-, L- and/or Y-blocks (machined blocks providing fluid communication between three flanges or ports and target and blind flanges used to close a flanged outlet of a BOP or redundant port of a three-way block ● Spacer Spool: a spool used to provide separation between two components with equal sized end connections ● Flex Loop & Jumper Hoses: pipe or hoses installed between C&K stabs of the LMRP and the fixed C&K connection to the riser to accommodate displacement of the flex joint ● Drape Hoses: provide communication form C&K Stabs on the slip joint outer barrel and rigid pipe of the surface C&K System. They accommodate vertical and angular displacement of the rig

Table A-1: BOP System Hierarchy and Definitions (cont'd)

<p>Connectors</p>	<ul style="list-style-type: none"> ● Hydraulic connector: hydraulically actuated equipment that locks and seals on end connections and provide mechanical and/or hydraulic path ● LMRP Connector: connects the LMRP to the BOP stack ● Well Head Connector: connects the BOP stack to the well head ● C&K Stabs: connecting C&K Lines between LMRP and BOP stack ● Conduit and Hotline Hydraulic Stabs: connectors coupling surface hydraulic fluid to the LMRP and/or Control Pods (pod connector) ● Wetmate Connector: offer wet make-up of electrical interfaces in subsea power systems ● High Pressure High Temperature (HPHT) Sensors: HPHT Sensors to detect and transmit pressure and temperature of well bore fluids at the well head. ● Electronic Riser Angle (ERA) Sensors: ERA Sensors to detect and communicate riser angle offset.
<p>Stack-mounted Accumulators (Autoshear)</p>	<p>Stack-mounted accumulator dedicated to provide hydraulic energy (volume and pressure) for emergency operation of casing shear rams and blind shear rams.</p> <p>Accumulator: a pressure vessel to store hydraulic energy charged with inert gas and used to store hydraulic fluid under pressure.</p>

***APPENDIX B – MAINTENANCE AND OPERATING MANUAL AND
MAINTENANCE PLAN
MIT ACTIVITIES***

B-1: Overall BOP MIT Activities

BOP System	Subsystem	Component	MIT Activity	MIT Activity Type	Maintenance Activity Interval													
					Drilling				Upon Latching	Pre-Deployment and Between Wells					Major Overhaul		Miscellaneous	
					Daily	7 Days	14 Days	30 Days		60 Days	90 Days	180 Days	Between Wells	Each Trip	Annually	Multiyear	As Required	As Needed
Overall BOP system	All Rams		Operate all rams	Scheduled Test	x													
Overall BOP system			Look for hydraulic leaks	Scheduled Inspection	x			x										
Overall BOP system	General		Function test all rams, annulars, subsea actuated gate valves, diverter, other items run subsea, choke manifold, kill and choke lines, standpipe manifold, top drive safety valves, safety valves, and IBOP	Scheduled Test		x			x				x					
Overall BOP system	General		During each function test, record and analyze (a) volumes to open and close each function, and (b) time to open and close each function to ensure that full working operation is maintained. Compare with previous results to ensure within API RP 53 3rd Edition Specifications	Scheduled Test		x			x				x					
Overall BOP system	General		Ensure that there are no leaks on the equipment	Scheduled Inspection		x			x									
Overall BOP system	General		Pressure test all BOP and related equipment as required by API RP53 / Pressure test all BOPs, annulars, wellbore components and their connections and BOP control/operating system	Scheduled Test			x (not to exceed 21 days)		x			x	x			2 years & 5 years		Prior to running assembled stack and/or when any component change/repair is made.

Table B-1: Overall BOP MIT Activities (cont'd)

BOP System	Subsystem	Component	MIT Activity	MIT Activity Type	Maintenance Activity Interval															
					Drilling				Upon Latching	Pre-Deployment and Between Wells					Major Overhaul		Miscellaneous			
					Daily	7 Days	14 Days	30 Days		60 Days	90 Days	180 Days	Between Wells	Each Trip	Annually	Multiyear	As Required	As Needed		
Overall BOP system	General		Pressure test all BOPs, annulars, wellbore components and their connections, BOP operating unit, choke manifold, kill and choke lines, standpipe manifold, top drive safety valves, safety valves and IBOPs	Scheduled Test													-When BOP is running and latched to the wellhead. - Prior to drilling into a suspected high pressure zone - Prior to initial opening of drill stem test tools.			
Overall BOP system	General		Function test all components with both control pods from the driller's and remote control panels.	Scheduled Test									x							
Overall BOP system	General		Function test all valves from both pods. Check all hydraulic connections in the circuit for operating fluid leaks.	Scheduled Test										x						
Overall BOP system	General		Final Surface Testing and Verifications prior to launching stack: - Perform function test on both pods and all SEMs. - Make sure that the pressure, temperature sensors, ERA sensors are operating correctly. - Perform pressure test of the pod to the maximum regulator output, not to exceed rated pressure, and visually examine for leaks. - Make sure that pre-charge pressure in all accumulators	Scheduled Test										x						

Table B-1: Overall BOP MIT Activities (cont'd)

BOP System	Subsystem	Component	MIT Activity	MIT Activity Type	Maintenance Activity Interval													
					Drilling				Upon Latching	Pre-Deployment and Between Wells					Major Overhaul		Miscellaneous	
					Daily	7 Days	14 Days	30 Days		60 Days	90 Days	180 Days	Between Wells	Each Trip	Annually	Multiyear	As Required	As Needed
			has not bled down since step one was performed. - Make sure that all inclinometers are operating correctly. - Make sure that all gyros are operating correctly.															
Overall BOP system	Accumulators - LMRP		Prior to well control pressure testing, perform the Accumulator Drawdown Test as required by API RP53, section 18.7.1 for subsea BOP	Scheduled Test									x					
Overall BOP system	Annular		Upper annular - Perform wellbore pressure test.	Scheduled Test	x			x							x			x
Overall BOP system	Annular		Lower Annular - Perform wellbore test.	Scheduled Test				x						x				
Overall BOP system	all rams		Function test ram locking devices	Scheduled Test									x					
Overall BOP system	all rams		Perform a low pressure signature test on each operator. Compare the minimum required closing and opening pressures, to the previous test pressures.	Scheduled Test											x			
Overall BOP system	all rams		Pressure test the ram operator hydraulic chambers to maximum operating pressure.	Scheduled Test											x			
Overall BOP system	all rams		Pressure test all rams to low pressure and maximum working pressure with the locks engaged and the closing pressure vented.	Scheduled Test											x			
Overall BOP system	all rams		Perform a field wellbore pressure test, an internal hydraulic pressure test, and a locking hydraulic pressure test.	Scheduled Test											x	3 years		

Table B-1: Overall BOP MIT Activities (cont'd)

BOP System	Subsystem	Component	MIT Activity	MIT Activity Type	Maintenance Activity Interval													
					Drilling				Upon Latching	Pre-Deployment and Between Wells					Major Overhaul		Miscellaneous	
					Daily	7 Days	14 Days	30 Days		60 Days	90 Days	180 Days	Between Wells	Each Trip	Annually	Multiyear	As Required	As Needed
Overall BOP system	Pipe & Test Rams		Rams - Hydraulic leak test (Operate all rams and check for external leaks)	Scheduled Test	x													Keep adequately greased
Overall BOP system	Pipe & Test Rams		Ram BOPs - Perform field wellbore pressure test. Check for leaks	Scheduled Test				x						x				
Overall BOP system	Pipe & Test Rams		Perform a field wellbore test, an internal hydraulic pressure test, and a locking hydraulic pressure test.	Scheduled Test						x								
Overall BOP system	Shear Rams		Pressure test blind/shear rams	Scheduled Test														Prior to drilling out after each casing string has been set. NOT TO EXCEED 42 days
Overall BOP system	Choke & Kill		Function test all stack mounted choke and kill valves.	Scheduled Test		x												
Overall BOP system	Choke & Kill		While running BOP's and riser, choke/kill lines are to be tested to the working pressure of the ram BOP's. (API RP53 18.3.2.2)	Scheduled Test								x						
Overall BOP system	Choke & Kill		After landing the BOP stack, test choke/kill lines to the working pressure of the ram BOP's. (API RP53 18.3.2.2)	Scheduled Test					x									
Overall BOP system	Connectors		Pressure test the ring gasket retaining circuit, if applicable. Chart record the tests.	Scheduled Test								x						
Overall BOP system	Connectors		Perform low pressure unlock test, as per the manufacturers specifications.	Scheduled Test								x						

Table B-1: Overall BOP MIT Activities (cont'd)

BOP System	Subsystem	Component	MIT Activity	MIT Activity Type	Maintenance Activity Interval													
					Drilling				Upon Latching	Pre-Deployment and Between Wells					Major Overhaul		Miscellaneous	
					Daily	7 Days	14 Days	30 Days		60 Days	90 Days	180 Days	Between Wells	Each Trip	Annually	Multiyear	As Required	As Needed
Overall BOP system	Connectors		On the test stump, measure and record unlatch to latch indicator rod travel.	Scheduled Test								x						
Overall BOP system	Connectors		Once the LMRP is installed, function test connectors, i.e., extend and retract, to confirm proper operation and alignment.	Scheduled Test									x			2 years		
Overall BOP system	Connectors		Pressure test the hydraulic operating chambers (primary lock, secondary lock, primary un-lock and secondary un-lock) to max operating pressure. All tests are to be chart recorded. (API RP 53 18.3.2.4)	Scheduled Test									x			2 years		
Overall BOP system		Hydraulic Hoses & Connections	Pressure test all BOP component operating lines to full rated working pressure. Reference API RP53, section 12.5.1 and 17.3.8 item 8.	Scheduled Test								x						
Overall BOP system	Emergency & Secondary Controls	Autoshear System	Test the Autoshear System on Surface (if equipped)	Scheduled Test									x					
Overall BOP system	Emergency & Secondary Controls	Deadman System	Test the Deadman System on Surface	Scheduled Test									x					
Overall BOP system	Emergency & Secondary Controls	EDS	Test the Emergency Disconnect System (EDS) on Surface	Scheduled Test									x					

Table B-1: Overall BOP MIT Activities (cont'd)

BOP System	Subsystem	Component	MIT Activity	MIT Activity Type	Maintenance Activity Interval													
					Drilling				Upon Latching	Pre-Deployment and Between Wells					Major Overhaul		Miscellaneous	
					Daily	7 Days	14 Days	30 Days		60 Days	90 Days	180 Days	Between Wells	Each Trip	Annually	Multiyear	As Required	As Needed
Overall BOP system	Emergency & Secondary Controls	Emergency Function	Test all functions and sequences of the EDS, autoshear and deadman	Scheduled Test									x			5 years	- At commissioning - When any changes are made - During BOP control system recertification	
Overall BOP system	Emergency & Secondary Controls	½ -gallon Accumulator	Check precharge	Scheduled Inspection									x					
Overall BOP system	Emergency & secondary controls		Function test the operation of the back-up control systems	Scheduled Test									x					
Overall BOP system	Emergency & Secondary Controls	Acoustic	Test all acoustic functions	Scheduled Test									x				- At commissioning - When any changes are made - During BOP control system recertification - 1 acoustic function every 21 days	
Overall BOP system	Emergency & Secondary Controls	ROV	Test one function of the ROV intervention panel for the BOP every time the BOP is function tested, while Subsea. Create a schedule for testing each function, ONLY ONE function is tested each time.	Scheduled Test		x												

Table B-1: Overall BOP MIT Activities (cont'd)

BOP System	Subsystem	Component	MIT Activity	MIT Activity Type	Maintenance Activity Interval													
					Drilling				Upon Latching	Pre-Deployment and Between Wells					Major Overhaul		Miscellaneous	
					Daily	7 Days	14 Days	30 Days		60 Days	90 Days	180 Days	Between Wells	Each Trip	Annually	Multiyear	As Required	As Needed
Overall BOP system	Emergency & Secondary Controls	ROV	Test all ROV functions	Scheduled Test									x					
Overall BOP system	Emergency & Secondary Controls	ROV	Function test all critical ROV functions, as defined by API	Scheduled Test							1 critical function every 90 days							- At commissioning - When any changes are made - During BOP control system recertification
Overall BOP system			Perform wellbore test	Scheduled Test									x					
Overall BOP system			Perform hydraulic test	Scheduled Test									x					

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Table B-2: Surface Control MIT Activities

BOP System	Subsystem	Component	MIT Activity	MIT Activity Type	Maintenance Activity Interval													
					Drilling				Upon Latching	Pre-Deployment and Between Wells					Major Overhaul		Miscellaneous	
					Daily	7 Days	14 Days	30 Days		60 Days	90 Days	180 Days	Between Wells	Each Trip	Annually	Multiyear	As Required	As Needed
Surface Control System	HPU	Filter/Strainer	Y-Type Strainer - Clean element	Planned Maintenance		x												
Surface Control System	HPU	Filter/Strainer	Hydraulic Suction Filter - Clean Filter	Planned Maintenance			x											
Surface Control System	HPU	Filter/Strainer	High Pressure Filter - Clean Filter	Planned Maintenance			x											
Surface Control System	HPU	Filter/Strainer	Check HP filter isolation valves for leaks	Scheduled Inspection			x											
Surface Control System	HPU	Mixing Unit	Water Regulator - Oil adjustment screw	Scheduled Inspection		x												
Surface Control System	HPU	Mixing Unit	Verify mixing system flowmeter and totalizer functions and check manual valves for leaks	Scheduled Inspection			x											
Surface Control System	HPU	Mixing Unit	Check on-off function of mixing system inlet water valve	Scheduled Test			x											
Surface Control System	HPU	Mixing Unit	Verify function and full stroking of inlet water valve and clean inlet water strainer	Scheduled Test					x									
Surface Control System	HPU	Mixing Unit	Check mixing system outlet filter elements and replace as necessary	Planned Maintenance			x											
Surface Control System	HPU	Pump	Pump - Check pump packing glands and belt drive,	Scheduled Inspection		x												
Surface Control System	HPU	Pump	Check suction valve stem for leaks	Scheduled Inspection			x											
Surface Control System	HPU	Pump	Pump - Check crankcase oil	Scheduled Inspection			x											

Table B-2: Surface Control MIT Activities

BOP System	Subsystem	Component	MIT Activity	MIT Activity Type	Maintenance Activity Interval													
					Drilling				Upon Latching	Pre-Deployment and Between Wells					Major Overhaul		Miscellaneous	
					Daily	7 Days	14 Days	30 Days		60 Days	90 Days	180 Days	Between Wells	Each Trip	Annually	Multiyear	As Required	As Needed
Surface Control System	HPU	Pump	Pump Motor - Check bearing lubrication	Scheduled Inspection			x											
Surface Control System	HPU	Pump	Change crankcase oil	Planned Maintenance														First 30 hours of operation and then every 300 hours
Surface Control System	HPU	Pump	Check coupling for wear	Scheduled Inspection						x								
Surface Control System	HPU	Pump – Engine-driven High Pressure Pumps	Check engine oil level, plunger coolant seals for leakage, plunger packing for leakage, suction and discharge valves are fully open, rod and main bearing oil seals for leakage, and drive train and clutch	Scheduled Inspection	x													
Surface Control System	HPU	Pump – Engine-driven High Pressure Pumps	Degrease and clean system, clean pump and engine air breathers, and check system studs, nuts, and screws for tightness	Planned Maintenance and Scheduled Inspection				x										
Surface Control System	HPU	Pump – Engine-driven High Pressure Pumps	Check pump and engine oil and coolant levels, inspect battery and cables, check engine fuel level, check PTO and drive train for looseness, check pump drives, ensure supply water filters and strainers are clean, and check supply water is flowing into the system	Scheduled Inspections														Prior to starting engine-driven pump system
Surface Control System	HPU	Reservoir, Mixing Unit	Test low fluid level alarms	Scheduled Test		x												

Table B-2: Surface Control MIT Activities

BOP System	Subsystem	Component	MIT Activity	MIT Activity Type	Maintenance Activity Interval														
					Drilling				Upon Latching	Pre-Deployment and Between Wells					Major Overhaul		Miscellaneous		
					Daily	7 Days	14 Days	30 Days		60 Days	90 Days	180 Days	Between Wells	Each Trip	Annually	Multiyear	As Required	As Needed	
Surface Control System	HPU	Reservoir, Mixing Unit	Visually inspect reservoir float	Scheduled Inspection							x								
Surface Control System	HPU	Reservoir, Mixing Unit	Clean reservoir breather caps	Planned Maintenance							x								
Surface Control System	HPU	Reservoir, Mixing Unit	Check reservoir piping and valves for leaks	Scheduled Inspection							x								
Surface Control System	HPU	Reservoir, Mixing Unit	Sample mixed fluids for cleanliness	Predictive Maintenance							x								
Surface Control System	HPU	Hydraulic Hoses & Connections	Ensure all control system interconnecting piping and hoses are protected from damage during drilling operations.	Scheduled Inspection								x							
Surface Control System	HPU	Hydraulic Hoses & Connections	Visually inspect the condition and security of all BOP pipe work and hoses between the hydraulic control unit and the BOP stack. Check fittings and fastenings for deterioration.	Scheduled Inspection								x							
Surface Control System	HPU	Regulators	Regulators - Rebuild all regulators or replace with rebuilt spares	Planned Maintenance											x	2 years			
Surface Control System	Power	Uninterrupted Power Source (UPS)	Visually inspect overall condition of batteries and battery charger.	Scheduled Inspection				x			x	x			x				
Surface Control System	Power	Uninterrupted Power Source (UPS)	Verify batteries are charging.	Scheduled Inspection							x								
Surface Control System	Power	Uninterrupted Power Source (UPS)	Verify unit is clean including ventilation.	Scheduled Inspection							x								
Surface Control	Power	Uninterrupted Power Source	Inspect cooling fans. (If applicable)	Scheduled Inspection							x								

Table B-2: Surface Control MIT Activities

BOP System	Subsystem	Component	MIT Activity	MIT Activity Type	Maintenance Activity Interval													
					Drilling				Upon Latching	Pre-Deployment and Between Wells					Major Overhaul		Miscellaneous	
					Daily	7 Days	14 Days	30 Days		60 Days	90 Days	180 Days	Between Wells	Each Trip	Annually	Multiyear	As Required	As Needed
System		(UPS)																
Surface Control System	Power	Uninterrupted Power Source (UPS)	Check light emitting diode (LED) status that UPS is not in Bypass mode (if applicable)	Scheduled Inspection							x							
Surface Control System	Power	Uninterrupted Power Source (UPS)	Verify that all controls and indicator lights operate correctly.	Scheduled Inspection							x			x				
Surface Control System	Power	Uninterrupted Power Source (UPS)	Check and record float voltage of batteries, in Rig's Register.	Scheduled Inspection							x			x				
Surface Control System	Power	Uninterrupted Power Source (UPS)	Clean out cabinet with a vacuum cleaner, ensure no moisture present.	Planned Maintenance										x				
Surface Control System	Power	Uninterrupted Power Source (UPS)	Verify the security and integrity of all cables, glands, enclosures and connections.	Scheduled Inspection										x				
Surface Control System	Power	Uninterrupted Power Source (UPS)	Simulate power failure and ensure that the battery backup system has sufficient duration or is able to perform desired function to the required standard, repair / replace as required.	Scheduled Test										x				
Surface Control System	Power, MUX Control System	Electrical Junction Boxes	Test functioning of electrical enclosure alarm	Scheduled Test			x											
Surface Control System	Power, MUX Control System	Electrical Junction Boxes	Inspect for corrosion & dampness	Scheduled Inspection						x								
Surface Control System	Power, MUX Control System	Electrical Junction Boxes	Inspect electrical enclosure interconnect cable for damage	Scheduled Inspection						x								
Surface Control System	Power, MUX Control System	Electrical Junction Boxes	Check electrical enclosure buttons and lenses for cracks or damage	Scheduled Inspection						x								
Surface Control System	MUX Control System	MUX Cable	Disconnect MUX cable at reel junction box and measure and record insulation resistance for	Scheduled Inspection											5 years			

Table B-2: Surface Control MIT Activities

BOP System	Subsystem	Component	MIT Activity	MIT Activity Type	Maintenance Activity Interval													
					Drilling				Upon Latching	Pre-Deployment and Between Wells					Major Overhaul		Miscellaneous	
					Daily	7 Days	14 Days	30 Days		60 Days	90 Days	180 Days	Between Wells	Each Trip	Annually	Multiyear	As Required	As Needed
			all MUX cores.															
Surface Control System	MUX Control System	MUX Cables	Insulation check on copper conductors throughout its entire length, including slip ring and connector.	Scheduled Inspection									x					
Surface Control System	MUX Control System	MUX Cables	Fiber optic conductors will need to be checked with Optical Time Domain Refractometer	Scheduled Inspection									x					
Surface Control System	MUX Control System	MUX Cables	Check outer sheath of the cable for any damage when spooling cables onto reel. Repair as required.	Scheduled Inspection											5 years			
Surface Control System	MUX Control System	MUX Connectors	Visual inspection of connector terminals while connector is removed for megging. (check for corrosion from water ingress and other contaminants)	Scheduled Inspection									x					
Surface Control System	MUX Control System	MUX Connectors	Visual inspection signs of cable twisting in connector.	Scheduled Inspection									x					
Surface Control System	MUX Control System	MUX Connectors	Inspect breakaway bolts if applicable	Scheduled Inspection									x					
Surface Control System	MUX Control System	MUX Connectors	Clean all connectors and refit.	Planned Maintenance											5 years			
Surface Control System	MUX Control System	Central Control Console	Test lamps	Scheduled Test	x													
Surface Control System	MUX Control System	Central Control Console	Verify module LED indicate normal operation	Scheduled Inspection		x												
Surface Control System	MUX Control System	Central Control Console	Confirm operation of cooling fan and clean filter	Planned Maintenance				x										
Surface Control	MUX Control System	Central Control	Inspect exterior of each bay for damage and corrosion and	Scheduled Inspection				x										

Table B-2: Surface Control MIT Activities

BOP System	Subsystem	Component	MIT Activity	MIT Activity Type	Maintenance Activity Interval															
					Drilling				Upon Latching	Pre-Deployment and Between Wells					Major Overhaul		Miscellaneous			
					Daily	7 Days	14 Days	30 Days		60 Days	90 Days	180 Days	Between Wells	Each Trip	Annually	Multiyear	As Required	As Needed		
System		Console	inspect for ingress of dust and moisture																	
Surface Control System	MUX Control System	Central Control Console	Clean and inspect interior of each panel	Scheduled Inspections														x		
Surface Control System	MUX Control System	Central Control Console	Measure power supply output voltage	Scheduled Inspection															x	
Surface Control System	MUX Control System	Central Control Console	Exercise manual controls that are not used in routine operations	Scheduled Test															x	
Surface Control System	MUX Control System	Central Control Console	Replace PLC CPU, PCM module and hand-held monitor batteries	Planned Maintenance															x	
Surface Control System	MUX Control System	Slip Ring	Inspect electrical slip ring and check inside for corrosion and moisture. Check gland ring and cables for damage and ensure all cable connections are tight. Grease slip ring bearings as required.	Scheduled Inspection																5 years
Surface Control System	MUX Control System	Reels	Ensure there is adequate protection on the multi-pin and cable connections.	Scheduled Inspection																5 years
Surface Control System	MUX Control System	Reels	If applicable, check silica gel bags. Blue color is OK. Pink color requires replacement.	Scheduled Inspection																5 years
Surface Control System	MUX Control System	Reels	Inspect electrical contacts inside junction boxes for corrosion.	Scheduled Inspection																5 years
Surface Control System	Rigid conduit & hotline	Reels	Function test all functions on the hose reel control panels	Scheduled Test																x
Surface Control System	Rigid Conduit & Hotline	Reels	Check and lubricate all moving parts as required.	Planned Maintenance																5 years

Table B-2: Surface Control MIT Activities

BOP System	Subsystem	Component	MIT Activity	MIT Activity Type	Maintenance Activity Interval													
					Drilling				Upon Latching	Pre-Deployment and Between Wells					Major Overhaul		Miscellaneous	
					Daily	7 Days	14 Days	30 Days		60 Days	90 Days	180 Days	Between Wells	Each Trip	Annually	Multiyear	As Required	As Needed
Surface Control System	Rigid Conduit & Hotline	Reels	If applicable, replace all corrosion inhibitor pads.	Planned Maintenance												5 years		
Surface Control System	Rigid Conduit & Hotline	Reels	Inspect inner unit for corrosion, damage, moisture etc. Clean carefully with dry cloth or vacuum cleaner.	Planned Maintenance												5 years		
Surface Control System	Rigid Conduit & Hotline	Reels	Ensure that openings and glands are properly sealed with correct, certified blanking plugs.	Scheduled Inspection												5 years		
Surface Control System	Rigid Conduit & Hotline	Reels	If applicable, check anti-condensation heaters for correct operation.	Scheduled Inspection												5 years		
Surface Control System	Rigid Conduit & Hotline	Reels	Grease main hydraulic supplies fluid swivel	Planned Maintenance														Rig Move
Surface Control System	Rigid Conduit & Hotline	Reels	Check conditions of the RBQ plate, receptacle seals and plate securing bolts clean and lubricate as required.	Scheduled Inspection														Rig Move
Surface Control System	Rigid Conduit & Hotline	Reels	Check quick disconnect nipple assembly connections move freely in RBQ plate holes. Any quick disconnect nipple assembly connections found to be seized must be removed and cleaned to allow movement in RBQ plates.	Scheduled Inspection														Rig Move
Surface Control System	Rigid Conduit & Hotline	Reels	Check condition and functionality of vent plate.	Scheduled Inspection														Rig Move
Surface Control System	Rigid Conduit & Hotline	Reels	Check function of all panel valves, regulator and gauges. Lubricate as required. Repair or replace as required	Scheduled Inspection														Rig Move
Surface Control System	Rigid Conduit & Hotline	Reels	Check security of shields on valves for critical functions	Scheduled Inspection														Rig Move

Table B-2: Surface Control MIT Activities

BOP System	Subsystem	Component	MIT Activity	MIT Activity Type	Maintenance Activity Interval													
					Drilling				Upon Latching	Pre-Deployment and Between Wells					Major Overhaul		Miscellaneous	
					Daily	7 Days	14 Days	30 Days		60 Days	90 Days	180 Days	Between Wells	Each Trip	Annually	Multiyear	As Required	As Needed
Surface Control System	Rigid Conduit & Hotline, MUX Control	Reels	Check oil and fill line lubricator	Scheduled Inspection	x													
Surface Control System	Rigid Conduit & Hotline, MUX Control	Reels	Change oil in motor and gearbox.	Planned Maintenance														Rig Move
Surface Control System	Rigid Conduit & Hotline, MUX Control	Reels	Check Motor and drive system functionality.	Scheduled Test														Rig Move
Surface Control System	Rigid Conduit & Hotline, MUX Control	Reels	Check and service brake system	Scheduled Test														Rig Move
Surface Control System	Rigid Conduit & Hotline, MUX Control	Reels	Check level wind spooler system (if fitted).	Scheduled Test														Rig Move
Surface Control System	Rigid Conduit & Hotline, MUX Control	Reels	Lubricate drum and level wind spooler drive chains and sprockets (if fitted)	Planned Maintenance														Rig Move
Surface Control System	Rigid Conduit & Hotline, MUX Control	Reels	Grease drum bearings.	Planned Maintenance										x				Rig Move
Surface Control System	Rigid Conduit & Hotline, MUX Control	Constant Tension System	Check oil level and fill air motor case to proper level prior to each operation	Planned Maintenance	x													
Surface Control System	Rigid Conduit & Hotline, MUX Control	Constant Tension System	Check air line lubricator	Scheduled Inspection		x												
Surface Control System	Rigid Conduit & Hotline, MUX Control	Constant Tension System	Service air motor and inspect breather cap	Scheduled Inspection														X
Surface Control System	Rigid Conduit & Hotline, MUX Control	Constant Tension System	Remove motor case condensate drain plug	Planned Maintenance														X
Surface Control System	Rigid Conduit & Hotline, MUX Control	Constant Tension System	Inspect and clean air motor drive sprocket and chain	Planned Maintenance														X

Table B-2: Surface Control MIT Activities

BOP System	Subsystem	Component	MIT Activity	MIT Activity Type	Maintenance Activity Interval													
					Drilling				Upon Latching	Pre-Deployment and Between Wells					Major Overhaul		Miscellaneous	
					Daily	7 Days	14 Days	30 Days		60 Days	90 Days	180 Days	Between Wells	Each Trip	Annually	Multiyear	As Required	As Needed
Surface Control System	Control Panels	Control Panels	Verify functioning of manual shear seal valves, solenoid air valves, and pressure switch feedback; and check panel plumbing and manual valves for leaks	Scheduled Inspection			x											
Surface Control System	Control Panels	Control Panels	Check control panel assembly air cylinder for leaks and full stroke	Scheduled Inspection						x								
Surface Control System	Control panel	HPU Control panel	Check all tubing fittings inside console for leaks	Scheduled Inspection								x					x	

Table B-3: Subsea Control MIT Activities

BOP System	Subsystem	Component	MIT Activity	MIT Activity Type	Maintenance Activity Interval													
					Drilling				Upon Latching	Pre-Deployment and Between Wells					Major Overhaul		Miscellaneous	
					Daily	7 Days	14 Days	30 Days		60 Days	90 Days	180 Days	Between Wells	Each Trip	Annually	Multiyear	As Required	As Needed
			spots or damage is evident. Lubricate o-rings with silicon grease.															
Subsea Control System	Blue & Yellow Subsea Control Systems	Flex hoses	Pod Piping - Inspect for leaks, tighten fittings. Repair and replace, as required.	Scheduled Inspection									x					
Subsea Control System	Blue & Yellow Subsea Control Systems	Flex hoses	Inspect, clean, and lubricate hoses. Plug ends of choke & kill lines	Planned Maintenance										x				
Subsea Control System	Blue & Yellow Subsea Control Systems	HPHT	Make sure that the pressure and temperature sensors are operating correctly.	Scheduled Inspection											x	2 years		
Subsea Control System	Blue & Yellow Subsea Control Systems	HPHT	Calibrate all the BOP transducers	Scheduled Test												2 years		
Subsea Control System	Blue & Yellow Subsea Control Systems	Manifolds	Manifold Blocks – Re-torque bolts	Planned Maintenance									x					x
Subsea Control System	Blue & Yellow Subsea Control Systems	MUX subsea	Prepare MUX control for time out of water; rinse with fresh water, visually inspect for damage, and keep stab and receptacle surfaces dry and greased.	Planned Maintenance									x					

Table B-3: Subsea Control MIT Activities

BOP System	Subsystem	Component	MIT Activity	MIT Activity Type	Maintenance Activity Interval													
					Drilling				Upon Latching	Pre-Deployment and Between Wells					Major Overhaul		Miscellaneous	
					Daily	7 Days	14 Days	30 Days		60 Days	90 Days	180 Days	Between Wells	Each Trip	Annually	Multiyear	As Required	As Needed
Subsea Control System	Blue & Yellow Subsea Control Systems	MUX subsea	Cables: Examine the Pressure Balanced Oil Filled (PBOF) cables for; - damage - loss of DC 200 - water ingress. Perform insulation resistance test on all PBOF cables using a meter and record readings. Perform continuity test on all PBOF cables. If PBOF cable is removed, perform pressure test.	Scheduled Inspection									x					
Subsea Control System	Blue & Yellow Subsea Control Systems	MUX subsea	Interconnecting Cables - Visually Inspect	Scheduled Inspection									x					
Subsea Control System	Blue & Yellow Subsea Control Systems	MUX subsea	Interconnect Cables (Maintain 15-20% on a rotating basis) - Inspect and test	Scheduled Test									x		2 years			
Subsea Control System	Blue & Yellow Subsea Control Systems	MUX subsea	Interconnecting Cables - Test	Scheduled Test											x			
Subsea Control System	Blue & Yellow Subsea Control Systems	MUX subsea	Interconnecting Cables - Replace	Planned Maintenance												2 years		
Subsea Control System	Blue & Yellow Subsea Control Systems	Pilot and supply filters	Filters - Replace filter cartridges.	Planned Maintenance									x					

Table B-3: Subsea Control MIT Activities

BOP System	Subsystem	Component	MIT Activity	MIT Activity Type	Maintenance Activity Interval													
					Drilling				Upon Latching	Pre-Deployment and Between Wells					Major Overhaul		Miscellaneous	
					Daily	7 Days	14 Days	30 Days		60 Days	90 Days	180 Days	Between Wells	Each Trip	Annually	Multiyear	As Required	As Needed
Subsea Control System	Blue & Yellow Subsea Control Systems	Pilot and supply filters	Replace all filters after all BOP pressure and function tests	Planned Maintenance									x					
Subsea Control System	Blue & Yellow Subsea Control Systems	Pilot and supply filters	Filters - Replace filter cartridge/bowl seal	Planned Maintenance									x					
Subsea Control System	Blue & Yellow Subsea Control Systems	POCV	Shear Seal Valves - Rebuild or replace 20% of the shear seals annually	Planned Maintenance											x	5years		
Subsea Control System	Blue & Yellow Subsea Control Systems	POD Compensation Chamber	Check for water entering the chamber and pressure test	Scheduled Inspection									x					
Subsea Control System	Blue & Yellow Subsea Control Systems	POD 5-gallon Compensator Assembly	Inspect and replace bladder	Scheduled Inspection									x					
Subsea Control System	Blue & Yellow Subsea Control Systems	POD Magnetic Flow Meter	Inspect electrical connection and check coil pick-up signal	Scheduled Inspection									x					
Subsea Control System	Blue & Yellow Subsea Control Systems	POD Magnetic Flow Meter	Replace flow meter	Planned Maintenance												2 years		

Table B-3: Subsea Control MIT Activities

BOP System	Subsystem	Component	MIT Activity	MIT Activity Type	Maintenance Activity Interval													
					Drilling				Upon Latching	Pre-Deployment and Between Wells					Major Overhaul		Miscellaneous	
					Daily	7 Days	14 Days	30 Days		60 Days	90 Days	180 Days	Between Wells	Each Trip	Annually	Multiyear	As Required	As Needed
Subsea Control System	Blue & Yellow Subsea Control Systems	Pod Receptacle	Examine wedge for damage and adjustment while BOP and LMRP are split, including : sealing surfaces, actuator assembly of LMRP disconnect switch, extend/retract cylinder piston, we make/break connector, mounting bolts and electrical connectors	Scheduled Inspection									x					
Subsea Control System	Blue & Yellow Subsea Control Systems	Pod Receptacles	Female Receptacles on Stack - Keep both tapered surfaces dry and greased when out of water. Check condition of packer seals.	Planned Maintenance									x	x				
Subsea Control System	Blue & Yellow Subsea Control Systems	Pod Receptacles	Packer Seals - Inspect for damage. Replace seals	Scheduled Inspection									x		x			
Subsea Control System	Blue & Yellow Subsea Control Systems	Pod Receptacles	Replace all packer seals with new seals.	Planned Maintenance												2 years		
Subsea Control System	Blue & Yellow Subsea Control Systems	POD Pressure Transmitter	Inspect connection and check calibration	Scheduled Inspection									x					
Subsea Control System	Blue & Yellow Subsea Control Systems	POD Pressure Transmitter	Replace transmitter	Planned Maintenance												5 years		
Subsea Control System	Blue & Yellow Subsea Control Systems	POD FCR Umbilical	Inspect	Scheduled Inspection									x					

Table B-3: Subsea Control MIT Activities

BOP System	Subsystem	Component	MIT Activity	MIT Activity Type	Maintenance Activity Interval													
					Drilling				Upon Latching	Pre-Deployment and Between Wells					Major Overhaul		Miscellaneous	
					Daily	7 Days	14 Days	30 Days		60 Days	90 Days	180 Days	Between Wells	Each Trip	Annually	Multiyear	As Required	As Needed
Subsea Control System	Blue & Yellow Subsea Control Systems	Regulator	Remote Hydraulic Regulator (HKR) Valves - Operate through pressure ranges every 30 days. Replace O-rings.	Scheduled Test									x					
Subsea Control System	Blue & Yellow Subsea Control Systems	Regulator	HKR Valves – Install repair kit	Planned Maintenance											x			
Subsea Control System	Blue & Yellow Subsea Control Systems	Regulator	Manual hydraulic regulator (MKR) Valves - Operate through pressure ranges. Replace O-rings if necessary.	Planned Maintenance									x					
Subsea Control System	Blue & Yellow Subsea Control Systems	Regulator	MKR Regulator Valves - Install repair kit	Planned Maintenance											x			
Subsea Control System	HPU, Blue & Yellow Subsea Control Systems	Regulators	Regulators - Rebuild all regulators or replace with rebuilt spares	Planned Maintenance											x	2 years		
Subsea Control System	Blue & Yellow Subsea Control Systems	SEM	Make sure that the 60 V pod power supply capacitors are correct. Replace the 60 V pod power supply.	Scheduled Inspection								x	x					
Subsea Control System	Blue & Yellow Subsea Control Systems	SEM	Check for water ingress into connector	Scheduled Inspection									x					

Table B-3: Subsea Control MIT Activities

BOP System	Subsystem	Component	MIT Activity	MIT Activity Type	Maintenance Activity Interval														
					Drilling				Upon Latching	Pre-Deployment and Between Wells					Major Overhaul		Miscellaneous		
					Daily	7 Days	14 Days	30 Days		60 Days	90 Days	180 Days	Between Wells	Each Trip	Annually	Multiyear	As Required	As Needed	
Subsea Control System	Blue & Yellow Subsea Control Systems	SEM	SEMs - Examine the internal connections in Sub Sea Electronic Modules (SEMs)	Scheduled Inspection												x	2 years		
Subsea Control System	Blue & Yellow Subsea Control Systems	Shuttle Valve	Shuttle Valves - Check fittings for tightness	Scheduled Test											x				
Subsea Control System	Blue & Yellow Subsea Control Systems	Shuttle Valves	Shuttle Valves - Rebuild or replace 20% of the pod shuttle valves annually	Planned Maintenance												x	5 years		
Subsea Control System	Blue & Yellow Subsea Control Systems	Shuttle Valves	Replace o-rings	Planned Maintenance												x			
Subsea Control System	Blue & Yellow Subsea Control Systems	Shuttle Valves	Rebuild all the shuttle valves in the wedge extend/retract circuit or replace with new or reconditioned spares.	Planned Maintenance													2 years		
Subsea Control System	Blue & Yellow Subsea Control Systems	Solenoid	CCSV Solenoid - Capacitance/insulation resistance test	Scheduled Test												x			
Subsea Control System	Blue & Yellow Subsea Control Systems	Solenoid	CCSV Solenoid - Replace	Planned Maintenance													5 years		

Table B-3: Subsea Control MIT Activities

BOP System	Subsystem	Component	MIT Activity	MIT Activity Type	Maintenance Activity Interval														
					Drilling				Upon Latching	Pre-Deployment and Between Wells					Major Overhaul		Miscellaneous		
					Daily	7 Days	14 Days	30 Days		60 Days	90 Days	180 Days	Between Wells	Each Trip	Annually	Multiyear	As Required	As Needed	
Subsea Control System	Blue & Yellow Subsea Control Systems	Solenoid	CCSV Fluid End - Install seal kit	Planned Maintenance														x	
Subsea Control System	Blue & Yellow Subsea Control Systems	solenoid valve	DDV (Maintain 15-20% on a rotating basis) - Perform capacitance/insulation resistance test on solenoid	Scheduled Test									x						
Subsea Control System	Blue & Yellow Subsea Control Systems	Solenoid Valves	Perform continuity check on the solenoid. Replace if required	Scheduled Test											x	2 years			
Subsea Control System	Blue & Yellow Subsea Control Systems	SPM Valves	Inspect all SPM Valve springs for cracks and breaks.	Planned Maintenance									x						
Subsea Control System	Blue & Yellow Subsea Control Systems	SPM Valves	Replace all cracked and broken springs.	Planned Maintenance									x						
Subsea Control System	Blue & Yellow Subsea Control Systems	SPM Valves	SPM Valves (Maintain 15-20% on a rotating basis between wells) - Install seal kit as needed; install repair kit (every 12th seal kit) as needed	Planned Maintenance									x						x (install seal kit or repair kit, as needed)
Subsea Control System	Blue & Yellow Subsea Control Systems	SPM Valves	SPM Valves - Rebuild or replace 20% of the SPM Valves (to be rebuilt with new springs) annually	Planned Maintenance											x	5 years			

Table B-3: Subsea Control MIT Activities

BOP System	Subsystem	Component	MIT Activity	MIT Activity Type	Maintenance Activity Interval														
					Drilling				Upon Latching	Pre-Deployment and Between Wells					Major Overhaul		Miscellaneous		
					Daily	7 Days	14 Days	30 Days		60 Days	90 Days	180 Days	Between Wells	Each Trip	Annually	Multiyear	As Required	As Needed	
Subsea Control System	Blue & Yellow Subsea Control Systems	SPM Valves	SPM Valves - Install repair kit	Planned Maintenance													5 years		
Subsea Control System	Blue & Yellow Subsea Control Systems	Tubing	Pod Piping - Inspect fittings and joints. Replace if necessary	Scheduled Inspection									x			x			
Subsea Control System	Blue & Yellow Subsea Control Systems		Replace all O-rings that have been removed and test after assembly if applicable.	Planned Maintenance									x						
Subsea Control System	Blue & Yellow Subsea Control Systems	Seal Assembly	Replace	Planned Maintenance									x				5 years		
Subsea Control System			BOP Overall - Inspect bolts, nuts, studs for fatigue. Clean all exterior surfaces.	Scheduled Inspection											x				
Subsea Control System	Accumulators - LMRP	Accumulators	Check precharge.	Scheduled Test										x	x				
Subsea Control System	Accumulators - LMRP	Accumulators	Install new bladder kit	Planned Maintenance													5 years		
Subsea Control System	All hydraulic surface & subsea	Hydraulic Hoses & Connections	Visually inspect the condition and security of all BOP pipe work and hoses between the hydraulic control unit and the BOP stack. Check fittings and fastenings for deterioration.	Scheduled Inspection									x		x				

Table B-3: Subsea Control MIT Activities

BOP System	Subsystem	Component	MIT Activity	MIT Activity Type	Maintenance Activity Interval													
					Drilling				Upon Latching	Pre-Deployment and Between Wells					Major Overhaul		Miscellaneous	
					Daily	7 Days	14 Days	30 Days		60 Days	90 Days	180 Days	Between Wells	Each Trip	Annually	Multiyear	As Required	As Needed
Subsea Control System	All hydraulic surface & subsea	Hydraulic Hoses & Connections	Ensure all control system interconnecting piping and hoses are protected from damage during drilling operations.	Scheduled Inspection								x						
Subsea Control System	Emergency & Secondary Controls		Rebuild or replace all of the following control components that control the BOP critical functions (i.e., EDS, Deadman (AMF), Auto Shear, EHBS, and pod select)	Planned Maintenance											x	2 years		
Subsea Control System	Emergency & Secondary Controls	EDS	Make sure that the inclinometers are operating correctly.	Scheduled Inspection											x	2 years		
Subsea Control System	Emergency & Secondary Controls	ROV	Test all ports on the ROV intervention panel while on surface.	Scheduled Test									x					
Subsea Control System	Annular, rams, C&K Valves		Clean and Inspect BOP Components	Scheduled Inspection									x					

Table B-4: BOP Stack MIT Activities

BOP System	Subsystem	Component	MIT Activity	MIT Activity Type	Maintenance Activity Interval													
					Drilling				Upon Latching	Pre-Deployment and Between Wells					Major Overhaul		Miscellaneous	
					Daily	7 Days	14 Days	30 Days		60 Days	90 Days	180 Days	Between Wells	Each Trip	Annually	Multiyear	As Required	As Needed
BOP Stack			Make sure the correct number and type of anodes are being utilized on the LMRP and Stack per the rig drawings.	Scheduled Inspection									x					
BOP Stack			Check the condition of the sacrificial anodes.	Scheduled Inspection							x							
BOP Stack			Verify zero resistance between anodes and material to be protected. Eliminate resistance, if found.	Scheduled Test									x					
BOP Stack			LMRP Spider Assembly - Inspect, clean and lubricate	Scheduled Inspection										x				
BOP Stack			Clean and Inspect BOP Components	Scheduled Inspection									x					
BOP Stack			Repair or replace parts require to bring equipment to original specifications	Planned Maintenance												3 Years		
BOP Stack			Overall BOP Stack - Inspect bolts, nuts, and studs for fatigue. Clean all exterior surfaces.	Scheduled Inspection										x				x
BOP Stack			Flex Joint - Inspect & clean all metal parts, elastomer of flex element, wear rings and sleeves, nipple, mating surfaces, and back flange	Scheduled Inspection									x	x				
BOP Stack			Ring Gaskets - Inspect, replace as necessary	Planned Maintenance										x				
BOP Stack			Guide legs - Inspect and clean	Scheduled Inspection										x				
BOP Stack			Shackles - Clean/grease. Replace if needed	Planned Maintenance										x				
BOP Stack			Overall LMRP - Inspect bolts, nuts, studs for fatigue	Scheduled Inspection										x				
BOP Stack			Overall LMRP - Clean all exterior surfaces	Planned Maintenance										x				
BOP Stack	Annular		Upper Annular - Inspect elements for severe wear or damage.	Scheduled Inspection	x			x							X			X

Table B-4: BOP Stack MIT Activities (cont'd)

BOP System	Subsystem	Component	MIT Activity	MIT Activity Type	Maintenance Activity Interval													
					Drilling				Upon Latching	Pre-Deployment and Between Wells					Major Overhaul		Miscellaneous	
					Daily	7 Days	14 Days	30 Days		60 Days	90 Days	180 Days	Between Wells	Each Trip	Annually	Multiyear	As Required	As Needed
BOP Stack	Annular		Lower Annular - Inspect each element for severe wear or damage.	Scheduled Inspection				x										
BOP Stack	Annular		Perform between wells and yearly maintenance	Planned Maintenance												2.5 years		
BOP Stack	Annular		<ul style="list-style-type: none"> Remove the annular BOP Head, Opening Chamber Head, piston and internal components. Remove and discard all seals. Visually and dimensionally inspect the piston and the body sealing areas; the annular head; wear plate and replace as required; the annular head latching profile for mechanical damage or corrosion. Remove and inspect the jaws and jaw operating screws, replace all seals and visually and dimensionally inspect the jaw recess and operating screw threads in the body. Reassemble the annular with all new seals. On completion of the rebuild, pressure test the opening and closing chambers to maximum operating pressure 	Planned Maintenance												2 years		
BOP Stack	Annular		<ul style="list-style-type: none"> Remove the annular top, piston and internal components. Remove and discard all seals. Visually and dimensionally inspect the piston and the body sealing areas and the annular top, paying particular attention the sealing areas. Rebuild the annular with all new seals. On completion of the 	Planned Maintenance												2.5 years		

Table B-4: BOP Stack MIT Activities (cont'd)

BOP System	Subsystem	Component	MIT Activity	MIT Activity Type	Maintenance Activity Interval													
					Drilling				Upon Latching	Pre-Deployment and Between Wells					Major Overhaul		Miscellaneous	
					Daily	7 Days	14 Days	30 Days		60 Days	90 Days	180 Days	Between Wells	Each Trip	Annually	Multiyear	As Required	As Needed
			rebuild, pressure test the opening and closing chambers to maximum operating pressure or as per OEM recommendations <ul style="list-style-type: none"> Pressure test the well bore to low pressure and to 70% of maximum working pressure as per the rig specific BOP test procedure 															
BOP Stack	Annular		<ul style="list-style-type: none"> Completely strip the annular to its component parts. Inspect the areas outlined below and compare the actual values found, to the OEM specifications. Visually, dimensionally and NDT inspect the annular upper and lower hub or flange connections and weld; the annular body and dogs; the end connection ring grooves; all threaded bolt / stud holes; all threaded fasteners; the piston and wear ring; and the OCH (API RP53 18.10.3). Carry out hardness tests (API RP53 18.10.3) Reassemble the annular with all new seals. On completion of the reassembly, pressure test the opening and closing chambers to maximum working pressure, prior to installing the element. Chart record the tests. (API RP53 18.13.4) Pressure test the well bore to low pressure and to maximum working pressure. Seal all ports and protect all sealing areas and paint the equipment to specification. Preserve for long term storage and protect for shipping. (API RP53	Planned Maintenance											5 years			

Table B-4: BOP Stack MIT Activities (cont'd)

BOP System	Subsystem	Component	MIT Activity	MIT Activity Type	Maintenance Activity Interval													
					Drilling				Upon Latching	Pre-Deployment and Between Wells					Major Overhaul		Miscellaneous	
					Daily	7 Days	14 Days	30 Days		60 Days	90 Days	180 Days	Between Wells	Each Trip	Annually	Multiyear	As Required	As Needed
			18.11.5)															
BOP Stack	Annular	Wedge Cover	Verify bolt torque on ring joint connections, inspect and clean ring joint sealing surface, inspect and clean all studs and nuts, inspect quick disconnect o-rings, clean inspect for damage and lubricate BOP,	Scheduled Inspection and Planned Maintenance									x					
BOP Stack	Annular	Wedge Cover	Remove and inspect upper housing and sealing element, Repair as needed. Perform hydraulic and well bore pressure test	Scheduled Inspection and Scheduled Test											X	3 years		
BOP Stack	Annular	Wedge Cover	Disassemble wedge cover, repair or replace all parts required to bring equipment back to OEM specification, replace all seals, and perform field wellbore pressure test, internal hydraulic pressure test, and locking hydraulic pressure test	Planned Maintenance and Scheduled Test												3 years.		
BOP Stack	All Rams	Ram Locks	Perform a back drive test and a minimum unlocking pressure test. Record information in work order notes.	Scheduled Test														Rig Move
BOP Stack	All Rams		Inspect locking system	Scheduled Inspection											x			

Table B-4: BOP Stack MIT Activities (cont'd)

BOP System	Subsystem	Component	MIT Activity	MIT Activity Type	Maintenance Activity Interval													
					Drilling				Upon Latching	Pre-Deployment and Between Wells					Major Overhaul		Miscellaneous	
					Daily	7 Days	14 Days	30 Days		60 Days	90 Days	180 Days	Between Wells	Each Trip	Annually	Multiyear	As Required	As Needed
BOP Stack	All Rams		<ul style="list-style-type: none"> Remove ram packers and top seals, Perform dimensional checks on all ram blocks NDT Ram shaft ends and ram blocks Measure the vertical height of the ram cavity at the seal area of the upper seal seat using an inside micrometer. Measure the vertical height of the ram block using an outside micrometer. N.D.T. 10% of the bonnet bolts. If problems are found NDT all bonnet bolts Check that the weep hole in the intermediate flange is clear. If a check valve is fitted ensure that it is installed properly and is clear. Remove the bonnet seal carriers and visually inspect for scoring, pitting or other damage. Replace all O rings and carrier spring. Remove the MPL assembly and inspect. Replace both of the overhauling nut bearings and the clutch springs. Ensure all locking devices are properly reassembled and all of the required parts are installed. 	Planned Maintenance											x			
BOP Stack	All Rams		If a pressure test fails, a lock out test should be carried out to verify the MPL clutch condition.	Scheduled Test											x			
BOP Stack	BOP Stack	BOP Stack	Completely disassemble	Planned Maintenance												3 years		
BOP Stack	BOP Stack	BOP Stack	Replace all seals, including secondary flow valve	Planned Maintenance												3 years		

Table B-4: BOP Stack MIT Activities (cont'd)

BOP System	Subsystem	Component	MIT Activity	MIT Activity Type	Maintenance Activity Interval													
					Drilling				Upon Latching	Pre-Deployment and Between Wells					Major Overhaul		Miscellaneous	
					Daily	7 Days	14 Days	30 Days		60 Days	90 Days	180 Days	Between Wells	Each Trip	Annually	Multiyear	As Required	As Needed
BOP Stack	BOP Stack	BOP Stack	<ul style="list-style-type: none"> Disassemble the entire BOP to its component parts. For tracking purposes, assign a RMS job identification number to all components (API RP53 18.10.3) Inspect the areas outlined below and compare the actual values found, to the OEM specifications. Carry out any required repairs in accordance with the OEM specifications or OEM approved procedures. (API RP53 18.10.3) Take body hardness readings and record in RMS, as per the OEM recommendations. (API RP53 18.10.3 and 18.3.7) Visually and dimensionally inspect the bonnet sealing areas on the bodies. (API RP53 18.10.3) Visually and dimensionally inspect the ram cavities. (API RP53 18.10.3) Visually and dimensionally inspect the through bore. (API RP53 18.10.3) Visually, dimensionally and NDT inspect the ram blocks. (API RP53 18.10.3) Visually, dimensionally and NDT inspect the bonnet bolt threads and NPT hydraulic ports if equipped on the body. (API RP53 18.10.3) Visually, dimensionally and NDT inspect the hinge assemblies if equipped. (API RP53 18.10.3) Visually, dimensionally and NDT inspect the cylinder liner, operating piston and lock assembly. Check the sealing 	Planned Maintenance												5 years		

Table B-4: BOP Stack MIT Activities (cont'd)

BOP System	Subsystem	Component	MIT Activity	MIT Activity Type	Maintenance Activity Interval													
					Drilling				Upon Latching	Pre-Deployment and Between Wells					Major Overhaul		Miscellaneous	
					Daily	7 Days	14 Days	30 Days		60 Days	90 Days	180 Days	Between Wells	Each Trip	Annually	Multiyear	As Required	As Needed
			<p>surfaces for wear or damage and for the hard facing separating from the parent material. (API RP53 18.10.3)</p> <ul style="list-style-type: none"> • Visually, dimensionally and NDT inspect the bonnet, including the bonnet seal groove and seal bores. (API RP53 18.10.3) • Visually, dimensionally and NDT inspect bonnet bolts/studs and nuts. (API RP53 18.10.3) • Re assemble the operators and Locks with all new seals, and install on the body. On completion of the re assembly, perform function of manual locks or signature test on hydraulic Locks then pressure test the opening and closing chambers to maximum working pressure. Chart record the tests (API RP53 18.13.4) • Pressure test the well bore to low pressure and to rated working pressure, with the locks engaged and the ram closing pressure (Lock pressure if applicable)vented. Chart record the tests. (API RP53 18.13.4) • Preserve for long term storage and protect for shipping. (API RP53 18.11.5) 															

Table B-4: BOP Stack MIT Activities (cont'd)

BOP System	Subsystem	Component	MIT Activity	MIT Activity Type	Maintenance Activity Interval														
					Drilling				Upon Latching	Pre-Deployment and Between Wells					Major Overhaul		Miscellaneous		
					Daily	7 Days	14 Days	30 Days		60 Days	90 Days	180 Days	Between Wells	Each Trip	Annually	Multiyear	As Required	As Needed	
BOP Stack	All Rams		a. Fixed-Bore Pipe Rams or Blind/Shear Rams: 1) If no pressure is lost, the integrity of the ram packers and seals is verified under low pressure and the proper operation of the MPL locks is confirmed. Continue to the Step 10. 2) If pressure is lost, stop the test and vent the pressure from the BOP. Make necessary repairs. If repairs require disassembly of the BOP, perform the wellbore test again, beginning with Step 2.	Scheduled Test														x	
BOP Stack	All Rams		<ul style="list-style-type: none"> • Clean & inspect lower double end connection and gasket prep. • Clean & inspect ram exterior for corrosion & coating condition. • Clean, inspect, grease & protect exposed side outlets & gasket preps. 	Planned Maintenance															Rig Move
BOP Stack	All Rams		Chart Low pressure signature test on MPL's and maximum working pressure test on operators. If test fails make repairs as required and repeat tests.	Scheduled Test															Rig Move

Table B-4: BOP Stack MIT Activities (cont'd)

BOP System	Subsystem	Component	MIT Activity	MIT Activity Type	Maintenance Activity Interval														
					Drilling				Upon Latching	Pre-Deployment and Between Wells					Major Overhaul		Miscellaneous		
					Daily	7 Days	14 Days	30 Days		60 Days	90 Days	180 Days	Between Wells	Each Trip	Annually	Multiyear	As Required	As Needed	
BOP Stack	All Rams		<ul style="list-style-type: none"> • Open Bonnets and clean the bonnet bolts. • Check the bonnet bolt threads for damage or thread loss through corrosion, using a thread profile gauge. Check the bolt shoulder bearing faces for signs of galling, burr's or raised edges that would cause excessive friction. • Visually check the bolt shanks for signs of diameter reduction (necking), which would indicate the bolt had been stressed beyond the material elastic limit. If in doubt, measure the outside diameter (OD) of the shank at various points along its length to ensure a consistent OD. • Lubricate the bolt threads and shoulders on completion. • Check the bolt shoulder bearing surfaces on the bonnets for galling, burr's or raised edges that would cause excessive friction. • Check the bonnet bolt threads in the BOP body for damage or thread loss through corrosion, using a thread profile gauge. • With the bonnets open and the rams in the closed position, inspect the exposed ram shaft for damage such as scoring, pitting or gouging, if light damage is found it can be smoothed off using fine emery paper. • Check that the ram shaft seal retainer is in place and secure. 	Planned Maintenance															Rig Move

Table B-4: BOP Stack MIT Activities (cont'd)

BOP System	Subsystem	Component	MIT Activity	MIT Activity Type	Maintenance Activity Interval													
					Drilling				Upon Latching	Pre-Deployment and Between Wells					Major Overhaul		Miscellaneous	
					Daily	7 Days	14 Days	30 Days		60 Days	90 Days	180 Days	Between Wells	Each Trip	Annually	Multiyear	As Required	As Needed
			<ul style="list-style-type: none"> Remove the bonnet seals and clean and inspect the seal grooves for pitting or indentations that could cause well bore leakage. Minor defects can be smoothed out with emery cloth. Clean the bop body to bonnet sealing face and check for pitting or indentations that could cause well bore leakage. Minor defects can be smoothed out with emery cloth. Check the ram packer condition and replace as required. Replace top seal if there are signs of cuts, wear or scoring that could cause well bore leakage. Refer to the next well program to determine if the ram packer condition warrants change out. Inspect the ram blocks for damage to the pipe guides or pipe bore due to closure on a tool joint or other oversized component of the drill string. Any raised burrs around the pipe bore that could score the ram cavity, can be removed with a file or 60 grit sanding disk. If the pipe guides show signs of damage, they should be MPI inspected to ensure there are no cracks. Inspect the ram bodies for scoring, pitting or indentations. Any minor defects should be smoothed out. 															

Table B-4: BOP Stack MIT Activities (cont'd)

BOP System	Subsystem	Component	MIT Activity	MIT Activity Type	Maintenance Activity Interval													
					Drilling				Upon Latching	Pre-Deployment and Between Wells					Major Overhaul		Miscellaneous	
					Daily	7 Days	14 Days	30 Days		60 Days	90 Days	180 Days	Between Wells	Each Trip	Annually	Multiyear	As Required	As Needed
			<ul style="list-style-type: none"> • Clean and inspect the ram cavities for scoring, pitting or any other damage. Pay particular attention to the top wear plate where the top seal makes sealing contact. Any scoring or pitting can be hand dressed using a smooth file or fine emery cloth. Remove only the sharp raised edges adjacent to the scores. • Ensure top seal/wear plate and bottom wear plates are in place and secure. • Inspect the intersection between the ram cavities and the well bore for damage caused by the drill bit. Any sharp raised edges should be filed smooth. • Check the through bore for key seating damage. • On completion of all checks and inspections, fit new bonnet door seals and lubricate the BOP body face and the bonnet face with light oil. • Lightly grease the ram blocks and ram cavities. • Close the bonnets and torque the bonnet bolts to the correct value. The coefficient of friction of the thread lubricant in use must be considered when selecting the torque value. 															

Table B-4: BOP Stack MIT Activities (cont'd)

BOP System	Subsystem	Component	MIT Activity	MIT Activity Type	Maintenance Activity Interval													
					Drilling				Upon Latching	Pre-Deployment and Between Wells					Major Overhaul		Miscellaneous	
					Daily	7 Days	14 Days	30 Days		60 Days	90 Days	180 Days	Between Wells	Each Trip	Annually	Multiyear	As Required	As Needed
			<ul style="list-style-type: none"> Perform low and rated working pressure well bore tests following the rig specific bop surface test procedures. (API RP53 18.13.4) These surface tests will be performed with the locking system engaged and the closing pressure vented. Chart record all well bore tests On completion of testing visually check that all ram blocks are fully retracted. Inspect weep holes on all bonnets to ensure they are clean and free from any blockage. 															
BOP Stack	Pipe & Test Rams			Planned Maintenance							x							
BOP Stack	Pipe & Test Rams		Open doors and inspect visually	Scheduled Inspection							x				x			
BOP Stack	Pipe & Test Rams		Remove and inspect ram assemblies	Scheduled Inspection									x					
BOP Stack	Pipe & Test Rams		Grease door hinges	Planned Maintenance									x					
BOP Stack	Pipe & Test Rams		Measure rams and ram cavity.	Scheduled Inspection											x			
BOP Stack	Pipe & Test Rams		Rams (non-intrusive (doors closed)) - Perform field wellbore pressure test to detect leaks	Scheduled Test				x					x					After cementing jobs
BOP Stack	Pipe & Test Rams		Rams (intrusive (doors open)) - Visually inspect	Scheduled Inspection							x							
BOP Stack	Pipe & Test Rams		Rams (intrusive (doors open)) - Perform (1) field wellbore pressure test, (2) internal hydraulic pressure test, and (3) locking hydraulic pressure test	Scheduled Test							x				x	3 years		
BOP Stack	Pipe & Test Rams		Rams (intrusive (doors open)) - Measure rams and ram cavities	Scheduled Inspection											x			
BOP Stack	Pipe & Test Rams		Rams (intrusive (doors open)) - Completely disassemble. Repair or replace all parts required to bring	Planned Maintenance												3 years		

Table B-4: BOP Stack MIT Activities (cont'd)

BOP System	Subsystem	Component	MIT Activity	MIT Activity Type	Maintenance Activity Interval													
					Drilling				Upon Latching	Pre-Deployment and Between Wells					Major Overhaul		Miscellaneous	
					Daily	7 Days	14 Days	30 Days		60 Days	90 Days	180 Days	Between Wells	Each Trip	Annually	Multiyear	As Required	As Needed
			to original specifications. Replace all seals, including secondary flow valve, and door bolts.															
BOP Stack	Pipe & Test Rams		Ram BOPs - Open ram doors and inspect assembly for wear. Replace components as necessary. Lubricate bolts and sealing surfaces. Grease hinges.	Planned Maintenance							x							
BOP Stack	Pipe & Test Rams		<ul style="list-style-type: none"> Open one bonnet and inspect. Check the sealing surface on the ram piston rod for wear, pitting, and damage. If the ram piston rod shows wear, pitting, or other damage replace it as follows; 1. Disassemble the ram BOP, 2. Inspect the bonnet to piston rod seal, wear ring, connecting rod seal, and wiper O-ring for wear, damage, and set. Replace if necessary. 3. Replace the ram piston rod with a new one. 4. Assemble the BOP, leaving the bonnets open. Replace seals as required. Remove the bonnet seal from the bonnet seal carrier ring installed in the face of the bonnet. Inspect the seal groove for wear, pitting, or other damage. Remove minor pits and cores in the bonnet seal area groove with emery cloth. Coat the repaired surfaces with grease. Replace the bonnet seal ring carrier assembly if the bonnet seal groove is severely worn or damaged. Inspect the bonnet seal for wear, damage, and set. Replace if necessary. Lubricate bonnet seal with castor oil and 	Scheduled Inspection								x						x

Table B-4: BOP Stack MIT Activities (cont'd)

BOP System	Subsystem	Component	MIT Activity	MIT Activity Type	Maintenance Activity Interval													
					Drilling				Upon Latching	Pre-Deployment and Between Wells					Major Overhaul		Miscellaneous	
					Daily	7 Days	14 Days	30 Days		60 Days	90 Days	180 Days	Between Wells	Each Trip	Annually	Multiyear	As Required	As Needed
			install it into the carrier ring. • Inspect the sealing surface where the bonnet seal contacts the BOP body for wear, pitting, and other damage. Remove minor pits and scores in the bonnet seal area groove with emery cloth. Coat the repaired surfaces with grease. • Clean the ram compartment thoroughly and inspect for wear, pitting, and damage. Remove minor pits and scores in the field with emery cloth. • Measure the maximum vertical clearance between the rams and the upper seal seat in the ram compartment. • Install the ram assembly onto the piston rod and remove the lifting eye. Lubricate the ram assembly and the ram bore with castor oil. Retract the ram assembly into the bonnet. • Lubricate the threads and shoulders of the bonnet bolt threads. • Close the bonnet and torque the bonnet bolts															
BOP Stack	Pipe & Test Rams		Perform the MPL overhauling nut break-in procedure.	Planned Maintenance											x			
BOP Stack	Pipe & Test Rams		If the BOP is equipped with fixed-bore pipe rams or variable pipe rams, inspect the front packer and top seal for wear, cracking, and excessive hardness by comparison with a new packer/top seal. Replace if necessary.	Planned Maintenance								x					x	

Table B-4: BOP Stack MIT Activities (cont'd)

BOP System	Subsystem	Component	MIT Activity	MIT Activity Type	Maintenance Activity Interval													
					Drilling				Upon Latching	Pre-Deployment and Between Wells					Major Overhaul		Miscellaneous	
					Daily	7 Days	14 Days	30 Days		60 Days	90 Days	180 Days	Between Wells	Each Trip	Annually	Multiyear	As Required	As Needed
BOP Stack	Shear Ram		Inspect elements for severe wear or damage.	Scheduled Inspection				x						x				
BOP Stack	Shear Ram		If equipped with blind shear rams, inspect the seal(s) on the shear ram for wear, cracking, and excessive hardness by comparison with new seal(s). Replace the seal(s) if necessary. Inspect the shear blades for wear and damage. Replace if necessary.	Planned Maintenance									x				x	Rig Move
BOP Stack	Shear Ram		NDT shear ram blocks, blades and blade retaining bolts	Planned Maintenance											x			If any pipe has been sheared
BOP Stack	Shear Ram		When changing the shear ram lateral 'T' seal carry out an inspection of upper blade retaining socket head cap screws. Check cap screws for stretch and cracks. Install new socket head cap screws if any defects are found.	Scheduled Inspection														Rig Move
BOP Stack			Pressure test poppets	Scheduled Test											x			
BOP Stack	Choke & Kill		Grease valve body	Planned Maintenance														Keep adequately greased
BOP Stack	Choke & Kill		Flush valve with water	Planned Maintenance									x					After cementing jobs
BOP Stack	Choke & Kill		Pressure test	Scheduled Test														In conjunction with testing of preventers on BOP Stack
BOP Stack	Choke & Kill		Check Stem Seals, Tail Rod Seals and Seat Seals for Leakage	Scheduled Test														In conjunction with testing

Table B-4: BOP Stack MIT Activities (cont'd)

BOP System	Subsystem	Component	MIT Activity	MIT Activity Type	Maintenance Activity Interval													
					Drilling				Upon Latching	Pre-Deployment and Between Wells					Major Overhaul		Miscellaneous	
					Daily	7 Days	14 Days	30 Days		60 Days	90 Days	180 Days	Between Wells	Each Trip	Annually	Multiyear	As Required	As Needed
																	of preventers on BOP Stack	
BOP Stack	Choke & Kill		Test Piston Seals	Scheduled Test													In conjunction with testing of preventers on BOP Stack	
BOP Stack	Choke & Kill		Flush C&K Lines	Planned Maintenance	x												Each Tour, 2x Daily	
BOP Stack	Choke & Kill		Prior to unlatching the BOP from the wellhead, open all choke and kill and annular bleed valves, and flush through the choke and kill lines with water.	Planned Maintenance									X					
BOP Stack	Choke & Kill		Flush valve with water	Planned Maintenance									X					After cementing jobs
BOP Stack	Choke & Kill		Lubricate the valve cavities with the manufacturers recommended lubricant and in accordance with the manufacturer's procedure.	Planned Maintenance									X					
BOP Stack	Choke & Kill		Where fitted, check the "failsafe" accumulator nitrogen pre charge, and adjust for water depth.	Planned Maintenance									X					
BOP Stack	Choke & Kill		Choke/Kill Female Stab Assemblies - Inspect, clean & lubricate	Planned Maintenance										x				
BOP Stack	Choke and Kill	Pipes/Hoses/Tubing	Visually inspect hoses, wires, and fittings. Repair or replace as required.	Scheduled Inspection									X				x	

Table B-4: BOP Stack MIT Activities (cont'd)

BOP System	Subsystem	Component	MIT Activity	MIT Activity Type	Maintenance Activity Interval														
					Drilling				Upon Latching	Pre-Deployment and Between Wells					Major Overhaul		Miscellaneous		
					Daily	7 Days	14 Days	30 Days		60 Days	90 Days	180 Days	Between Wells	Each Trip	Annually	Multiyear	As Required	As Needed	
BOP Stack	Connector	Choke & Kill Stabs	Choke/Kill Female Stab Assemblies - Check polypak inserts for wear	Scheduled Inspection												x			
BOP Stack	Connectors	LMRP Connector	LMRP Connector should be function tested under controlled conditions in the BOP set back area or other suitable location.	Scheduled Test		x													
BOP Stack	Connectors	Control Pod Gripper Assembly	Inspect locking dogs and pack with grease and inspect and grease shear pin and hub and pack with grease	Scheduled Inspections									X						
BOP Stack	Connectors	Control Pod Gripper Assembly	Pressure test	Scheduled Test												x			
BOP Stack	Connectors	Control Pod Gripper Assembly	Replace seal and springs on primary assembly, and replace seals on the secondary cylinder	Planned Maintenance													3 years		
BOP Stack	Connectors		Measure the clearance between the dogs and the upper body or the dogs and the upper body wear plate if fitted using a feeler gauge. (API RP53 18.2.1) If the clearances recorded with a feeler gauge are not within the above minimum and maximum range, remove the dogs and confirm the clearances. Also check the dog springs for overall length and damage. Replace as necessary. Check the upper body to lower body cap screw torque and the cylinder head to lower body cap	Scheduled Inspection								x							

Table B-4: BOP Stack MIT Activities (cont'd)

BOP System	Subsystem	Component	MIT Activity	MIT Activity Type	Maintenance Activity Interval													
					Drilling				Upon Latching	Pre-Deployment and Between Wells					Major Overhaul		Miscellaneous	
					Daily	7 Days	14 Days	30 Days		60 Days	90 Days	180 Days	Between Wells	Each Trip	Annually	Multiyear	As Required	As Needed
			screw torque.															
BOP Stack	Connectors		Pressure test the operating chambers to maximum working pressure. Chart record the tests.	Scheduled Test								x						
BOP Stack	Connectors		Pressure test the ring gasket retaining circuit, if applicable. Chart record the tests.	Scheduled Test								x						
BOP Stack	Connectors		Perform low pressure unlock test, as per the manufacturers specifications.	Scheduled Test								x						
BOP Stack	Connectors		On the test stump, measure and record unlatch to latch indicator rod travel.	Scheduled Test								x						
BOP Stack	Connectors		<ul style="list-style-type: none"> • Flush all accessible external and internal surfaces with fresh water • remove and release the VX ring gasket from the connector • Clean and visually inspect the VX ring gasket and the mating seal surface in the connector. • Lightly grease the VX ring gasket and install in the connector to protect the VX seal surface. • Lubricate the connector as directed 	Planned Maintenance									x					

Table B-4: BOP Stack MIT Activities (cont'd)

BOP System	Subsystem	Component	MIT Activity	MIT Activity Type	Maintenance Activity Interval														
					Drilling				Upon Latching	Pre-Deployment and Between Wells					Major Overhaul		Miscellaneous		
					Daily	7 Days	14 Days	30 Days		60 Days	90 Days	180 Days	Between Wells	Each Trip	Annually	Multiyear	As Required	As Needed	
BOP Stack	Connectors		While the lower body is extended, use water to flush out the exposed chamber between the 'OD' of the upper body and the inside diameter (ID) of the retracting cylinder. Once complete, purge the chamber with mixed BOP fluid.	Planned Maintenance									x						
BOP Stack	Connectors		Perform a visual inspection of the inside diameter and seal grooves in the lower body to see if there is any sign of mechanical damage, corrosion and or pitting. Polish the inside diameter and seal grooves with emery paper to remove any sharp edges and apply a light coating of grease prior to installing new seals	Scheduled Inspection									x						
BOP Stack	Connectors		Pressure test the hydraulic operating system (i.e., extend and retract) to the maximum operating pressure. All tests are to be chart recorded.	Scheduled Test									x			2 years			
BOP Stack	Connectors		<ul style="list-style-type: none"> Once testing is complete, record the minimum extend and retract operating pressure to overcome the resistance of the snap ring in the 'ID' of the retract piston, i.e., only required if the snap ring is installed. Wash the connector male stabs on the lower BOP with water. Inspect the pin profile and seal surface for any signs of mechanical damage, corrosion and or pitting. Polish the 'OD' of the pin to remove and sharp edges and apply a light coating of grease. Once the LMRP is installed, function test connectors, i.e. 	Scheduled Test									x			Function & Pressure tests are done also at 2 years.			

Table B-4: BOP Stack MIT Activities (cont'd)

BOP System	Subsystem	Component	MIT Activity	MIT Activity Type	Maintenance Activity Interval													
					Drilling				Upon Latching	Pre-Deployment and Between Wells					Major Overhaul		Miscellaneous	
					Daily	7 Days	14 Days	30 Days		60 Days	90 Days	180 Days	Between Wells	Each Trip	Annually	Multiyear	As Required	As Needed
			extend and retract, to confirm proper operation and alignment. <ul style="list-style-type: none"> Record the initial unlock pressure of riser connector. Wash the connector through bore with water, before landing on the test stump. (API RP 53 18.10.1) Inspect the latching profile of the dog segments for mechanical damage. Ensure the dogs move freely and are not jammed between the upper and lower wear plates. If at this time the dogs have to be removed then the dog springs should be checked for damage, overall length and replaced if required. (API RP 53 18.10.1) Measure the clearance between the dogs and the upper body or the dogs and the upper body wear plate if fitted using a feeler gauge. Inspect the hydrate seal, where fitted and replace if required. (API RP 53 18.10.1) Inspect the through bore for key seating damage. (API RP 53 18.10.1) Check the gasket retainer pins and nudge pins if installed, for damage and function / pressure test to max operating pressure. Consult operations & maintenance manual for max recommended operating pressure and chart record all tests. Lubricate the connector as per the manufacturer's recommendations. 															

Table B-4: BOP Stack MIT Activities (cont'd)

BOP System	Subsystem	Component	MIT Activity	MIT Activity Type	Maintenance Activity Interval													
					Drilling				Upon Latching	Pre-Deployment and Between Wells					Major Overhaul		Miscellaneous	
					Daily	7 Days	14 Days	30 Days		60 Days	90 Days	180 Days	Between Wells	Each Trip	Annually	Multiyear	As Required	As Needed
			<ul style="list-style-type: none"> • Pressure test the hydraulic operating chambers (primary lock, secondary lock, primary un-lock and secondary un-lock) to max operating pressure. All tests are to be chart recorded. (API RP 53 18.3.2.4) • Perform minimum unlock pressure test (i.e., primary un-lock only) once pressure testing is complete and record minimum un-lock pressure. • Install new gasket prior to running BOP. 															
BOP Stack	Connectors	Riser Connector	Riser Adapter - Inspect, clean & Lubricate	Scheduled Inspection										x				
BOP Stack	Connectors	Well Head	Stack (wellhead) Connector - Inspect & Clean	Scheduled Inspection										x				x
BOP Stack	Connectors		Clamp Assemblies - Inspect, clean and lubricate	Scheduled Inspection										x				
BOP Stack	Connectors		Choke/Kill Female Stab Assemblies - Inspect, clean & lubricate	Planned Maintenance										x				
BOP Stack	Connectors		Choke/Kill Female Stab Assemblies - Check polypak inserts for wear	Scheduled Inspection											x			
BOP Stack	Connectors		Mandrel - Inspect and clean	Scheduled Inspection										x				
BOP Stack			Guideposts - Inspect, clean and grease	Scheduled Inspection										x				
BOP Stack	Connectors		Wash the connector through bore with water, before landing on the test stump.	Planned Maintenance														Rig Move
BOP Stack	Connectors		Remove the well head gasket, and clean and inspect ring groove.	Scheduled Inspection									x					Rig Move
BOP Stack	Connectors		Inspect the latching profile of the dog segments for mechanical damage. Ensure the dogs move freely and are not jammed between the upper and lower wear plates. If at this time the dogs have to be removed then the	Scheduled Inspection														Rig Move

Table B-4: BOP Stack MIT Activities (cont'd)

BOP System	Subsystem	Component	MIT Activity	MIT Activity Type	Maintenance Activity Interval													
					Drilling				Upon Latching	Pre-Deployment and Between Wells					Major Overhaul		Miscellaneous	
					Daily	7 Days	14 Days	30 Days		60 Days	90 Days	180 Days	Between Wells	Each Trip	Annually	Multiyear	As Required	As Needed
			dog springs should be checked for overall length and damage. Replace as necessary.															
BOP Stack	Connectors		Inspect the hydrate seal, where fitted.	Scheduled Inspection														Rig Move
BOP Stack	Connectors		Inspect the through bore for key seating damage.	Scheduled Inspection														Rig Move
BOP Stack	Connectors		Check the gasket retainer pins for damage and function test.	Scheduled Test														Rig Move
BOP Stack	Connectors		Lubricate the connector as per the manufacturer's recommendations.	Planned Maintenance														Rig Move
BOP Stack	Connectors		<ul style="list-style-type: none"> • Disassemble connector • Perform OEM inspection • Perform complete dimensional inspection. • Perform a MPI inspection on the dog ring segments, cam ring, connecting rods, operating pistons, high stress areas and fasteners. • Renew / rework all worn parts and seals. On completion of assembly, measure the dog ring to upper body wear plate gap. (API RP 53 18.10.3) • Pressure test the well bore to low pressure and to maximum working pressure. Chart record all tests. (API RP 53 18.3.2.2) • Clean and inspect the mating component (i.e. flange or hub connection) gasket prep for wear, pitting or mechanical damage. Place a new ring gasket in the prep and check for proper fitment. • Lubricate all stud and nut threads with an average coefficient of friction 0.064. • Lubricate the gasket prep with 	Planned Maintenance											2 years			

Table B-4: BOP Stack MIT Activities (cont'd)

BOP System	Subsystem	Component	MIT Activity	MIT Activity Type	Maintenance Activity Interval													
					Drilling				Upon Latching	Pre-Deployment and Between Wells					Major Overhaul		Miscellaneous	
					Daily	7 Days	14 Days	30 Days		60 Days	90 Days	180 Days	Between Wells	Each Trip	Annually	Multiyear	As Required	As Needed
			light oil, place the new ring gasket in the groove and install the connector. <ul style="list-style-type: none"> • Torque all nuts using the three level torque sequences to the required torque for the size of the stud and the coefficient of the lubricant used. • Function test connector • Stump test the connector 															
BOP Stack	Connectors		<ul style="list-style-type: none"> • Perform OEM inspection. A thorough visual examination should be performed on the male stabs at this time and if visual condition dictates, (i.e. mechanical damage and or corrosion and pitting, etc.) these should be removed and included in the scope of work for inspection and repair. • Perform complete visual and dimensional inspection, of all the components including the flange connections on the upper body assembly, connector male stab and the API-BX-154 gasket preps. • Perform a MPI inspection on the high stress areas and fasteners. • Perform dye-pen inspection on all the seal surfaces, seal grooves and BX-154 gasket prep which are clad with corrosion resistant alloys. 	Scheduled Inspection											2 years			

Table B-4: BOP Stack MIT Activities (cont'd)

BOP System	Subsystem	Component	MIT Activity	MIT Activity Type	Maintenance Activity Interval													
					Drilling				Upon Latching	Pre-Deployment and Between Wells					Major Overhaul		Miscellaneous	
					Daily	7 Days	14 Days	30 Days		60 Days	90 Days	180 Days	Between Wells	Each Trip	Annually	Multiyear	As Required	As Needed
			<ul style="list-style-type: none"> • Compile the scope of work as confirmed by the inspection, complete repairs as per OEM requirements and assemble connector. • Pressure test the well bore to low pressure and to maximum working pressure and all tests are to be chart recorded. • Record the minimum extend and retract operating pressure to overcome the resistance of the snap ring in the 'ID' of the retract piston, i.e., only required if the snap ring is installed. • Lubricate all stud and nut threads with an average coefficient of friction 0.064. • Lubricate the gasket prep with light oil, place the new ring gasket in the groove and install the connector and male stab if it has been removed / replaced for inspection / repair. 															

Table B-4: BOP Stack MIT Activities (cont'd)

BOP System	Subsystem	Component	MIT Activity	MIT Activity Type	Maintenance Activity Interval													
					Drilling				Upon Latching	Pre-Deployment and Between Wells					Major Overhaul		Miscellaneous	
					Daily	7 Days	14 Days	30 Days		60 Days	90 Days	180 Days	Between Wells	Each Trip	Annually	Multiyear	As Required	As Needed
Stack	Connectors		<ul style="list-style-type: none"> • Completely disassemble the connector and thoroughly clean all component parts. Remove and discard all seals • Visually inspect each component part for mechanical damage • Visually inspect the cylinder bores for pitting and corrosion, especially the areas of the cylinder liner and cylinder head seals. • Visually inspect all internal components for damage, scoring, corrosion, and pitting • Dimensionally inspect the upper and lower bodies, and all internal components; cylinder heads, pistons, cam ring, dog ring, end plates, wear rings, cylinder liners, retainer rods, and indicator rods. • Gage all primary load carrying fastener threads, male and female. • Using LP, inspect all seal grooves, piston rods, and cylinder bores with clad overlay • Using MT, examine all surfaces of the lower body, upper body, bolt shanks and heads, cylinder heads, dog ring, cam ring, and wear rings • Resurface the cam ring ID and dog ring OD • take hardness readings on the upper and lower bodies at three places, 120 degrees apart. • Reassemble the connector using all new rubber goods and test • Apply protective coatings to all external surfaces. • Record all data & serial numbers 	Planned Maintenance												5 years		

Table B-4: BOP Stack MIT Activities (cont'd)

BOP System	Subsystem	Component	MIT Activity	MIT Activity Type	Maintenance Activity Interval													
					Drilling				Upon Latching	Pre-Deployment and Between Wells					Major Overhaul		Miscellaneous	
					Daily	7 Days	14 Days	30 Days		60 Days	90 Days	180 Days	Between Wells	Each Trip	Annually	Multiyear	As Required	As Needed
			for future reference															
Stack	Connectors		<ul style="list-style-type: none"> Disassemble the entire connector to its component parts. For tracking purposes, assign a job identification number to all components. (API RP53 18.10.3) Inspect the areas outlined below and compare the actual values found, to the OEM specifications. Carry out any required repairs in accordance with the OEM specifications or other Field Support approved and qualified procedures. (API RP53 18.10.3) Visually, dimensionally and NDT inspect the CX or BX ring groove on the upper body connection. (API RP53 18.10.3) Visually, dimensionally and NDT inspect the VX or VXVT ring groove. (API RP53 18.10.3) Visually, dimensionally and NDT inspect the upper body hub, flange or studded connection. NDT the welds in this area. (API RP53 	Planned Maintenance											5 years			

Table B-4: BOP Stack MIT Activities (cont'd)

BOP System	Subsystem	Component	MIT Activity	MIT Activity Type	Maintenance Activity Interval													
					Drilling				Upon Latching	Pre-Deployment and Between Wells					Major Overhaul		Miscellaneous	
					Daily	7 Days	14 Days	30 Days		60 Days	90 Days	180 Days	Between Wells	Each Trip	Annually	Multiyear	As Required	As Needed
			18.10.3) • Visually, dimensionally and NDT inspect the upper body connection threaded fasteners. (API RP53 18.10.3) • Take upper body & lower body hardness readings, as per the OEM recommendations. (API RP53 18.10.3) • Visually and dimensionally inspect the upper body through bore. (API RP53 18.10.3) • Visually and dimensionally inspect the upper body and lower body wear plates. (API RP53 18.10.3) • Visually, dimensionally and NDT inspect the cylinder heads. (API RP53 18.10.3) • Visually, dimensionally and NDT inspect the pistons, liners and cylinder end plates. (API RP53 18.10.3) • Visually, dimensionally and NDT inspect the connecting rods. (API RP53 18.10.3) • Visually, dimensionally and NDT inspect the lower body cylinder bores. (API RP53 18.10.3) • Visually, dimensionally and NDT inspect the cam ring. (API RP53 18.10.3) • Visually, dimensionally, and NDT inspect the dog ring. (API RP53 18.10.3) • Visually and dimensionally inspect the seal subs. (API RP53															

Table B-4: BOP Stack MIT Activities (cont'd)

BOP System	Subsystem	Component	MIT Activity	MIT Activity Type	Maintenance Activity Interval													
					Drilling				Upon Latching	Pre-Deployment and Between Wells					Major Overhaul		Miscellaneous	
					Daily	7 Days	14 Days	30 Days		60 Days	90 Days	180 Days	Between Wells	Each Trip	Annually	Multiyear	As Required	As Needed
			18.10.3) • Visually and dimensionally inspect the gasket retainer pins. (API RP53 18.10.3) • Visually and dimensionally inspect the gasket retainer pin ports in the upper body. (API RP53 18.10.3) • Visually, dimensionally and NDT inspect the lower body threads. (API RP53 18.10.3) • Visually, dimensionally and NDT inspect the cylinder head to lower body and upper body to lower body cap screws. (API RP53 18.10.3) • Re assemble the connector with new seals, and dog ring springs. On completion of the re assembly, measure the dog ring to upper body gap. (API RP53 18.10.3) If the gap does not meet the correct specification for the connector, the upper and lower body wear rings may have to be machined or replaced. For studded top connectors, the dog ring gap should be checked with the connector torqued to the test flange. Pressure test the primary lock, primary unlock and secondary unlock chambers to maximum working pressure, 3,000psi. Chart record the tests. • Pressure test the well bore to low pressure and to maximum working pressure. Chart record the															

Table B-4: BOP Stack MIT Activities (cont'd)

BOP System	Subsystem	Component	MIT Activity	MIT Activity Type	Maintenance Activity Interval													
					Drilling				Upon Latching	Pre-Deployment and Between Wells					Major Overhaul		Miscellaneous	
					Daily	7 Days	14 Days	30 Days		60 Days	90 Days	180 Days	Between Wells	Each Trip	Annually	Multiyear	As Required	As Needed
			tests. (API RP53 18.13.4) Note: If machining or weld and heat treatment repairs have been carried out, pressure test the body to the OEM recommended test pressure. A back drive test should also be performed after any major repairs. <ul style="list-style-type: none"> Seal all ports and protect all sealing areas and paint 															
Stack	Connectors		Perform Annual Maintenance Tasks	Planned Maintenance												5 years		
Stack	Connectors		<ul style="list-style-type: none"> Disassemble female assembly. (API RP53 18.10.3) Clean all components and inspect for damage to sealing areas and condition of coatings. (API RP53 18.10.3) Inspect the area where the snap ring locks when in the retracted position for damage or wear. (API RP53 18.10.3) Inspect the ring groove on the upper body. (API RP53 18.10.3) NDT lower body and upper body (API RP53 18.10.3) Re assemble using all new seals. (API RP53 18.10.3) 	Planned Maintenance											5 years			
Stack	General	Frame	Clean the exterior of the stack with water	Planned Maintenance									x				x	
Stack	General	Frame	Check fastener security for all flanges, joints, and other fasteners on the LMRP and BOP Stack for proper type, size, condition and tightness.	Scheduled Inspection							x				x			

Table B-4: BOP Stack MIT Activities (cont'd)

BOP System	Subsystem	Component	MIT Activity	MIT Activity Type	Maintenance Activity Interval													
					Drilling				Upon Latching	Pre-Deployment and Between Wells					Major Overhaul		Miscellaneous	
					Daily	7 Days	14 Days	30 Days		60 Days	90 Days	180 Days	Between Wells	Each Trip	Annually	Multiyear	As Required	As Needed
Stack	General	Frame	Inspect all BOP guidance system framework components, connections and fasteners for security and condition.	Scheduled Inspection							x							
Stack	General	Frame	MPI all lifting points on LMRP.	Scheduled Inspection									x			5 years		
Stack	General	Frame	MPI all load bearing welds on stack frame. Repair any defective welds.	Scheduled Inspection												5 years		
Stack	Flex joint & Connectors	ERA & HPHT	Calibrate all the BOP transducers	Scheduled Test												2 years		

APPENDIX C – MIT MANAGEMENT SYSTEM SURVEY QUESTIONS

DEMOGRAPHICS

For which type of company do you work? *

- Drilling Contractor
- BOP Manufacturer

Which BOP manufacturer is most used on your companies deepwater rigs? *

- Cameron
- GE/Hydril
- NOV

To what is your job function most related? *

- BOP Maintenance
- BOP Operations
- BOP Technical Support
- Rig Management

What is your job role? *

- BOP Maintainer
- BOP Maintenance Supervisor
- Maintenance Planner
- Maintenance Scheduler
- Other Maintenance Support Personnel
- Rig Operations Leader
- Rig Operations Supervisor
- Reliability and Maintenance Engineer
- BOP Technical Expert
- Rig Manager
- Maintenance Manager/Director
- BOP Engineering Manager/Director
- Operations Manager
- Other

How many years of industrial experience? *

- 1 to 5 years
- 5 to 10 years
- 10 to 20 years
- More than 20 years

How many years of offshore experience? *

- Less than 1 year
- 1 to 5 years
- 5 to 10 years
- 10 to 20 years
- More than 20 years

How many years of in your current position? *

- Less than 1 year
- 1 to 5 years
- 5 to 10 years
- 10 to 20 years
- More than 20 years

INTERMEDIATE QUESTION TO DETERMINE VERSION

Where do you spend the majority of your time? *

- On a rig or the shop floor
- In the office

MANAGER VERSION

Check the most descriptive or most typical answer unless otherwise noted

If you are being asked to participate in this survey, it is because your company is participating in this study. As part of the study, all information sources will be maintained confidential and company-specific results will not be provided to BSEE.

How would you describe the parts replacement philosophy for Subsea equipment? *

- Upon failure
- On a set schedule either based on calendar or operational time
- Performed when equipment is not being used, even before typical service interval
- Based on the condition of equipment determined during regular inspections/test

How would you describe the parts replacement philosophy for Surface equipment? Upon failure *

- Upon failure
- On a set schedule either based on calendar or operational time
- Performed when equipment is not being used, even before typical service interval
- Based on the condition of equipment determined during regular inspections/test

How would you best describe the method to determine preventive maintenance periodicity? *

- Set based on original equipment manufacturer recommendation
- Informed by original equipment manufacturer, but adjusted based on our corporate experience with the same or similar equipment
- Based on reliability, availability, maintainability, RAM techniques and equipment criticality

Most part maintenance intervals are based on *

- Calendar time
- Operational time
- Part condition

Once a preventive maintenance frequency is set, it is *

- Never changed
- Only changed when designs change
- Revisited on a regular basis and adjusted based on equipment history
- Don't know

Procedures are in place to note trends in equipment condition and failures? *

- Yes
- No

Which BOP failures are identified and documented? *

- All BOP failures, including minor failures
- Only BOP failures interrupting operations or discovered during a test or inspection
- Only BOP failures resulting in significant downtime or safety issues
- Only BOP failures which must be reported to management
- Only BOP failures which must be reported to a regulatory agency

When a BOP failure is identified, how is the failure documented? *

- No formal documentation required
- Enter in the rig shift/downtime log
- Initiate a work order
- Enter in dedicated failure tracking system

When are BOP failures formally investigated? *

- Not routinely investigated
- Only when BOP failure involves a safety incident or major downtime
- Repeat failure of the BOP component within a year
- A single failure or trending of repeat BOP failures meet set criteria
- All BOP failures are investigated

Which tools are used during a formal BOP failure investigation? *Check all that apply:

- Multi-discipline team
- Data gathering
- Failure analysis/testing (e.g., lab testing of failed components)
- Structured root cause analysis (RCA)/root cause failure analysis (RCFA) methods
- RCA/RCFA software

When formal teams are formed to investigate a BOP failure, personnel from which departments are involved? *Check all that apply:

- Operations
- Maintenance
- Engineering

- Safety
- BOP Manufacturer
- Do not know

What are typical outcomes of formal investigations of BOP failures? *Check all that apply:

- Changes in preventive maintenance activities or frequency
- Change in inspection/test activities or frequency
- Update to maintenance procedures
- Use of reliability analysis (e.g., RCM) to determine proper maintenance strategy
- Updates to maintenance management system
- None of the above

What level of corrective actions is typically identified? *Check all that apply:

- Basic causes correction (i.e., fix the problem)
- Specific equipment item improvements (e.g., increase maintenance, change design, operation)
- Personnel performance improvements (e.g., more training, better procedures)
- Similar equipment item improvements (e.g., increase maintenance, change design, operation)
- Management system changes (e.g., corrections to PM program)

Which steps are taken to ensure corrective/preventive actions are implemented and effective? *

- No specific follow-up steps taken
- Corrective/preventive actions entered into database and status report generated
- Corrective/preventive actions status reports routinely reviewed by management
- Corrective/preventive action key performance indicator (KPI) generated and monitored

Which type of a work order/maintenance work management process is used to manage BOP maintenance? *

- Not aware of process
- Informal process
- Formal process with procedure, but not followed
- Formal process with procedure that is working well

What is the primary means used to identify and communicate the BOP maintenance work to BOP maintainers? *

- Verbal communication from operations personnel

- Verbal communication from supervisor
- Rig shift/log books
- Paper work order
- Computer-based work order system

Who determines the priority of the BOP maintenance work performed? *

- Do not know
- Operations personnel determines what is worked on
- Supervisor determine what is worked on
- Maintenance schedule developed by maintenance and operations personnel

What percentage of BOP maintenance work performed is managed by work orders (or similar written document)? *

- Almost never, < 1%
- Rarely, 1 % to 10%
- Occasionally, 10% to 25%
- Often, 25% to 75%
- Frequently, 75% to 95%
- Always, >95%
- Do not know

How often is the BOP maintenance work planned? * (Planned means a planner has reviewed the job, ensured information and parts are available, and scheduled the work)

- Almost never, < 1%
- Rarely, 1 % to 10%
- Occasionally, 10% to 25%
- Often, 25% to 75%
- Frequently, 75% to 95%
- Always, >95%
- Do not know

Once work is completed, which information is typically documented? *

- Nothing
- Mark the work order as complete
- Record time required

- Record equipment is OK (for PM results)
- Record actual PM results (when requested)
- Materials and parts used
- Failure information (for repairs)
- Failure code (for repairs)

If a work order/work management procedure exists, which areas are included in this procedure? *Check all that apply:

- Not aware of a written procedure
- Work Identification
- Work Approval
- Planning and Scheduling
- Work Execution
- Work Documentation
- Work Order Closeout
- Provisions for Emergency Work

How is the performance of the BOP maintenance work process tracked? *Check all that apply:

- No formal tracking mechanism
- Work backlog routinely reviewed
- Work management key performance indicators established and monitored
- Periodic audits of BOP maintenance work performed

Is BOP maintenance managed via a computerized maintenance management system (CMMS)? *

- Yes
- No

If there is a CMMS, which functions are in use? Check all that apply: *Check all that apply:

- No CMMS in use
- Asset register
- Asset Criticality
- Work request
- Work order
- Work prioritization
- Planning
- Scheduling
- Preventive Maintenance (PM)
- Work Closeout
- PM optimization (PMO)
- Reliability analysis
- Failure tracking
- Stores Inventory
- Document Management
- Cost Accounting
- Stores Purchasing
- Parts procurement
- Do not know

If there is a CMMS, how years has it been in use? *

- No CMMS in use
- Less than 1 year
- 1 to 2 years
- Between 2 and 5 years
- More than 5 years
- Do not know

For which types of management activities is the CMMS used? Check all that apply *

- Maintenance cost management
- Regulatory Compliance management
- Crew Management/scheduling
- Stores Inventory Management
- Reliability Engineering analysis
- Key performance indicator generation and monitoring

Which types of written instructions do BOP maintainers have access when performing BOP maintenance? *

- No written instructions
- BOP operation & maintenance manuals
- Technical information and drawings
- Work order job descriptions
- Site-specific step-by-step repair procedures
- Site-specific step-by-step PM procedures

How do BOP maintainers obtain written information when performing BOP maintenance? *

- Provided on or with work order
- Available via electronic document library
- Maintained in paper files
- Must request information from supervisor or others
- No too little information is available

Which types of BOP maintenance activities written instructions are provided BOP maintainers? *

- No written instructions
- BOP operation & maintenance manuals
- Technical information and drawings
- Work order job descriptions
- Site-specific step-by-step repair procedures
- Site-specific step-by-step PM procedures

How does the company ensure BOP maintenance information is up to date? *

- No system in place
- Depends on individuals to update information as needed
- Document control standard requiring information to be maintained
- Formal document control system with roles and responsibilities

Which types of information is be included in/with a typical repair work order? *

- Little information other basic equipment information (e.g., tag no., location)
- Task description
- Step-by-step task instructions
- References to other standard maintenance procedures or information (e.g., OEM manuals)
- Bill of material information

How are the accuracy of written instructions validated to be correct: *

- No validation or quality control process
- Instructions are written by knowledge personnel
- Instructions are provided by the OEM
- Formal procedure review and approval process
- Formal procedure review and approval process with field validation

What are the expectations on the use of written instructions? *

- No expectations
- A reference and informational tool
- Communication of safety information only
- General guideline on performing tasks
- Training tool only
- Step-by-step instructions on performing tasks

Which answer best describes typical use of written instructions when performing BOP maintenance? *

- Almost never
- Occasionally before beginning a task
- Usually before beginning a task
- Occasionally during the performance of a task
- Usually during the performance of a task
- Always during the performance of a task

Which type of training do BOP maintainers receive before working on a BOP? *Check all that apply:

- Informal training
- On-the-job training
- Formal training
- Previous work experience
- No training

When do maintainers receive training related to maintaining BOPs? *Check all that apply:

- No scheduled training
- Training when assigned to a maintenance position
- Regularly scheduled refresher training on BOP maintenance
- Training when major BOP configuration or operational changes occur
- Training when BOP maintenance or PM procedures change

On which of these topics do maintainers receive training? *Check all that apply:

- Safety policy and procedures
- Maintenance craft skills
- General BOP operations
- General BOP maintenance
- BOP repair procedures
- BOP PM procedures
- Other maintenance policies and procedures

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FIELD PERSONNEL VERSION

Check the most descriptive or most typical answer unless otherwise noted

If you are being asked to participate in this survey, it is because your company is participating in this study. As part of the study, all information sources will be maintained confidential and company-specific results will not be provided to BSEE.

Which BOP failures are identified and documented? *

- All BOP failures, including minor failures
- Only BOP failures interrupting operations or discovered during a test or inspection
- Only BOP failures resulting in significant downtime or safety issues
- Only BOP failures which must be reported to management
- Only BOP failures which must be reported to a regulatory agency

When you identify or are notified of a BOP failure, how is the failure documented? *

- No formal documentation required
- Enter in the rig shift/downtime log
- Initiate a work order
- Enter in dedicated failure tracking system

When a BOP failure occurs, which actions are taken to prevent repeat failures? *

- Fix BOP with no follow up
- Incident report completed for selected BOP failures
- Incident report completed for all BOP failures
- Formal investigation by a team if BOP failure is a safety or major downtime issue
- Formal investigation by team of all BOP failures

When formal investigation teams are formed for a BOP failure, personnel from which of the following departments are involved? *Check all that apply:

- Operations
- Maintenance
- Engineering
- Safety
- BOP Manufacturer
- Do not know

What type of information is communicated by BOP failure investigations? Check all that apply *Check all that apply:

- Description of the BOP failure
- Direct causes of the BOP failure
- Root causes of the BOP failure
- Corrective actions to prevent repeat BOP failure
- Preventive actions to prevent repeat BOP failure
- Status update on corrective actions taken

How are the results from BOP failure investigations typically communicated to you? *Check all that apply:

- E-mail
- Posted incident investigation report
- Normal shift communications
- Scheduled meetings (e.g., weekly toolbox meetings, safety meetings)
- Specially called communication sessions
- Not normally communicated

How would you describe the parts replacement philosophy for Subsea equipment? *

- Upon Subsea equipment failure
- On a set schedule either based on calendar or operational time
- Performed when Subsea equipment is not being used, even before typical service interval
- Based on the condition of Subsea equipment determined during regular inspections/test

How would you describe the parts replacement philosophy for Surface equipment? *

- Upon Surface equipment failure
- On a set schedule either based on calendar or operational time
- Performed when Surface equipment is not being used, even before typical service interval
- Based on the condition of Surface equipment determined during regular inspections/test

When active moving parts (e.g., actuators, rams, pumps) are rebuilt do you? *

- Assemble them by hand using only lifting equipment, when needed
- Rely on standard assembly tooling to rebuild some equipment
- Rely on standard assembly tooling to rebuild all equipment
- Rely on standard assembly tooling to rebuild critical equipment

What is done with parts when they are removed from service? *

- Visually inspected for wear/failure
- Dimensionally inspected for wear/failure
- NDT for wear/failure
- Only failed parts are further inspection
- Scrapped without inspection

Condition of parts removed from service is? *

- Recorded on paper maintenance forms
- Recorded and entered into CMMS
- Not Recorded

For which equipment is condition recorded? *

- For all equipment
- Only for critical equipment
- Only for equipment failures
- For no equipment

Most part maintenance intervals are based on? *

- Calendar time
- Operational time
- Part condition

Once a preventive maintenance frequency is set, it is? *

- Never changed
- Only changed when designs change
- Revisited on a regular basis and adjusted based on equipment history
- Don't Know

Are you aware of a work order/maintenance work management process? *

- Not aware of process
- Informal process
- Formal process with procedure, but not followed
- Formal process with procedure that is working well

What is the primary means used to identify and communicate the BOP maintenance work that you perform? *

- Verbal communication from operations personnel
- Verbal communication from supervisor
- Rig shift/log books
- Paper work order
- Computer-based work order system

Who determines the priority of the BOP maintenance work that you perform? *

- Do not know
- Operations personnel determines what is worked on
- Supervisor determines what is worked on
- Maintenance schedule developed by maintenance and operations personnel

What percentage of BOP maintenance work that you perform is managed by work orders (or similar written document)?*

- Almost never, < 1%
- Rarely, 1 % to 10%
- Occasionally, 10% to 25%
- Often, 25% to 75%
- Frequently, 75% to 95%
- Always, >95%

How often is the BOP maintenance work you perform planned? *Planned means a planner has reviewed the job, ensured information and parts are available, and scheduled the work

- Almost never, < 1%
- Rarely, 1 % to 10%
- Occasionally, 10% to 25%
- Often, 25% to 75%
- Frequently, 75% to 95%
- Always, >95%

Once work is completed, which information do you typically document? *

- Nothing
- Mark the work order as complete
- Record time required
- Record equipment is OK (for PM results)
- Record actual PM results (when requested)
- Materials and parts used
- Failure information (for repairs)
- Failure code (for repairs)

If there is a work order/work management procedure, which areas are included in this procedure? *Check all that apply:

- Not aware of a written procedure
- Work Identification
- Work Approval
- Planning and Scheduling
- Work Execution
- Work Documentation
- Work Order Closeout
- Provisions for Emergency Work

Is BOP maintenance managed via a computerized maintenance management system (CMMS)? *

- Yes
- No

If there is a CMMS, how many years has it been in use? *

- No CMMS in use
- Less than 1 year
- 1 to 2 years
- Between 2 and 5 years
- More than 5 years
- Do not know

Do you use the CMMS, if yes how often do you use the system? *

- Never use the system
- Once a month
- Once a week
- Once a day
- Multiple times each day

What types of activities, do you use the CMMS for? *Check all that apply:

- Enter work requests
- Review spare parts or bill of materials
- Order parts or materials from stores
- Other parts or materials inventory activities
- Retrieve/look up asset information
- Document task notes or results
- Close work orders (after completing work)
- Do not routinely use the CMMS

To which types of BOP maintenance activities written instructions do you have access? *Check all that apply:

- No written instructions
- BOP operation & maintenance manuals
- Technical information and drawings
- Work order job descriptions
- Site-specific step-by-step repair procedures
- Site-specific step-by-step PM procedures

How do you obtain written information when performing BOP maintenance? *Check all that apply:

- Provided on or with work order
- Available via electronic document library
- Maintained in paper files
- Must request information from supervisor or others
- No too little information is available

Which BOP maintenance activities are written instructions the most helpful? *Check all that apply:

- Written instructions are rarely helpful or needed for BOP maintenance
- Troubleshooting
- Repair tasks
- Scheduled tests
- Scheduled inspections
- Planned maintenance, such as rebuilding tasks)
- Lubrication tasks
- Regulatory-required tests

How are written instructions used when performing BOP maintenance? *

- Not used or needed
- As a reference during the task
- As a guideline for performing the task
- As a step-by-step procedure

Which type of information is typically provided in a maintenance work instruction? *Check all that apply:

- Little information other than basic equipment information (e.g., tag no., location)
- Task description
- Step-by-step task instructions
- References to other standard maintenance procedures or information (e.g., OEM manuals)
- Bill of material information

How helpful is the information provided in typical maintenance work instructions in properly completing the task? *

- No or little work order information needed to complete the task
- Provides little information needed to complete the task
- Provides sufficient information with references to other information
- Provides all needed details

Which answer best describes typical use of written instructions when performing BOP maintenance? *

- Almost never
- Occasionally before beginning a task
- Usually before beginning a task
- Occasionally during the performance of a task
- Usually during the performance of a task
- Always during the performance of a task

In general, what is the quality of the written instructions? *

- Poor
- Need work (many errors or missing information)
- Fair (some significant errors, by mostly correct)
- Good (95+% correct)
- Excellent (accurate and up to date)

Which type of training did you as a BOP maintainer receive before working on a BOP? *Check all that apply:

- Informal training
- On-the-job training
- Formal training
- Previous work experience
- No training
- Does not apply

How much initial training did you receive relative to BOP maintenance? *

- Less than a shift
- Between one to two shifts
- One week
- Two to four weeks
- More than one month

How was your understanding of BOP maintenance training topics verified? *Check all that apply:

- No verification
- Written test
- Informal on-the-job observation
- Formal on-the-job documented evaluation
- Hands-on practical evaluation

When do you, as a maintainer, receive training related to maintaining BOPs? *

- No scheduled training
- Training when assigned to a maintenance position
- Regularly scheduled refresher training on BOP maintenance
- Training when major BOP configuration or operational changes occur
- Training when BOP maintenance or PM procedures change
- Does not apply

How often do you receive training related to BOP maintenance? *

- Very frequently
- Monthly
- Quarterly
- Annually
- As needed when there is a major change or problems
- Rarely

How much on-going training do you receive each year relative to BOP maintenance? *

- No periodic training provided
- 1 to 4 hours
- 4 to 8 hours
- 8 to 16 hours
- 20 to 40 hours
- More than 40 hours

On which of these topics have you as a maintainer received training? *Check all that apply:

- Safety policy and procedures
- Maintenance craft skills
- General BOP operations
- General BOP maintenance
- BOP repair procedures
- BOP PM procedures
- Other maintenance policies and procedures
- Does not apply

How would you rate the BOP maintenance training program? *

- What program?
- Needs major improvements
- Barely adequate
- Meets the my need
- Best training I have had