Hazard assessment of well operations from vessels

Prepared by
Team Energy Resources Limited
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Hazard assessment of well operations from vessels

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The use of dynamically positioned vessels rater than mobile drilling units is becoming more prevalent for intervention and maintenance of subsea wells. Recently the range of vessels being considered to perform this work has expanded to include diving vessels, ice breakers, ROV support vessels and other specialised vessels in order to minimise costs. The latter types may not have the equivalent dynamic positioning capability or level of redundancy associated with the classes of intervention vessels originally considered for use. This trend towards lower costs coupled with new applications of technology may also introduce other low cost vessels into the market such as supply vessels.

In the light of the increased range of intervention work likely to be undertaken from vessels the Health and Safety Executive (HSE) has commissioned Team Energy Resources Ltd to produce this study to assess the hazards specific to well operations from vessels other than mobile drilling units.

It should be noted that environmental risks are specifically excluded from this report.

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Keywords/Buzzwords

Well intervention
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Well Operators
Vessel Owners
Contractors
Inspectors

DSV
Mono-hull
Dynamically positioned (DP)
Mobile offshore drilling unit (MODU)
Drilling rig

Subsea wireline
SSWL
Coiled tubing
Diving
Subsea
Wireline
Well testing
Oil storage
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Inspection Repair Maintenance (IRM)

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Kicks

Planning
Safety
Permit to work (PTW)
Project management
Competence

1. INTRODUCTION

The use of dynamically positioned vessels rater than mobile drilling units is becoming more prevalent for intervention and maintenance of subsea wells. Recently the range of vessels being considered to perform this work has expanded to include diving vessels, ice breakers, ROV support vessels and other specialised vessels in order to minimise costs. The latter types may not have the equivalent dynamic positioning capability or level of redundancy associated with the classes of intervention vessels originally considered for use. This trend towards lower costs coupled with new applications of technology may also introduce other low cost vessels into the market such as supply vessels.

In the light of the increased range of intervention work likely to be undertaken from vessels the HSE has commissioned Team Energy Resources Ltd to produce this study to assess the hazards specific to well operations from vessels other than mobile drilling units.

It should be noted that environmental risks are specifically excluded from this report.

2. SUMMARY

The Hazard Assessment of well operations from vessels is an HSE funded study to identify the risks associated with well operations from mono-hull vessels. The study is based on feed back from well operators and vessel owners involved or intending to be involved in this type of well intervention.

The study identifies the risks associated with general well intervention and for various complexities of well intervention operations ranging from subsea xmas tree repairs to coiled tubing drilling and hydrocarbon storage.

The main conclusions are:-

- Operations from a dynamically positioned vessel should be safer than from a moored vessel
- Personnel competency in all aspects of the operations from technicians to management is critical
- Safety and management systems must be implemented and adhered to
- Proper planning, procedures and contingencies are essential for safe operations
- Isolations and barriers must be designed to cope with all contingencies

3. OBJECTIVES

The objectives of the study are outlined below:

- To produce an inventory of the type of vessels which might be considered for well maintenance and intervention operations in the North Sea now and in the future
- To identify and analyse well related significant hazards that typify well maintenance and intervention activities with various vessels and highlight the critical operational elements of these activities
- To review the effectiveness of the available operational measures to prevent/mitigate/control risk during vessel operations

4. METHODOLOGY

Initially a number of interviews were conducted with key personnel from those Well Operators and Contractors involved or interested in becoming involved in the well intervention market. These interviews gave an insight into the direction in which the market was proceeding, its drivers, objectives and concerns.

Following these interviews and a series of guidance meetings with the HSE a list of hazards, risks and failure mechanisms was compiled. The interviews focussed around the actual, perceived and potential problems associated with all aspects of well intervention. These are included in the **Table of Hazards (Section 8 of this document).** This table highlights the causes and effects of hazards and what measures could be undertaken to mitigate those effects. In addition the table provides a detailed check list of the main issues which must be considered prior to well intervention from a Dynamically Positioned (DP) vessel.

In view of the wide range of workscopes encompassed by the term "well intervention" this report includes a section entitled **Well Intervention Operations and Vessel Requirements** which identifies a number of workscopes of increasing complexity from "blow and go" well abandonments (ie straightforward removal of a wellhead using explosive charges) to coiled tubing drilling. For each of these workscopes different vessel or operational requirements have been identified which must be considered prior to well intervention.

Also included in the report are conclusions and discussions which provide an overview of the requirements.

The report sets out to aid those involved in well intervention. It is not meant to be exhaustive and Companies involved in well intervention should not limit their risk analysis to items highlighted in this report alone.

5. CONCLUSIONS

5.1

Operations from dynamically positioned well intervention vessels can be as safe as from a moored drilling rig, provided proper planning, management, equipment and training is practised. When the ability to drive off from a potential hazard is included the safety to vessel and personnel may be improved.

(Historically, most vessel well intervention work has been carried out from diving support vessels. Generally the diving industry has an established safety culture although there is considerable variation between Contractors and their individual personnel and room for improvement. However, well intervention is a big step into risk and operational complexity. Well intervention will require a new skill set and an even more determined attitude towards maintaining a safe working environment.)

5.2

The industry is still relatively young and an influx of new players may occur bringing with it new problems, equipment, ideas and personnel further compounded by commercial pressures. Some of these new players may come from marine contractors outside the diving industry and will not necessarily be familiar with its aforementioned safety culture.

5.3

The main issues are:

- Project Management, Safety Management Systems and personnel
- Procedures, planning and contingencies
- Isolations
- Vessel and equipment

5.4

The biggest risks centre on inexperienced and untrained crews working under extreme commercial pressures, using equipment with which they are unfamiliar. The prime objective for management is to ensure that adequate time and resources are allowed for quality personnel to gain experience and become familiar with the equipment, and to ensure that a continuous training and competence programme is employed.

5.5

The Contractor must consider all safety issues and demonstrate that his conclusions and procedures are logical and objective.

5.6

The Contractor is responsible for the safety of his employees.

5.7

The Well Operator is the duty holder for the whole system and takes the ultimate responsibility for safety.

5.8

The Well Operator must ensure operations comply with the Safety Case that covers the wells.

5.9

The market is driven by cost effectiveness and the perception that dynamically positioned (DP) vessels can under cut an industry dominated by moored drilling rigs.

5.10

The Contractor Vessel Owners are driven either by various motives such as

- vessel utilisation
- added value vessel utilisation
- or the desire to provide an integrated service combining other existing in-house resources.

5.11

Since DP vessels offer a cost effective solution for well intervention there will be a large incentive for vessel owners with limited experience of well intervention to attempt such workscopes. Unless these companies employ competent well specialists in their intervention teams the risks of failure will be high.

5.12

Companies new to well intervention will need to show Well Operators that their procedures and practices are thoroughly researched and proven and carried out by qualified experienced personnel

6. DISCUSSION

The discussion provides an overview of the issues highlighted in this report.

Well intervention differs from conventional DSV work of pipeline and manifold installation/maintenance as it involves changing barriers to a hydrocarbon reservoir which is capable of producing large volumes of hydrocarbons at high rates and pressures. A well intervention of a benign well with zero surface pressure and no production capability could, under circumstances of bad management and planning, become an uncontrollable hydrocarbon release capable of sinking the vessel along with the entire crew. This scenario would create an ecological disaster with further hazards for the personnel and equipment required to rectify the situation. It should be noted that uncontrolled flow from wells is still a common occurrence in the UKCS.

The three main focus areas to reduce risk are Personnel, Planning and Isolation.

6.1 Personnel

The lead contractor for well intervention from vessels will usually be the vessel owner. The vessel owner will probably have minimal experience of well intervention. The intervention combines a number of distinct disciplines – DP vessel operations, diving and ROV support, marine activities, well intervention and well control. Although there is a wealth of experience in all these disciplines there is very limited experience in a combination of them all at management, technical support or operator level. Coupled with the requirement for new equipment and procedures there is a huge onus on Well Operators and contractors to make allowances to train, inform and instruct all personnel involved.

With personnel coming in from different industries there is a requirement to build teams and implement and enforce a strong safety culture – nothing should be assumed.

In addition to key management players with a broad perspective of the operations there is also a requirement for specialists in DP operations, diving, well intervention operations and equipment.

6.2 Planning, Procedures and Contingencies

For any well intervention workscope sufficient time must be allowed in advance to:

- plan the workscopes
- prepare procedures and engineering solutions
- train personnel and allocate responsibilities
- set up contingencies which cover all major failure mechanisms
- allow operations personnel sufficient opportunity to familiarise themselves with equipment and workscopes

Safety systems must be properly set up and implemented and personnel must be well versed and trained in the issues.

Sufficient time must be allowed for procedures to be properly reviewed and signed off. No deviations should be allowed without formal change procedures or HAZOPS.

The contingencies must cover DP run offs, hydrocarbon releases, fire on board the vessel, loss of control systems etc. They must address safe escape and evacuation of personnel, protection of equipment and the environment. All key personnel must be fully trained in contingency procedures.

6.3 Isolation Barriers

The design and location of barriers must enable the well to be shut in safely under all scenarios and leave the well in a safe status for subsequent intervention by another vessel or MODU.

If an emergency disconnection occurs for any reason, controlled or uncontrolled, the equipment must enable safe intervention by a rig or vessel running a BOP or subsea wireline lubricator system. Spares, connectors, cross-overs and procedures must be in place to facilitate response.

The location of barriers on the workover system must be designed to cope with all eventualities including:

- DP run off
- Tools becoming stuck across the BOP or tree
- Failsafe mechanisms
- Position of shear seal valves relative to weak points and disconnect points
- Requirement to leave the well suspended or requirement for a rig intervention
- Weak points of the work string used to enter the well
- Failure mechanisms

Control of the barriers requires careful consideration with control sharing between the fixed installation and the vessel. Loss of either control system must not prevent isolation.

Careful consideration should be given to the location and use of shear seal valves. Where possible they should be considered as part of the well head structure, that is below the Emergency Disconnect Package and weak point. The shear rating should be sufficient to cut through any equipment run into the well, or, if this is not possible, the operational scenario should be analysed and methods of isolating the well identified for all tool positions.

Special consideration of isolations must be taken when linking the well to the vessel by conduits such as coiled tubing, risers or flowlines due to the added hazards below.

- The potential for bringing hydrocarbons to surface runs the risk of release on deck - associated fire and explosions must be controlled. The risk of contamination of air systems must be evaluated. Gas and fire detection must be considered as well as potential for hydrogen sulphide, wind direction and safe escape and evacuation of all personnel including divers.
- Reservoir volume is, in relative terms, immense and so therefore is the potential for hydrocarbon release to surface through the conduit
- Vessel excursion criteria will be much more onerous with a riser and excursions may result in equipment failures

6.4 General

Dynamic positioning (DP) system capability will have a direct bearing on the riser and lubricator design. The allowable operating criteria, watch circle and weather limitations must be clearly defined. There must be no confusion as to what is acceptable and there must be no allowances for deviation from the predefined operating criteria. Disconnection from the wellhead should be performed in a controlled manner. Isolations must be designed to cater for failure at the weak points in the riser/lubricator system.

Leak detection on topsides and subsea must be considered, a small leak will accumulate or grow if left undetected.

Diving is a high risk activity, though when properly managed it has an excellent safety record. Simultaneous operations (SIMOPS) with drilling requires good management and safety systems, with a clear understanding of all operations and the interfaces between them. Supervision and management must assure a comprehensive understanding of the risks in all aspects of the operations and include clear definitions of roles and responsibilities between disciplines.

The requirement for divers as opposed to ROVs should be analysed. The safe escape and evacuation of divers in sat. should be considered under all possible scenarios.

Dropped objects are always an issue with live hydrocarbon systems on deck and subsea. Handling of equipment subsea may require heave compensation systems to soft land on the tree / wellhead. Handling on the vessel will require competent riggers who understand the effects of vessel motions on free hanging loads.

Well operators and contractors must state their isolations standards for hydrocarbon containment and pressure systems and ensure that these are met in all failure scenarios. Any deviation from these standards must be fully justified through a risk assessment and recorded.

Procedures must be detailed, they must highlight problem areas, they must include contingency procedures to accommodate failure scenarios and they must define roles and responsibilities clearly. Operating personnel must be conversant with the procedures.

The safety management system should enforce a culture of safety throughout the personnel involved. It must capture previous incidents and accidents, close the issues out and ensure that points learned are captured and fed back to personnel.

7 INVENTORY OF VESSEL REQUIREMENTS FOR VARIOUS OPERATIONS

This section addresses the objectives set out "to produce an inventory of the type of vessel that may be required for well maintenance and intervention operations".

This section highlights current and future well intervention capabilities in an approximate order of hazard complexity. In addition the specific requirements on an intervention vessel for each operation are identified as guidance, although the actual method of intervention will determine these requirements.

IMO guidelines (MSS circ. 645) explicitly state that:-
'The equipment class of vessel chosen for any particular operation should be agreed between the owner of the vessel and the customer based upon a risk analysis of the consequence of a loss of position'

This should be taken as an over-riding requirement, however the information below gives some generic considerations.

7.1

Operation	**Subsea xmas tree repairs**
Description	Change out tree valves, chokes and sensors etc where no additional barriers are required
Requirement	Basic crew IRM competency, Hydrocarbon isolation system, DP watch, fixed installation PTW training Isolations performed and controlled by fixed installation

7.2

Operation	**Abandonment class 1**
Description	Sever wellheads
Requirement	As above Remote detonation for explosives Gas detection Hydrocarbon detection and procedures to cover eventuality

7.3

Operation	**Abandonment class 2**
Description	Set plugs and sever wellheads
Requirement	Procedures for hydrocarbon release if perforating casing. Ability to leave well safe if operations suspended Safe annulus fluids storage (non hydrocarbon) Perforating procedures

7.4

Operation	**Slick line well intervention on live wells**
Description	Set plugs, replace DHSVs and gas lift valves, recover whole trees
Requirement	Subsea lubricator, isolation valves, fail safe control systems, emergency disconnect Heave compensated deployment system Procedures for SIMOPS diving and well intervention Hydrocarbon release detection and mitigation Procedures and equipment for DP run off/system failure Control of tree valves from vessel (coordination with fixed installation) Well control systems and experience Failsafe valves and shear seal valves

7.5

Operation	**Electric line Intervention**
Description	PLT logging, perforating etc.
Requirement	As above Procedures for coordinating flowing well to fixed installation Electric line stuffing box Perforating procedures

7.6

Operation	**Well Stimulation**
Description	Acidise, Fracturing reservoir etc.
Requirement	Procedures and equipment to cater for the conduit which could bring hydrocarbons from well to vessel Chemical storage and handling procedures Failsafe closed valves and shear seal valves Weak point location relative to failsafe valves DP run off procedures and equipment to failsafe Check valves Hydrocarbon detection on vessel Vessel capability to mitigate effects of hydrocarbons on vessel Vessel isolations from HC gas on deck Control of tree valves from fixed installation?

7.7

Operation	**Coiled tubing Intervention**
Description	Setting plugs, logging, milling scale etc inside existing completions
Requirement	As for Well stimulation and electric line intervention but more stringent Control of Tree valves and intervention equipment from vessel Ability to shut in valves from fixed installation? Weak point analysis on string Shear seal valve position and capability to cater for stuck tool and run off Requirement for a second shear seal valve? Recovery procedures from a failed situation Hydrocarbons (HC)on surface detection (high probability) HC on surface mitigation (contamination of vessel systems, fire, explosion, etc)

7.8

Operation	**Well testing (cold storage)**
Description	Bringing well fluids to a storage facility on the vessel
Requirement	As for coiled tubing intervention Protection of storage area Capability to deal with explosion of full HC inventory Protection of personnel Over pressure protection of storage vessel HC Bleed off system and disposal method Leaks in process system on vessel Shutdown systems

7.9

Operation	**Well testing (flaring)**
Description	Bringing well fluids onto the vessel for flaring
Requirement	As for coiled tubing intervention Leaks in process system on vessel Shutdown systems Minimum onboard hydrocarbon inventory Capability deal with fire/explosion of on deck hydrocarbon inventory Fire protection Flare boom or contained flare system Ability to deal with rapid changes in wind direction of up to 180 degs

7.10

Operation	**Coiled tubing drilling**
Description	Drilling formations with coiled tubing
Requirement	As for coiled tubing intervention Protection of mud storage area from hydrocarbon release Capability to accommodate explosion of inventory of HC Protection of personnel Disposal of Hydrocarbons in mud Effects of wind direction on hydrocarbon release Leaks in process system on vessel Shutdown systems Ability to withstand kicks Mitigation for equipment failures Well control capability Ability to leave well safe after catastrophic failure for subsequent intervention

8 TABULATED HAZARDS

1 Hazards (general)
2 Loss of Well Integrity
3 Hydrocarbon releases at Wellhead
4 Hydrocarbon Releases on Vessel
5 Well Intervention
6 Vessel criteria
7 Topsides Equipment
8 Personnel
9 Diving
10 Planning, Procedures and Contingencies

1	Hazards (General)		
	CAUSE	**EFFECT**	**MITIGATION**
1.1	Pressures	Burst equipment, damage to equipment and personnel, hydrocarbon escape, compromise of vessel safety Tampering with equipment under pressure Tightening up leaks Wrong assumptions of depressurisation Dropped objects	Pressure testing to required margins Keep operating personnel away from HP equipment Do not allow interference of equipment under pressure Never assume systems depressurised- have robust confirmation systems in place No heavy lifts over pressurised equipment unless protected
1.2	Equipment failures	Equipment failures leading to any dangerous situations	Design review for failures and effect Back up systems in place Monitoring and feedback systems to identify failures rapidly
1.3	SIMOPS	Diving, well testing, perforating, hydrocarbons to surface, explosives on wellheads, high pressure systems, pressure testing, crane lifts causing incidents between disciplines	Good project management and control Tool box talks keeping personnel informed Work permit systems Strong safety management culture Clear roles and responsibilities especially interface areas
1.4	Kicks	High pressure hydrocarbons to subsea well head	Knowledge of max bottom hole pressures Equipment pressure ratings to meet gas to surface pressures. Equipment and procedures capable of dealing with kicks and well control or suspending operations until well control vessel available
1.5	Uncontrolled release from well	Uncontrolled hydrocarbons to surface Fire	Emergency escape procedures to protect life, equipment and the environment, ESD barriers

2	Loss of Well Integrity		
	CAUSE	**EFFECT**	**MITIGATION**
2.1	Loss of well integrity (including adjacent wells)	Burst or rupture from adjacent well causing danger to diver and or vessel	Not an issue unless heavy lifts, perforating etc being performed. If wells have a history of failures (ruptured flowlines etc.) adjacent wells should be shut in.
2.2	Well failures caused by intervention	Loss of barriers, over pressure or mechanically damage pressure barrier, damage valve seats etc.	Procedures should ensure integrity of barriers is protected. (see section 3). Quality and experience of personnel. Supervision of subsurface operations.

3	Hydrocarbon Releases at wellhead		
	CAUSE	**EFFECT**	**MITIGATION**
3.1	Barrier location	Barriers form part of wellhead and riser/lubricator system	Adequate barriers required to independently cover both wellhead and riser/lubricator
3.2	Barrier location	Spacing to cater for stuck tools	Barriers must be able to be closed with tool strings stuck across worst case position
3.3	Control of barriers	Loss of control on intervention vessel due to local damage, no secondary control system leading to deteriorating situation/hydrcarbon release	Control of barriers from either fixed installation or vessel must cover loss of one control station with no adverse effects Operation and coordination of barriers must be controlled between two operation stations Is this considered in safety case?
3.4	Control system failure for barriers	Uncontrolled hydrocarbon release	Failsafe system Back up controls, feed back
3.5	Unsure of barrier status	Valves in wrong positions causing uncontrolled flow of hydrocarbons	Must have clear feed back on position of valves (open /closed) Hydrocarbon detection systems
3.6	Ineffective location of shear seal valve	Well left open after emergency disconnect	Must cover emergency disconnect, drive off etc. One shear seal valve to be part of wellhead
3.7	Shear seal valve unable to close across tools	Well remain open to flow despite being shut in	Must be capable of sealing after cutting through any tools run through well Other valves must be spaced to address situation
3.8	Pressure control system	Pressure rating	Capable of maximum expected well pressure with gas column to surface
3.9	Massive release of Hydrocarbons (particularly gas)	Loss of vessel buoyancy	Ensure these issues addressed in the procedures and design of intervention programme, especially well control and ability to leave location
3.10	Hydrocarbon release	Environmental damage	Procedures in place to cater for responding to environmental damage.

4	Hydrocarbon release on Vessel		
	CAUSE	**EFFECT**	**MITIGATION**
4.1	Hydrocarbons on vessel	Potential explosion	Gas detection. Leak detection Potential ignition sources removed (Zone 1 or 2 equipment) Temporary equipment specs comply with requirements Fire handling equipment Blast protection of control rooms and diving accommodation Ability to isolate at source from vessel or fixed installation
4.2	Hydrocarbons contamination diving system	Explosion, H2S, suffocation	Gas detectors Leak detection Potential to isolate diving system Procedures in place
4.3	Hydrocarbons into air system	Explosion, H2S, suffocation	Detection Isolation of air systems Procedures and training
4.4	Hydrocarbons into engine rooms	Explosion, loss of engines, fire	Detection Fire protection Engine shutdown, dual redundancy Isolation systems
4.5	Hydrocarbons on surface	Explosion or fire causing loss of control of vessel	Failsafe shutdown Isolation of well Disconnection from well Removal of vessel from source

5	Well intervention		
	CAUSE	**EFFECT**	**MITIGATION**
5.1	Conduits onto live systems allowing hydrocarbons on vessel	Explosion	Permits systems and procedures in place Isolations in place Control of barriers Failsafe valves Hydrocarbon Detection system
5.2	Tools stuck across barriers	Unable to shut in well	Shear seal valves in place and capable of coping with all tool positions
5.3	Barriers Leaking	Uncontrolled flow of hydrocarbons to surface	Barriers to be tested Barrier policy (i.e. no of barriers)
5.4	Loss of control due to equipment failure or fire	Uncontrolled flow of hydrocarbons to surface	All valves failsafe closed where required Dual controls from vessel and fixed installation on critical valves Set failsafe system criteria
5.5	Lubricator and valves leaking hydrocarbons to sea	Pollution Fire and explosion Uncontrolled flow of hydrocarbons	Ensure equipment properly tested. Ensure contingencies in place to cater for failure.
5.6	Weather causing high offsets Weather causing failures DP run off Loss of control on vessel	Suspension of operations (planned or unplanned)	Clearly defined operating limits for vessel with respect to weather Established and practiced procedures for safe planned suspension of operations Design caters for catastrophic failure of system leaving well in safe conditions for reentry Effective fail safe systems for uncontrolled disconnection Location of barriers take account of weak points and disconnection

5.7	Incorrect Handling of explosives	Potential uncontrolled explosion on surface	Standard procedures of explosives Trained and qualified personnel Safe systems to be used
5.8	Loss of well control during emergency	Fire and explosion Uncontrolled flow of hydrocarbons	Fail safe systems in place Design caters for all failure mechanisms Location of barriers (especially shear seal valves) to be justified Emergency procedures agreed with fixed installation

6	Vessel criteria		
	CAUSE	**EFFECT**	**MITIGATION**
6.1	Weather	Poor station keeping, difficult on deck equipment handling, heave on subsea ops	Defined operating criteria for vessel. Constant assessment of operating conditions
6.2	DP systems failure	Failure to maintain station Damage riser Hydrocarbon release	DP Audits, Check past history Failsafe isolation of well from vessel or fixed installation Criteria for well shut in Ensuring station keeping kept within defined equipment limitations
6.3	Run off/drift off	Danger to divers Severance of equipment and umbilicals	Standard diving operating procedures and umbilical management Contingency in design for run offs. Must have contingency plans for all situations with procedures and equipment lists. Weak point of riser system to be defined and maximum loading identified Controlled disconnection times meet vessel excursion characteristics
6.4	Poor station keeping will put high stresses on riser joints	Riser failure, hydrocarbon release	Riser design and limitations defined Accurate simulation of dynamics required to predict operating limitations. Accurate monitoring of riser stresses and angles required during ops. Clearly defined operating criteria required
6.5	Vessel motions	Moving objects on deck, crane loads, water on deck, roll and heave, damaged equipment	All personnel to be fully aware of extreme vessel motion capability and requirements for safe storage and lashing down of equipment. Grillage checks, qualified riggers on crane ops

6.6	Vessel motion effect on routine ops	On deck or on hook handling of heavy loads causing damage to personnel or equipment	Well trained deck crew and crane operators used to marine activities. Clearly defined procedures Clearly defined operating limits
6.7	Manual vs automated deck handling	Heavy reliance on manual handling to minimise capital expenditure will lead to injury especially on board dynamic vessel	Minimise amount of handling offshore (especially manual handling). Identify manual handling requirements and procedures
6.8	Vessel size	Smaller vessels tend to have more lively motions making equipment handling more onerous in heavy seas Green water on deck	Strict operating criteria updated regularly to reflect operating experience. Adequate grillages, safe working areas.
6.9	Unsuitable vessels driven by cost reductions	Motions and station keeping not applicable Cranes not suitable	Prime key to job safety with experience of crew. Criteria for checking vessels to be determined
6.10	Collision	Insignificant. Main risk from trawlers on fixed course	Constant supervision of watch with DP officers.

7	**Topsides equipment**		
	CAUSE	**EFFECT**	**MITIGATION**
7.1	Use of temporary equipment	Ignition source Electrocution Equipment failure leading to well control issues Health and safety of operators at risk	Zone rated equipment where HC possible Electrical isolations and earthing Noise level surveys required Grillage checks Emergency escape routes on deck plan Maintenance access for repairs Layout and access route checks Rated for salt water environment
7.2	Temporary equipment not designed for vessel motions	Failure to operate, swinging loads, moving equipment	Confirm fit for purpose
7.3	Handling systems not designed for vessel motions	Vessel motions causing equipment to move violently , damage to personnel and equipment Crane loads swinging	Use proper lifting equipment Use experienced personnel Use hold backs Design systems for operations
7.4	Heavy equipment handling (lubricator, well head, DH tools)	Dangerous swinging heavy loads	Remote handling systems designed to safely manouver heavy equipment with minimum personnel handling

8	Personnel		
	CAUSE	**EFFECT**	**MITIGATION**
8.1	Non standard workscopes, personnel training	Lack of awareness causing damage to self, equipment or other personnel	Broad based training on all activities to make personnel aware of all risks Experienced personnel required Good management and safety culture IIT&S systems in place Quality of supervision Regular tool box talks to clearly define workscopes PTW system Specialist support
8.2	Diving hazards and lack of diving focus	Non standard diving activities leading to reduction in diver safety Escape of hydrocarbons into diving system Effect on divers of well intervention problems	Good strong diving supervision, offshore project manager aware of diving issues, good communications Keep bell offset from any source of hydrocarbons Diving supervisor fully aware of risks of emergency disconnect and constantly prepares for eventuality, bell on leeward side of well, fire protection on surface of diving systems, pressure testing procedures, training and awareness of risks
8.3	Intervention crews not accustomed to vessel motions	Many fixed installation or semi submersible based crews will be new to operations on a lively monohull	Corporate tolerance (vessel Contractor and Client) to allow people to settle in and rest, extra personnel to cover for initial sickness, awareness of risks to self and others

9	Diving		
	CAUSE	**EFFECT**	**MITIGATION**
9.1	Dropped objects	Dropped objects on personnel, equipment or hydrocarbon lines	Lifting and over boarding procedures to address dropped objects, vessel offsets from hydrocarbon lines, bleed off pressure on hydrocarbon lines, divers back to the bell.
9.2	Fluid releases from well or vessel	Risks of fire, contamination of diving system or support team and DSV on surface, contamination of diving system in bell subsurface	Habitation and Sat control should be protected from fire and explosion on surface Sat control personnel to be protected from fire and gas Vessel fire and gas detection to automatically close in air systems from outside Bell to have offset from source of hydrocarbon release
9.3	Pressure testing	Burst pipes and equipment, surface and subsurface explosions	Personnel to be kept clear unless involved and supervised, use ROV where possible, No tightening of loose equipment whilst under pressure, Training and safety culture
9.4	Breaking into pressure systems	Breaking into a pressure system without being properly bled down or isolated	Isolations and bleed systems in place Isolation requirements clearly identified and all personnel fully aware, training
9.5	Isolations for divers	As above	As above
9.6	Confirmation of pressures	Wrong diagnosis of pressure within system	Vital that nothing is assumed Use of pressure gauges as indication only – not confirmation Use of block and bleed valves to confirm pressures Risk assess where deviations found Design to provide reliable indication of pressures and monitoring

9.7	Being adjacent to wells (diving, marine etc)	Risk of diver umbilical or down lines snagging adjacent wells	Sound and focussed supervision, good diving and operating procedures.
9.8	Focus split between diving and Well intervention	SIMOPS – lack of focus and awareness causing hazardous conditions	Good project management and safety culture Good awareness of total workscope by all personnel through tool box talks
9.9	Poor access requiring long umbilicals Diving within anchor patterns Vessel blow on	Trapped umbilicals or divers	Any restricted access diving requires special risk analysis to determine and highlight hazards. Supervisors monitor umbilical management Diving within anchor patterns must be subject to risk assessment and special procedures

10	Planning, Procedures and Contingencies		
	CAUSE	**EFFECT**	**MITIGATION**
10.1	Lack of knowledge or understanding of issues	Danger to personnel, vessel equipment and environment	Allow time for train, inform and instruct all personnel Select competent personnel Impose strong safety culture and management systems
10.2	Lack of adequate procedures	Operations not covered by procedures Deviation from procedures Not enough detail in procedures	Allow time for preparing procedures and checking by competent personnel Set up change control procedures Set up offshore risk assessment Ensure safety culture prevents deviation from procedures
10.3	Lack of familiarity	Ill advised and dangerous actions causing danger to personnel or equipment	Ensure all personnel are competent Employ STOP system or similar

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