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Human Factors Assessment of Safety Critical Tasks

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ASSOCIATES

Dr Andrew Brazier

Paul Richardson

Dr David Embrey

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Contents

1. Overview of Project and Methodology 1
    1.1 Overview of the Project 1
    1.2 Overview of the Methodology 2
        1.2.1 Identify Critical Tasks Performed on an Installation 3
        1.2.2 Analyse each Critical Task to the Appropriate Level of Detail 3
        1.2.3 Qualitatively Assess Risks Associated with Critical Tasks 4
        1.2.4 Identify Risk Control Strategies 4
        1.2.5 Incorporate the Results of Applying the Methodology into the Safety Case 4
    1.3 Structure of the Report 5
2. Production Task Criticality Screening 6
    2.1 Development of the Generic Task Inventories 6
        2.1.1 Generic Production Task Inventory 7
    2.2 Development of Diagnostic Questions 8
    2.3 Production Tasks Screening Technique. 9
        2.3.1 Production Screening Diagnostic Questions 9
        2.3.2 Task Criticality Ranking 12
3. Well Operations Task Criticality Screening 13
    3.1 Generic Well Operations Task Inventory 13
    3.2 Well Operations Screening Technique 14
        3.2.1 Intrinsic Hazards 14
        3.2.2 Human Interactions 15
        3.2.3 Well Operations Screening Diagnostic Questions 15
        3.2.4 Developing the Task Criticality Ranking 19
4. Depth of Analysis Technique 20
    4.1 Methodology Overview 20
    4.2 Developing and Applying the Breakdown Criteria to Determine Depth of Analysis 22
        4.2.1 Pre-requisites 22
        4.2.2 Development of Criteria for Continuing Breakdown of Tasks 22
        4.2.3 Applying the Depth of Analysis Technique 26
        4.2.4 Testing the Depth of Analysis Technique 26
    4.3. Predictive Human Error Analysis (PHEA) 26

5. Application of the Methodology to an Offshore Case Study 30
    5.1 Methodology Overview 30
        5.1.1 Identify Critical Tasks Performed on an Installation 31
        5.1.2 Analyse Each Critical Task to the Appropriate Level of Detail 31
        5.1.3 Qualitatively Assess Risks Associated with Critical Tasks 32
        5.1.4. Identify Risk Control Strategies 32
        5.1.5 Incorporate the Results of Applying the Methodology into the Safety Case 32
    5.2. Example Case Study 33
        5.2.1 Identify Critical Tasks Performed on an Installation 33
        5.2.2 Analyse Each Critical Task to the Appropriate Level of Detail 34
        5.2.3 Qualitatively Assess Risks Associated with Critical Tasks 40
        5.2.4 Identify Risk Control Strategies 42
        5.2.5 Incorporate the Results of Applying the Methodology into the Safety Case 44
        5.2.6 Case Study Conclusion 44
Recommendations for Further Work 45
    6.1 Validation and consistency testing 45
    6.2 Extension of the scope of the methodology to assess other types of offshore tasks 45
    6.3 Development of a combined process to address both occupational and major hazard risks 45
    6.4 Trial Application and Revision of Training Course 46
Appendix 1 47
User Guide for Production Tasks Methodology 47
    Generic Production Task Inventory 48
    Production Task Criticality Screening 52
    Production Task Screening Score Sheet 53
    Production Generic Task Screening Results 54
    Separation 54
    Oil Export 54
    Gas Dehydration 55
    Gas Compression 55
    Vent, Flare, Blow Down, Closed Drains 56
    Produced Water 56
    Water Injection 56

Utilities 57

Power Generation 57

Emergency Scenarios 57

Production Task Depth of Analysis Criteria 59

Appendix 2 User Guide for Well Operations Tasks Methodology 60

Generic Well Operations Task Inventory 61

Well Operations Task Screening 63

Well Operations Task Screening Score Sheet 64

Generic Well Operations Task Screening Results 65

Drilling Task Depth of Analysis Criteria 68

Appendix 3 Additional Information Concerning Well Operations 69

Rig Systems 70

Well Operation System States 70

Development of a Human Factors Assessment Methodology for Safety Critical Tasks in the Offshore Industry

1. Overview of Project and Methodology

1.1 Overview of the Project

The overall objective of this project has been to develop a methodology to assist safety review teams in the offshore oil production sector by providing a simple, resource efficient method for the comprehensive and systematic treatment of human factors in Safety Cases. Although it is widely recognised that human error accounts for a high proportion of the risk in offshore operations, safety cases currently provide a predominantly hardware centred approach to the analysis of risks.

One of the barriers to systematically addressing human factors is the perception that a considerable amount of effort would need to be devoted to analysing the very large number of tasks that typically occur in offshore drilling and production platforms. The first objective of the project has therefore been to develop a tool that can be used to assign a criticality rating to the majority of offshore tasks. This rating is directly related to the risk that arises when one or more human errors occur in the tasks being assessed. The criticality assessment process should enable a review team to focus on those tasks that have the greatest impact on risk. This would allow analysis resources to be assigned to areas where the greatest benefits could be achieved in terms of risk reduction.

Once critical tasks have been identified, there is a requirement to assess the specific errors likely to arise together with their consequences. This enables error prevention strategies to be developed for tasks that pose a significant risk. This process needs to be as efficient as possible, and an explicit method is needed to guide the user in terms of how to analyse tasks and how to choose the depth of analysis that is necessary to identify the risks. The development of this depth of analysis method has been the second main objective of the project.

The third objective of the project has been to show how the results of human factors analyses can be used as inputs to offshore safety cases. Although this objective was not, strictly speaking, included in the project specification, it was felt to be essential to indicate how the screening and depth of analysis tools then led on to the identification of specific human errors which would need to be considered in the safety case.

The practical application of these analytical techniques is likely to be limited unless they are effectively transferred to the offshore industry. The final objective of the project was therefore to develop a set of materials that could be used as the basis for training the offshore safety analysis community. In order to ensure that the results of this project are perceived as credible by the offshore industry, a considerable amount of consultation has taken place with experienced drilling and production personnel. We are grateful for the resources provided by a number of offshore operators, including BP, Talisman and Reading and Bates.

The resulting methodology is a mixture of standard methods used for human factors analysis and tools developed specifically for this purpose. The first stage of the project involved developing Task Inventories, which are systematic classifications of commonly occurring production and well operations tasks. These inventories have been subjected to the criticality analysis process so that they provide a predefined database of generic tasks, which have already been assigned criticality ratings. Whilst these generic task lists are believed to be comprehensive they must be reviewed in any analysis to ensure all tasks are captured. The generic task inventories therefore provide initial guidance to assist the review team in deciding which tasks need to be analysed in more detail. The screening method also includes guidance for identifying further tasks, not covered by the generic tasks, to which the criticality assessment methodology must also be applied. In summary, the methodology includes the following elements:

- Generic task inventories for the activities associated with production and well operations, with pre-defined criticality ratings.
- Screening techniques for ranking production and well operations tasks not currently in the generic task inventories according to their criticality.
- A depth of analysis technique which provides guidance for performing task analysis and specifies the level of detail required to ensure all relevant risks are considered.
- An application process for identifying human errors and their consequences for use in safety analyses.

In order to use the methodology, it is useful for the review team to be competent in Hierarchical Task Analysis (HTA) and familiar with error prediction methods, human factors guidelines in risk management and offshore safety cases. These competencies will be provided by the training courses based on the materials developed in this project. These training materials are provided in a separate report.

1.2 Overview of the Methodology

The methodology is used to identify and assess all the critical tasks carried out on an offshore installation. Its implementation involves five stages, as shown in Figure 1 below. These will first be described in overview in this section, and in more detail in subsequent sections.

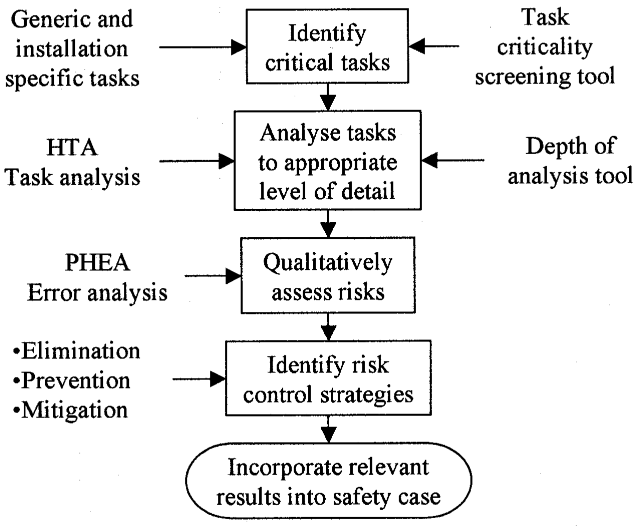

Figure 1: Five Stages of the Methodology

1.2.1 Identify Critical Tasks Performed on an Installation

The result of performing this stage is a list of critical tasks requiring further analysis. The activities required to develop this list are as follows:

- Review the generic critical-task inventories to identify which tasks are performed on the installation.
- Review the non-critical tasks in the generic task inventories to identify where tasks are performed on the installation which, for whatever reason, have a higher criticality than that considered at the generic level.
- Identify tasks performed on the installation that are not covered by the generic task inventories. Apply the criticality diagnostics questions to these tasks to identify those that should be included in the list of critical tasks requiring analysis.

1.2.2 Analyse each Critical Task to the Appropriate Level of Detail

Each task identified as critical in stage 1 will be analysed using HTA. The level of detail of this analysis will, however, be kept to a reasonable minimum based on the depth of analysis tool developed for this methodology. For the generic critical-tasks the level of analysis required will have already been determined. Other tasks performed on an installation and identified as critical will be analysed using the tool.

The Depth of Analysis tool gives three options:

Low criticality level analysis means that only the top level of the HTA is performed. This identifies *what* subtasks are performed but does not go on to describe *how* they are performed. This is the default level of analysis for all critical tasks.

Medium criticality level analysis means that the first level of the HTA is re-examined to determine which of the sub-tasks are most critical. Only the most critical sub-tasks are analysed further.

High criticality level analysis means that the whole task is analysed in detail.

The output from this stage of the methodology is set of analyses of all the tasks identified as critical in the first stage.

1.2.3 Qualitatively Assess Risks Associated with Critical Tasks

At this stage each of the critical tasks is examined to determine what types of errors may occur, their likely consequences and possible opportunities for recovery. This is based on the task analyses developed in stage two hence the detail at this stage depends on the results of the depth of analysis assessment for each task.

The output from this stage of the methodology is a qualitative assessment of risk associated with each of the tasks which have been identified as critical. This provides a useful input to stage 4 of the methodology. It also provides information about human errors that act as accident initiators and the actions performed that allow recovery and mitigation. The results of this stage should be used during other risk analyses performed for the safety cases. Finally, it will also provide an insight into activities performed on an installation that may have been overlooked during the first two stages of the methodology. This may prompt a reassessment of some tasks.

1.2.4 Identify Risk Control Strategies

Having identified the risks associated with tasks, it is necessary to identify appropriate methods of preventing human errors and supporting recovery, so that those risks are minimised. The main options available include hardware modification, the provision of written instructions, the design of information systems interfaces, task specific training and competency assessment.

1.2.5 Incorporate the Results of Applying the Methodology into the Safety Case

The overall aim of the methodology is to ensure that human factors are adequately covered in safety cases. The methodology thus guides the review team in the identification of information to be included in the safety case.

1.3 Structure of the Report

Following this introduction and project overview, Sections 2 and 3 set out the rationale and details of the production and well operations screening techniques. Section 4 describes the development of the Depth of Analysis Technique. A complete case study of the application of the methodology in the context of an offshore safety case is provided in Section 5 of the report. It is recommended that readers unfamiliar with Hierarchical Task Analysis (HTA) and Predictive Human Error Analysis (PHEA) refer to this section when these techniques are discussed in the methodology sections.

Appendices 1 and 2 provide a set of resources that can be used by an assessor when applying the criticality assessment diagnostics to production and well operations tasks respectively. They include definitions of the diagnostic questions, scoring forms, and the generic task inventories that have been pre-assessed using the screening tools. Appendix 3 is a summary of additional information concerning well operations that has been used in developing the methodology that may be useful to people analysing well operations tasks

2. Production Task Criticality Screening

The methodology described in this section allows tasks to be ranked according to their criticality. This involves the development of a task inventory, to which a set of diagnostic questions is applied to determine relative risks. The methodology is illustrated in Figure 2 below.

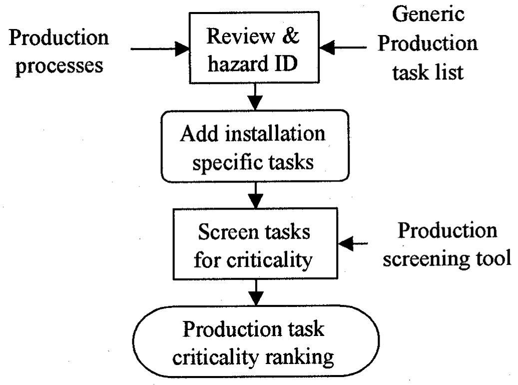

Figure 2: Production Task Screening

Two screening techniques have been developed, for offshore production and well operations tasks respectively. Both techniques include a generic task inventory and set of diagnostic questions. The criticality ranking has been applied to all the tasks in the generic task inventory. For each installation the inventory should be extended to cover non-generic tasks and the appropriate screening technique used to rank their criticality.

The production and well operations screening techniques have been tested with experienced offshore personnel. They were able to apply the techniques to the generic task inventories with minimal coaching. The results showed a good correspondence with the perceptions of the assessors regarding the levels of risk associated with a representative sample of these tasks. The technique is relatively quick to apply and will only require a modest proportion of the resources required for a full human factors assessment of safety critical tasks.

2.1 Development of the Generic Task Inventories

A Task Inventory is simply a list of all tasks performed in a specified domain such as well operations or production. Its purpose is to ensure all significant human activities are considered by human factors assessments. A completed task inventory should cover all phases of a systems operation including normal and abnormal situations, start-up and shutdown. It provides a focus for the human factors aspects of the system being examined.

The development of task inventories is essentially a brainstorming exercise where people are asked to list all the tasks they can think of that are performed in the domain being considered. It is useful, however, to provide a structure to the inventory that acts as a prompt to the review team and gives some organisation to the developing list. The structure is usually formed by developing a set of tasks that are listed under a series of headings, to form a task classification. There are a number of different bases for classifications that can be used. These include:

- Major items of equipment or process units, for example separation unit, gas compression unit.
- Phases of operation or plant status, for example, start-up, normal operation, and emergencies.
- Types of tasks, for example monitoring, responding to process conditions, and starting up equipment.
- Job descriptions, for example control room operator, separation operator, or shift supervisor.

For the production screening technique, the process units have been used to provide the overall structure. The phases of operation are used as prompts to ensure the review team considers all tasks. For the well operations screening technique, different types of well operations were identified and used to provide an overall structure.

Human behaviour is influenced to a large extent by local conditions. Thus, any human factors analysis performed has to be specific to an installation and this includes the development of installation-specific task inventories. Offshore oil production and well operations activities are broadly similar across all installations and this has allowed the development of generic task inventories, which can be used as a starting point for specific analyses. The aim is to provide some consistency throughout the industry so that the same task performed on different installations is considered in the same way. This should reduce duplication of effort and thus the amount of work involved in performing human factors analyses for each installation.

2.1.1 Generic Production Task Inventory

The structure of the Generic Production Task Inventory is based on nine main process units, identified as common to most production installations, which form the headings under which tasks are listed. The headings are:

- Separation
- Oil Export
- Gas Dehydration
- Gas Compression
- Vent, Flare, Blow Down, Closed Drains
- Produced Water

- Injection
- Utilities
- Power Generation

A tenth heading, 'Emergency Scenarios', has been added which includes tasks that are concerned generally with the whole installation rather than a particular unit. Under each of these headings a set of generic tasks have been identified. The full inventory is shown in Appendix 1, but for each set the tasks include some or all of the following:

- Start-up / shutdown individual items of equipment or processes
- Start-up / shutdown major items of equipment or process
- Adjust conditions of operation
- Perform tasks to maintain or improve operation
- Respond to process conditions and upsets.

The result is a list of 66 tasks considered to be generic. A further 34 tasks have been identified that are common, but not entirely generic, which are included as a prompt to the review team in identifying installation-specific tasks.

2.2 Development of Diagnostic Questions

The screening technique provides the review team with a set of questions to be answered for each task. The questions aim to identify the extent to which errors in the performance of a task constitute a risk to the safety of an installation. The answers to these questions are used to calculate a score that measures how the criticality of a task relative to other tasks in an inventory. The criticality ranking of a task determines the level of analysis required to ensure that its risk is being assessed to an appropriate level.

The purpose of the screening process is to minimise the amount of detailed analysis required. The questions developed are based on human factors principles that identify the greatest source of risk from human activities. They have been aimed, however, at users without a human factors background and have been tested and adapted to suit offshore production tasks. Another important consideration has been to minimise the number of questions and to make them as simple as possible, consistent with retaining sufficient diagnostic capability.

The screening questions for Production Tasks are based on the assessment of four major dimensions of risk:

- The level of severity of the intrinsic hazard(s) associated with the task that might be released if an error occurs
- The extent to which the systems containing the hazards are affected by task errors (a measure of vulnerability)

- The extent to which protective systems intended to mitigate a release of the hazard are affected by errors
- The nature of the human interaction associated with the task

Most of the factors for the production tasks focus on the severity of the consequences of error.

For production tasks, it was decided that it would be inappropriate to try to elicit diagnostic information at the screening stage about factors influencing error probability. This is partly because the screening process is meant to be applied by individuals without an extensive knowledge of human factors principles. Also, since the screening process will be applied, at least initially, as an off-line process, the assessor may not have a detailed knowledge of the operational conditions. Their inclusion in the diagnostic tool would therefore reduce rather than enhance its precision. Finally, the probability of human error in these tasks is regarded as relatively low and constant. This is because most production tasks are discrete in nature, with a reasonable likelihood of recovery if errors occur. Differences in criticality between tasks will therefore be mainly influenced by the severity of the consequences of human errors, rather than their probability.

In the case of well operations tasks, the situation is different. Here the tasks involved in the safety critical aspects of operations tend to involve close interaction between the operator and the hardware, and often require considerable communication between members of a team. The well operations diagnostics therefore include factors that directly influence the probability of human error in well operations tasks.

2.3 Production Tasks Screening Technique.

The components of the Production Screening Technique are shown in Table 1 below and Appendix 1, which also includes a score sheet for recording the results of the screening. Appendix 1 also shows the results of applying the screening to the generic task inventory.

2.3.1 Production Screening Diagnostic Questions

The screening technique contains five diagnostic questions. For each question, a score between 0 and 3 is possible. A score of 0 for a question means that the task does not involve any aspects of the characteristics influencing risk covered by the question. A score between 1 and 3 means there is an increasing risk potential because of the nature of the task. Examples are included to guide the review team in assigning scores. The diagnostic questions and their origin are listed below.

How hazardous is the system involved? The nature of offshore oil production means that hazardous materials and conditions cannot be avoided. The aim is to control the hazards in order to minimise the risk. The fact that a task involves interaction with a hazardous system means that there may be the opportunity for the control of a hazard to be lost. This diagnostic relates to the potential consequence of errors committed during the performance of a task.

To what extent are ignition sources introduced into the task when it is performed? The possibility of fire or explosion is of great concern to offshore production installations. This diagnostic recognises that certain tasks introduce the possible ignition sources that could ignite releases of flammable materials. Thus, such tasks may introduce a risk even if they do not involve flammable materials themselves.

To what extent does the task involve change to the operating configuration? Steady state operations generally involve little or no interaction with systems. The requirements for change usually involve interaction and hence those tasks introduce risk. This diagnostic relates to the task initiating a system failure that may in turn initiate an accident.

To what extent could incorrect performance of the task cause damage? Intrinsically safe systems fail in such a way that the control of hazards is maintained. This diagnostic relates to the potential for an error committed whilst performing a task to cause a direct, delayed or knock-on system failure that may act as an accident initiator.

To what extent does the task involve defeating protection devices? Where systems cannot be made intrinsically safe, protection devices can be added to maintain control of hazards should a failure occur. These protection devices can, however, interfere with systems operations so that some tasks involve defeating them. Obviously these tasks involve the removal of some layers of protection and this diagnostic relates to the risk posed by the task due to the reduction in system protection.

Five questions are listed with definitions. Every question should be answered for every task on the task inventory being considered. Examples are included to guide the review team in assigning scores. However, this should not be considered as a definitive set of possible answers and some judgement is required. The scores from the questions are totalled in order to rank the criticality.

Diagnostic	Definition	Rating Guide and Score		
		Low (1)	**Medium (2)**	**High (3)**
1. How hazardous is the system involved?	Task involves systems with intrinsically hazardous substances or conditions	Small amount of low hazard substance / condition	Large amount of low hazard or small amount of a high hazard	High amount of a high hazard / condition
2. To what extent are ignition sources introduced into the task when it is performed?	Task uses or may produce heat, sparks or flames	Static spark or low current electrical supply	High current electrical supply, sparks from grinding	Flames for welding or cutting, internal combustion engines
3. To what extent does the task involve changes to the operating configuration?	Task involves valve moves, temporary connections, change to process flows.	Simple changes to valve process status.	Complex or multiple changes to valve and process status or temporary connections	Complex and multiple changes and temporary connections
4. To what extent could incorrect performance of the task cause damage?	Deviations from best practices may have detrimental effect on equipment integrity.	Equipment weakened with potential to cause damage in the long term.	Equipment requires repair but maintains integrity.	Equipment fails catastrophically.
5. To what extent does the task involve defeating protection devices?	Task requires bypass or override of indications, alarms or trips.	Disabling gauges, meters or electronic displays.	Disabling alarms.	Overriding trip systems or isolating safety valves.

Table 1: Production Task Criticality Screening tool

2.3.2 Task Criticality Ranking

The sum of the scores for each diagnostic for a task is used to develop a criticality rating between 0 and 15. The assignment of a task to a criticality category on the basis of the scores currently includes some flexibility to allow specific installations to use their discretion to decide if a task falls in a higher or lower ranking. All emergency tasks are considered to be high criticality, without an assessment needing to be made. The criticality categories are shown in the table below. The number of tasks ranked in each category from the application of the screening tool to the Generic Production Task Inventory is also shown (See Appendix 1).

Score	Criticality band	Number of generic tasks from the Production Task Inventory in band
Emergency scenarios	High	5
9 and greater	High	5
8	High/Medium	4
5-7	Medium	25
4	Medium/Low	10
3 and below	Low	17

3. Well Operations Task Criticality Screening

The well operations task criticality screening method is the same as for production tasks described above. However, the different nature of the operations carried out requires a different set of diagnostic questions to be used.

To implement the risk analysis the drilling contractor could consider all the tasks in the generic list, or proceed on a contract by contract basis, identifying tasks relevant to specific contracts. The components of the methodology are discussed below. Appendix 2 includes the Generic Well Operations Task Inventory, a guide to applying the diagnostic questions and a score sheet for recording the results of the screening. It also shows the results of applying the screening to the generic task inventory.

In order to refine the screening technique, drilling engineers with extensive practical experience of offshore operations were consulted. An iterative approach was used where sets of tasks were selected from the generic task inventory and examined to determine whether they were accurate descriptions of generic tasks performed offshore. As a result, a number of tasks were added, removed and combined. This type of iterative process should continue throughout the use of the tool. As more is learnt about the tasks being evaluated, the criticality assessment becomes more accurate. Also, the working environment and techniques employed are continuously changing and this has a considerable impact on the nature of the tasks that are performed and their associated risks. This means that offshore organisations will need to continually update and tailor the screening process for their own environment. This requires the active participation of the workforce in order to maintain a 'living' methodology.

So far a generic task inventory has been developed, together with a criticality screening tool relevant to the inventory, and the tool has been applied to the generic tasks to develop sets of tasks categorised as being High, High/Medium, Medium, Medium/Low and Low criticality. In Appendix 2, the screening technique was applied to the generic Well Operations Task Inventory. This can be used to pre-screen tasks for analysis. The criticality diagnostic scores for the generic tasks have been evaluated by drilling engineers who considered the scores given were a good reflection of their perception of the risks.

3.1 Generic Well Operations Task Inventory

For the well operations screening technique different types of well operation were identified and used to provide an overall structure.

The structure of the Task Inventory is based on six types of well operation, identified as common to most drilling installations, forming the headings under which tasks are listed. The headings are:

- Making hole and clearing hole
- Pumping activities
- Hoisting activities

- Reeling activities
- Surface and seabed activities
- Contingency activities

Under each of these headings a set of generic tasks has been identified that may include some or all of the following categories:

- Start-up / shutdown individual items of equipment
- Commencement / completion of generic well operations
- Adjust conditions of operation
- Perform tasks to maintain or improve operation
- Respond to abnormal conditions and upsets.

The full inventory, in Appendix 2, lists 37 tasks considered to be generic to offshore drilling installations. Appendix 3 includes information about rig systems and well operation system states that provide a guide for identifying tasks, in addition to those in generic inventory, required to develop an installation specific task inventory.

3.2 Well Operations Screening Technique

The components of the Well Operations Screening Technique are shown in Table 2 below and Appendix 2, which also includes a score sheet for recording the results of the screening. Appendix 2 also shows the results of applying the screening to the generic task inventory.

The well operations criticality tool is based on the assessment of two major dimensions of risk:

- The nature of the intrinsic hazards associated with the task
- The nature of the human interaction associated with the task

3.2.1 Intrinsic Hazards

Intrinsic hazards are those associated with the system and operating environment within which a task is performed. Unique hazards or combinations of hazards can be identified from specific well operations. Only hazards with implications for kick and blow-out scenarios are considered, since these are considered to be the greatest sources of risk in well operations. The nature of these hazards can be direct, indirect or knock-on.

3.2.2 Human Interactions

The assessment of the human interaction associated with the task is performed to estimate the degree to which the integrity or safety of the system may become vulnerable while the task is being performed. Certain indicators of vulnerability can be identified to assess the severity of the anticipated demands on the operator and the potential for error.

In the performance of any task there are various characteristics affecting the potential for error, including:

- The environment in which the task is performed, such as noise, access and lighting
- Individual characteristics of the operator(s), such as motivation and ability to cope with stress
- Organisational and social factors, such as peer pressure and procedures culture
- The nature of the task, such as the extent to which manual operations or problem solving are required.

Of these characteristics, only those relating to the nature of the task itself can be assessed generically, that is, without reference to installation-specific features. The remaining categories require some knowledge (or assumptions to be made) of the situation or context in which the task is performed.

In discussions with offshore drilling personnel, three task characteristics were identified as having particular relevance to well operations:

- Task complexity
- Degree of person-to-person communication involved
- Extent to which monitoring and control are involved.

This combination represents the smallest group of characteristics that can be considered without affecting the comprehensiveness or accuracy of the assessment required. In addition, they can be assessed by individuals without a background in human factors methods. These task characteristics can be used to evaluate the generic tasks in the Task Inventory, without specific reference to individual installations. This allows the criticality ranking to be used as a starting point for safety cases, before installation specific factors are considered.

3.2.3 Well Operations Screening Diagnostic Questions

The screening technique contains five diagnostic questions. For each question, a score between 1 and 3 is possible related to the risk potential due to the nature of the task. A score of 3 indicates that the task characteristic has the maximum risk potential Examples are included to guide the review team in assigning scores. The diagnostic questions and their origin are listed below.

Interaction with Subsurface Hydrocarbon Reservoirs

The greatest risks associated with well operations are directly related to the hazards of the reservoir involved. Individual reservoirs have different characteristics and hence introduce different levels of risk. The risk can be analysed at a generic level, however, by identifying how tasks involve interaction with reservoirs as this is an indication of the potential for kicks to occur.

Predicted hazards associated with a reservoir can be controlled in order to achieve a tolerable risk. Thus, an added dimension to that risk is uncertainty where the precise conditions encountered during a task are not known, such as drilling into a new reservoir.

Interaction with well pressure barriers

The nature of well operations means that hazardous conditions, namely the conditions of the reservoir, cannot be avoided. A number of different pressure barriers are used to control the hazards. Certain tasks, however, require the removal of some of these pressure barriers and this increases the risk of those operations.

The number of pressure barriers required depends on the system state. Thus identifying critical tasks involves comparing the "normal" number of barriers required for a given system state with those actually in place whilst the task is being performed, rather than a simple count of the barriers in place.

Person-to-Person communication

The nature of any person-to-person communication involved in a task affects the potential for error. The main factors affecting error are the criticality of information being communicated, the frequency at which information must be communicated and the number of lines of communication involved. The first two of these factors are particularly important.

Criticality of information considers how important the information is for the successful completion of the task rather than the importance of the task itself. For example, information may be highly critical to the successful completion of a task with low intrinsic hazards, or of little importance to the successful completion of a task with very high intrinsic hazards.

The frequency at which information must be communicated is determined by the rate of change of system conditions and the requirements of the task for up to date information regarding these conditions. Tasks dependent upon regularly communicated updates of dynamic data present greater mental demands to operators. Higher frequencies of communication also reduce opportunities for error recovery (e.g. through requests for clarification) which increases the potential for error.

The last of these factors, lines of communication, refers to the number of person-to-person communication interfaces involved in carrying out a task. Generally, the more lines of communication the greater the potential for error.

Complexity

This definition of complexity considers the increased mental demands placed on the operator when performing simple action based tasks compared with decision making and problem solving tasks. These latter tasks are generally performed infrequently and require more concentrated conscious thought. The more decisions involved and the greater their complexity the greater the potential for error.

The total number of steps that must be carried out in order to complete a task should also be considered. Generally, the greater the number of task steps involved the greater the potential for error. A routinely performed task, for example, involving a large number of task steps, may be considered to be as error prone as an infrequently performed task involving some decision making but very few task steps.

Monitoring and control

This characteristic considers the intensity of the interchange between the operator and the system for tasks involving monitoring and control type activities. The more intense the interchange the greater the demands on the operator and the greater the potential for error. System states showing slow rates of change will require less intensive monitoring and control than those associated with higher rates. The nature of the control aspects is also considered. Fine control within narrow and unforgiving limits will obviously increase the potential for error.

Task Characteristic	Rating Guide and Score		
	Low (1)	**Medium (2)**	**High (3)**
1 - Interaction with subsurface hydrocarbon reservoirs	Task does not usually involve interaction with open reservoirs	Task may involve direct interaction with open reservoirs but pressure and other characteristics are reasonably well known	Task may involve direct interaction with newly penetrated reservoirs
2 - Interaction with well pressure barriers	Task is not interacting directly with any barriers or involves a negligible chance to remove the normal barriers	Task is carried out with all normal barriers in place but could potentially cause the removal of one	Task is carried out with at least one of the normal barriers removed or seriously affected
3 - Person-to-person communication	One line of communication (2 people) with many opportunities for clarification and/ or recovery.	More lines of communication relating to more important information with some opportunities for clarification and/or recovery.	Many lines of communication relating to critical control parameters with few opportunities for clarification and/or recovery.
4 - Complexity	Highly practised tasks requiring little or no conscious effort.	Tasks performed less frequently involving more conscious effort and some decision making based on <u>known</u> situations and solutions. *OR* – Lengthy routine tasks with many steps involving some conscious effort.	Tasks performed infrequently involving intense conscious effort, more decision making and possible problem solving in <u>unfamiliar</u> or highly stressful situations.
5 - Monitoring and control	System shows slow rate of change. Intermittent monitoring involved that does not require fine control.	System shows higher rate of change. More frequent monitoring requiring more attention to control.	System shows high rate of change. Continuous monitoring requiring fine control.

Table 2: Well Operations Task Criticality Screening Tool

3.2.4 Developing the Task Criticality Ranking

The well operations criticality tool has been applied to the Generic Well Operations Task Inventory in order to rank task criticality and determine the depth of analysis required. The full results of this exercise are shown in Appendix 2. Appendix 2 also provides a scoring sheet for use in these analyses.

The sum of the intrinsic hazard and human interaction scores for each task is used to rank the criticality as High, High/Medium, Medium, Medium/Low or Low. The assignment of a task to a criticality category on the basis of the scores currently includes some flexibility to allow specific installations to use their discretion to decide if a task falls in a higher or lower ranking.

The suggested criticality categories and the assignment of the generic tasks to the categories on the basis of the exercise described in Appendix 2 are as follows:

Score	Criticality band	Number of generic tasks in band
14 - 15	High	4
12 - 13	High/Medium	4
10 - 11	Medium	14
8 - 9	Low/Medium	7
5 - 6	Low	8

4. Depth of Analysis Technique

The objective of the Depth of Analysis Technique is to ensure that all error modes with safety case implications are identified as efficiently as possible. This objective presents two directly opposing demands. Decomposing all tasks to the detailed step-by-step level, and then considering all possible errors that could arise at each step could guarantee effective identification. Unfortunately this would entail unrealistic resources. The Depth of Analysis Technique has been developed to focus resources on tasks where indications show that there are likely to be a number of error modes with safety case implications.

4.1 Methodology Overview

Although well operations and production tasks are very different, a common approach has been developed to determine appropriate depth of analyses. This is illustrated in Figure 3.

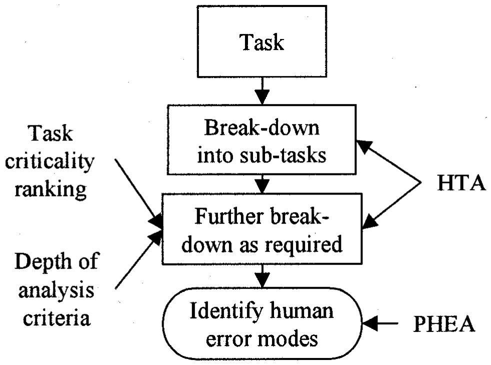

Figure 3: Depth of Analysis Technique

The *Criticality Band* of a task, evaluated from the appropriate screening tool, determines which of three levels of analysis are required: High, Medium or Low. These levels of analysis are described in terms of HTA structure and are summarised in Table 3.

Criticality Band	HTA Decomposition	Error Prediction
HIGH	Break all sub-tasks down to a level at which Predictive Human Error Analysis (PHEA) can be applied	Perform Predictive Human Error Analysis
MEDIUM	1. Break down task into 1st level subtasks 2. Break down subtasks containing one or more breakdown criteria to next level of detail 3. Repeat 2 at this level 4. Stop task breakdown at level of detail that allows errors and their consequences to be predicted (normally PHEA)	Perform Predictive Human Error Analysis
LOW	1. Break down to 1st level subtasks 2. If more than 2 subtasks have associated breakdown criteria, re-classify task as Medium	No Further Analysis Required

Table 3: Overview of Depth of Analysis Technique

Tasks falling within the high criticality band are simply broken down to step-by-step detail following the normal rules for HTA.

Tasks falling within the medium criticality band are broken down to the first level of the HTA and then assessed to determine which of these require further breakdown. This selective breakdown is based on the application of a set of *Breakdown Criteria,* i.e. criteria for continuing decomposition which will be described in detail later. Sub-tasks that fulfil one or more criteria are broken down to the next level of detail. The criteria are then reapplied at each level of break down of the task until a level is reached at which specific errors and their consequences can be predicted, normally using the Predictive Human Error Analysis (PHEA) technique (see Section 5). The lowest level of task break down normally considered is that of individual task steps.

Tasks falling within the low criticality band are generally assumed not to require analysis. However, as an additional check to ensure that no potentially safety critical task steps are missed, low criticality tasks are broken down to the first level of the HTA and assessed to determine if any first level sub-tasks can be associated with the breakdown criteria. If one or more criteria are associated with more than one of the subtasks that make up the task, consideration should be given to re-classifying it as Medium criticality. However, if the first level task criticality rating exercise is correctly carried out, this is unlikely to occur in practice.

4.2 Developing and Applying the Breakdown Criteria to Determine Depth of Analysis

The use of breakdown criteria combined with HTA to decompose medium criticality tasks to the appropriate level of detail can be considered analogous to the use of a map and compass. HTA provides the terms of reference, the map, while the breakdown criteria provide the compass, directing the review team through the appropriate branches of the HTA towards specific safety critical task steps.

4.2.1 Pre-requisites

There are two essential pre-requisites in order to decompose tasks using breakdown criteria: a minimum level of skill in applying the HTA technique and an 'operational' knowledge of the tasks involved. Review teams should fully appreciate the 'level of detail' rules associated with HTA, otherwise excessively detailed analyses will be generated, thus negating the objectives of the technique.

Operational knowledge of tasks is also essential to the effectiveness of the technique. It is assumed that review teams will be based offshore, and will be working within an operational context, although not necessarily on a day to day basis. Operational experience should be similar to that of driller or assistant driller, for well operations tasks, and production supervisor, for production tasks, so there is sufficient familiarity with a wide range of tasks. Sufficient on-the-job knowledge of tasks is required for review teams to be able to identify whether breakdown criteria apply to sub-tasks before additional decomposition is carried out. Since there is some degree of discretion in applying the methodology, a reasonable level of knowledge and experience of the tasks being analysed is necessary in order to obtain accurate and consistent results. Inadequate knowledge will detrimentally effect the level of detail required in HTAs; resulting in excessive detail in low risk areas and insufficient detail in high-risk areas. At best this would result in inefficient use of resources and at worst in the omission of safety critical task steps.

4.2.2 Development of Criteria for Continuing Breakdown of Tasks

A primary objective in developing breakdown criteria was simplicity. This involved minimising the number of criteria, and simplifying text and technical embellishment. It is intended that review teams would consider the criteria as reflecting "applied common sense" and that after a number of applications, they would only occasionally need to refer to the criteria for prompting.

The significant difference in the major hazards associated with well operations and production tasks is reflected in the fact that respective breakdown criteria have only two common criteria. It also worth noting the similarity between the well operations criterion *'Potential to reduce overbalance'*, and the production criterion *'Potential to damage equipment'* which can be directly associated with the respective hazards of 'kick induction' and 'loss of containment'. All other criteria reflect task characteristics with indirect hazardous affects.

Criteria within the same group can be considered as generic or specific. It is likely that that more than one criterion is applicable to a sub-task. This redundancy improves the effectiveness of the technique by providing the opportunity for a safety critical sub-task to be identified on the basis of one criterion even if it has been omitted on the basis of another that is equally valid. An example of overlap is between the production criteria 'Changing the operating configuration of a system', 'Changing the operating conditions' and 'Potential to damage equipment'. All of these criteria could be associated with a sub-task with the potential to result in plant damage.

The breakdown criteria for production and well operations tasks are shown in Tables 4 and 5 and Appendices 1 and 2 respectively.

Criteria Type	Criteria	Description	Examples
System	1. Changing operating configuration of system / sub-system	Changes to configuration of systems containing, or that have contained, flammable or toxic substances.	• Changing well configuration
System	2. Changing operating conditions.	Changes in operating conditions with the potential to approach or exceed operating limitations with the potential to result in plant damage or deterioration.	• Changing separator mode from stabilised crude to semi-stabilised crude (pressure change).
System	3. Establishing or defeating safety critical / protective systems.	Sub-tasks involving the activation of safety critical / protective systems from a non-operational or defeated state. Sub-tasks that involve defeating safety critical / protective systems that would otherwise prevent or hinder the successful completion of a task.	• Removing override on interface level trip during separator water wash.
System	4. Removing or minimising the presence of hazardous substances and conditions.	Sub-tasks that involve the purging, venting or flushing of flammable or toxic materials. Sub-tasks involving the depressurisation of high-pressure systems.	• Purging gas compressor during start–up.
Human Interaction	5. Monitoring and control	Sub-tasks involving monitoring and control of critical operational parameters.	• Monitoring separator levels on production start-up.
Human Interaction	6. Potential to damage equipment.	Potential for errors committed whilst performing the task to cause a direct, delayed or knock on system failure.	• Valves in high pressure flow lines left in closed position during start-up.

Table 4: Production Task Depth of Analysis Criteria

Criteria Type	Criteria	Description	Examples
System	Controlling pressure.	Sub-tasks involving pressurising, depressurising and bleeding operations.	• Pressurising formation. • Controlling the expansion associated with gas migration.
System	Potential to reduce overbalance.	Potential for errors committed whilst performing the task or for effects associated with the task to lead to an undesired reduction in overbalance.	• Cementing (drying effect) • Filling hole when retrieving • Cementing production liner (circulating low density spacer near formation)
System	Establishing and testing safety critical/ protective systems.	Activation of specific safety critical / protective systems from a non-operational or defeated state.	• Lining up correctly to a trip tank • Ensuring choke manifold lined up for a kill.
Human Interaction	Detection - Action	Sub-tasks involving anticipated critical conditions that require detection followed by a known appropriate action.	• Anticipated Pressure changes indicating when to stop pumping during a well kill
Human Interaction	Monitoring and control	Sub-tasks involving monitoring and control of critical operational parameters.	• Monitoring trip tank returns when retrieving. • Monitoring and controlling drilling torque

Table 5: Well Operations Task Depth of Analysis Criteria

4.2.3 Applying the Depth of Analysis Technique

These criteria focus on both the Systems associated with tasks and the 'Human Interaction' involved in the tasks. System criteria are concerned with the *Intrinsic Hazards* referred to in the production and well operations screening techniques. Intrinsic hazards are associated with system hardware and operating conditions. Human Interaction criteria consider the degree to which the integrity or safety of the system may become vulnerable while a task is being performed and should be considered with System criteria in mind. Obviously errors committed within a system with no or low intrinsic hazards require little further consideration.

When a task has been broken down to the first level of the HTA, each sub-task is considered with regard to the appropriate set of breakdown criteria. Sub-tasks associated with one or more criteria should be considered for further breakdown. Obviously the more criteria that apply to a sub-task the stronger the indication that it should be broken down. If only one criterion applies, the review team can use evidence from external sources (e.g. incident data) to decide if further analysis is justified. The breakdown criteria are then re-applied to the constituent sub-tasks that result from a particular level of breakdown and the process repeated. If, at any stage of the task breakdown, it is clear that sufficient detail is available to perform a PHEA analysis, the task breakdown should be suspended at that point, and the PHEA analysis performed. Usually, it will be possible to perform such an analysis as soon as the level of individual task steps is reached. Examples of this process will be provided in the case study in Section 5.

4.2.4 Testing the Depth of Analysis Technique

The breakdown criteria were developed in consultation with operations personnel who considered them practical and easy to use. Although the personnel were unfamiliar with HTA at the outset, in trials they quickly appreciated the effectiveness of the tool in decomposing tasks compared with the traditional approach of breaking tasks down to the level of step-by-step detail by default. All personnel appreciated that the technique minimised task decomposition by focusing only on sub-tasks with safety critical implications.

Although a minimum working level of skill in applying the HTA tool is required to use the technique successfully, past experience from the petrochemical and chemical industries has shown that operations personnel quickly grasp the principles with very little coaching. Training in the application of HTA provides a valuable skill that can be used for a range of other applications including general hazard identification and risk assessment, training plan development, and the design of procedures and job aids.

4.3. Predictive Human Error Analysis (PHEA)

Having analysed each task to the appropriate level of detail, determined by the 'depth of analysis technique,' a further analysis is performed in order to identify the errors that may occur in performing the task. PHEA is a technique that provides the review team with a structured approach to error identification.

PHEA consists of a set of 'guide words' (analogous to those used in a hardware HAZOP) that the review team applies to the lowest level of the task analysis in order to identify the possible errors that could arise. The guide words used depend on the type of operation being performed. The error types considered include the following:

- Action errors
- Checking errors,
- Information retrieval errors,
- Communication errors
- Errors in selection between alternatives.

The error guide words are shown below:

Action error guide words	**Checking error guide words**
Action too late / early	Check too late / early
Action too fast / slow	
Action omitted	Check omitted
Action too much	
Action too little/incomplete	
Action in wrong direction	
Right Action on wrong object	Right Check on wrong object
Retrieval error guide words	**Communication errors**
Information not obtained	Information not communicated
Wrong information obtained	Wrong Information communicated
Retrieval incomplete	Communication incomplete
Information incorrectly interpreted	
Selection errors (between alternatives)	
Selection omitted	
Wrong selection made	

When the review team identifies potential errors using the guide words, they are required to identify the likely consequences and possibilities for recovery. This gives a qualitative indication of the risks associated with the task and an opportunity to identify possibilities for improvement. In general the best strategy is to remove hazards wherever possible. Error prevention strategies, such as procedure and job aid development, training and advanced control system, will reduce risk through the reduction in accident probabilities. Improving error recovery and mitigation is the final risk reduction strategy and includes the use of process alarms and other forms of feedback, e.g. temperature and pressure changes observed directly or via a display system.

The following information from the HTA and PHEA analyses is recorded in a tabular format as shown in Table 6:

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The following information from the HTA and PHEA analyses is recorded in a tabular format as shown in Table 6:

- Task step
- Error Type (using the guide words)
- Error description
- Consequences (immediate or delayed)
- Recovery (immediate steps that can be taken to prevent the consequences after the error has been made)
- Error prevention measures

Task Step	Error Type	Description	Consequences	Recovery	Error Reduction
1. Identify off-line filter	S2 Wrong Selection made*	On-line filter selected	Wrong filter (on-line) will be subsequently primed at sub task 2. Resulting in **compressor trip** (pressure trip safeguard).	Feel the filters to compare temperatures. Position of arm.	Provide interlocks. Train operators to be able to identify online filter and consequences of error
2. Prime off-line filter.	A9 Action omitted.	Off-line filter not primed prior to change over.	**Compressor trip** (pressure trip safeguard).	No	Training Job aid (warning, reminder)
2.1 Slowly open fill valve on the equalisation line.	A5 Action too fast.	Fill valve opened too quickly.	Pressure surge could **trip compressor** (pressure trip safeguard)	No	Limit flow using an orifice restriction. Train operators in need to fill slowly and provide a job aid
2.2 Slowly open vent valve	A5 Action too fast.	Vent valve opened too quickly	Pressure surge could **trip compressor** (pressure trip safeguard)	No	Limit flow using an orifice restriction. Train operators in need to vent slowly and provide a job aid

Table 6: Format for HTA and PHEA analysis

5. Application of the Methodology to an Offshore Case Study

This section describes a comprehensive case study, based on the Production Task Inventory, to demonstrate how companies will apply the methodology, in preparing their safety cases, and what the results will look like. The main focus of the case study will be on demonstrating the use of Hierarchical Task Analysis (HTA), Predictive Human Error Analysis (PHEA) and the Depth of Analysis techniques in the context of an offshore safety analysis. Less emphasis will be given to the criticality screening, since it is assumed that the starting point of the analysis will be the pre-screened tasks in the Production Task Inventory.

5.1 Methodology Overview

In this section, the overall methodology will be summarised from the point of view of its application to an offshore safety analysis. It includes an assessment of generic offshore tasks which identifies tasks that have to be analysed for each installation, and a guide for identifying further tasks, not covered by the generic analysis, to which the methodology must also be applied.

The complete methodology includes:

1. Generic task inventories for the activities associated with production, and well operations tasks,
2. A set of diagnostic questions which are used to assess task criticality for each of the activities,
3. Generic critical-task inventories for each of the activities,
4. A method for determining the depth of analysis required for critical tasks,
5. The analysis tool, Hierarchical Tasks Analysis, used to analyse tasks,
6. The error prediction tool, Predictive Human Error Analysis (PHEA), used to predict the errors and potential error recoveries associated with each task or task step,
7. A set of guidelines for determining appropriate measures, based on human factors principles, for managing the risks associated with each task,
8. A specification for the inclusion of human factors assessments in safety cases.

Items 1 to 4 are contained in the Appendices 1 and 2, which can be regarded as tool kits for use by safety case analysts.

The methodology can be used to identify and assess all the critical tasks carried out on an offshore installation. Currently, it focuses specifically on production and well operations tasks, as set out in the project specification. It could, however, be extended to address other types of task such as maintenance and marine operations. Its implementation involves five stages, which are described below.

5.1.1 Identify Critical Tasks Performed on an Installation

The result of performing this stage is a list of critical tasks requiring further analysis. The following activities are required to develop this list.

- Review the generic critical-task inventories to identify which tasks are performed on the installation.
- Review the ranking of tasks in the generic task inventories to identify where tasks are performed on the installation which, for whatever reason, have a higher criticality than that considered at the generic level.
- Identify tasks performed on the installation that are not covered by the generic task inventories. Apply the criticality diagnostics questions to these tasks to identify those that should be included in the list of critical tasks requiring analysis.

5.1.2 Analyse Each Critical Task to the Appropriate Level of Detail

Each task identified as critical, in stage 1, will be analysed using HTA. Due to the differences in hardware and operating procedures generic HTA can not be produced for the generic tasks. The level of detail of this analysis will, however, be kept to a reasonable minimum based on the depth of analysis tool developed for this methodology. For the generic critical-tasks the level of analysis required will have already been determined. Other tasks performed on an installation and identified as critical will be analysed using the tool.

The depth of analysis tool gives three options:

1. Low criticality means that only the first level of the HTA is performed. This identifies what subtasks are required but does not go on to describe how they are performed. This is the default level of analysis for all critical tasks.
2. Medium criticality means that the top level HTA is re-examined to determine which of the sub-tasks need to be broken down to a finer level of detail, using the breakdown criteria. Only the sub-tasks containing one or more criteria are analysed further.
3. High criticality means that the whole task is analysed in detail.

The output from this stage of the methodology is set of analyses, to an appropriate level of detail to allow a PHEA analysis to be performed if required, of all the tasks identified as critical in the first stage.

5.1.3 Qualitatively Assess Risks Associated with Critical Tasks

At this stage each of the critical tasks is examined to determine what types of errors may occur, their likely consequences and possible opportunities for recovery. PHEA is used to perform this assessment. It is applied to the task analyses developed in stage two hence the detail at this stage depends on the results of the depth of analysis assessment for each task.

The output from this stage of the methodology is a qualitative assessment of risk associated with each of the tasks performed on an installation, which have been identified as critical. This provides a useful input to stage 4 of the methodology. It also provides information about human errors that act as accident initiators and the actions performed that allow recovery and mitigation. The results of this stage should be used during other risk analyses performed for the safety case. Finally it may also provide an insight to activities and tasks performed on an installation that may have been overlooked during the first two stages of the methodology and may therefore prompt a reassessment of some tasks.

5.1.4. Identify Risk Control Strategies

The aim of this stage of the methodology is to ensure the risks associated with a particular task are tolerable. This should start with an investigation of how hazards can be removed to make the task intrinsically safe. Where this is not possible efforts should be made to minimise the hazard thus minimising the potential consequences of an incident. Finally the task is examined to identify the most appropriate methods of preventing human errors, and encouraging recovery. The methods to be used include the provision of written instructions, the design of information systems interfaces, and training of personnel in the correct way to perform the task backed up competency assessment to ensure they achieve and maintain the required levels of knowledge and understanding. The methodology includes guidance about the appropriate mix of these based on the nature of the task and its criticality.

5.1.5 Incorporate the Results of Applying the Methodology into the Safety Case

The overall aim of the methodology is to ensure that human factors are adequately covered in safety cases. The methodology thus specifies what information could be included in the safety case. It is suggested this information could be summarised in a new, separate chapter.

The 'human factors' chapter could include a list of all the tasks performed on an installation identified as critical. For each of the tasks the following information may be recorded in the chapter:

- The level of analysis performed
- The results of applying PHEA including likely errors, their consequences and possible recovery

- The methods chosen to manage the risks
- Details of where the human factors assessment has been incorporated into other parts of the safety case.

This will represent a summary of the results of applying the methodology. It is expected that the analyses performed will be retained for audit purposes and could form the basis for written instructions, information systems specification, training programmes development and as a standard against which competency is assessed.

5.2. Example Case Study

For this case study the methodology will be applied to an example set of tasks.

5.2.1 Identify Critical Tasks Performed on an Installation

The first stage of identifying critical tasks involves a review of the generic task inventories to ensure the generic ranking is appropriate for the installation being considered. For example some of the tasks ranked low criticality in the generic assessment may be more critical on the installation in question. These tasks may include "water wash separator unit" because, for example, part of the system no longer works as intended so that operational "work-arounds" are employed to complete the task successfully but which have an impact on the operation of certain control and safety systems.

The installation specific task inventory may require additional tasks to those included on the generic list. This may be because the installation has some non-standard equipment. For example the installation may have a nitrogen booster compressor. For this unit the following tasks have been identified:

- Start-up N_2 booster compressor
- Respond to low N_2 pressure
- Shut-down N_2 booster compressor

The task criticality diagnostics are applied to any additional tasks so that they can be added to the appropriate section of the criticality ranked inventory.

For the purposes of this case study the following 5 "hypothetical" tasks are analysed to illustrate the tools and techniques.

- Remove valve from well head
- Leak test equipment
- Internally inspect electrical equipment
- Water wash separator unit
- Start-up N2 booster compressor

5.2.2 Analyse Each Critical Task to the Appropriate Level of Detail

The default level of detail of analysis for each critical task is a top level HTA. At this stage the analysis will still be of a generic nature.

Having developed the top level HTAs the required depth of analysis will be determined. If the task is assessed as low criticality the HTA is complete. For the other tasks the analysis will continue, but from now on installation specific tasks will be considered, which may result in the same task being analysed a number of different times to take into account where and when it is actually performed.

Stage 2 of the methodology is illustrated by means of an HTA for each of the critical tasks identified in Stage 1.

Task 1

Task: remove valve from well head
Preconditions: well shut in and depressured
Plan: Do 1 to 4 in order.

1. Drain, flush and / or purge riser
2. Prepare for valve removal
3. Verify riser hydrocarbon free
4. Remove valve

This HTA can also be represented in a graphical format, as shown in Figure 4 below.

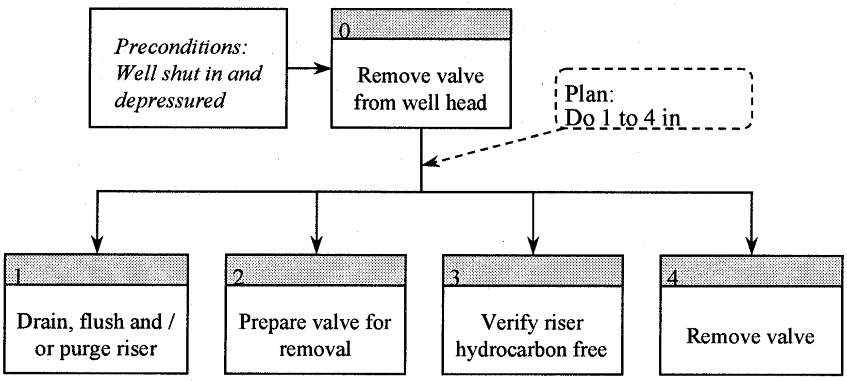

Figure 4: Graphical HTA of Task 1: Remove Valve from Well Head

For the purposes of this case study, we identify the criticality of this task as being high. This means a full HTA has to be developed for each specific case where this task is performed. It is not necessary to apply any breakdown criteria, because all high criticality tasks are broken down to the lowest level of detail for all subtasks. For this task there are two specific cases - a valve can be removed from an oil well head and a gas well head and so each of the these cases is analysed in further detail.

Specific task: remove V101 oil valve.
Preconditions: well 1 shut in and depressured
Plan: Do 1 to 4 in order

1. Drain and flush riser
   Plan: Do 1.1 to 1.4 in order. Then do 1.5 for 2 hours
   1.1 Line-up cement pump to unloading header
   1.2 Line-up riser to separator
   1.3 Line-up unloading header to riser
   1.4 Reset logic
   1.5 Pump flush water to separator via riser
2. Prepare valve for removal
   Plan: Do 2.1 to 2.5 in order
   2.1 Stop flush
   2.2 Isolate flush
   2.3 Vent oil pressure to zero
   2.4 Vent gas pressure to zero
   2.5 Isolate valve

3 Ensure valve is hydrocarbon free
   Plan: Do 3.1 and 3.2 in order
   3.1 Attached gas analyser to sample point
   3.2 Ensure analyser shows hydrocarbon levels below LFL

4 Remove valve
   Plan: Do 4.1 to 4.3 in order
   4.1 Remove securing bolts
   4.2 Lift valve off
   4.3 Fit blank

To further illustrate the graphical representation of the HTA technique, this analysis of the specific task 'remove V101 oil valve from well head' is presented in Figure 5 and includes 2 separate diagrams – the top level HTA followed by a representation of one of the four subtasks.

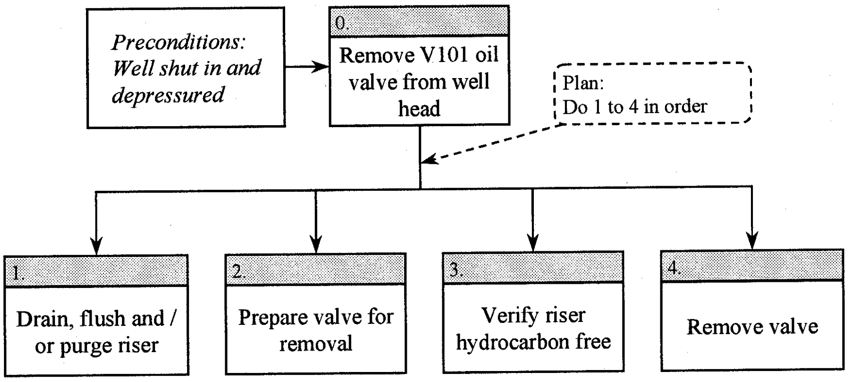

Figure 5.1: Top Level HTA of the specific task remove V101 oil valve

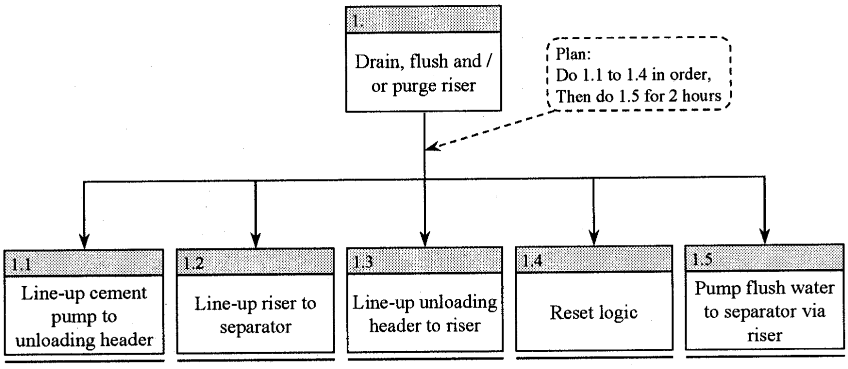

Figure 5.2: Further detail of the sub-task 'drain, flush and / or purge riser'

In fact this is not the full HTA. Some of the second level sub-tasks could be broken down further. Guidance about when this has to be done is included in the HTA training module but for the purposes of this case study the HTA has been limited to two levels.

To illustrate that the same generic sub-task may be different when analysed in detail in different specific settings, the same task has been reanalysed for a gas well head. It can be seen in Figure 6 that the sub-tasks for the task 'drain, flush and / or purge riser' for the gas valve differ in some respects from the same sub-task for the above oil valve. This illustrates the requirement to represent the task analysis in further detail for specific tasks.

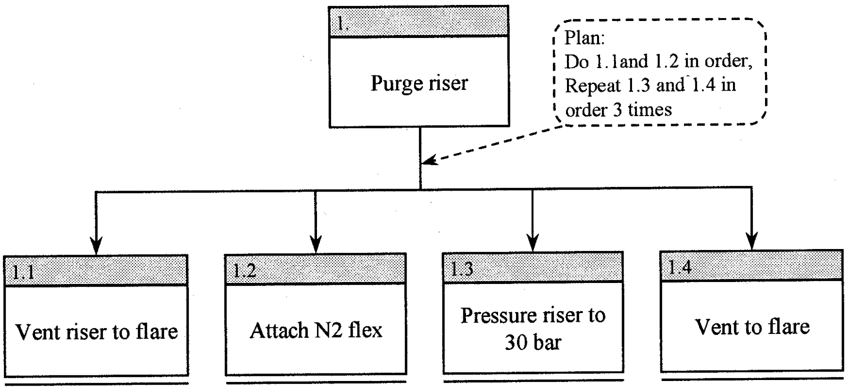

Figure 6: Sub-task Purge Riser for the Removal of the Gas Valve

Specific task: remove V 302 gas valve
Preconditions: well 1 shut in and depressured
Plan: Do 1 to 4 in order

1. Purge riser
   Plan: do 1.1 and 1.2 in order. Repeat 1.3 and 1.4 in order 3 times
   1.1 Vent riser to flare
   1.2 Attach N2 flex
   1.3 Pressure riser to 30 bar
   1.4 Vent to flare
2. Prepare valve for removal
   Plan: Do 2.1 to 2.2 in order
   2.1 Remove N2 flex
   2.2 Isolate valve
3 Ensure valve is hydrocarbon free
   Plan: Do 3.1 and 3.2 in order
   3.1 Attached gas analyser to sample point
   3.2 Ensure analyser shows hydrocarbon levels are below lower flammable limit
4 Remove valve
   Plan: Do 4.1 to 4.3 in order
   4.1 Remove securing bolts
   4.2 Lift valve off
   4.3 Fit blank

Task 2

Task: leak test equipment
Preconditions: equipment shutdown
Plan: Do 1 and 2 in order. Repeat 3 and 4 as required by test schedule. Then do 5

1. Line-up test medium
2. Line-up process
3. Pressure-up equipment to required pressure
4. Conduct leak test
5. Return equipment to normal status

From the top level HTA, and for the purposes of this case study, we identify this task as being medium criticality. This means further analysis is required and hence specific tasks must be identified. In this case one of the specific tasks is "Leak test gas compression module (GCM)."

The Depth of Analysis diagnostic questions from Table 4 and Appendix 1 are applied to identify which sub-tasks require further breakdown.

Sub-task	Applicable breakdown criteria	Description
1. Line-up test medium		
2. Line-up process	1	Change in configuration
3. Pressure-up equipment to required pressure	2	Change in operating conditions
4. Conduct leak test		
5. Return equipment to normal status		

For the purposes of this case study sub-tasks 2 and 3 are identified as requiring further analysis.

Specific task: leak test gas compression module (GCM)
Preconditions: equipment shutdown
Plan: Do 1 and 2 in order. Repeat 3 and 4 as required by test schedule. Then do 5

1. Line-up test medium
2. Line-up process
   Plan: Do 2.1 to 2.3 in order
   - 2.1 Start cooling water to all 3 stages of GCM
   - 2.2 Start-up GCM
   - 2.3 Line-up GCM on full recycle
3. Pressure-up equipment to required pressure
   Plan: Do 3.1 to 3.4 as each stage of the test is passed OK
   - 3.1 Pressure to 30 bar
   - 3.2 Pressure to 70 bar
   - 3.3 Pressure to 100 bar

    3.4 Pressure to 140 bar
4. Conduct leak test
5. Return equipment to normal status

Task 3

Task: Internally inspect electrical equipment
Preconditions: equipment shutdown, external inspection complete
Plan: Do 1 to 3 in order. Do 4 and 5 if required. Then do 6 and 7 in order

1. Isolate equipment
2. Remove cover
3. Inspect cables and terminals
4. Remove any moisture or contamination
5. Arrange or perform required repair
6. Replace cover
7. Make weatherproof

For the purposes of this case study, we identify this task as being low criticality. This means no further analysis is required.

Task 4

Task: water wash separator unit
Preconditions: separator unit operating normally
Plan: Do 1 and 2 in order. Do 3 continuously until water turns clear. Then do 4

1. Line-up wash water to separator
2. Start wash water and achieve required flow rate
3. Monitor wash water outlet for oil content
4. Return to normal status

From the top level HTA, and for the purposes of this case study, we identify this task as medium criticality. This means further analysis is required. In this case the generic task is performed for both the production separator and test separator so again specific analyses will have to be performed. For illustration only one is shown.

Once again the Production Task Breakdown criteria are to identify which sub-tasks require further analysis.

Sub-task	Applicable breakdown criteria	Description
1. Line-up wash water to separator		
2. Start wash water and achieve required flow rate	5	Monitoring and control
3. Monitor wash water outlet for oil content		
4. Return to normal status		

In this case sub-task 2 (that is where the "work-arounds" are required) is shown to require further breakdown.

Specific task: water wash production separator unit
Preconditions: separator unit operating normally
Plan: Do 1 and 2 in order. Do 3 continuously until water turns clear. Then do 4

1. Line-up wash water to separator
2. Start wash water and achieve required flow rate
   Plan: Do in order
   - 2.1 Put override on interface level trip
   - 2.2 Start wash water pump
   - 2.3 Open wash water inlet valve on separator
   - 2.4 Put water flow control valve on maximum in manual
3. Monitor wash water outlet for oil content
4. Return to normal status

Task 5

Task: Start-up N2 booster compressor
Preconditions: all maintenance work completed, equipment is de-isolated and energised
Plan: Do 1 to 4 in order. If all OK then do 5

1. Ensure all equipment is in good order
2. Prepare equipment for start-up
3. Start compressor
4. Ensure all equipment runs OK
5. Achieve normal operating conditions

For the purposes of this case study, we identify this task as Low Criticality. This means no further analysis is required.

5.2.3 Qualitatively Assess Risks Associated with Critical Tasks

PHEA is used to examine each task step to identify potential errors, their consequences and opportunities for recovery. In PHEA, a set of human error 'guide words' (analogous to those used in HAZOPs for hardware) is applied to each action in the tasks that have been identified as having a risk potential, on the basis of the Depth of Analysis criteria. A full list of these words is set out in the training material, but an example for action errors is given below:

Operation	Checking
Operation too late	Checking too late
Operation too early	Checking too early
Operation omitted	Checking omitted
Operation too much	
Operation too little/incomplete	
Operation in wrong direction	
Right Operation on wrong object	Right Check on wrong object

Some of these guide words are applied in the following PHEAs:

PHEA of remove V101 oil valve (Task 1).

Task step	Error	Description	Consequence	Recovery
Precon: Well shut-in	Precondition omitted	Well head still live	Hydrocarbon release	Task scheduling, PTW, local instruments
1.1 - 1.5: line-up	Right operation on wrong object	Flush not complete	Hydrocarbon release	Check in sub-task 3
3: HC test	Check omitted	Previous error not recovered	Hydrocarbon release	Procedure

This analysis identifies a number of high potential incidents and highlights its criticality.

PHEA of leak test as compression module (Task 2).

Task step	Error	Description	Consequence	Recovery
2.1: start cooling	Operation omitted	GCM failure	Operational	Procedural
3.1 - 3.4: pressure test	Operation too much	Overpressure	Hydrocarbon release	Local instrument, procedural
5: Return to normal	Operation omitted / incomplete	Not available for start	Operational	Procedural

This analysis identifies that errors committed during this task are mainly operations critical although there is the chance of a hydrocarbon release because of long-term degradation caused by overpressure during testing.

PHEA of internally inspect electrical equipment (Task 3).

Task step	Error	Description	Consequence	Recovery
1: isolate	Right action on wrong object	Equipment live	Electrocution	PTW
2: make weather-proof	Operation incomplete	Water ingress	Equip damage, operational	Procedural, equipment design

This analysis identifies that errors committed during this task have personal injury and operational consequences.

PHEA of water wash production separator (Task 4).

Task step	Error	Description	Consequence	Recovery
2.1: override	Right operation on wrong object	Wrong override used	System failure, hydrocarbon release	Design
4: return to normal	Operation incomplete	Override on, control on manual	System failure, hydrocarbon release	Design, procedural

This analysis identifies that errors committed during this task have potential systems implications with the possibility of hydrocarbon releases occurring.

PHEA of start-up N2 booster compressor (Task 5).

Task step	Error	Description	Consequence	Recovery
1: ensure all in good order	Operation incomplete	Required equipment not available	Equipment damage	Procedural
4: ensure runs OK	Operation incomplete	Damaged equipment operated	Equipment damage, operational	Procedural, instruments

This analysis identifies that errors committed during this task have mainly operational consequences.

5.2.4 Identify Risk Control Strategies

Having performed the above analyses the areas of risk associated with critical tasks have been identified. There are other aspects of a task, which are used to define the method of risk control to be employed. Typically these include the type of task (routine, non-routine or contingency), complexity and operator experience. For the purposes of this case study example risk control strategies have been developed.

Remove V101 oil valve (Task 1)

This is a highly critical, non-routine task. It is of a medium complexity and individuals only have a medium level of familiarity. From this assessment the most appropriate risk control strategy is:

- Review the design of the equipment to ensure the flushing and purging of the valve is as safe and simple as possible
- Ensure valves used are suitable for the duty so that the need for removal is minimised
- Any person performing the task has to have been trained on this specific task
- Trainees to learn this task as part of their on-the-job training programme
- Develop a competency assessment test to ensure personnel have understood the critical nature of the task
- Develop a job aid which summarises the main activities of the task
- A refresher training plan to be used during a tool box talk before the task is commenced

Leak test GCM (Task 2)

This is a medium criticality non-routine task. It is of medium complexity and individuals only have a medium level of familiarity. It does, however, involve the task of starting-up the GCM, which will need to be analysed to ensure all risk control measures are identified. From this assessment, the most appropriate risk control strategy is:

- Install interlocks to ensure equipment can not be started without auxiliary systems functioning
- Install over-pressure protection devices so that errors do not cause damage to equipment
- Any person performing the task has to have been trained in leak testing equipment but not necessarily specifically for the GCM
- Trainees to learn the leak test task on a number of different types of equipment
- If the person performing the leak test will also start the GCM they have to be competent, otherwise another, competent, person will be required to perform that part of the test
- Develop job aids which give information about test pressures as this is the most important information required when performing the task

Internally inspect electrical equipment (Task 3)

This is a low criticality, routine task. It is of low complexity and individuals will have a high level of familiarity. From this assessment the most appropriate risk control strategy is:

- Any person performing the task must have been trained in the internal inspection of all electrical equipment
- Trainees to learn the generic skills required to perform this task by what ever means are available
- To avoid complacency setting in, develop a risk awareness refresher programme
- Ensure equipment design is easy to weather proof thus minimising the risk associated with reinstated equipment failing due to water ingress

Water wash separator unit (Task 4)

This would normally be considered to be a low criticality contingency task performed in response to possible fouling in the separator. In this case the nature of the system introduces some additional risk. It is of a medium complexity and individuals will have a medium level of familiarity. From this assessment the most appropriate risk control strategy is:

- Change system design to prevent need to use override when performing this task
- Any person performing the task must have been trained in the generic task method for water washing but must have had specific training to cover the problems associated with this particular situation

- A job aid is to be developed to ensure the correct overrides are used and that they are removed after task completion

Start-up N2 booster compressor (Task 5)

This is a low criticality routine task. It is of medium complexity but because the task is performed sporadically some individuals have a high familiarity whilst for others this is only medium. From this assessment the most appropriate risk control strategy is:

- Train all personnel required to start the compressor in the specific task method
- Develop job aids which summarise the main activities to act as an aide memoir for the personnel who have lower familiarity
- Develop a system of updating operators' level of familiarity with the task to ensure that they do not slip into the low category because of the sporadic nature of the task performance
- Install trip systems to protect equipment if running incorrectly after start-up.

5.2.5 Incorporate the Results of Applying the Methodology into the Safety Case

The safety case could contain a summary of Sections 5.3 and 5.4, which will cover all critical tasks. This may include descriptions of systems put in place to manage the risks identified.

5.2.6 Case Study Conclusion

The case study illustrates the following benefits of the methodology:

- The criticality screening limits the amount of analysis required in a way that minimises effort whilst capturing essential factors
- The generic task inventories mean a certain amount of work has already been done to reduce the effort required in performing the analysis
- The analysis encourages the identification of systems failures, relevant to safety cases, whilst filtering out other factors which are relevant to other systems outside the safety case, such as occupational and operational consequences of incidents
- The methodology encourages and leads analysis of tasks so that risk control methods chosen are appropriate from a human factors point of view
- The results from applying the methodology are easily incorporated into the safety case, in a separate chapter, in a clear and concise format

Recommendations for Further Work

This project has developed a comprehensive methodology for addressing the human factors aspects of offshore Safety Cases. However, a number of possible areas of future research remain. These will be briefly set out in the following sections.

6.1 Validation and consistency testing

There is clearly a requirement to test the application of the methodology in a number of case studies. These need to cover the whole spectrum of installations that are currently covered in Safety Cases submitted to OSD. It is anticipated that these application studies will lead to further refinements of the methodology. An important aspect of this work will be to evaluate the consistency of analyses that are produced, to ensure that different review teams will produce similar results if they follow the structure set out in the methodology.

6.2 Extension of the scope of the methodology to assess other types of offshore tasks

Although the general structure of the present methodology should in theory apply to all types of offshore tasks, there are some important areas that will require specific Task Inventories and modifications of the existing analytical tools. Some examples of these areas are marine operations, lifting operations and helicopter operations. It is not envisaged that major resources will be required to extend the methodology to these areas.

6.3 Development of a combined process to address both occupational and major hazard risks

The present methodology has been developed to focus the review team on considering the contribution human error can make to high potential incidents. They aim to identify where errors act as an initiator of an accident, cause the failure of defences or prevent recovery from an incident. They do not, however, cover occupational safety issues which, although important and of interest to the industry in general, are not within the scope of HSE safety cases. A similar approach could however, be used to develop questions that covered this area. Such a combined technique, which addressed both occupational and technical risks, would probably be of considerable interest to the offshore industry, since injuries to personnel occur much more frequently, and have a very high profile in the industry. The possibility of addressing both aspects of risk in the same analysis would appear to be an attractive option from the point of view of the return on investment of resources.

There would be considerable benefits in ensuring acceptance of the methodology by offshore operators if it could be shown to address both occupational and major hazards as part of the same analysis. It would then be seen as providing benefits for the high profile area of personnel safety as well as satisfying HSE safety case requirements.

6.4 Trial Application and Revision of Training Course

As part of the present project, training materials have been developed to support a training course in the Safety Critical Tasks methodology. These training materials need to be applied in a prototype version of the course, and then updated on the basis of the feedback from this trial.

Appendix 1
User Guide for Production Tasks Methodology

Generic Production Task Inventory

Tasks shown in *italics* are not generic but are included here as prompts for the review team when performing an installation specific analysis.

Separation

Start-up following a controlled shut-down
Start / stop individual transfer / booster pumps
Start / stop chemical injection to separation
Start-up test separator
Open / close individual wells
Sample water
Blow-down sight-glass to sample oil
Change well from main to test separator
Increase / decrease well rate (choke setting)
Respond to separation trip caused by pressure, level or interface excursion
Clean separator vessel
Flush heat exchangers

Start-up individual vessels
Back-flush deoilers
Sand wash
Add non-routine chemicals
Change filters

Oil Export

Start Exporting
Shut-down well for wire-line
Pig export pipeline
Open export ESD valves
Sample export oil
Change over metering stream
Equalise well DHSV
Perform meter proving
Shut-down export pump

Change-over export pumps
Start-up booster pumps
Inject chemicals to export pipeline
Respond to metering errors
Back flush / clean turbine meters

Gas Dehydration

Start-up

Perform manual status changes
Start-up individual items of equipment
Top-up glycol system
Respond to changes in gas quality / quantity
Change filters
Flush heat exchangers

Gas Compression

Start-up
Start lube oil heater
Start Lube oil pump
Start individual motors
Commission fuel gas system
Start gas lift
Inject methanol / IMS
Blow down compressor casing drains
Adjust load
Change over filters
Stop one of two running compressors
Stop fuel gas
Stop gas lift

Start-up turbines
Water wash turbines
Drain scrubbers
De-ice blocked lines
Change fuel supply to turbines
Respond to surge
Flush heat exchangers

Vent, Flare, Blow Down, Closed Drains

Start-up
Light flare
Maintain liquid levels in KO drums
Vent process plant into system
Respond to low levels

Transfer liquid from KO drums
Sand wash KO drums
Change over duty pumps

Produced Water

Start-up
Start-up degasser
Start chemical injection
Adjust reject oil return to process
Respond to high / low oil
Respond to oil in water outlet

Start-up hydrocyclones
Start oil analyser
Sand wash pump

Injection

Start-up
Start individual feed pump
Start individual ejector pumps
Start individual booster pumps
Start individual injection pumps
Start chemical injection
Start individual lift pumps
Sample medium
Changeover ejector pumps
Respond to injection trip

Reroute filtration
Shut down filters

Utilities

Start-up instrument air

Change-over air filters
Respond to low pressure

Power Generation

Start-up
Change fuel
Put generation onto bars
Change-over lube oil filters whilst turbine online

Change intake filters
Steam Generation

Emergency Scenarios (all considered critical)

Respond to power failure
Respond to instrument air failure
Respond to hydraulic failure
Respond to ESD
Respond to Fire & Gas shutdown
All module trips (analysis to include knock-on effects)

Production Task Criticality Screening

Five questions are listed with definitions. Every question should be answered for every task on the task inventory being considered. Examples are included to guide the review team in assigning scores, this should not be considered as a definitive set of possible answers and some judgement is required. The scores from the questions are totalled in order to rank the criticality

Diagnostic	**Definition**	**Rating Guide and Score**		
		Low (1)	**Medium (2)**	**High (3)**
1. How hazardous is the system involved?	Task involves systems with intrinsically hazardous substances or conditions	Small amount of low hazard substance / condition	Large amount of low hazard or small amount of a high hazard	High amount of a high hazard / condition
2. To what extent are ignition sources introduced into / during the task?	Task uses or may produce heat, sparks or flames	Static spark or low current electrical supply	High current electrical supply, sparks from grinding	Flames for welding or cutting, internal combustion engines
3. To what extent does the task involve changes to the operating configuration?	Task involves valve moves, temporary connections, change to process flows.	Simple changes to valve process status.	Complex or multiple changes to valve and process status or temporary connections	Complex and multiple changes and temporary connections
4. To what extent could incorrect performance of the task cause damage?	Deviations from best practices may have detrimental effect on equipment integrity.	Equipment weakened with potential to cause damage in the long term.	Equipment requires repair but maintains integrity.	Equipment fails catastrophically.
5. To what extent does the task involve defeating protection devices?	Task requires bypass or override of indications, alarms or trips.	Disabling gauges, meters or electronic displays.	Disabling alarms.	Overriding trip systems or isolating safety valves.

Production Task Screening Score Sheet

Installation ________________________ Process Area ________________________ Page ________

Task	**Comments**	**Diagnostic Question Scores**						**Risk Ranking**	
		1	**2**	**3**	**4**	**5**	**Total**	**Preliminary**	**Final**

Task Score	9 – 15	8	5 – 7	4	0 – 3
Risk Ranking	High	Medium / High	Medium	Medium / Low	Low

Production Generic Task Screening Results

Task	Comments	Generic Scores						Risk Ranking
		1	2	3	4	5	Total	
Separation								
Start-up	From "Normal," not after trip, ESD etc.	3	0	1	2	3	9	H
Start / stop individual transfer / booster pumps	Assumed same risk, maybe different procedure	2	1	0	0	0	3	L
Start / stop chemical injection to separation		1	1	0	1	0	3	L
Start-up test separator		2	0	2	2	3	9	H
Open / close individual wells		3	0	1	1	3	8	H / M
Sample water		1	0	1	0	0	2	L
Blow-down sight-glass to sample oil		1	0	1	0	0	2	L
Change well from main to test separator		1	0	2	1	2	6	M
Increase / decrease well rate (choke setting)		3	0	1	1	0	5	M
Respond to separation trip caused by pressure, level or interface excursion		3	0	2	2	3	10	H
Clean separator vessel	Assumed vessel out of service	2	0	2	0	0	4	M / L
Flush heat exchangers		3	0	1	1	0	5	M
Oil Export								
Start Exporting		3	2	1	1	0	7	M
Shut-down well for wire-line		3	0	1	0	0	4	M / L
Pig export pipeline	Assumed all valves interlocked	3	0	3	2	0	8	H / M

Task	Comments	Generic Scores						Risk Ranking
		1	**2**	**3**	**4**	**5**	**Total**	
Open export ESD valves		3	0	1	0	0	4	M / L
Sample export oil		3	0	1	0	0	4	M / L
Change over metering stream		3	0	1	0	0	4	M / L
Equalise well DHSV		3	0	2	2	0	7	M
Perform meter proving		3	0	2	0	0	5	M
Shut-down export pump		3	0	1	0	0	4	M / L
Gas Dehydration	Assumed mol sieve beds with auto start and regeneration							
Start-up		3	0	2	0	0	5	M
Gas Compression	Assumed electric motors, no gas export							
Start-up		3	2	2	1	0	8	H / M
Start lube oil heater		1	1	1	2	0	5	M
Start lube oil pump		1	1	1	2	0	5	M
Start individual motors		1	2	0	2	0	5	M
Commission fuel gas system		3	0	1	0	0	4	M / L
Start gas lift		2	0	2	0	0	4	M / L
Inject methanol / IMS	Assumed only during start-up	1	0	1	0	0	2	L
Blow down compressor casing drains		2	0	2	2	0	6	M
Adjust load	Assumed no surge problem	3	0	1	3	0	7	M
Change over filters	Assumed plant shut down	0	0	0	0	0	0	L
Stop one of two running compressors		3	0	1	1	0	5	M

Task	Comments	Generic Scores						Risk Ranking
		1	2	3	4	5	Total	
Stop fuel gas	Assumed LP gas	2	0	1	0	0	3	L
Stop gas lift	Assumed HP gas	3	0	2	1	0	6	M
Vent, Flare, Blow Down, Closed Drains								
Start-up		3	0	2	0	0	5	M
Light flare		3	2	0	0	0	5	M
Maintain liquid levels in KO drums	Assumed gravity drain of drums	1	0	0	0	0	1	L
Vent process plant into system	Assumed during start--up	3	0	1	0	0	4	M / L
Respond to low levels		2	0	1	0	0	3	L
Produced Water								
Start-up		2	0	1	0	0	3	L
Start-up degasser		2	0	1	0	0	3	L
Start chemical injection		1	0	1	0	0	2	L
Adjust reject oil return to process		2	1	0	2	0	5	M
Respond to high / low oil		2	0	0	0	0	2	L
Respond to oil in water outlet		2	0	1	0	0	3	L
Water Injection								
Start-up		2	1	2	2	0	7	M

Task	Comments	Generic Scores						Risk Ranking
		1	2	3	4	5	Total	
Start individual feed pump		2	1	2	2	0	7	M
Start individual ejector pumps		2	1	2	2	0	7	M
Start individual booster pumps		2	1	2	2	0	7	M
Start individual injection pumps		2	1	2	2	0	7	M
Start chemical injection		2	1	2	2	0	7	M
Start individual lift pumps		2	1	1	0	0	4	M / L
Sample water		2	1	0	0	0	3	L
Changeover ejector pumps		2	1	1	2	0	6	M
Respond to water injection trip		2	0	1	0	0	3	L
Utilities								
Start-up instrument air		1	1	1	2	0	5	M
Power Generation								
Start-up		3	3	1	2	0	9	H
Change fuel		3	3	2	2	0	10	H
Put generation onto bars		3	3	1	1	0	8	H / M
Change-over lube oil filters whilst turbine online		1	1	1	0	0	3	L
Emergency Scenarios	All considered to be high criticality							

Task	Comments	Generic Scores						Risk Ranking
		1	2	3	4	5	Total	
Respond to power failure		▨	▨	▨	▨	▨	▨	H
Respond to instrument air failure		▨	▨	▨	▨	▨	▨	H
Respond to hydraulic failure		▨	▨	▨	▨	▨	▨	H
Respond to ESD		▨	▨	▨	▨	▨	▨	H
Respond to Fire & Gas shut-down		▨	▨	▨	▨	▨	▨	H

Production Task Depth of Analysis Criteria

Criteria Type	Criteria	Description	Examples
System	1. Changing operating configuration of system / sub-system	Changing the configuration of systems containing, or that have contained, flammable or toxic substances.	• Changing separator set points
System	2. Changing operating conditions.	Changes in operating conditions with the potential to approach or exceed operating limitations possibly resulting in plant damage or deterioration.	• Changing separator mode from stabilised crude to semi-stabilised crude (pressure change).
System	3. Establishing or defeating safety critical / protective systems.	Sub-tasks involving the activation of safety critical / protective systems from a non-operational or defeated state. Sub-tasks that involve defeating safety critical / protective systems that would otherwise prevent or hinder the successful completion of a task.	• Removing override on interface level trip during separator water wash.
System	4. Removing or minimising the presence of hazardous substances and conditions.	Sub-tasks that involve the purging, venting or flushing of flammable or toxic materials. Sub-tasks involving the depressurisation high pressure systems.	• Purging gas compressor during start–up.
Human Interaction	5. Monitoring and control	Sub-tasks involving monitoring and control of critical operational parameters.	• Monitoring separator levels on production start-up.
Human Interaction	6. Potential to damage equipment.	Potential for errors committed whilst performing the task to cause a direct, delayed or knock on system failure.	• Valves in high pressure flow lines left in closed position during start-up.

Appendix 2
User Guide for Well Operations Tasks Methodology

Generic Well Operations Task Inventory

Making Hole / Clearing Hole

Drilling
Coring
Milling or Drilling Junk / Shoe track
Milling casing window / stub

Pumping Activities

Mixing / Treating mud
Pumping / Circulating mud
Pressurising well / hole
Pumping / Circulating cement slurry
Pumping acid

Hoisting Activities

Running drill string / work string
Retrieving drill string / work string
Running casing
Retrieving casing
Running Liner
Retrieving Liner
Running well completion
Retrieving well completion

Reeling Activities

Tripping coiled tubing
Running / retrieving thru DP tools
Logging
Setting casing packers and plugs
Perforating
Running / retrieving thru-tubing tools

Surface / Seabed activities

Installing / removing guide base
Installing /removing template
Driving conductors
Installing / removing BOP stack

Installing / removing wellhead components
Producing well for testing purposes
Skidding rig

Contingency Activities

Combating circulation losses
Combating gas-cut mud
Pumping / circulating through choke
Snubbing drill string / work string
Stripping drill string / work string
Safeguarding well in response to equipment failure
Safeguarding well in response to adverse weather

Well Operations Task Screening

Five questions are listed with definitions. Every question should be answered for every task on the task inventory being considered.

Task Characteristic	Rating Guide and Score		
	Low (1)	**Medium (2)**	**High (3)**
1 - Interaction with subsurface hydrocarbon reservoirs	Task does not usually involve interaction with open reservoirs	Task may involve direct interaction with open reservoirs but pressure and other characteristics are reasonably well known	Task may involve direct interaction with newly penetrated reservoirs
2 - Interaction with well pressure barriers	Task is not interacting directly with any barriers or involves a negligible chance to remove the normal barriers	Task is carried out with all normal barriers in place but could potentially cause the removal of one	Task is carried out with at least one of the normal barriers removed or seriously affected
3 - Person-to-person communication	One line of communication (2 people) with many opportunities for clarification and/ or recovery.	More lines of communication relating to more important information with some opportunities for clarification and/or recovery.	Many lines of communication relating to critical control parameters with few opportunities for clarification and/or recovery.
4 - Complexity	Highly practised tasks requiring little or no conscious effort.	Tasks performed less frequently involving more conscious effort and some decision making based on known situations and solutions. *OR* – Lengthy routine tasks with many steps involving some conscious effort.	Tasks performed infrequently involving intense conscious effort, more decision making and possible problem solving in unfamiliar or highly stressful situations.
5 - Monitoring and control	System shows slow rate of change. Intermittent monitoring involved that does not require fine control.	System shows higher rate of change. More frequent monitoring requiring more attention to control.	System shows high rate of change. Continuous monitoring requiring fine control.

Well Operations Task Screening Score Sheet

Installation ______________________ Process Area ______________________ Page ________

Task	Comments	Diagnostic Question Scores						Risk Ranking	
		1	2	3	4	5	Total	Preliminary	Final

Task Score	14 - 15	12 - 13	10 - 11	8 - 9	5 - 7
Risk Ranking	High	Medium / High	Medium	Medium / Low	Low

Generic Well Operations Task Screening Results

Task	Comments	Diagnostic Question Scores						Risk Ranking
		1	2	3	4	5	Total	
Making Hole / Clearing Hole								
Drilling	Circulating, rotating, adding singles	3	2	2	2	2	11	M
Coring	Circulating, rotating, adding singles	3	2	1	2	2	10	M
Milling or Drilling Junk / Shoe track	Circulating, rotating	1	1	1	1	2	6	L
Milling casing window / stub	Circulating, rotating, adding singles	1	2	2	2	2	9	M / L
Pumping Activities								
Mixing / Treating mud	Circulating through surface system	1	1	1	2	1	6	L
Pumping / Circulating mud	Conditioning hole / mud	2	1	2	2	2	9	M / L
Pressurising well / hole	Integrity, leak-off tests, squeezing, fracturing	1	2	2	2	3	10	M
Pumping / Circulating cement slurry	Placing slurry downhole	2	2	2	1	2	9	M / L
Pumping acid	Placing acid downhole	2	2	2	2	2	10	M

Task	Comments	Diagnostic Question Scores						Risk Ranking
		1	2	3	4	5	Total	
Hoisting Activities								
Running drill string / work string		2	2	2	1	3	10	M
Retrieving drill string / work string		3	2	2	1	3	11	M
Running casing		2	3	1	1	2	9	M / L
Retrieving casing		2	3	1	1	2	9	M / L
Running Liner		2	2	1	1	2	8	M / L
Retrieving Liner		2	2	1	2	3	10	M
Running well completion		2	2	2	2	3	11	M
Retrieving well completion		2	3	2	2	2	11	M
Reeling Activities								
Tripping coiled tubing		2	3	2	3	2	12	M / H
Running / retrieving thru DP tools		2	3	1	2	2	10	M
Logging		3	2	1	1	2	9	M / L
Setting casing packers and plugs		2	3	1	2	2	10	M
Perforating		2	3	3	3	3	14	H
Running / retrieving thru-tubing tools		2	2	2	2	2	10	M

Task	Comments	Diagnostic Question Scores						Risk Ranking
		1	2	3	4	5	Total	
Surface / Seabed activities								
Installing guide base		1	1	1	2	1	6	L
Installing template		1	1	1	2	1	6	L
Driving conductors		1	1	1	2	2	7	L
Installing BOP stack		1	1	1	2	1	6	L
Installing wellhead components		1	2	1	2	1	7	L
Producing well for testing purposes		3	2	2	2	2	11	M
Skidding rig		1	1	1	2	2	7	L
Contingency Activities								
Combating circulation losses		3	3	2	1	2	11	M
Combating gas-cut mud		3	3	2	2	3	13	M / H
Pumping / circulating through choke	Kick control, well kill	3	3	3	3	3	15	H
Snubbing drill string / work string		3	3	3	3	3	15	H
Stripping drill string / work string		3	3	2	3	2	13	M / H
Safeguarding well in response to equipment failure		3	3	3	1	3	13	M / H
Safeguarding well in response to adverse weather		3	2	3	3	3	14	H

Drilling Task Depth of Analysis Criteria

Criteria Type	Criteria	Description	Examples
System	1. Controlling pressure.	Sub-tasks involving pressurising, depressurising and bleeding operations.	• Pressurising formation. • Controlling the expansion associated with gas migration.
System	2. Potential to reduce overbalance.	Potential for errors committed whilst performing the task or for effects associated with the task to lead to an undesired reduction in overbalance.	• Cementing (setting effect) • Filling hole when retrieving • Cementing production liner (circulating low density spacer near formation)
System	3. Establishing and testing safety critical/ protective systems.	Activation of specific safety critical / protective systems from a non-operational or defeated state.	• Lining up correctly to a trip tank • Ensuring choke manifold lined up for a kill.
Human Interaction	4. Detection - Action	Sub-tasks involving anticipated critical conditions that require detection followed by a known appropriate action.	• Anticipated Pressure changes indicating when to stop pumping during a well kill
Human interaction	5. Monitoring and control	Sub-tasks involving monitoring and control of critical operational parameters.	• Monitoring trip tank returns when retrieving. • Monitoring and controlling drilling torque

Appendix 3
Additional Information Concerning Well Operations

Rig Systems

In generating the well operations generic task inventory it has been assumed that the following systems are present on most rigs. Where other well operation systems exist it will be necessary to identify additional tasks to be added to the inventory. Other system, such as utilities, will also exist on most rigs but these have not been considered as they are not part of well operation.

- Main hoisting system: draw works, drilling cable, blocks and pipe handling and make-up equipment
- Pipe storage system: piperacks, fingerdecks etc.
- Rotating systems: rotary table and top drive
- HP mud system: HP mud pumps and pipework
- LP mud system: mud tanks and mixing or transfer equipment
- Solids removal system: shakers, centrifuges, desilters, desanders, degasser etc.
- BOP system: diverter, BOP stack, riser, chokelines and choke manifold
- Bulk mud system: bulk silo and pipework for mud additives, including bulk air system
- Bulk cement system: bulk silo and pipework for cement, including bulk air system
- Chemical storage system: non-bulk mud and treatment chemicals
- Cementing system: cement unit and pipework, including bulk air system
- Secondary hoisting system: braided wire and draw works winch
- Conductive wire system: logging winch and auxiliary equipment
- Piano wire system: wireline unit and winch, and auxiliary equipment
- Coiled tubing system: coil, injector head, CT BOP's and auxiliary equipment
- Production test system: flowhead, temporary separating facilities, temporary flares
- Conductor driving system: hammer and auxiliary equipment
- Derrick skidding system: winches, hydraulic units etc.

Well Operation System States

In discussing the intrinsic hazard of well operations seven system states were identified. Tasks performed during these system states have a similar potential to cause kick and blow-out scenarios through direct and indirect routes. These system states may be useful when comparing the criticality of specific tasks with those listed in the generic task inventory.

Kick Control

Kick control undoubtedly represents the most safety critical system state encountered in drilling operations. A kick has entered the well and has started rising to surface (migration) due to the formation pressure overcoming the pressure exerted on the formation by the well bore fluid. The circulation system must be shut-down and the well shut-in to slow the rate of migration. The kick must then be carefully controlled as it is circulated out of the system. Without this control, the pressure exerted by a kick will increase with the potential to damage containment barriers (casing and BOP) that can exacerbate the kick or induce blow-out. Kick control refers to activities associated with controlling kick conditions and then re-establishing normal well control operations.

Drilling and Coring

Drilling and coring consist of the same generic activities associated with cutting into formation. As risk is increased when cutting into hydrocarbon bearing formation, this was taken as the default condition. The intrinsic hazards associated with drilling and coring are encountering pockets of high-pressure gas, which directly induce kicks, and the potential for the cutting action to effect loss of circulation that is a precursor to a kick. Another intrinsic hazard is presented when making connections. This involves stopping circulation and disconnecting the top drive. Stopping circulation effectively removes a defence in the form of the equivalent circulation density (ECD) which reduces the hydrostatic overbalance. The point at which the ECD is lost has the potential to directly induce a kick. Disconnecting the top drive also effectively opens the well through the centre of the drill pipe, as the kelly cock is no longer available for isolation in the event of a kick. Although a stab-in valve is available for isolation purposes, it must be physically inserted into the top of the drill pipe. An alternative course of action would be to reconnect the drill pipe to the top drive.

Retrieving

Retrieving refers to the process of lifting long lengths of connected sections of 'pipe' completely out of the well. Although the drilling term '*retrieving*' usually describes the lifting of drill pipe out of the well it has been used generically in this context to describe the lifting of any 'pipe' including casing and test string.

Circulation must be stopped before retrieving. Retrieving operations are repetitious in nature as single sections, or stands, of tubing are lifted into the derrick using the elevators. Before another section can be lifted, the connection joining the two sections must be broken and the single section removed from the drill string.

Retrieving is particularly hazardous as it has the potential to directly induce kicks through the 'swabbing' effect. This describes the tendency for well fluid to be sucked into the volume left behind by tubing as it is lifted up the well. This ingress of fluid exerts a domino type effect extending back to the formation fluids that influx into the well (kick). The magnitude of the swabbing effect depends on what is being lifted and the manner in which it is lifted. Another hazard with the potential to directly induce kicks is the failure to fill the hole while retrieving. As 'tubing' is pulled from the hole the mud level drops due to the volume of pipe being removed. As the mud level drops the hydrostatic pressure may be reduced enough to lose primary well control. Tripping–out operations are therefore carefully monitored and controlled. Increased sensitivity to potential influxes is obtained by using the trip tank compared to the pit tank used during normal circulating operations.

In common with running, 'tubing' is unlikely to be on or near the bottom of the well if a kick occurs. In this situation the system is more vulnerable as well kill operations require the 'tubing' to be at or near the bottom of the well in order to be effective. Stripping-in would be required if circumstances allowed.

Another intrinsic hazard is presented when breaking connections. This has also been identified under 'Drilling and Coring' which includes the adding of singles. In both cases circulation is stopped and the top drive is disconnected. Stopping circulation removes the ECD that can potentially induce kicks and disconnecting the top drive opens the well.

Circulating

Circulating refers to any system that solely involves circulating fluids though the well. Circulating can involve a variety of different fluids such as mud, cement and sea water and can be done for a number of different purposes such as testing, cleaning, treating and cementing. The intrinsic hazard associated with circulating is pressure. Excessive pressures can result in losses of circulating fluid that can indirectly lead to kicks. Although drilling can be seen to involve circulating, it also involves cutting into hydrocarbon bearing formation which represents a different combination of intrinsic hazards and therefore a different generic task (i.e. Drilling & Coring).

Closed in pressurising

This system state involves the planned shut-in of the BOP in contrast to the 'kick control' system state that involves the unplanned shut-in. Pressure is purposely applied to the well representing an intrinsic hazard with the potential to lose circulation fluids and damage containment barriers such as casing and BOP. Risk, however, is limited when pressurising the well, as this operation is always performed under controlled conditions. Most tasks associated with this system state involve testing.

Running

Running refers the process of lowering long lengths of connected sections of 'tubing' down the well. As for *'retrieving'*, the term *'running'* is being used in a generic context to describe the lowering of any 'tubing' into the well, such as casing and test string, and not just drill pipe.

Circulation must be stopped before running. Running operations are repetitious in nature as single sections of tubing are run one at a time using the top drive. Before another section can be run it must be connected to the top of the previous section, which involves disconnecting from the top drive.

Running is associated with the intrinsic hazard of 'surging' that can indirectly induce kicks through losses of circulation fluids. Although the surging effect is considered an important hazard, it is less hazardous than the swabbing effect, associated with tripping–out operations, that has the potential to directly induce kicks. Running operations are also carefully monitored and controlled. Increased sensitivity to potential losses of circulating fluids and influxes results from using the trip tank rather than the pit tank used during normal circulating operations. Tripping speed directly affects surging and must be carefully controlled. The magnitude of the surging effect depends on what is being tripped-in and the manner in which it is being tripped-in.

Making connections while running introduces the same intrinsic hazard (i.e. loss of ECD) as already identified under 'Drilling and Coring' and 'Retrieving' system states. Again, in common with retrieving, both system states are relatively vulnerable to the occurrence of a kick as the 'tubing' is unlikely to be at or near bottom, which limits the effectiveness of the well, kill techniques.