Model code of safe practice
Part 17 Volume 1

High pressure and high temperature well planning
ENERGY INSTITUTE

MODEL CODE OF SAFE PRACTICE IN THE PETROLEUM INDUSTRY

PART 17: VOLUME 1
HIGH PRESSURE AND HIGH TEMPERATURE (HPHT) WELL PLANNING
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Norman Day                      BP Exploration Operating Company Ltd
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Steve Mellor                    Rowan Drilling & IADC Liaison
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FOREWORD

Volume 1 of the Model Code of Safe Practice Part 17 has been developed as a guide for those concerned with the planning of high pressure and high temperature offshore wells. It covers those activities associated with HPHT wells which have an impact on safety offshore and therefore require special care and attention. The contents should be viewed as the minimum good practice to be applied in order to achieve a safe working environment in HPHT operations.

Production of this additional volume to Part 17 was commissioned in response to the requirements of the UK industry for the scope of the Model Code to be expanded to include planning. Good planning is also important for reducing commercial risk as well as being the first stage in the assurance of safety during the drilling and completions phases.

Guidance provided in this Model Code should be considered as a starting point for the operators and drilling contractors in developing the work programme and associated operational plans for HPHT wells. While this Model Code provides good industry practice, each operator and drilling contractor should review and apply the guidance to its own policies and experience for the particular area of operation.

The Model Code has been developed in a United Kingdom Continental Shelf (UKCS) context of HPHT well operations; however, its guidance is universally applicable provided it is read, interpreted and applied in conjunction with relevant national and local statutory legislation and publications (codes of practice, design standards, specifications, recommended practices, guidance, etc.). Where requirements differ, the more stringent should be adopted. In addition, readers should take account of developments in legislation and publications which have been issued since this Model Code was published.

Although the adoption of this publication should help to promote safe well planning practice, the Energy Institute and the technical representatives listed in the Acknowledgements cannot accept responsibility in any way for injury to personnel or damage to equipment, installations or property which may arise from the use of any of the information contained in this Model Code.

This Model Code forms Volume 1 of Part 17 of the Model Code of Safe Practice. It complements two further volumes: Volume 2 Well Control During the Drilling and Testing of High Pressure High Temperature Wells and Volume 3 High Pressure and High Temperature Well Completions and Interventions. Each volume examines safe practice in a specific context; however, reference should be made to the other volumes for relevant information in other contexts.
INTRODUCTION

This Model Code provides guidance on good practice for those planning high pressure high temperature (HPHT) wells. High pressures and temperatures can encroach on the limits of available equipment, materials and fluids leaving little margin for error; adhering to good practice will help ensure that all operations are conducted in a safe and proper manner. However, the conditions of HPHT restrict the choice of equipment, which in turn may place constraints on the well design to all but the most basic and simplest form. For safe, successful planning with designs that are fit for purpose, rigorous attention to detail to every aspect of the planning operation is essential.

In general, operations involving HPHT wells carry much higher risk. Fundamentally the possibility of integrity failures and the consequence of these failures are much greater when working in high energy environments. Risk factors can combine to create complex and serious threats to well operations; these could include the erosion of HS&E margins with a corresponding increase in the risk in loss of well control, loss of the well itself, injuries, fatalities, environmental damage and of damage to economics and business reputation.

It is a principle of Health and Safety legislation in the UK that risks relating to health and safety are reduced to as low as is reasonably practicable (ALARP). Therefore it is essential that risks relating to all HPHT well operations are identified, evaluated and reduced as required under ALARP principles and that this process should begin at the planning stage. These risks must also be communicated to all parties involved including management, service providers, designers, safety advisors and environmental advisors.

Compliance with international, national and regional laws, statutory instruments and regulations is imperative. Liaison with legislative, fiscal and regulatory stakeholders should be given a high priority from the beginning. Both company and contractor policies and procedures should be reviewed for their suitability for operating within the HPHT environment.

The selection and procurement of equipment, materials, people, products and services can prove demanding by extending lead and planning times and these issues should be factored into the well planning process. The range of tool choice for HPHT conditions is much smaller and the high specification needed for materials and equipment may not be readily available or, in some circumstances, not yet designed.

In this introductory section the risk management processes and their importance to HPHT well planning are described. Risk management should be an integral and continuous process throughout well planning, design, procurement and operations. A robust, systematic risk management system should be in place with full documentation of each step in the process. This will help to demonstrate that the ALARP principle has been achieved. It will also assist in the communication of HPHT risks to management and others, emphasising the company’s duty of care.
1.1 HPHT DEFINITIONS

High Temperature in this context can be defined as when the undisturbed bottom hole temperature is greater than 149°C (300°F).

High Pressure can be defined as either the maximum pore pressure of any porous formation that exceeds a hydrostatic gradient of 0,18 bar/m (0,8 psi/ft) (representing an equivalent mud weight (EMW) of 1,85 SG or (15,4 ppg) or, needing deployment of pressure control equipment with a rated working pressure in excess of 690 bar (69 MPa, 10 000 psi).

Note that areas of high pressure (abnormal pressure) need not necessarily be accompanied by high temperatures and vice versa.

1.2 HEALTH SAFETY AND ENVIRONMENT (HS&E)

When planning an HPHT well, health, safety and environment (HS&E) should be considered the primary value driver. Therefore, HS&E considerations should have the highest priority and weighting which should be factored into the work flow.

1.3 ALARP

It is a principle of UK Health and Safety Law that risks to persons are reduced to as low as is reasonably practicable. This is commonly referred to by the acronym ALARP.

A demonstration of ALARP should cover all HPHT projects and associated components, systems and HSEMS (health, safety and environmental management system). All phases of the project should be assessed and managed such that the residual risks can be demonstrated as being ALARP.

The means of demonstrating ALARP is through the risk assessment process. The aim is to identify and rank the risks so that they can be adequately managed. The basic steps of the risk assessment process are: hazard identification, risk estimation and ranking, risk evaluation and reduction and a continuous review process. Each stage of the risk assessment should be seen as an opportunity to identify and reduce risk.

1.4 HAZARD IDENTIFICATION

Hazard identification must be a comprehensive and systematic process that is likely to involve one or more of the following methods:

- **HAZID** (hazard identification) is a high level systematic assessment of a system using guidewords to help identify potential hazards.

- **HAZOP** (hazard and operability) takes a full description of a process system and questions every part of it to discover what deviations might occur and what the causes and consequences of these deviations might be. [Ref: Hazard and Operability Studies (HAZOP) – Application Guide BS IEC 61882:2001].

- **FME(C)A** (failure mode and effects (critical) analysis) is a qualitative reliability technique for the systematic analysis of each possible failure mode within a hardware system. It also identifies the resulting effect on that system, mission and personnel. Critical analysis (CA) ranks failure modes according to their probability and consequences. [Ref: Reliability of Systems Equipment and Components Part 5. Guide to Failure Modes, Effects and Criticality Analysis (FMEA and FMECA) BS 5760-5 1991].

1.5 RISK ESTIMATION

Risk estimation entails assessing both the severity (consequences) and frequency (likelihood) of hazardous events. The detail and effort required to perform this increases from qualitative (Q) to semi-quantitative (SQ) to quantified risk assessment (QRA). One or all of these techniques may be applied to components within a system. Selecting which technique to apply to a component will depend on criticality, complexity, field proven reliability and the availability of suitable numerical databases.

1.6 RISK REDUCTION

Risk reduction is an integral part of the process to determine if more needs to be done. It involves an iterative loop that re-evaluates the risk to measure the improvement. A hierarchical approach to effective risk reduction is:

- Elimination/minimisation through design.
- Prevention (reduce likelihood).
- Detection.
- Control.
- Mitigation of consequences.
- Evacuation, escape and rescue.


INTRODUCTION

1.7 RISK EVALUATION

The process of risk evaluation starts with the highest risk and proceeds down the ranked list of identified potential risks until it is evident that no further risk reduction measures can be justified.

1.8 DEMONSTRATING ALARP

Reducing risk to 'ALARP' is a sound engineering principle and should be considered good engineering practice regardless of legislative requirement. The reduction of risk is a necessary and vital process in all engineering projects. Formalising this process can bring many benefits. The demonstration of ALARP within a risk management framework can be achieved through a combination of several established methods. The interaction between these methods is simply illustrated in Figure 1. [Ref: Industry Guidelines on a Framework for Risk Related Decision Support, Oil & Gas UK (UKOOA)].

Figure 1 clearly illustrates the role, for example, of recognised codes and standards in dealing with risk and demonstrating ALARP. The role of risk analysis techniques can be seen as providing a contribution to this risk picture at the appropriate level.

Overall risk management uses a combination of tools and techniques to achieve the goal of ALARP. There are numerous analysis and evaluation techniques that have been developed in addition to those previously mentioned. These include:

- Fault tree analysis.
- Event tree analysis.
- What-if analysis.
- Checklists.
- Cost benefit analysis.
- Human factor risk assessments.
- Health risk assessments.
- Preliminary hazard assessments.
- Job hazard assessments.
- Physical effects modelling.
- Safety integrity level (SIL) evaluations.
- Layers of protection analysis (LOPA).

![Figure 1: Criticality Awareness Framework](image)

---

3
Expert advice should be sought in selecting the techniques to be used to ensure the most applicable technique is used for the circumstances. [Ref: Recommended Practice for Design and Hazard Analysis for Offshore Production Facilities, API RP14J; Petroleum and Natural Gas Industries – Offshore Production Installations- Guidelines on Tools and Techniques for Hazard Identification and Risk Assessment, BS EN ISO 17776:2002.]

1.9 REVIEW

The review process is a key component of any risk management system. Periodic reviews should be performed and when significant changes in the well design occur that affect the risks.

Any remedial measures adopted should and will change the relative risk ranking. The review process ensures that the changing risk priorities are understood and communicated.

Management of change (MOC) is a relevant and important component of the review process which is dealt with under a separate heading.

1.10 MANAGING THE ENGINEERING PROCESS

Risk management must be an integral part of the engineering process. Other key components of the engineering process are: establishing objectives, establishing early communication with all stakeholders and establishing an appropriate work group which should include: sub-surface, drilling, completion, production and facilities disciplines. Planning must have input from these disciplines and influence engineering design if completion, production and operational compromises are to be avoided.

1.11 MANAGEMENT OF CHANGE

Management of change is a fundamental element of the project development process and contributes to the demonstration of ALARP. The change management process should be clearly documented, understood and should:

— Identify triggers that initiate the management of change process.
— Record the causes of the change during all phases of the development of the design through to operation.
— Record and evaluate the change and ensure the evaluation includes technical, HS&E and commercial considerations such as to allow the demonstration of risk reduction to ALARP.
— Ensure that the change is process executed by suitably experienced and competent assessors.

Changes or deviations should be assessed fully and communicated to all stakeholders. These changes may impact on the safety case and those that affect the project schedule critical path may impact on lead times and material supply. All new components, replacements or changes in execution of the well plan should be assessed for risk, consequences and impact on other equipment, with any resulting impact on documented HS&E.

Late changes, change encountered during operations for example, can be the most difficult to process given time constraints. The same rigorous process should be applied. Short cutting the process at this stage has led to many difficulties and failures.

Due to the complex, higher risk nature of HPHT wells a health, safety and environment impact assessment will be needed for each change. Change can introduce new risks and the identification, evaluation and reduction process should be rigorously applied. This may involve additional testing, modelling and analysis of the new component, process or procedure as an integrated part of the system. Such activities should be thoroughly documented as part of the change management process including any analysis, testing, input from lessons learnt, implementation of good practice, codes or standards.

It is imperative that management of change covers the approval and communication process.

1.12 TRAINING

For personnel involved in HPHT planning the following should be addressed:

— Levels of experience.
— A formal competency system for well design personnel.
— Training short term staff in the prevailing company management system.

In addition to any specialist technical training requirements, it is recommended that personnel involved should:

— Be aware of the installation safety case.
— Be familiar with company policies and procedures.
— Be familiar with local legislation, regulation and guidelines, including company policy and procedure.
— Be aware of the impact that other engineering restraints may have on their responsibilities.
— Fully understand the well control issues.
— Be fully conversant with the objectives of the project.
— Understand the nature of the HPHT environment in the well, its constraints and limitations on materials and operations.
— Understand the impact of uncertainties on well planning and design.

In general those involved in HPHT well planning should be experienced and of the highest calibre.

1.13 REFERENCES AND FURTHER READING

Hazard and Operability Studies (HAZOP) – Application Guide; BS IEC 61882:2001

Reliability of Systems Equipment and Components Part 5, Guide to Failure Modes, Effects and Criticality Analysis (FMEA and FMECA); BS 5760-5: 1991

Industry Guidelines on a Framework for Risk Related Decision Support; Oil & Gas UK (UKOOA)

Recommended Practice for Design and Hazard Analysis for Offshore Production Facilities; API RP 14J


Websites:

www.hse.gov.uk/offshore (general)

http://stepchangeinsafety.net (general)

www.hse.gov.uk/risk/theory/alarp.htm (ALARP)

www.ptl.no (Petroleum Safety Authority, Norway)

www.irfoffshoresafety.com (International Regulators Forum)
Model code of safe practice
Part 17 Volume 2

Well control during the drilling and testing of high pressure, high temperature offshore wells

2nd edition
ENERGY INSTITUTE

MODEL CODE OF SAFE PRACTICE IN THE PETROLEUM INDUSTRY

PART 17: VOLUME 2
WELL CONTROL DURING THE DRILLING AND TESTING OF HIGH PRESSURE, HIGH TEMPERATURE OFFSHORE WELLS

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The Steering Group comprised the following members:

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FOREWORD

Volume 2 of Model Code of Safe Practice Part 17 has been developed as a guide for those concerned with well control during the drilling and testing of high pressure and high temperature (HPHT) offshore wells. It provides guidance on those well control activities associated with HPHT wells which have an impact on safety offshore, and therefore require detailed care and attention.

This 2nd edition replaces the original version published in 1992. The revision was commissioned in response to the requirements of the UK industry for the Model Code to include updated changes to equipment and procedures that supersede those referenced in the original publication. The Model Code now includes an Introduction that sets out the additional corporate and legislative demands on company systems and their personnel for improved safety performance through additional emphasis on risk evaluation and mitigation and application of as low as reasonably practicable (ALARP) principles. The revision exercise has also provided an opportunity to incorporate where appropriate, the valuable operational experience gained in the UK Continental Shelf (UKCS) over recent years.

Guidance provided in this Model Code should be considered as a starting point for the operators and drilling contractors in developing the programme and associated operational plans and procedures for drilling and testing a HPHT well. While this Model Code provides good industry practice, this is only a starting point: each operator and drilling contractor should review and apply the guidance provided in this Model Code according to its own policies and experience for the particular area of operation.

The Model Code has been developed in a UKCS context of HPHT well drilling and testing; however, its guidance is universally applicable provided it is read, interpreted and applied in conjunction with relevant national and local statutory legislation and publications (codes of practice, design standards, specifications, recommended practices, guidance, etc.). Where the requirements differ, the more stringent should be adopted. In addition, readers should take account of developments in legislation and publications which have been issued since this Model Code was published.

For the purpose of this publication, definitions of pertinent terms and abbreviations which are in common usage in the oil and gas industry are given in Annex F: these apply irrespective of any other meaning they have in other connections.

Although the adoption of this publication should help to promote safe well control practice, the Energy Institute and the technical representatives listed in the Acknowledgements cannot accept responsibility in any way for injury to personnel or damage to equipment, installations or property which may arise from the use of any of the information contained in this Model Code.

The Model Code forms Volume 2 of Part 17 of the Model Code of Safe Practice. It will be complemented by two further volumes which are under technical development with publication expected in 2008/9: Volume 1 – HPHT well planning (provisional title) and Volume 3 – HPHT well completions and interventions (provisional title).
INTRODUCTION

This code is intended to provide guidance for those planning and managing operations relating to 'high pressure high temperature' (HPHT) well construction. It is intended to assist in identification and assessment of risk and risk mitigation that may be required, and to help demonstrate that the ALARP principle has been achieved.

It is a principle of Health and Safety Legislation in the UK that risks of personal injury are reduced to 'as low as reasonably practicable' (ALARP). Therefore, it is imperative that risks involved in HPHT well operations are clearly communicated to everyone involved, including management, service providers, designers, and safety and environmental advisors.

It is also imperative to comply with all relevant international, national, and regional laws, statutory instruments and regulations. Therefore liaison with legislative, fiscal, and regulatory stakeholders is paramount and should be given high priority from day one. Attention to detail is needed throughout when planning, designing, drilling, testing, and operating HPHT wells. Both company and contractor policies should be reviewed for their suitability for operating within an HPHT environment.

Also important is that appreciation of the lead times that are often required for the selection and procurement of a suitable drilling facility, associated safety critical equipment, people, products, and services can prove demanding and can greatly extend the time needed for planning.

This publication is intended to provide advice and help communicate HPHT risks to management and others, emphasising the company’s duty of care.

1.1 HPHT DEFINITIONS

HT: high temperature and HP: high pressure

High temperature in this context can be defined as when the undisturbed bottom hole temperature at prospective reservoir depth (or total depth) is greater than 300 °F (149 °C).

High pressure can be defined as either when the maximum anticipated pore pressure of any porous formation to be drilled through exceeds a hydrostatic gradient of 0.8 psi/ft (representing an EMW of 1.85 SG or 15.4 ppg) or, needing deployment of pressure control equipment with a rated working pressure in excess of 10 000 psi (690 bar, 69 MPa).

Note that areas of high pressure (abnormal pressure) need not necessarily be accompanied by high temperatures and vice versa.

1.2 HEALTH SAFETY AND ENVIRONMENT (HS&E)

1.2.1 HS&E

When planning an HPHT well, HS&E should be considered the primary value driver. Therefore, HS&E considerations should have high priority/weighting and be factored into the planning of the following work
flows:

- project objectives;
- well objectives;
- recommended codes of practice/best practices and guidelines;
- rig selection and audit;
- management of simultaneous operations (SIMOPS);
- management of combined operations;
- safety management system (SMS) interfaces;
- well type (people exposure);
- HPHT procedures;
- classification v. certification;
- drill the well on paper (DWOP);
- complete well on paper (CWOP), and
- test well on paper (TWOP).

1.2.2 ALARP

It is a principle of UK Health and Safety Law that risks to persons are reduced to 'as low as is reasonably practicable'. This is commonly referred to by the acronym ALARP.

A demonstration of ALARP should cover the HPHT project and associated components, systems and HSEMS (health, safety and environment management system). All phases of the development should be assessed and managed such that the residual risks can be demonstrated as being ALARP.

The means of demonstrating ALARP is via a risk assessment process the main purpose of which is to identify and rank the risks so that they can be adequately managed. The main stages of the risk assessment process are shown in the following Figure 1.

Each stage of the risk assessment can be seen as an opportunity to identify potential risk reduction options.

1.2.3 Hazard identification

Hazard identification needs to be comprehensive whatever approach to risk assessment is used. Typical methods of hazard identification that can be used are hazard identification (HAZID), hazard and operability (HAZOP) and failure modes effects analysis (FMECA).

1.2.3.1 HAZID

HAZID is a high level systematic assessment of a system using guidewords to help identify potential hazards.

1.2.3.2 HAZOP

HAZOP is a well-established method, which takes a full description of a process system and questions every part of it to discover what deviations from the intention of the design can occur and what the causes and consequences of these deviations may be. This is done systematically by applying suitable guidewords (the methodology is detailed in 1.6 Ref. A) and is an

![Figure 1: The risk assessment process](image-url)
Model code of safe practice
Part 17 Volume 3

High pressure and high temperature well completions and interventions
The Energy Institute (EI) is the leading chartered professional membership body supporting individuals and organisations across the energy industry. With a combined membership of over 13,500 individuals and 300 companies in 100 countries, it provides an independent focal point for the energy community and a powerful voice to engage business and industry, government, academia and the public internationally.

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Eric Low Think-Well (Scotland)

Acknowledgement is also attributed to other personnel who provided valuable assistance to the Steering Group at various stages in the project:

Steve Mellor Rowan Drilling & IADC Liaison
Dave Cameron ADTI
FOREWORD

In response to the requirements of the UK industry, Volume 3 of the Model Code of Safe Practice Part 17 has been developed to assist those involved with completions and interventions in high pressure and high temperature offshore wells. It provides a guide on those completion and intervention activities associated with HPHT wells which have an impact on safety offshore and therefore require detailed care and attention.

Guidance provided in this Model Code should be considered as a starting point for the operators and drilling contractors in developing the programme and associated operational plans and procedures for performing completions and interventions in a HPHT well. While this Model Code provides good industry practice, each operator and drilling contractor should review and apply the guidance to its own policies and experience for the particular area of operation.

The Model Code has been developed in a UKCS context of HPHT well operations; however, its guidance is universally applicable provided it is read, interpreted and applied in conjunction with relevant national and local statutory legislation and publications (codes of practice, design standards, specifications, recommended practices, guidance, etc.). Where requirements differ, the more stringent should be adopted. In addition, readers should take account of developments in legislation and publications which have been issued since this Model Code was published.

Although the adoption of this publication should help to promote safe well operational practice, the Energy Institute and the technical representatives listed in the Acknowledgements cannot accept responsibility in any way for injury to personnel or damage to equipment, installations or property which may arise from the use of any of the information contained in this Model Code.

This Model Code forms Volume 3 of Part 17 of the Model Code of Safe Practice. It complements two further volumes: Volume 1 – High Pressure High Temperature Well Planning and Volume 2 – Well Control During the Drilling and Testing of High Pressure High Temperature Wells. Each volume examines safe practice in a specific context, however, reference should be made to the other volumes for relevant information in other contexts.
1

INTRODUCTION

This code provides guidance on safe practice for those planning and managing completion and intervention operations in High Pressure High Temperature (HPHT) wells. High pressures and temperatures can encroach on the limits of available equipment, materials and fluids leaving little margin for error. This restricts equipment choice, which in turn may restrict completion design to all but the most basic. Completion installation and well intervention procedures must be adapted to ensure safe practices and appropriate barriers are used. For safe, successful completions to be deployed that are fit for purpose for the life of the well requires a considerable escalation in the rigorous attention to detail to every aspect of the operation.

HPHT well completions and interventions, in general, carry much higher risk than other wells. Fundamentally the possibility of integrity failures and the consequence of such failures are much greater when working in high energy environments. Risk factors can combine to create complex and serious threat to well operations; including the erosion of HS&E margins and increased risk of well control, loss of well, injury, fatalities, environmental impact or damage, economics and business reputation.

It is a principle of Health and Safety legislation in the UK that risks of personal injury are reduced to as low as is reasonably practicable (ALARP). Therefore it is imperative that risks are identified, evaluated and reduced under ALARP principles. These risks must be communicated to all parties including management, service providers, designers, safety advisors and environmental advisors.

Compliance with international, national and regional laws, statutory instruments and regulations is an imperative. Liaison with legislative, fiscal and regulatory stakeholders is essential and should be given a high priority from the beginning. Both company and contractor policies and procedures should be reviewed for their suitability for operating in HPHT environments.

The selection and procurement of equipment, materials, people, products and services can prove demanding, extending lead times and planning times. The choice of equipment for HPHT operations is much smaller and the high specification materials and equipment may not be readily available.

In this introductory section risk management processes and their importance to HPHT completion and intervention operations are described. Risk management is an integral and continuous part of the process throughout planning, design, procurement and operations. A robust, systematic risk management system should be in place with full documentation of each step. This will demonstrate that the ALARP principle has been achieved and assist in communicating HPHT risks to management and others, emphasising the company’s duty of care.

1.1 HPHT DEFINITIONS

High Temperature in this context can be defined as when the undisturbed bottom hole temperature is greater than 149 °C (300 °F).
High Pressure can be defined as either the maximum pore pressure of any porous formation that exceeds a hydrostatic gradient of 0.18 bar/m (0.8 psi/ft) (representing an Equivalent Mud Weight (EMW) of 1.85 sg or 15.4 ppg) or, needing deployment of pressure control equipment with a rated working pressure in excess of 690bar, 69MPa (10 000 psi).

Note that areas of high pressure (abnormal pressure) need not necessarily be accompanied by high temperatures and vice versa.

1.2 HEALTH SAFETY AND ENVIRONMENT (HS&E)

When planning an HPHT well operation, HS&E should be considered the primary value driver. Therefore, HS&E considerations should have high priority and weighting and be factored into the work flow.

1.3 ALARP

It is a principle of UK Health and Safety Law that risks to persons are reduced to as low as is reasonably practicable. This is commonly referred to by the acronym ALARP.

A demonstration of ALARP should cover all HPHT projects and associated components, systems and HSEMS (Health, Safety and Environmental Management System). All phases of the project should be assessed and managed such that the residual risks can be demonstrated as being ALARP.

The means of demonstrating ALARP is through the risk assessment process, the main purpose of which is to identify and rank the risks so that they can be adequately managed. The basic steps in the risk assessment process are: hazard identification, risk estimation and ranking, risk evaluation and reduction and a continuous review process. Each stage of the risk assessment should be seen as an opportunity to identify and reduce risk.

1.4 HAZARD IDENTIFICATION

Hazard identification must be a comprehensive and systematic process that is likely to involve one or more of the following methods:

HAZID (Hazard Identification) is a high level systematic assessment of a system using guidewords to help identify potential hazards.

HAZOP (Hazard and Operability) takes a full description of a process system and questions every part of it to discover what deviations might occur and what the causes and consequences of these deviations might be. [Ref 1.1]: Hazard and Operability Studies (HAZOP) – Application Guide BS IEC 61882.

FME(C)A (Failure Mode and Effects (Critical) Analysis) is a qualitative reliability technique for the systematic analysis of each possible failure mode within a hardware system. It also identifies the resulting effect on that system, mission and personnel. Critical Analysis (CA) ranks failure modes according to their probability and consequences. [Ref 1.2]: Reliability of Systems Equipment and Components Part 5. Guide to Failure Modes, Effects and Criticality Analysis (FMEA and FMECA) BS 5760-5.

1.5 RISK ESTIMATION

Risk estimation entails assessing both the severity (consequences) and frequency (likelihood) of hazardous events. The detail and effort required to perform this increases from Qualitative (Q) to Semi-Quantitative (SQ) to Quantified Risk Assessment (QRA). One or all of these techniques may be applied to components within a system. Selecting which technique to apply to a component will depend on criticality, complexity, field proven reliability and the availability of suitable numerical databases.

1.6 RISK REDUCTION

Risk reduction is an integral part of the process to determine if more needs to be done. It involves an iterative loop that re-evaluates the risk to measure the improvement. A hierarchical approach to effective risk reduction is:

— Elimination / minimisation through design.
— Prevention (reduce likelihood).
— Detection.
— Control.
— Mitigation of consequences.
— Evacuation, escape and rescue.

1.7 RISK EVALUATION

The process of risk evaluation starts with the highest risk and proceeds down the ranked list of identified potential risks until it is evident that no further risk
reduction measures can be justified.

1.8 DEMONSTRATING ALARP

A requirement to reduce risk to ‘as low as is reasonably practicable’ is a key element of UK health and safety legislation; it is commonly known by the acronym ALARP. The achievement of ALARP, though, is good engineering practice regardless of any legislative requirement. The reduction of risk is a necessary and vital process in all engineering projects. Formalising this process can bring many benefits.

The demonstration of ALARP within a risk management framework can be achieved through a combination of several established methods. The interaction between these methods is simply illustrated in Figure 1. [Ref 1.3]: Industry Guidelines on a Framework for Risk Related Decision Support, Oil & Gas UK (UKOOA).

Figure 1 clearly illustrates the role, for example, of recognised codes and standards in dealing with risk and demonstrating ALARP. The role of risk analysis techniques can be seen as providing a contribution to this risk picture at the appropriate level.

Overall risk management uses a combination of tools and techniques to achieve the goal of ALARP. There are numerous analysis and evaluation techniques that have been developed in addition to those previously mentioned. These include:

- Fault tree analysis.
- Event tree analysis.
- What-if analysis.
- Checklists.
- Cost benefit analysis.
- Human factor risk assessments.
- Health risk assessments.
- Preliminary hazard assessments.
- Job hazard assessments.
- Physical effects modelling.
- Safety integrity level (SIL) evaluations.
- Layers of protection analysis (LOPA).

Expert advice should be sought in selecting the techniques to be used to ensure the most applicable technique is used for the circumstances. [Ref 1.4] Recommended Practice for Design and Hazard Analysis for Offshore Production Facilities, API RP14J and [Ref 1.5] Petroleum and Natural Gas Industries- Offshore Production Installations- Guidelines on Tools and Techniques for Hazard Identification and Risk Assessment, BS EN ISO 17776.
1.9 REVIEW

The review process is a key component of any risk management system. Periodic reviews should be performed routinely and when significant changes occur that affect the risks.

Any remedial measures adopted should and will change the relative risk ranking. The review process ensures that the changing risk priorities are understood and communicated.

Management of change (MOC) is a relevant and important component of the review process which is dealt with under a separate heading.

1.10 MANAGING THE ENGINEERING PROCESS

Risk management must be an integral part of the engineering process. Other key components of the engineering process are: establishing objectives, establishing early communication with all stakeholders and establishing an appropriate work group which should include: sub-surface, drilling, completion, production and facilities disciplines. Completions must have input and should have influence on well planning if completion compromises are to be avoided. Similarly well interventions whether planned or contingent should influence well design. This assumes that an integrated life of well planning philosophy is adopted.

A completion’s 'basis of design', or equivalent, should be prepared to outline the engineering and configuration requirements of the completion. The early communication of the completion requirements to all disciplines is an important aspect for integrated project engineering and risk management.

A ‘joint operations manual’, or equivalent, will have been established for drilling and well operations between the operator and drilling contractor. This may not always be appropriate for completion or intervention operations and may have to be amended or replaced. The areas that may need attention include: onshore and offshore organisational structure, communication and reporting lines, well control equipment and procedures, HS&E issues and commonly agreed procedures. The early agreement on these issues, bridging safety management, policy and procedure between operator, drilling contractor and possibly third party services is key for the safe, efficient performance of complex HPHT operations.

In order to assist future operations accurate written records should be collated and documented. These should include recommendations and 'lessons learned' which are easily accessible for future reference.

1.11 MANAGEMENT OF CHANGE

Change management is a fundamental element of the project development process and contributes to the demonstration of ALARP. The change management process should be clearly documented, understood and should:

- Identify triggers that initiate the change management process.
- Record the causes of the change during all phases of the development of the design through to operation.
- Record and evaluate the change and ensure the evaluation includes technical, HS&E and commercial considerations such as to allow the demonstration of ALARP.
- Ensure that the change is process executed by suitably experienced and competent assessors.

Changes or deviations should be fully assessed and communicated to all stakeholders. They may impact on the safety case and those that affect the scheduled critical path may impact on lead times and material supply. All new components, replacements or changes in execution of the well plan should be assessed for risk, consequences and impact on other equipment, with any resulting impact on documented HS&E.

Late changes, change encountered during operations for example, can be the most difficult to process given time constraints. The same rigorous process should be applied. Short cutting the process at this stage has led to many difficulties and failures.

Due to the complex, higher risk nature of HPHT wells a HS&E impact assessment will be needed for each change. Change can introduce new risks and the identification, evaluation and reduction process should be rigorously applied. This may involve additional testing, modelling and analysis of the new component, process or procedure as an integrated part of the system. Such activities should be thoroughly documented as part of the change management process including any analysis, testing, input from lessons learned, implementation of good practice, codes or standards.

It is imperative that management of change includes the appropriate approval and communication functions.

1.12 QUALITY ASSURANCE AND QUALITY CONTROL (QAQC)

QAQC process is critical for all HPHT well operations. Completion components will be expected to function
INTRODUCTION

Any defect, manufacturing error or mishandling is likely to result in a failure with the potential for severe consequences. This extends to all components including elastomers, metallurgy, fluids, etc. Equipment choice is limited for HPHT conditions, what does meet specification will need to be verified as being fit for purpose and prepared without defect, error or compromise and installed in the well in that condition.

There is much we still have to learn about the survivability of materials during long term exposure to the corrosive environments in HPHT wells. During periods of inactivity static pressures, temperatures and fluids may increase degradation of well components. An uncompromising approach to completion component QAQC will help eliminate failure modes that are known.

Completion equipment is exposed long term to high stresses, corrosion, erosion and cyclic loads. The expected loadings may be very close to specification leaving little margin for unknowns or uncertainties. Components can and have been used beyond manufacturers’ specification. This can be as a result of uncertainties in subsurface and hydrocarbon properties, other equipment failure, software inaccuracies or failures or human error. Every effort should be made to determine as accurately as current knowledge will allow the environment, stresses and loads that will be encountered throughout the life of well. Both deterministic and probabilistic methodologies can be employed. Uncertainties and low grade QAQC can no longer be accommodated with large blanket safety factors. We must rely on reducing uncertainty to a minimum and uncompromising QAQC processes.

A QAQC system for completion and well intervention operations that aids the management of risk process by identifying safety critical elements and management of technical integrity should be considered. HPHT technical and functional performance standards should be developed and communicated to critical suppliers of people, products and services; all of which impact completion integrity and design.

HPHT equipment requires rigour in design review, validation and quality assurance. A ‘statement of requirement’ can provide an audit trail and support ‘management of change’ processes in meeting the ALARP standard.

Design and equipment specifications for HPHT wells may fall outside international (e.g. API, etc.), regional, local or company standards. In these cases dispensation will be required and the internal, or in some cases external dispensation process will have to be followed. This is likely to include peer review and possibly further external QAQC and testing requirements.

1.13 TRAINING

For personnel involved in HPHT completions and interventions the following should be addressed:

— Levels of experience.
— Consider a formal competency system for completion design personnel.
— Training short term staff in the prevailing company management system.

In addition to any specialist technical training requirements, it is recommended that personnel involved should:

— Be aware of the safety case.
— Be familiar with local legislation, regulation and guidelines, including company policy and procedure.
— Be aware of the impact that other engineering restraints may have on their responsibilities.
— Be aware of well control issues.
— Be fully conversant with the objectives of the project.
— Understand the nature of the HPHT environment in the well, its constraints and limitations on materials and operations.
— Understand the impact of uncertainties on well and completion design and their impact on completion operations.

In general drill crews on HPHT wells are extremely well trained and are familiar with handling heavy weight fluids and fluid phenomena that occur in such environments. However, completion operations and the handling of completion equipment are not routine functions and can adversely impact established procedures. Extra care, instruction and training may be required. This is particularly relevant in ensuring that sufficient competent barriers are in place at all times and in respect of establishing contingency plans.

1.14 REFERENCES AND FURTHER READING

[Ref 1.3] Industry Guidelines on a Framework for Risk
Related Decision Support; Oil & Gas UK (UKOOA), EHS08: 1999


Websites:

www.hse.gov.uk/offshore (General)

http://stepchangeinsafety.net (General)

www.hse.gov.uk/risk/theory/alarp.htm (ALARP)

www.ptil.no (Petroleum Safety Authority, Norway)

www.iroffshoresafety.com (International Regulators Forum)