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GP 10-15

Pore Pressure Prediction

Group Practice

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BP GROUP
ENGINEERING TECHNICAL PRACTICES

Introduction

The introduction to this ETP mirrors section 16 of the revised DWOP.

All Pore Pressure Prediction activity [redacted] conform to Engineering Technical Practice GP10-15 – Pore Pressure Prediction.

1. A Single Point of Accountability [redacted] be defined for the preparation of a pore and fracture gradient prediction for any given well.
2. The prediction of pressure for a BP well [redacted] be prepared by a qualified individual who has been trained on BP practices and workflows.
3. All individuals preparing pressure predictions for BP wells [redacted] have attended the BP 21st Century Pore Pressure Principles training course.
4. All individuals preparing pressure predictions for BP wells [redacted] have been trained on the use of Presgraf.
5. The methods used to predict pressure [redacted] be consistent with the BP pore pressure practices workflow (Appendix A).
6. Every well operated by BP [redacted] have a pressure profile which [redacted] include pore, sand fracture, shale fracture, and overburden pressures.
7. The pressure profile [redacted] express the uncertainties associated with the prediction.
8. The pressure profile [redacted] be updated to include all learning's from offset wells (offset pressure measurements, kicks, current state of depletion, etc.).
9. A validation review [redacted] be conducted on any prediction subsequent to any major changes in the profile. The validation review [redacted] have included at least one approved auditor and one qualified pore pressure expert from outside the asset (can be the same individual). Once the validation review is completed, the PPFG profile [redacted] be frozen and further changes to the profile [redacted] require management of change (MOC) process.
10. Software used to prepare pore and fracture pressure predictions [redacted] meet BP safety critical software standards as defined in Section 12 of the BP Drilling and Well Operations Practice (BPA-D-001).

Foreword

This is the first issue of Engineering Technical Practice (ETP) BP GP 10-15 dealing with Pore Pressure Prediction. This Group Practice (GP) replaces the relevant parts of the Drilling and Well Operations Policy BPA-D-01.

Description of Risk

The prediction of pore and fracture pressures in wells is considered a zero tolerance activity within BP. Errors associated with the prediction of pore and fracture pressures could lead to the harm to people, damage to the environment, and undermine BP's operational reputation. For these reasons pressure prediction requires a definition of practices that establish the minimum requirements for performing pressure prediction.

The purpose of this document is to establish the minimum requirements in the prediction of pore and fracture pressures in planned wells. These requirements should be met by both employees and contractors acting on the behalf of BP in planning the design of wells to be operated by BP.

> **Note:** This Practice reflects the balanced judgment of the BP Group and is based on experience and inputs from a variety of sources. However, it should be recognised that risk can never be eliminated and, as we learn, the Group may have to adjust the acceptable risk envelope and the Minimum Requirements of this Practice. This would result in an updated edition of this Practice being issued by the relevant authority.

What is the Pore Pressure Prediction Recommended Practice?

This PPP Practice is intended to ensure that there is a formal approach to managing the risks associated with predicting pore and fracture pressure in BP operated wells, that these risks are identified, assessed and controlled in a methodical way so that they can be removed or reduced to an acceptable level.

The primary aim of this Practice is to prevent safety incidents. However, the processes may be extended to include other aspects of performance.

Who is it for?

This Practice is intended for the use of following groups:

- Those involved in the pre-drill prediction of pore and fracture pressure for BP operated wells
- Those directly involved in the selection and management of those employees and contractors who will conduct pressure prediction on BP wells

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1. Scope

This Practice applies to work on any BP operated well. A BP Company is a company in the BP Group or other legal entity where BP has operational control, is responsible for HSSE and has the right to impose these requirements. In situations where BP does not have control (i.e. a joint venture where BP is not the operator) we should endeavour to confirm that the operator implements processes that meet the minimum requirements in this document.

Applicability

For the purpose of this Group Practice, the workforce comprises BP employees and every employee of any other company or other legal entity that has been engaged to perform work on BP-operated reservoirs or production/injection infrastructure. A BP-operated reservoir for the purposes of this document includes any site or location used for the injection or extraction of fluids that is owned or operated by or for a BP Company.

In situations in which BP does not have control (i.e. a joint venture where BP is not the operator) BP should attempt to persuade the operator to employ practices at least meeting the Minimum Requirements in this document.

In the event of a conflict between this Group Practice and a relevant law or regulation, the relevant law or regulation will be followed. If the Group Practice creates a higher obligation, it should be followed as long as full compliance with the law or regulation is achieved.

Subject to the Group Practice's intent and subject to existing contractual constraints (to the extent that they cannot be renegotiated) this Group Practice [redacted] be applied to all contractors and their associated subcontractors who perform work on BP-operated reservoirs or on behalf of BP and [redacted] be incorporated in all tenders and contracts.

2. Normative references

The following normative documents contain requirements that, through reference in this text, constitute requirements of this technical practice. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this technical practice are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies.

BP

BPA-D-001	BP Drilling & Well operations Practice
BPA-D-002	BP Well Control Manual Volume 2
http://ppfg.bpweb.bp.com/training.htm	Training course materials of the 21st Century Pore Pressure Principles course

3. Terms and definitions

For the purposes of this GP, the following terms and definitions apply:

Accountable Person
The person in the organization who has ultimate responsibility.

Activities
Specific actions or pursuits.

Assess
To consider and make a judgment upon.

Assurance
A guarantee, giving certainty.

Auditing
A formal or official examination and verification. The audit process should include monitoring, review, and reporting of the outcome of the audit to those people who can implement any changes needed.

Authority
Official permission.

A position that has the power to make a judgement; an individual cited or appealed to as an expert.

The power to influence or command.

BP Company
A company in the BP Group, or a company or other legal entity where BP has operational control, is responsible for HSSE and has the right to impose this Standard.

BP Employee
A person employed by a BP Company.

BP Operations
BP Business Units, projects, facilities sites and operations

BP Premises
Any site, location or marine vessel that is owned or operated by or for a BP Company.

Competency
The ability to perform a task in the correct manner with the correct understanding and reasoning behind the task.

Competent Person
A person who has demonstrated that they have the knowledge, training and experience required to perform the defined role to the standard required.

Confirm
To support or establish the certainty or validity of; verify.

Contractors
A Company or individual who is under a contractual relationship to supply BP plc or one of its subsidiary companies with Goods and Services and is working solely for the benefit of BP.

A contractual relationship includes:

- All individuals contracted directly or sub-contracted.
- All employees of companies contracted directly or sub-contracted.
- All situations where a contract has not been raised but BP's procurement policy would normally expect there to be a contract in place. This applies to all levels including sub-contracted relationships.

Note: For the purposes of HSSE reporting any sub-contractor should be treated as if they held a contract directly with BP plc or one of its subsidiary companies.

Control
a) A mechanism used to regulate a physical process or activity.

b) An action to mitigate risk.

c) The power to direct (usually through authority).

Document Control Management System
An established means of controlling the issue, use and updating of documents used in the management of a site. A full document control management system (DCMS) will include reference numbers on documents, means of tracking changes and updates and regular audits of the system to confirm compliance.

Eliminate
To remove or get rid of.

Formal
A formal process or agreement is one that is written, recorded and audited. It may also include tracking to confirm that work is following the process or agreement.

Minimum Requirements
The activities, tasks or deliverables that [redacted] be completed to comply with this Practice.

Monitoring
The routine function of regular inspection carried out by a responsible and competent person.

Operational Control
Where BP has responsibility for the activity as owner or under a contractual obligation with the owners of the entity and, as a consequence, has appropriate authority to manage directly all HSSE aspects of the operational activities to meet BP policy and expectations.

Plan
The function of task (work) identification, interaction and sequencing including, preparation and completion requirements, to achieve an outcome.

Policy
Plan of action pursued by the Company (BP) with which all personnel [redacted] comply.

Procedure
A detailed document either in paper or electronic form which sets out sequential or parallel actions which [redacted] be followed by those engaged in carrying out an activity.

Process
A detailed description of a management system or a production operation.

Risk
Possibility of loss, injury, damage, or exposure to hazard or danger.

Risk Assessment
The process of hazard identification and the assessment of the potential for identified hazards to be realised in any given activity.

Roles
The documented description of personnel functions within a management structure.

Routine
A procedure that does not vary in its execution.

Single Point Accountable
The person in the organization (site/Business Unit) who has been appointed as being accountable for the delivery and performance of an activity.

Training
The bringing of a person to a desired degree of proficiency in some activity or skill. Training should only be carried out by people who have been assessed as being competent to train.

Task
An activity in support of a piece of work.

Work
An activity made up of a number of different tasks.

Workflow
An activity made up of a sequence of different tasks designed to deliver a desired outcome.

Workforce
BP employees and every employee of any other company (includes all contractors) or other legal entity that has been engaged to perform work on BP Premises.

Zero Tolerance Activity
A BP well planning activity that potentially places people or the environment at risk and requires a minimum set of requirements for performing those activities.

4. Symbols and abbreviations

For the purpose of this GP, the following symbols and abbreviations apply:

CoP	Community of Practice
DCMS	Document Control Management System

HSSE	Health, Safety, Security and Environment
PPFG	Pore Pressure Fracture Gradient
OMS	Operating Management System
SPA	Single Point of Accountability
SPU	Strategic Performance Unit
TVP	Technology Vice President

5. Practice Structure

5.1. Requirements and Recommendations

Minimum Requirements and Operational Excellence

Minimum requirements describe the minimum processes and activities that [redacted] be completed to deliver the intent of this Practice. These Minimum Requirements [redacted] become the "benchmark" for acceptable operating within BP.

Recommendations provide details of good practice – both internal and external to BP – which go beyond the Minimum Requirements of this Practice. These are intended to provide options for continuous improvement that will take businesses beyond the "getting the basics right" and towards operational excellence. Adherence to recommendations will not be required to meet the intent of this Practice.

5.2. Language

"[redacted]" and "Should"

Throughout this document the following language is used:

- "[redacted]" is used where a provision is a Minimum Requirement of the Practice and is mandatory.
- "Should" is used where a provision is a Recommendation or is used to identify a preferred option.

5.3. References and Responsibilities

References

References, where appropriate, are made to other relevant guidelines, procedures and documents that may be used in order to support the application of this Practice. Any relevant Normative References will be made available at the technical practices portal:

http://ppfg.bpweb.bp.com/practices.htm

Responsibilities

Where appropriate, roles and responsibilities to deliver any process/activities required within this Practice are clearly defined. Delivery of these responsibilities will be locally assigned.

6. Accountability

Intent

BP Executives, Managers and Supervisors [redacted] actively participate in and recognize that effective technical management of this zero tolerance activity is critical to our business success. Clearly identifying the roles, responsibilities, and competencies for both BP employees and contractors and holding them accountable for desired behaviors and performance is essential to effective pore pressure prediction.

6.1. Minimum Requirements

a. A Single Point of Accountability [redacted] be defined for the preparation and uptake of a pore and fracture gradient prediction for any given well and its associated uncertainties.

6.2. Recommendations

a. The Segment Engineering Technical Authority should be consulted by the Single Point of Accountability (SPA) for clarification of pore pressure prediction recommended practices as required.

7. Competence

Intent

To ensure that those individuals preparing pressure predictions have the necessary experience, capability and knowledge to undertake the work in a manner that meets BP's expectations.

7.1. Minimum Requirements

a. The prediction of pressure for a BP well [redacted] be prepared by a qualified individual who has been trained on BP practices and workflows (Appendix A).

b. All individuals preparing pressure predictions for BP wells [redacted] have attended the BP 21st Century Pore Pressure Principles training course.

c. All individuals preparing pressure predictions for BP wells [redacted] have been trained on the use of Presgraf.

7.2. Recommendations

a. Individuals preparing pressure predictions should participate in PPFG community of practice (CoP) activities to maximize knowledge shared with other parts of the organization.

- Be a member of the PPFG email distribution list
- Attend PPFG CoP meetings.

8. Practices and Procedures

Intent

To ensure that practices and procedures used by pressure prediction practitioners meet all relevant technical requirements and are kept up-to-date and accessible.

8.1. Minimum Requirements

a. The methods used to predict pressure [redacted] be consistent with the BP pore pressure practices workflow (Appendix A).

b. Every well operated by BP [redacted] have a pressure profile which [redacted] include pore, sand fracture, shale fracture, and overburden pressures.

c. The pressure profile [redacted] express the uncertainties associated with the prediction.

d. The pressure profile [redacted] be updated to include all recent learning's from offset wells (offset pressure measurements, kicks, current state of depletion, etc.).

8.2. Recommendations

a. Inconsistencies with BP pore pressure practices should be recorded in a peer review summary.

b. Pressure uncertainties can be expresses as either multiple curves or as a written dialog.

c. The pore pressure assessment tool should be used to identify appropriate methods to be used in predicting pressure (basin modelling, seismic, and/or analogues).

d. In areas where well density is sufficient and pore and fracture gradients are well understood from location to location, a generic pressure profile may be used. Wells drilled to greater depths or on the flanks of these fields should require an explicit pressure prediction

9. Software

Intent

To assure that software used to prepare predictions meets BP specifications, design, programme changes, fault tracking, documentation, implementation, testing, and acceptance requirements.

9.1. Minimum Requirements

a. Software used to prepare pore and fracture pressure predictions [redacted] meet BP safety critical software standards as defined in Section 12 of the BP Drilling and Well Operations Practice (BPA-D-001).

9.2. Recommendations

a. Approval of the Segment Engineering Technical Authority and the relevant applications domain expert [redacted] be obtained in establishing that used software meets BP safety critical standards.

b. Currently, pressure prediction software which has been confirmed to meet BP safety critical standards are:

- Landmark version of Presgraf
- Temispack basin modelling

10. Assurance

Intent

To insure BP recommended practices are utilized in preparing a pressure prediction and to share lesson's learned in a rapid and timely manner.

10.1. Minimum Requirements

a. A validation review [redacted] be conducted on any prediction subsequent to any major changes in the profile. The validation review [redacted] have included at least one approved auditor and one qualified pore pressure expert from outside the asset (can be the same individual). Once the validation review is completed, the PPFG profile [redacted] be frozen and further changes to the profile [redacted] require management of change (MOC) process.

10.2. Recommendations

a. The validation review should follow the "PPFG Pre-Drill Prediction Validation Review Terms of Reference" and resulting high risk concerns should be articulated in the validation review summary (Appendix B).

b. Qualified auditors should be posted at the PPFG website:

http://ppfg.bpweb.bp.com

c. When possible, the SPA for delivery of the Pore Pressure Detection should participate in the Validation Review of the Pore Pressure Prediction

Annex A

Pore Pressure Prediction Recommended Workflow

Overall...

Run the Pore Pressure Assessment Tool to identify appropriate method(s) to use to conduct a pressure prediction. This should be done as a subsurface team effort to insure all knowledge is brought to bear on the results.

If one method gives a very high score, then it may only be necessary to do the one method.

If several methods give intermediate values, then consider doing both or all methods and using the differences to characterize the uncertainty.

If all methods give low values, then determine if any of the methods can provide results that are meaningful. Hold a peer assist to identify the best approaches to use.

A.1. Analogue methods

- Identify relevant offset or analogue wells.
- Gather relevant pressure data including measured formation pressures, kick pressures, leak-off data, mud weight, measured annular pressures, drilling pressure indicators, velocity and resistivity logs.
- Build an overburden curve, preferably using measured density measurements, supplemented with pseudo density data from acoustic measurements, and, if required, modelled density data.
- Convert high graded acoustic log shale measurements to pressure using a preferred BP calibrated compaction trend. If acoustic data is from deviated wells, correct velocities fro the effects of deviation induced anisotropies.
- Convert resistivity data to pressure using a preferred BP compaction trend and calibrate the trend to direct measurements of pressure and sonic inferred pressure measurements from the well.
- Reconcile all pressure measurements to produce a most likely pressure profile.
- Calculate a sand fracture gradient curve using the overburden and most likely pressure curves and a Poisson's ratio of 0.33.
- Calculate a shale fracture gradient curve using the BP Deepwater relationship (Brumfield).
- Collect and validate leak-off data from the offset wells. Reconcile predictions of sand and shale fracture gradients with the leak-off data. If an alternative fracture gradient to Brumfield is required document the justification and reconcile its impact upon total stress in calculating pressures.
- If tectonic stress or surface erosion is present, use mean stress relationships for Dt based pressure and fracture gradient analysis and calibrate tectonic stress magnitudes to known leak-off values in shale.
- Project offset well results to the proposed location. If much relief is present or recent sedimentation rate (last 1 million years) differs significantly between locations or if sands are suspected to not be connected between locations, use basin model techniques to project the pressure to the new location.

A.2. Seismic methods

- Generate an interval velocity model from properly imaged seismic velocities specifically generated for pressure purposes and checked by a seismic processing QC specialist.
- Correct seismic velocities for "anisotropy effects" based upon nearby calibration so that interval velocities are consistent with time depth conversions.
- Build an overburden curve using acoustic to density transforms that have been calibrated in analogue wells, and, if required, modelled density data.
- Convert the calibrated seismic interval velocities to pressure using a preferred BP calibrated compaction trend.
- Calculate a sand fracture gradient curve using the overburden and most likely pressure curves and a Poisson's ratio of 0.33.
- Calculate a shale fracture gradient curve using the BP Deepwater relationship (Brumfield). If an alternative fracture gradient to Brumfield is required document the justification and reconcile its impact upon total stress in calculating pressures.
- If tectonic stress or surface erosion is present, use mean stress relationships for Dt based pressure and fracture gradient analysis and calibrate tectonic stress magnitudes to known leak-off values in shale.
- Use "centroid" techniques to determine the potential for the presence and magnitude of structural effects. If necessary, run basin models to calibrate the magnitude of these effects.

A.3. Basin modelling methods

- Identify relevant offset or analogue wells.
- Gather relevant pressure data including measured formation pressures, kick pressures, leak-off data, mud weight, measured annular pressures, drilling pressure indicators, velocity and resistivity logs. Conduct an analysis of the analogue using the analogue best practices.
- Select an appropriate dimension for running the model (3D preferred, 2D where the 3D problem can be adequately collapsed into 2D, 1D only for exceptions where the 3D aspects are poorly understood).
- Use offset well data to calibrate lithology used in the porosity-permeability-effective stress relationships.
- Use geologic back stripping to define the structure through geologic time.
- Calibrate the basin model to the offset analogue data. If no analogue data is available, calibrate to seismic based velocity pressure analysis where velocities are easily imaged and appropriate compaction trends understood.
- Compare basin model overburden data to analogue well overburdens. If results differ significantly, recalibrate the model.
- Reconcile all pressure measurements to produce a most likely pressure profile.
- Calculate a sand fracture gradient curve using the overburden and most likely pressure curves and a Poisson's ratio of 0.33.
- Calculate a shale fracture gradient curve using the BP Deepwater relationship (Brumfield). If an alternative fracture gradient to Brumfield is required document the justification and reconcile its impact upon total stress in calculating pressures.
- Capture reasonable uncertainties in geologic understanding as a sequence of basin models.

Annex B

PPFG Pre-Drill Prediction Review Terms of Reference

B.1. Review Team (minimum requirements):

- Leader (needs to be a PPFG qualified peer auditor)
- At least one reviewer from outside the asset (to insure transfer of lessons learned both to and from the team)
- Experienced practitioners of drilling pressure indicators, seismic pressure methods, and/or basin modelling. Which skills depends upon methods used to make the prediction
- Note: If one individual fulfils the combined requirements above, then it is not required to have multiple team members.

B.2. Planning Team Participants:

- Single Point of Accountability (SPA) for the prediction
- SPA for delivery of the wellsite pressure detection (if possible)
- Prospect geologist
- Prospect petrophysicist
- Prospect geophysicist
- Prospect drilling engineer
- Basin Modeller (if applicable)
- Person who did velocity based work (if applicable)

B.3. Objectives:

The primary objective of the review is to determine if the prediction is appropriate for proceeding with well execution and that the methods used meet the Engineering Technical Practice on Pore Pressure Prediction (GP 10-15). As a minimum the Validation Review Team should answer the following questions:

1. Have the appropriate analog wells been identified and used?
2. Were the analogs properly analyzed to determine or constrain pore and fracture pressures in sands and shale?
3. Were the appropriate methods used to project offset pressures to the proposed well location?
4. Were the analogs properly used to calibrate seismic velocities and/or basin models at the proposed location (consistent with BP approved workflows)?
5. Have deviations from approved workflows been properly defended (compaction trends for sonic and resistivity, fracture relationships, porosity-effective stress and porosity-permeability relationships for basin models)?
6. Have uncertainties with pore and fracture pressure prediction been properly described?
7. Should any additional work be mandatory before proceeding with execution?

B.4. Desired Outcomes

- Identification of mandatory additional work that needs to be completed before proceeding to execution.
- Assurance that the work performed meets the standards of BP Engineering Technical Practices on Pressure Prediction and is consistent with approved BP pressure prediction workflows.
- Documentation of the review and any major accident risks that need to be expressed to relevant business leaders.

Annex C

Administration

C.1. Administration and Authorisation

Administration and Authorisation

Administration and authorisation responsibilities for this Practice are:

Custodian:	The pore pressure prediction Segment Engineering Technical Authority
Maintainer:	The pore pressure prediction Segment Engineering Technical Authority
Adjudicator:	Head of Discipline Appraisal and Pre-Development under delegation from the TVP Subsurface and Wells

The Custodian is responsible for confirming the accuracy and integrity of content and proposed changes to the Practice.

The Maintainer is responsible for the upkeep and continued integrity of the Practice, including regular reviews and audits.

The Adjudicator is responsible for authorising and approving changes to the Practice.

Interpretation

Questions of interpretation should be directed in writing to the custodian of this Practice for the purpose of clarification.

Changes and Amendments

Any suggested changes or amendments to this Practice should be forwarded to the document custodian along with the reasons for the change.

All suggestions should be acknowledged and, if rejected, the reasons given for their rejection.

Accepted changes should be administered through the document change control system employed by the Document Control Management System (DCMS).

Document Control and Review

The Practice [redacted] be held and controlled on the DCMS.

This Practice is subject to regular review and also to review whenever circumstances dictate. All reviews, regular and otherwise, [redacted] be initiated by the Custodian.

C.2 Auditing, Compliance and Deviation

Auditing and Compliance

Monitoring adoption of this Practice and reporting on implementation and progress on meeting targets [redacted] be locally owned and included as part of the annual self verification process for each Business and Functional Unit.

BP businesses that are within the scope of this Practice [redacted] adopt or modify their procedures and practices to conform to the Minimum Requirements described in this document.

In the event of a conflict between this Practice and a relevant law or regulation, the relevant law or regulation [redacted] be followed. If this Practice creates a higher obligation, it should be followed as long as full compliance with the law or regulation is also achieved.

Deviation from Minimum Requirements

Change/deviation procedures [redacted] be defined within each Segment and approved by the Segment Engineering Technical Authority. This procedure [redacted] specify recording and notification levels for any such change.