Call for Expressions of Interest

Subsurface HPHT Challenges

Experts from oil & gas operating and service companies and academia, have identified key business needs relating to **Subsurface HPHT (High Pressure High Temperature) Challenges** and, through ITF, they wish to promote development of collaborative, world-class solutions to these needs.

This call for Expressions of Interest is the first step in identifying consortia to undertake funded research & development work in this area.

1. About the Proposed Programme

The objective of this Programme is that it should stimulate innovative solutions with the potential for major impact on oil & gas exploration and production operations. Input is encouraged from across the R&D community from both oil and non-oil technology sectors. It is envisaged that within the overall Programme, there will be a number of inter-related projects undertaken by different R&D consortia.

The following pages summarise the key business needs, as defined by the group of experts. Researchers are asked to address as many of the issues as they feel appropriate. Significant deliverables will be expected from each project.

It is expected that projects will be up to three years in duration and will produce clear, tangible outputs. Consideration of routes to implementation/ commercialisation should form an integral part of each submission.

2. About ITF

ITF is a not-for-profit organisation owned and supported by major oil operating and service companies. It is the vehicle through which these companies identify and coordinate joint industry research. ITF has the remit to facilitate the creation of funded consortia to nurture development of new, high impact technologies that will aid hydrocarbon exploration and increase hydrocarbon recovery. Further information about ITF, including a full list of Member Companies, can be found at www.oil-itf.com

One of ITF's principal activities is to identify technology needs through consultation with its member companies and then work with the R&D community to develop projects of interest to its members.

3. Key Dates

Deadline for Expressions of Interest	**01/09/2008**
Presentation of Short-listed Proposals to Potential Sponsors	End November 2008
Sanction / Start Date	Quarter 1 2009

4. Key Business Needs

In addition to existing HPHT provinces such as the Central Graben and Viking Graben of the North Sea, operating companies are pursuing new and deeper geological horizons in the Gulf of Mexico and in other areas around the world. As well depths increase, wellbore construction and production operations become much more challenging because of HPHT extremes. In addition, abnormal fluid pressure influences many fluid-related aspects of geology including diagenesis, reservoir quality and hydrocarbon migration.

5. Issues Identified by the Expert Group – The Call

Researchers are invited to consider the questions posed below and to map their own connections. Integrated proposals involving collaborative teams of geoscientists, reservoir engineers and geomechanics specialists are particularly encouraged. This call should also be of interest to those concerned with the design of downhole equipment for HPHT conditions.

HPHT Definition

For the purposes of this call High Pressure is defined as >15,000 psi (103.4 MPa) and High Temperature as >300°F (>149°C).

It is recognised that the greatest challenges exist where there is a combination of HP with HT. The relationship between the two is not linear. The industry is seeking to develop reservoirs with ever greater temperatures and pressures and it is recognised that 350°F and 25,000 psi marks a step change in equipment specification and the challenges faced.

In addition to elevated temperatures and pressures, complexity and connectivity may also be features of these reservoirs.

Overpressured shallow reservoirs also present their own challenges for safe development.

Pore Pressure Prediction Modelling

Pore pressure prediction is required in depleted reservoirs when in-fill wells are planned i.e. *not* just during the exploration phase when virgin pressures are likely to be encountered. It is the compacting reservoir (or rather, the contracting reservoir) that leads to a reduction in the total stress in and around the reservoir. Also the minimum total principal stress decreases by several percent or even tens of percent of the depletion. Therefore the mudweight needs to be adapted, and typically lowered, when drilling above, into and below depleted reservoirs, in order to prevent tensile failure formation and subsequent mud-losses and possible loss of well control. At the same time, however, the mudweight must be high enough to prevent a blow-out in case unexpected high-pressure sands are hit by the drill-bit.

- Modelling approaches are required to help explain what is causing overpressure. It is recognised that compaction is not the sole cause, and the role of other factors like metamorphic reactions during diagenesis need to be better understood.
- What is the effect of HPHT (or anomalous pressure & temperature) on the pore pressure/fracture pressure relationship before production starts?
- Can basin modelling approaches be adapted to pore pressure prediction and help reduce the error bars? Can basin modelling techniques be applied at different (i.e. smaller) scales?
- Methods are required for improving the estimation/determination of sealing capacity.

- What techniques can be used for more accurate pre-drill pore pressure prediction, particularly in complex geological environments such as the North Sea? Even with good seismic and well data, uncertainties still exist. For example, can velocity inversion and the use of long offset seismic contribute to an improved understanding?
- Is there another way to 'see' pressure distribution in the subsurface (e.g. through the use of techniques such as heat flow imaging, refraction or passive seismic)?

Pore Pressure Prediction in Real-time

- Even the most sophisticated pore pressure prediction techniques cannot rule out that kicks can still be experienced. Therefore techniques which provide a look-ahead-of-the-bit capability are requested. Seismic while drilling and resistivity ahead of the bit have been developed, along with other techniques. There is an interest in re-visiting these to determine how successful they have been, and to contribute to further development.
- Can we make better use of existing data through re-processing?
- Ideally, real-time pore pressure prediction should be used to quickly update pore pressure models, and then influence the drilling procedure (e.g. orientation, mudweight, rate). Where and how can improvements be made?
- Techniques to acquire new types of data at the bit and process in real time are encouraged.

Depleted Drilling

During production, it is not just the pore pressure that changes, but also the stress regime in the rock around the wellbore and in the depleting formation proper. These changes can be substantial (tens of percent of the depletion), making the formation more susceptible to tensile failure due to too-high mudweight (in the well) or too-high pore pressure (in the seal) fracturing the rock. The overburden or the top seal may deplete as well as the reservoir (though probably at a much slower rate than the reservoir rock, via pore-pressure diffusion), and therefore the minimum total principal stress (the "fracture gradient") may reduce there too. Models and predictive tools are required to help explain the loss of fracture gradient within a changing stress state. Further work should consider the following:

- There is a coupling between the reservoir and its surroundings, since the fracture gradient changes with the pore pressure – how are they linked?
- How do we handle depleted reservoirs/overburden during depleted drilling, especially where strong pressure contrasts exist between the rocks at virgin pore pressure and those that have been depleted ?
- Drilling above and into depleted HPHT reservoirs – how do we prevent losses due to wellbore fracture ? Are there novel ways to strengthen the wellbore (i.e. make it less prone to tensile or shear failure) by addition of chemical or mechanical techniques ?
- Temperature, especially high temperature, controls quartz cementation. This may result in compartments within the reservoir with different pore fluid pressures. There is a risk of breaching the top seal by drilling into these formations – advances are required into how to handle this.

- How close can we go to the fracture gradient with mud pressure? We need to understand the depletion effects.

Impact of Reservoir Quality

- Well and reservoir deliverability are directly linked to reservoir quality. As a reservoir depletes and compresses, we observe a loss of quality. Productivity changes (or is lost) due to pressure changes. Approaches to help define the loss of quality and the implications of this for well and reservoir deliverability are required. Sandstone and other reservoir types should be considered.
- What are the effects of HPHT (or anomalous pressure and temperature) on porosity over geologic timescales, and during production ?
- Estimation of reservoir quality requires an understanding of cements and faulting mechanisms and their breakdown.

Sand Prediction Modelling

The strength of a sandstone will exert an important control over the amount of sand produced. Current sand prediction models tend to *over*predict the amount of sand production. Overprediction may result in unnecessary over-specification of equipment at great cost. In contrast, underprediction can result in unexpected erosion and damage of wellbore and associated equipment, therefore more accurate models of predicting sand production are required.

- Methods of log analysis are sought which will enable the prediction of the competence of a formation under various conditions.
- What influence does the presence of water have on sand production?
- What effects do corrosive gases (e.g. CO_2 & H_2S) have on sanding – could they accelerate silica-cement dissolution?
- Do stress changes act to accelerate water breakthrough?

Effects of Compaction & Geomechanics

Production geomechanics aims to predict the displacements, deformations and stress changes resulting from production. Most models describe the effects of depletion, which can be viewed as a very sudden perturbation of the geologic equilibrium in the rock before it is drilled. Geomechanical models for the behaviour of rock over production timescales are much easier to set-up for a continuous rock mass than for a fractured one. Hence, even though a calibrated model may be able to resolve shear and normal stresses on the fault, it is very difficult to predict *when* and *where* a fault will slip, and *when* such slip will damage or destroy the well (stop production).

The problem of prediction of the timing of fault slip in and above compacting reservoirs is similar to that of earthquake prediction due to tectonic forces (though the driving forces and energy release rates are very different). Because technical advances would be of great economic benefit to field managers, (wells in basins like the North Sea and the Gulf of Mexico costs tens of millions of USD), previous work done in the realm of earthquake prediction should be critically reviewed, and may shed light on the following questions:

- How should reservoir-compaction-induced fault slip be modelled?

- What faults should be incorporated in the geomechanical model? Not all faults identified on seismic can be included, but how to select the most relevant ones, i.e., those that may slip and affect production operations?
- How should these faults appear in numerical models, and what laws (equations) describe their behaviour? For instance, what are the fault frictional properties?
- How does fault slip relate to the country rock deformation?
- What is the role of layer parallel sedimentary inhomogeneity?
- How do we handle the uncertainty relating to fault movement - can we improve on +/- 50%?
- How strong does the casing need to be?
- The geochemical and geodynamic environment is changing, can we make predictions when water injection is in progress/has been actioned?
- How many well failures are caused by slippage in the overburden, versus well loss due to buckling of the casing caused by high compaction in the reservoir?
- What is the nature of compaction in the overburden and relationship to fault re-activation?

Better Seismic Imaging

Obtaining quality seismic is an issue especially in deep reservoirs (>5 km depth). Multi wide-azimuth surveys are sometimes undertaken in order to obtain better reservoir characterisation.

- Life-of-field seismic monitoring has benefits, but has costly deployment and requires frequent re-shooting. Alternative approaches to life-of-field monitoring are invited.
- Data acquisition is an issue as there is a need to get sufficient energy down and back-up again – can resolution and penetration be improved?
- Passive seismic monitoring may have a role, but there are both cost and technical/interpretation issues. Some of the interpretation challenges are:
  - What are the anomalies caused by?
  - Can we use more appropriate processing to work out what is going on?
  - Can we invert (reverse) model the response?

Impact on Fluid Flow

- Do faults open or close as the pressure fluctuates?
- What is the effect of fluid flow on reservoir compartments – can they be opened up? At what point does a fault seal or vent? Does the fault angle affect sealing? It is believed that compaction will cause low angle faults to seal better.
- Are different faulting mechanisms involved in this environment – small scale slip rather than clay smear formation?
- In this context how important is diagenetic (quartz/clay/calcite) sealing of faults?
- Can we better predict how much differential pressure a fault can handle – pressure differences of 8,000 psi can be observed over a small area?
- Can you breach compartments by drilling?
- It is often difficult to model the fluid flow in this environment to determine if it is being constrained by faults as the flow rate is so high. Condensate

banking and scale formation may contribute to the observed flow patterns. Can we better discriminate between the different factors?

Changing Recovery Mechanisms

Improved understanding of the different recovery mechanisms is required for the various stages of production. The mechanisms of recovery will change with time.

- What happens in a partially depleted HPHT reservoir?
- Strong stress changes are experienced and the fracture pressure has changed – is it possible to make use of this in a positive sense to aid production? For instance, fault slip in consolidated granular materials is often accompanied by rock volume increase (dilation). This may increase the fault-rock (gouge) permeability, and lead to interconnection, fluid-flow and pore pressure equilibration of adjacent reservoir compartments.

Downhole Equipment Longevity

The high temperatures frequently destroy downhole tools and gauges. How can we improve their survivability and continued accuracy. The industry is now drilling wells in temperatures which are close to or exceed the temperature rating for many electronic components. Similarly elastomeric seals and cable sheathing are at risk. We need better high temperature resistant / long life materials.

- Can pressure gauges and other downhole instrumentation be ruggedised to operate more reliably to operate (within specs) for years in a downhole HPHT environment?
- There is a requirement for accurate downhole-compaction monitoring tools and techniques.
- Formation-Pressure-While-Drilling tools are very useful; however there are concerns over potential failure at high temperatures.
- Tool calibration and accuracy at high temperature is a concern – experience has shown that tools drift over time, e.g. PWD tools.

Data Acquisition

- Drift on measurements and resulting data quality is an issue - how much do gauges actually drift over 3/4/5 years?
- Operational experience has shown that gauges are affected by temperature cycling – can improvements be made? Is auto recalibration a possibility?

As a general point ***if software is to be proposed as a deliverable it must be capable of being integrated with existing industry standard software platforms***.

6. Expression of Interest - Issues to be addressed

The completed Expression of Interest should detail the innovation proposed. In addition, it should address some or all of the following questions plus any other information considered relevant. Proposers are requested to limit submissions to the four A4 pages provided. The blank Expression of Interest form is available for download from the ITF website.

i. How does the proposed contribution fit with the overall theme of this Call?

ii. What collaborations have been established, or will be established, to fulfil delivery of the proposed contribution?

iii. What are the track records of researchers in this or related areas, such as technology transfer between industrial sectors?

iv. What is the proposed route to delivery/implementation of outputs?

v. Does the submission contain confidential information? If so, you can complete the Researcher Confidentiality Agreement available on:

   http://www.oil-itf.com/home/downloads.asp

vi. What steps have been taken to protect/exploit intellectual property arising?

7. Next Steps

Expressions of Interest should be emailed, as a Word document, to Colin Sanderson, ITF Technology Analyst. Contact details are given below.

After the 1st September 2008 closing date, a panel of experts will review the submissions. These will be judged on their relevance to the overall Programme and to the issues detailed on previous pages, the track record of the researchers in developing practical, innovative solutions and the potential impact of outputs from the proposal on the understanding and development of hydrocarbon reserves around the world.

Following this review, successful consortia will be invited to present more comprehensive proposals according to the timetable summarised on page 2.

8. ITF Contacts

If you would like to discuss any matters related to this programme or any other issue related to ITF, please contact either Colin Sanderson or Duncan Anderson.

Contact	**E-mail**	**Telephone**
Colin Sanderson	c.sanderson@oil-itf.com	+44 (0)1224.853408
Duncan Anderson	d.anderson@oil-itf.com	+44 (0)1224.853405