[PS]Hostile Sequential Formation Tester-II (HSFT-II™ Tool) Highest Temperature Rated Wireline Formation Tester - 450 DEG F & 30,000 PSI*

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Abstract

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The first-generation tool, introduced in 2002, provided a wealth of experience in collecting pressure measurements and samples in formations of approximately 400°F. In the Gulf of Thailand (GOT), these hostile wells are typically slim hole and highly deviated, which increases the risk for tools to become stuck. The southern fields of the GOT are the most challenging, with higher geothermal gradients, relatively deeper burial depths, higher mud weights, reversal in pore-pressure profile, lower permeability, and depleted zones. Previous tool statistics showed that many pressure tests failed to obtain an effective pad seal because of the adverse borehole environment.

The new tool, with its dual pads and independent deployment configuration, can run two different probe pads that are designed specifically for different scenarios based on well conditions. Increased pad life enables the same tool to be run for an extended range of pressure test programs.

This case study reviews examples and job profiles to illustrate the best practices for HTHP testing. Success rates are tracked to demonstrate how the improvements have led to successful testing in progressively more hostile conditions. As of 2011, more than 40 jobs were completed

successfully. Conclusions are presented regarding the future of hostile formation testing and how the new technologies that are anticipated for these tools will continue to extend their capabilities.

HOSTILE SEQUENTIAL FORMATION TESTER-II (HSFT-II™ Tool)
HIGHEST TEMPERATURE RATED WIRELINE FORMATION TESTER – 450 DEG F & 30,000 PSI

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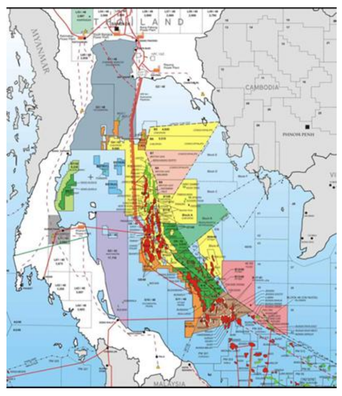
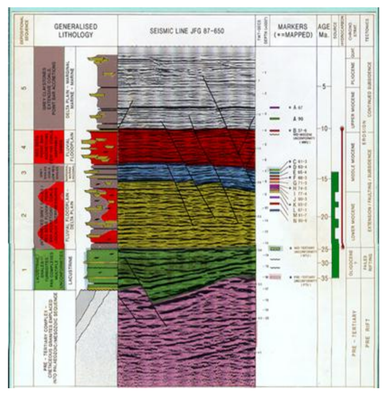
Gulf of Thailand Geology

The majority of petroleum produced in Thailand comes from offshore Tertiary basins in the Gulf of Thailand. The Ko Kra Ridge splits the Gulf into two parts. The western portion contains ten main basins of various sizes. Discoveries have been made in the Chumporn and Songkhla Basins. The eastern part is composed of the Pattani, Khmer, and Malay Basins. Pattani and Malay are hydrocarbon prolific basins. Sediments are non-marine in origin, mainly fluvio-lacustrine deposits. However, the eastern portion was influenced by marine incursion during the early Miocene age.





Multi-well Development Plan
Estimate 300+ wells drilled per year
Highly-Deviated Wells (50°+)
Hostile Condition and Slim Hole (6-1/8 in.)

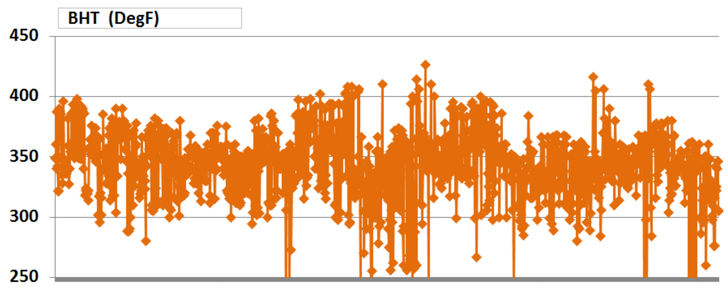
Northern Fields
Shallower (~12,000 ft , BHT ~ 350°F)

Southern Fields
Deeper (~15,000 ft, BHT ~ 400°F +)
Pore pressure reversal and high differential possible in depleted zones

Hydrocarbons are found in Oligocene and Miocene sandstones. Source rocks are of Oligocene and Miocene sediments. The Oligocene sources are oil-prone source rocks that contain Type-I kerogen. The Miocene sources are fluvial flood plain and delta plain sediments that mainly consist of Type-III kerogen and tend to yield gas. A variety of trap types are present in the Gulf, including anticlinal faults, tilted faults, rollover, and buried hills. A number of oil and gas fields have been found in the Pattani and North Malay basins. Most of the gas fields are distributed all over the central part of the Pattani basin, while oil fields are gathered in the shallower part of the basin margin. Blocks are available for bid throughout the Gulf, particularly in the northern and southern portions.

Lessons Learned from Past Pressure Testing Data

- The maximum operating temperatures reached in a series of jobs performed over the last eight years indicate that the range of temperatures in which the tool has been operating is increasing, and the maximum temperature of several wells is exceeding the 204°C (400°F) temperature limit for the market-available pressure-testing tool.

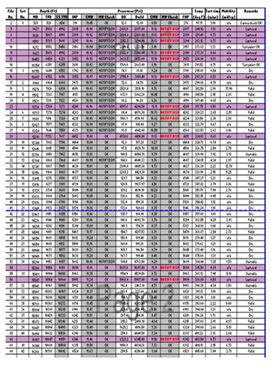


- Multiple 'pad' designs and materials have been tested to obtain the best 'pad' for the GOT operation.
- The challenge is to make a suitable pad that is soft enough to seal and strong enough to retain its mechanical properties to survive high drawdowns and last throughout the entire run.
- Two pad designs have been fully optimized thus far.

Standard Pad
- Softer
- More Elastomer
- Better sealing but gets damaged faster in High temp
- Good success in Northern fields

Capture Pad
- Harder
- Metal captured base
- Less Elastomer
- Survive Longer in High temp
- Better success in Southern fields

- In southern fields with higher BHT, a capture pad is needed for HSFT to be able to survive throughout the entire testing program.
- A typical test result shows that the capture pad has a low success rate in the shallower, lower-temperature section (failure to obtain proper seal), as shown by the shaded rows.
- Needed a tool that could run both types of pads in a single run.
- Low-permeability zones cause larger draw-downs, which adds stress to the pad.
- Depleted zones cause high differential, which adds stress to the pad.
- Suspected non-circular holes cause further aggravation.
- Deviation causes the pad to erode from one side.
- Effect of oil-based mud on elastomers
- Avoid fishing. Retain the successful HSFT™ tool configuration and design.
- Be able to spend more time in high temperatures for longer testing programs



Shallow depth, Low temp

Deeper depth, high temp

Standard Pad (good seal but damage quickly)

Capture Pad (More durable, but compromise sealing)

The standard pad is severely damaged in high-temperature / high-differential pressure testing.

The capture pad is more durable. With a metal capture base and less rubber, it requires high temperatures to deform and to properly seal.

Therefore, a high-temperature well will require 2 pads to have the best success.

Halliburton's New Hostile Sequential Formation Tester (HSFT-II™) Tool

delivers sizzling performances in extreme temperatures and pressures. The tool acquires formation pressure data and fluid samples under extreme conditions with 2 packers, up to 232°C, 30,000 psi, and in boreholes as small as 4 in. in diameter. The HSFT-II tool can also be combined with HEAT™ Suite resistivity, sonic, and porosity tools, thus saving valuable rig time. In hostile conditions, this may be the only chance you have to acquire accurate logging data. In addition, it minimizes operation risks and saves rig time with its unrivaled reliability.

2 samples can be taken in 1 run

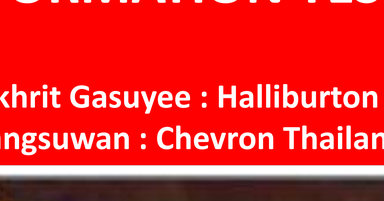
HSFT-II™ Introduction

	HSFT™	HSFT-II™
Max Temp (Deg F)	400	450
Max Press (PSI)	25000	30000
Max O.D. (inch)	3.125	3.25
No. of pad	1	2
No. of pretest	1	2

Additional Features
- Shut-In valves on each probe for isolate the 'undesired' pad
- Temperature sensors on each Probe for Fluid ID
- Capable of Pump Out

Pad Deployment Option

Several options are available to customize the testing program based on key factors (i.e., bottomhole temperature, number of testing points, fluid mobility).



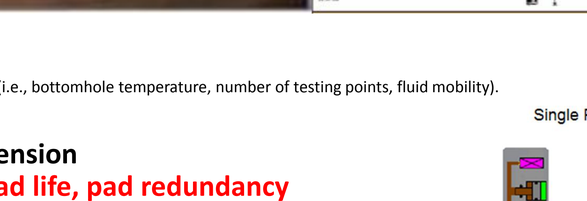
Single Pad Extension
- **Double pad life, pad redundancy**
- Toggles pad to find the valid test
- Can run different type of Pads

Dual Pad Extension
- Redundancy at the same test, double chance to get valid test
- Improved sampling time
- Can run different type of Pads

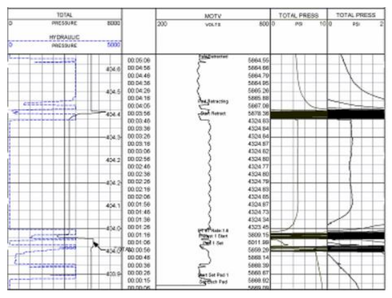
Oval Pad
- Laminated shale – sand
- Low-mobility sampling
- Near-saturation pressure

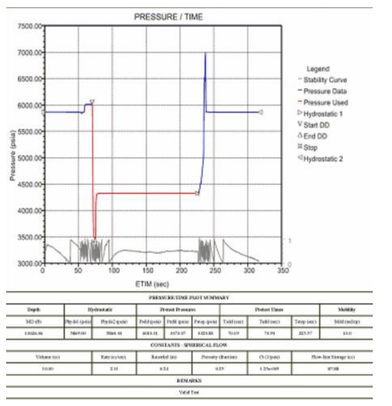
The HSFT-II tool uses a new flask design, and, with newer electronics inside, the internal heat generated by electronics is less than the heat generated by the HSFT or an equivalent pressure-testing tool, thereby allowing for longer testing times. In addition, more testing points can be achieved prior to the tool reaching the internal temperature limit of 350°F.

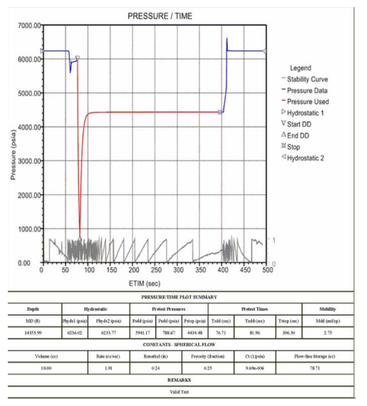
The graph below illustrated that the HSFT or an equivalent tool will have 11–14 hrs operating time prior to reaching the internal temperature limit, while HSFT-II can be used for up to 19–23 hrs.

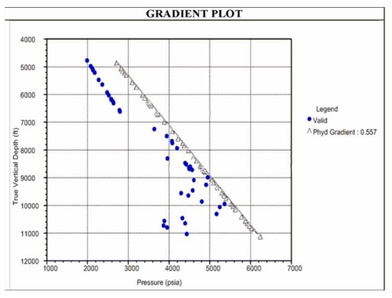


A total of 76 jobs have been performed in the GOT. The tool delivers high reliability and, with an extra pad, allows more pressure testing points to be achieved in one run (see example).
This particular well has completed 68 tests with 2 pads, one standard pad and one capture pad, and a highest temperature test at 420°F, with a single-pad extension configuration (this had never been achieved in this particular field and with this range of BHT).

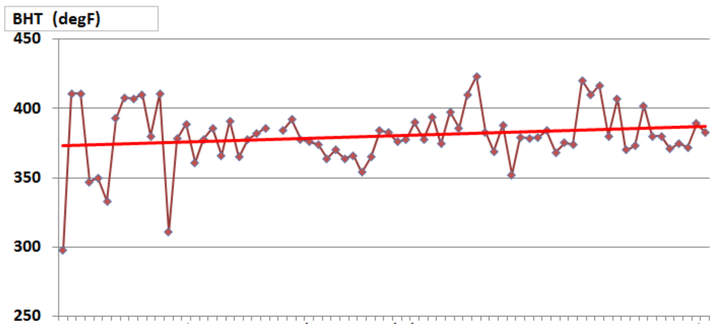




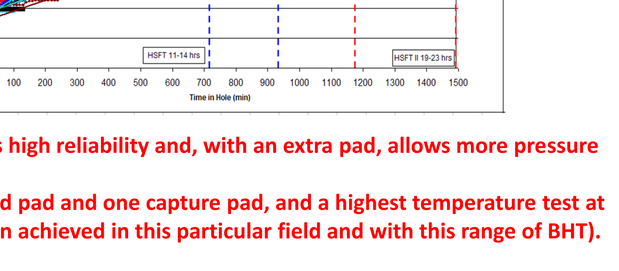




The graph below illustrates total HSFT-II tool jobs vs. bottomhole temperature (BHT) from 2010–2012. The BHT has a tendency to increase more in the future.



Summary



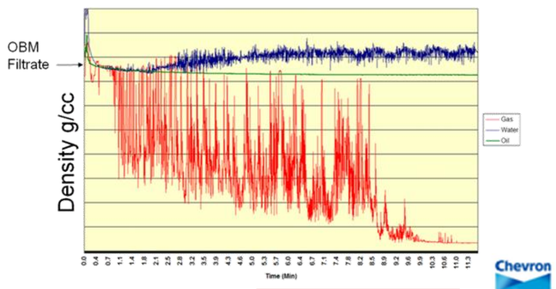
- Hostile formation testing at 450°F and 30 Kpsi is a reality.
- Higher temperature rating (450°F vs. 400°F)
- Saving rig time for HSFT™ tool failure after exceeding temperature
- Single / Dual Pad Configuration, Pad Redundancy
- Ability to put two different pad types (low-temperature type and high-temperature type) in the same run
- Double chance to obtain a valid test from one stop of the tool
- Reduce the waiting time for stabilization if both probes are used for pressure test
- Internal-temperature build is slower compared to HSFT tool, allowing for more time / tests in the well.

Future Development

Slim Hole Fluid ID
- Resistivity- / density-based sensors
- Initial tests show that it is possible to identify the fluid within 10 minutes
- Bubble point test

Slim Hole Pump Out and PVT Quality Sampling
- In progress

Example OBM Oil – Gas & Water



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