

# PermSpotter Testing Solutions



## RELIABLE OPEN-HOLE PERMEABILITY AND SKIN TESTING



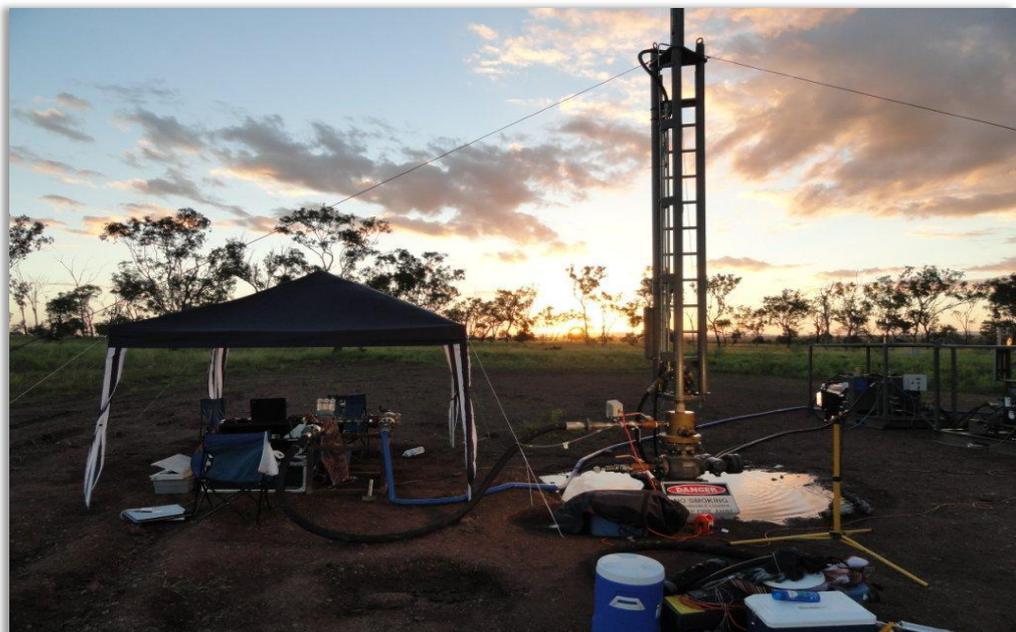
### Challenges

In order to certify proven and probable (2P) economic reserves estimates, asset teams must quantify original hydrocarbons in place and predict reservoir recovery factors. This latter variable is greatly influenced by reservoir deliverability, known more commonly as production potential. This in turn is influenced by reservoir and fluid properties, which is captured in definition of fluid phase mobility, a term which incorporates reservoir permeability. Quantifying reservoir permeability is thus a crucial goal.

Permeability is essentially a measure of the resistance to flow in a porous media, and, in accordance with Darcy's Law, is the constant of proportionality linking pressure drop in the direction of flow to flow rate, under steady state incompressible flowing conditions. It is thus not a parameter directly observed or measured, only inferred from the ratio of other physical parameters. Furthermore, reservoir permeability can vary in direction (anisotropy), location (heterogeneity), and change over time with changes in effective earth stresses. Mapping these variations across the field requires extensive individual permeability tests, supported by studies in reservoir Petrology, Geology and surface lineaments to identify trends linking permeability with other pertinent reservoir characteristics.

### FEATURES & BENEFITS

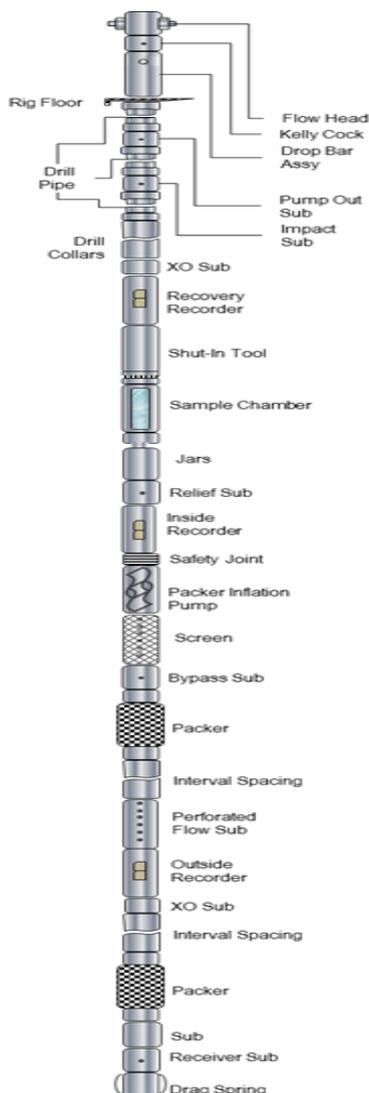
- > Accurate determination of reservoir bulk permeability by inducing and monitoring reservoir pressure transients
- > Pressure transient analyses techniques enables computation of additional reservoir parameters, augmenting reservoir characterisation, thereby boosting understanding of reservoir behaviour



## FEATURES & BENEFITS

*continued*

- > Various alternative systems are available to cater for wide range of test types, and that can be configured to suit field, well and reservoir conditions
- > Complemented by a Reservoir Engineering Support function to aid test type selection and test design
- > Expert PTA can also be provided, including diagnosis and reservoir modelling
- > All systems permit isolated testing of multiple zones to be conducted in a single trip



## Constraints

Geological setting, reservoir structure, tectonic activity, natural fracturing, reservoir composition and reservoir physical characteristics can vary widely, all of which can impact matrix and bulk permeability. Bulk permeability is impacted by frequency of natural fractures, their interconnections and fissure aperture. In coal seam reservoirs, bulk permeability is also influenced by direction of butt and face cleats, burial depths, matrix shrinkage upon desorption, post-fracture mineralization and in-situ stresses.

The test methodology selected to quantify permeability for each reservoir unit must be sufficiently flexible to accommodate these wide variations in test conditions. Parameter ranges to be accommodated include:

- > Reservoir Type: Sandstone, Carbonate, Shale and Coal
- > Permeability Range: 0.001-10,000 mD
- > Maximum Depth: 14000+ feet TVD
- > Fluid Types: Oil, Water and Gas
- > Viscosity Range: 0.01 – 10 cp
- > Reservoir thickness: 1-100+ feet

### Core Studies

It is possible to quantify permeability from tests on whole cores under precise controlled laboratory conditions. However, accuracy of such tests can be impacted by number of factors, including method used to capture the cores, extent of filtrate invasion, damage to cores during retrieval, poor core preservation at surface, improper re-stressing of cores in the laboratory, re-stress hysteresis of cores, and scaling effects (core diameter relative to primary, secondary and tertiary fracture network spacing). Furthermore, the high cost of coring and core laboratory studies imposes an economic limit on the number of such tests that can be performed, resulting in a discrete data set that is often too small to adequately capture field-wide variations and establish trends.

### Wireline Logging

It is also possible to construct continuous profiles of permeability through the reservoir using wireline logs. Given it is not possible to measure permeability directly, complex multi-parameter correlations are used instead which equate permeability with other measured physical reservoir characteristics. The correlation coefficients are calibrated through comparison of computed permeability's with measured values obtained at discrete depths from core laboratory studies, which as mentioned previously, are in any case prone to sizeable errors. Measuring the parameters used by the correlations also involves running a combination wireline toolstring (typically gamma, Microlog, NMR, Bulk Density & Neutron Porosity), which again can be cost prohibitive. Furthermore, the values of permeability derived from these correlations are not deemed sufficiently accurate for certification of 2P reserves.

## Solution

### Well Testing using PermSpotter

WellDog's PermSpotter technology offering provides a means for determining bulk permeability from monitoring and analysis of pressure transients induced in the reservoir. Pressure transient analysis (PTA) techniques also yield values of average reservoir pressure, radius of investigation, total skin, conductivity and half-length of hydraulically induced fractures, depending on the type of test employed to induce the pressure transient.

In order to accommodate a wide range of reservoir conditions and test objectives, PermSpotter systems can be configured to conduct variety of test types, including:

- > Inflow Tests & Buildup Tests
- > Slug Tests
- > Injection Falloff Tests (IFT), including:
  - Tank Tests
  - Below Fracture Pressure Injection Fall-Off Tests (BFP-IFT)
  - Diagnostic Fracture Injection Test (DFIT)



### *Reservoir Engineering Technical Support*

Another important aspect of WellDog's PermSpotter service is provision of reservoir engineering technical support to help assist with test selection and design. Test selection methodology is driven by a decision tree that takes into consideration the well type, design, and status, as well as stimulation status, anticipated permeability, expected reservoir pressure, produced fluids from the target zone of interest, level of saturation and rig equipment.

Test design is driven by need to optimize quality of the pressure data acquired. This means performing tests, if possible, under single phase flowing conditions or, if multi-phase flowing conditions are unavoidable, minimizing saturation changes. It is also important to minimize changes in effective earth stresses, and prevent sudden pressure shocks to minimize completion skin effects. This needs to be counter-balanced against the desired radius of investigation.



### *Real-Time Data Acquisition*

While technical due-diligence is crucial in shaping test selection and test design, uncertainties in reservoir characteristics may require changes to the test design during execution in order to optimize validity of pressure transient analyses. Access to real-time formation pressures during the flow and shut-in periods is therefore critical. WellDog's PermSpotter technology offering also includes provision of either wire-less or electric-line surface readout formation pressure monitoring systems.

The wire-less system relays pressure data to surface using a low frequency electromagnetic (E-M) signal propagated through the surrounding overburden to one or more receivers staked in the ground at surface, eliminating the need for complex inductive coupling systems or wet-mate connections and associated wireline equipment, thus saving costs and mitigating interruptions to rig operations. However, the use of a low frequency signal limits available bandwidth, constraining both data rate and pressure resolution.

For high permeability reservoirs, resulting in small and rapid pressure transients, pressure data can instead be acquired real-time using a pressure gauge deployed on conventional electric-line. Use of electric-line allows more resolute pressure data to be transmitted to surface at much higher data rates.

### *Pressure Transient Analysis*

Real-time data from the surface readout pressure gauges is captured using ResPlot RTTM, which provides a means for viewing data as text, and also graphically as Cartesian plots. Basic real-time pressure transient analyses (PTA) can also be performed, comprising display of both semi-log (Horner) plots and log-log plots ( $c/w$  derivative). Data acquired by ResPlot RT can also be shared real-time with remote client offices via an Internet connection using Webex.