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# Multi-function Neutron Imaging System (MNIS)

Tool Background

Funded and developed by Advanced Applied Physics Solutions (AAPS), a Canadian designated Centre of Excellence for Research and Development established at TRIUMF – Canada's national laboratory for particle and nuclear physics, the MNIS technology was created for application within the oil and gas market to target enhanced hydrocarbon recovery, determine bypassed pay, cavern interface requirements, time-lapse monitoring and as an open hole log alternative.

The MNIS system integrates advantages of neutron-gamma and neutron-neutron measurements in one pass. The technology measures multiple well parameters and provides imaging of neutron/gamma decay in addition to gas index and the most accurate and precise saturation information available via downhole measurement. The MNIS is suitable for high, medium and low-salinity environments as well as high, medium and low-porosity formations. The MNIS features optimal detector layout, and provides superior performance with excellent reliability.

Features

- High precision macro-capture cross section (Σ) benefits from neutron and gamma detection, dynamic time-window optimizing and improved data processing

- Neutron and gamma detection provide accurate and pre-cise saturation from low to high porosity and salinity reservoirs

- Advanced interpretation and optimal detector placement distinguishes between gas reservoirs and low-porosity formations

- Determine reservoir saturation and porosity parameters simultaneously

- Multi-detector array, multi-parameter data acquisition and data imaging

- Reliable modular design yields reliability and repeatability of the formation evaluation results

- Versatile data acquisition platform, on-site data processing and interpretation yielding definitive results
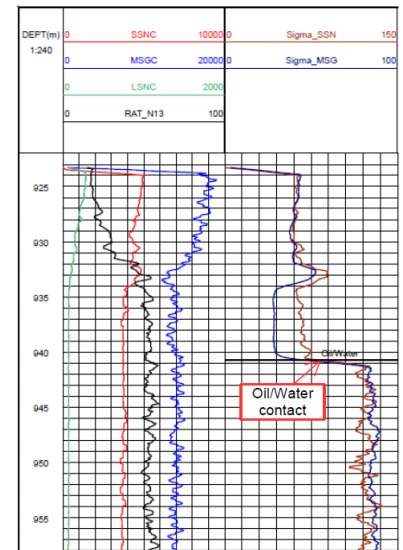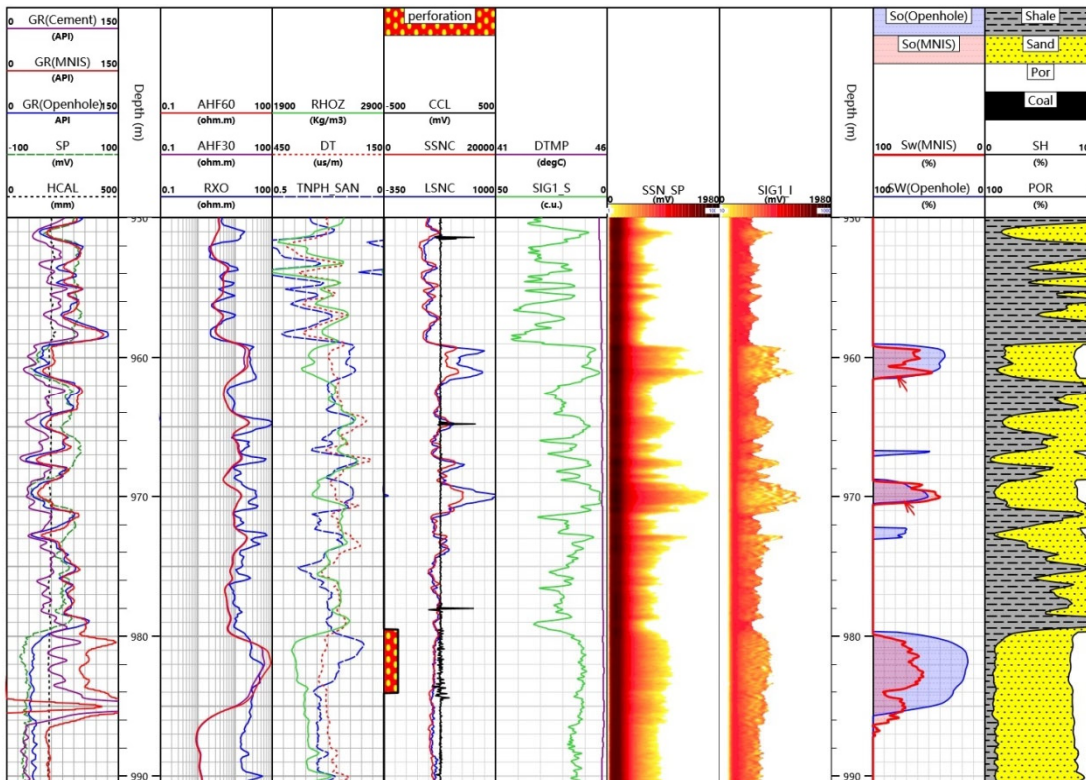
An example from the Galahad field, in Alberta Canada: This example shows the application of the MNIS for cased-hole formation evaluation to analyze oil-water distribution in a well that has been producing for 12 years. Recent production showed water up to 98.3% as 320bbl/d liquid. After MNIS log, analysis and water shutoff procedures, water production dropped to 200bbl/d liquid and oil production increased by 47%. In addition, the MNIS log highlighted two bypassed hydrocarbon reservoirs available for production just shallower than the produced zone.

A Cavern example, Alberta Canada: The real-time log of the cavern showed a distinct oil/saline interface despite the interface within the 3cm annulus. Natural Gamma (GR), Casing Collar Locator (CCL) and borehole temperature (TBH) are all available measured parameters that are not shown here

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Principle and Methodology

The pulsed neutron generator (PNG) emits "fast" neutrons at 14 MeV and bombards the surrounding formation nuclei. The formation information is then extracted by recording the interactions that occur during the process of a neutron's life cycle; specifically, the MNIS records and processes the thermal neutron absorption (die-away). The speed of thermal neutron die-away is proportional to the macro-capture cross section (Σ) of the logged formation while the energy level of the incident gamma rays are used to differentiate gas, oil and water in the pore space of the formation. The decay of the emitted fast neutron and resultant gamma rays produced during thermal neutron absorption by the formation and are used to accurately quantify the makeup of the formation and its bound fluid. The Σ output, decay and energy levels of the released gamma rays are used to calculate formation water saturation. The multi-detector array also provides the formation gas index.

Applications

- Evaluate produced wells to locate bypassed hydrocarbons and water entry for enhanced oil recovery
- Evaluate cavern interface, static or dynamic
- Evaluate steam chamber development in SAGD applications
- Determine saturations in high/medium/low salinity and high/medium/low porosity formations
- Evaluate and monitor reservoir residual oil and gas index in cased hole
- Evaluate new cased holes and perform time-lapse logging to monitor reservoir saturation

Benefits

- The MNIS provides accurate data in open-hole and cased-hole environments, oil, gas and water wellbores, vertical and horizontal wells
- The MNIS measures 43 mm in diameter and can be run through casing and tubing with no need to kill well yielding reduced cost and down time
- On-site interpretation and processing ensuring the desired information is recorded and delivered before leaving location

MNIS Tool Specificaitons	
Dimensions and ratings	
Maximum O.D.	1.69 in (43 mm)
Maximum Pressure	15 kpsi (103.4 Mpa)
Maximum Temperature	302°F (150°C)
Minimum Csg/Tbg ID	2.05 in (52 mm)
Maximum Csg/Tbg ID	9.625 in (24.45 cm)
Weight	110 lbs (50 kg)
Length	22.87 ft (697 cm)
Hardware characteristics	
Source Type	14-MeV DT neutron generator, lifetime up to 800 hours
Number of Sensors	4 (three capture detectors and one natural gamma detector), CCL and TBH
Sample Rate	10 - 40 variable samples per meter
Measurements	
Vertical Resolution	~ 16 in (40 cm) @ typical formation
Depth of Investigation	~ 6" (15 cm) inelastic/ ~ 12" (30 cm) capture @ typical formation
Primary Curves	macro capture cross section Σ, near/far/long capture CR, near/ long CR ratio, inelastic CR, near/far/long time spectrum
Secondary Curves	Σ, porosity ϕ, gas index etc