WELL LOGGING TECHNIQUES

WELL LOGGING DEPARTMENT
OIL INDIA LIMITED
The Hydrocarbon E & P Process

- In the exploration process, a most probable hydrocarbon bearing rock structure is defined based on seismic and geological surveys, and a drilling location is then released and the well is drilled.

- It is now necessary to ascertain the hydrocarbon potential of the well vis-à-vis the reservoir.

- Many sub-surface data are obtained from drill coring and cuttings, but the method is highly expensive and has many limitations.
WELL LOGGING – The Eye of Oil Industry

• Here comes the role of Well Logging Technique

• Well logging provides a cheaper, quicker method of obtaining accurate sub-surface petrophysical data

• Well Logging measurements can:
  • Ascertain hydrocarbon potential of the well
  • Determine hydrocarbon type and volume
  • Determine what types of fluid will flow and at what rate
  • Optimize well construction and hydrocarbon production

• Well Logging finally serves to:
  • Identify Hydrocarbon Reservoirs
  • Define Total and Recoverable Reserves
TO DEFINE…

• Well Logging is the technique of making petrophysical measurements in the sub-surface earth formations through the drilled borehole in order to determine both the physical and chemical properties of rocks and the fluids they contain.

• The objective is to locate, define, and produce from a given reservoir, also known as “Formation Evaluation”
WELL LOGGING TECHNIQUES

• Due to the enormous amount of data Well Logging can provide, the technology plays a pivotal role in Hydrocarbon Exploration & Production industry.

• Used in all the phases of Hydrocarbon E&P processes.

• Rapid and sophisticated developments in Well Logging technology has revolutionized the Hydrocarbon E &P industry.
WELL LOGGING TECHNIQUES

• Well Logging Measurements are carried out through the drilled borehole.

• The drilled borehole may be either an **Open Hole** or a **Cased Hole**.

**Open Hole:**
- A borehole drilled in the formation, usually available immediately after drilling.
  - All basic petrophysical measurements for Formation Evaluation.

**Cased Hole:**
- A borehole wherein steel casing pipes have been placed and cemented suitably.
  - Measurements mostly concern with Reservoir Development & Production.
Basic Well Logging Equipments

• **Logging Unit**
  – A specialized truck installed with a full computer system for data acquisition & processing

• **Logging cable or the Wireline**
  – An electro-mechanical cable reel mounted on the truck and operated by the truck hydraulics

• **Logging Tool or Sonde**
  – An electronic instrument containing sensors and processing circuitry for data acquisition and transmission

  The logging tool is lowered into the wellbore by means of the logging cable or wireline. The wireline also connects the logging tool electrically to the surface computer system. Data acquired by the tool are transmitted to the surface system over the logging cable using digital telemetry. The surface computer records, processes and plots these data as a function of well depth and produces what is called a “log” or “well log”.

• **This is normally called the Wireline Logging Technique**
BASIC WELL LOGGING TECHNIQUE

LOGGING UNIT WITH COMPUTER SYSTEM

WIRELINE

LOGGING TOOL
A present-day Logging Unit
ELECTRONIC CIRCUIT BOARDS INSIDE LOGGING TOOLS
WELL LOG SAMPLES
BASIC FORMATION EVALUATION

• To estimate Hydrocarbon potential of a reservoir, we need to know
  – Porosity
  – Permeability
  – Water Saturation

• Well Logging measurements aim at determining these three main Petrophysical parameters of the earth formation
What Do We Need To Measure?

- Density?
- Travel time?
- Bed thickness?
- Fluid samples?
- Reservoir pressure?
- Neutron porosity?
- Resistivity?
- Coring?
Basic Well Logging Petrophysical Measurements:

- Natural Gamma Radioactivity
- Formation Resistivity
- Formation Density
- Formation Porosity
- Acoustic Travel Time
- Formation Pressure / Fluid Sampling / Coring
MEASUREMENT OF NATURAL GAMMA RAY

• Earth formations are radioactive due to presence of naturally occurring radioactive isotopes of Uranium, Thorium and Potassium

• Gamma Ray logging measures the natural Gamma radiations

• Applications:
  – To identify permeable zones, lithology
  – Shale volume calculation
  – Well depth correlation
FORMATION RESISTIVITY MEASUREMENT

- Resistivity is the physical property of a formation which impedes the flow of electric current.

- Resistivity is measured by the Resistivity Logging Tools like DLL, HRI, HRAI etc.

- Based on Induction or Latero-log (current focus) principle

- Applications
  - Determine the True Resistivity of the formation and depth of invasion.
  - Indicate the presence of movable hydrocarbons
FORMATION DENSITY MEASUREMENT

- Formation Bulk Density is measured by the Density Logging Tool
- Tool uses high energy gamma ray source (Cesium 137, 1.5 Curie) to allow interaction of gamma rays with formation atoms

Applications:
- Determine accurate formation porosity
- Identify lithology
- Delineate thin beds
- Indication of gas when used in combination with a neutron log

(Courtesy Schlumberger Well Services)
NEUTRON POROSITY MEASUREMENT

- Porosity can be estimated from a variety of “porosity logs” (sonic, density, neutron, or magnetic resonance log)
- Neutron porosity logging is a nuclear technique based on neutron-nuclei interactions in the borehole environment
- Neutrons are emitted into the formation by an external Neutron source (AmBe 241, 18.5 Curie) mounted on the tool

Applications:
- To measure total porosity of formation for saturation calculation
- Gas detection in conjunction with density log
ACOUSTIC (SONIC) LOGGING

- Based on propagation of sound waves in the reservoir rock matrix and fluid filled pores
- Measures a number of formation sonic parameters like compressional & shear velocities and travel time using both monopole and dipole transmitters & receivers
- Uses:
  - Find porosity, identify lithology, gas detection
  - Study rock mechanical properties, anisotropy analysis
  - Seismic correlation & AVO study
  - Hydro-fracture evaluation etc.
VERTICAL SEISMIC PROFILING (VSP)

- Utilizes sensitive geophones to acquire high-quality seismic data from the borehole

- Uses:
  - enhancing and supplementing surface seismic data
  - Predict stratigraphy, lithology, and structure ahead of the drill bit to save drilling time and costs
MAGNETIC RESONANCE IMAGING LOGGING (MRIL)

Like its counterpart in Medical sciences, Nuclear Magnetic Resonance (NMR) technology is used in well logging to find:

- Total fluid-filled porosity
- Provide fluids-only measurement
- Identify low-resistivity pay within immovable water volumes
- Determine Permeability, fluid types and fluid contacts
CARBON/OXYGEN (C/O) LOGGING TECHNIQUE

• Carbon/Oxygen (C/O) Logging is a pulsed neutron logging technique for monitoring and managing the production of hydrocarbon reserves.

• Used widely to:
  – Accurately determine oil and gas saturations
  – Identify bypassed reserves
  – Pinpoint fluid contacts
  – Identify lithologies and mineralogies
  – Detect water flow behind casing pipe
WIRELINE FORMATION TESTING & SAMPLING

• Provides accurate reservoir pressure measurement and reservoir fluid samples

• Uses:
  – accurate, reliable hydrocarbon/fluid typing
  – improved permeability estimates
  – evaluate reservoir potential and plan well completions
ELECTRICAL MICRO IMAGING TECHNIQUE

• Based on measurement of formation microconductivity with pad-mounted button electrodes.

• Provides a core-like image of the borehole wall with direction and orientation

• Applications:
  • Detailed stratigraphic and sedimentological analysis
  • Thin bed delineation
  • Potential secondary porosity identification & Fracture analysis
  • Quantitative high-resolution resistivity for improved net pay estimation
  • Fault mapping & general structural analysis
SIDE WALL CORING

• To recover cores or samples from a prospective formation for analyzing in laboratory

• Application:
  – Porosity, permeability, fluid saturation estimation
  – Grain size & matrix determination
  – API oil gravity determination
  – Gas & oil presence
LOGGING IN DIFFICULT CONDITIONS

• Conventional method wireline logging can not be used in case of highly deviated or horizontal wells or wells with severe downhole problems

• Techniques like Measurement While Drilling (MWD), Logging While Drilling (LWD) and Tool Pusher Logging (TPL) had been developed to transport logging tools into the well via drill pipes as part of drilling BHA

• Other methods of tool conveyance like Downhole Tractor, Well Shuttle etc. are also available
WELL LOGGING TECHNIQUES

• After acquisition of well logging data, it is now necessary to interpret and integrate the data in order to locate, define and produce from a selected reservoir.

• Open hole is now “cased” by running in casing pipes into the borehole and cementing the pipes to surrounding formation.

• A number of well logging operations are carried out in a cased hole before the well is put to flow.
CASED HOLE LOGGING TECHNIQUES

• For development, Testing and Production completion of a well.

• Basic Cased Hole operations include:
  • Cased Hole Completion Logs
  • Well Perforation techniques
  • Production Logging
  • Cased Hole Formation Evaluation Logs
Cased Hole completion Logs include:

- **Cement Bond Log**: To evaluate quality of cement bond between casing to cement and formation to cement

- **Gamma ray Log & Casing Collar Log**: For depth correlation

- **Neutron Log**: To know oil-water contact

- **Pulsed Neutron Log**: For reservoir saturation determination

- **Temperature Log**: For cement top determination
Perforation

- To make holes in steel casing and cement & into the prospective formation so as to allow fluids to flow to the wellbore and finally to the surface

- Holes are created using high explosives (called shaped charges)

- Critical perforation parameters are
  - Entry Hole Diameter of the Shaped Charge
  - Total Target penetration of the Shaped charge
  - Shot Density (no. of shots per foot) fired
  - Shot orientation
CASED HOLE LOGGING TECHNIQUES

Production Logging Measurements include:

- Well Flow Rate measurements with various types of Flowmeters
- Pressure Measurements (Draw-down & build-up tests)
- Temperature, Fluid Density, Dielectric properties of fluid, gamma ray, etc.

Applications:

- Monitor reservoir performance for production/injection efficiency
- Diagnosis of production/injection problems
CASED HOLE FORMATION EVALUATION

- Formation Evaluation parameters can now be recorded in Cased Hole also.

- Logging Tools have been designed to measure Resistivity, Porosity, Density, Saturation, Reservoir Pressure etc. through casing as well.

- Recent improvements in hardware and software designs allow to produce open hole quality logs from cased hole measurements.

Uses:

- Enables to re-evaluate old wells.
- Detect any bypassed reserves.
- Evaluate/monitor recent cased hole wells where there is no or insufficient open hole data.
CONCLUSION

• Well Logging Techniques play a fundamental role in the Hydrocarbon E & P processes

• Effective use of well logging formation evaluation data requires high level of integration that can only be achieved by inter-disciplinary team work and adequate knowledge and resource management

• Integrated interpretation of well logging data can strongly reduce Uncertainties in Formation Evaluation and in Reservoir Characterization studies
Integration… *In the Words of Patrick Corbett*

… in recent years we have been singing the praises of integration between Geosciences disciplines ...

… lets just knock down the remaining physical and perceived walls and merge geophysics, geology, petrophysics and engineering into a seamless profession …

“A changing Role for the petrophysicist?”, 2005
THANK YOU