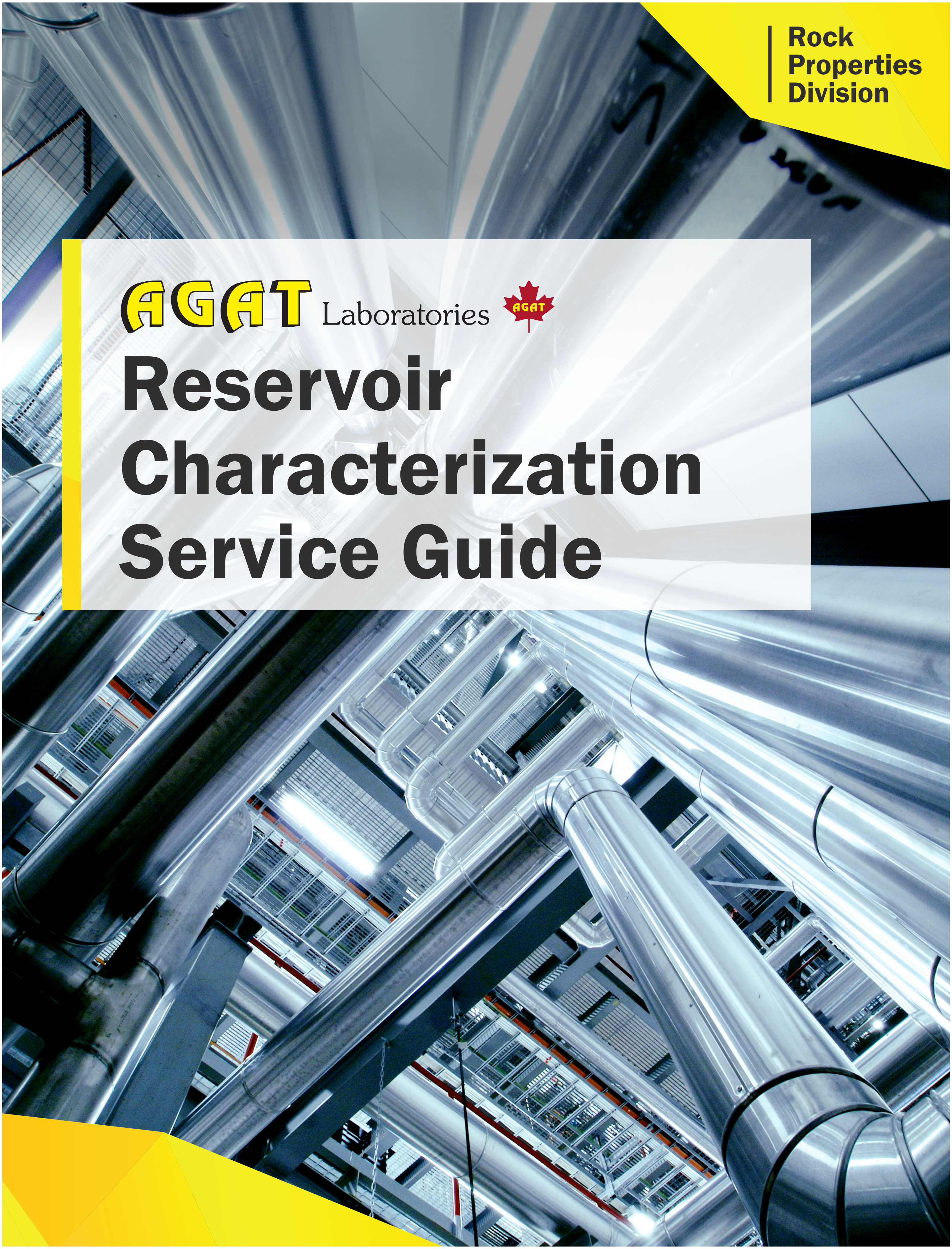
Rock
Properties
Division

AGAT Laboratories

Reservoir Characterization Service Guide



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Special Core Analysis

Petrophysical Measurements

- Petrophysical measurements include routine and net overburden (NOB) porosity and permeability.
- Core plug samples (1½” diameter) are cut, cleaned and oven dried prior to testing.
- Plugs are loaded into a combination porosimeter / permeameter, and helium gas is used to determine the porosity, while nitrogen gas is used to measure the permeability.
- Plugs are subject to a confining stress to determine the corresponding NOB values.

Testing/Sample Requirements
- Reservoir Pressure & Temperature
- Core for Sample Selection & Cutting

Duration
- 1 – 2 weeks*

Deliverables
- Gas Porosity, Gas Permeability & Grain Density
- Gas Porosity & Gas Permeability at Net Overburden Pressure

Klinkenberg Permeability

- The Klinkenberg Effect is the observation that the absolute gas permeability is always greater than the absolute liquid permeability as a result of “slip flow” between gas molecules and the solid walls of the porous medium.
- This analysis involves measuring the gas permeability of a core plug sample at a series of increasing pressures while held at a specific confining stress.
- Extrapolation of the data to infinite mean pressure will afford the Klinkenberg permeability and the slippage factor (b).

Testing/Sample Requirements
- Reservoir Pressure & Temperature
- Core for Sample Selection & Cutting

Duration
- 1 – 2 weeks*

Deliverables
- Klinkenberg or Equivalent Liquid Permeability
- Slippage Factor (b)
- Forchheimer Turbulence Factors (α & β)

* Please note that all test duration times are estimates, and that actual experimental times will vary according to the number, type and quality of samples received. This test time can be greatly extended if the sample is to undergo a wettability restoration process, which involves sample aging at reservoir pressure and temperature conditions for a minimum of 40 days.

Pore Volume Compressibility

- This analysis is used to evaluate the pore volume compressibility, which is the fractional change in pore volume per unit pressure change.
- The porosity of a core sample is measured at a series of different confining pressures to evaluate the changes in the pore volume as a function of pressure.

Testing/Sample Requirements

- Reservoir Pressure & Temperature
- Core for Sample Selection & Cutting

Duration

- 1 – 2 weeks*

Deliverables

- Pore Volume Compressibility & Pore Volume vs. Pressure Curve

Electrical Properties

- Electrical property tests are used to calibrate well logs to help determine reservoir porosity and petroleum content.
- The formation resistivity factor (F) is determined from the resistivity of a brine saturated plug sample, and is used to determine the cementation (m) and tortuosity (a) exponents.
- Tests on samples that span a range of porosity will afford more accurate F data.
- The hydrocarbon resistivity index is determined from the resistivity of a plug sample at different brine saturations, and is used to determine the saturation exponent (n).
- For samples that contain clays, the cation exchange capacity can be used as a correction factor to more accurately determine the formation resistivity factor.

Testing/Sample Requirements

- Reservoir Pressure & Temperature
- Core for Sample Selection & Cutting
- Formation Brine or Water Composition

Duration

- 2 – 3 weeks*

Deliverables

- Resistivities (Ro, Rw & Rt)
- Formation Resistivity Factor (F)
- Hydrocarbon Resistivity Index (I_R)
- Cementation Exponent (m), Tortuosity Exponent (a), Saturation Exponent (n)
- Cation Exchange Capacity (CEC)

AGAT's custom-built Electrical Properties instrument allows measurement of electrical resistivity throughout the drainage or imbibition cycle of core samples. The instrument is a coreflooding apparatus with in-line differential pressure transducers and injection pumps for controlled unsteady state coreflooding experiments, with electrical contacts placed at the injection and production faces of the core samples to allow resistivity measurements at various saturation states throughout the experiment.

Mercury Injection Porosimetry

- This analysis involves the high-pressure (up to 414 MPa or 60000 psi) injection of liquid mercury into a core sample in order to evaluate the capillary pressure.
- Advantages of this test are that it can be performed quickly, low permeability samples can be analyzed (ca. 0.0001 mD) and uniform sample shapes or sizes are not required.
- The resulting data can also be used to evaluate the pore throat size distribution of the core sample, affording a breakdown into micro- (< 1 µm), meso- (1 – 3 µm) and macropores (> 3 µm).

Testing/Sample Requirements
- Core for Sample Selection & Cutting
- Please Note: This is a destructive test and the sample cannot be re-used or returned due to mercury contamination.

Duration
- 1 – 2 weeks*

Deliverables
- Capillary Pressure & Capillary Pressure vs. Saturation Curve

Capillary Pressure by Centrifuge

- This analysis involves spinning a plug sample at high rotational speeds in an ultra-centrifuge at reservoir temperature conditions to determine the capillary pressure and water saturation parameters.
- Several different displacement methods can be performed: air-oil drainage, air-brine drainage, oil-brine drainage or oil-brine imbibition.
- Experimental data is input into a numerical simulator that models the capillary pressure – saturation relationship until the best-fit parameters of the Bentsen capillary pressure model are achieved.

Testing/Sample Requirements
- Reservoir Pressure & Temperature
- Core for Sample Selection & Cutting
- Formation Brine or Water Composition and Oil

Duration
- 2 – 3 weeks*

Deliverables
- Capillary Pressure
- Fractional & Irreducible Water Saturation
- Capillary Pressure vs. Water Saturation Curve

Samples are spun in the Ultra Rock Centrifuge at a series of spin rates with automated data capture software to determine saturation changes at each centrifugal speed. This multi-deliverable instrument allows determination of air-oil, air-water, or oil-water capillary pressure curves, wettability indices, and relative permeability.

Capillary Pressure by Porous Plate

- This analysis involves desaturating a plug sample using a semi-permeable diaphragm in order to evaluate the capillary pressure and water saturation.
- The advantage of this method is that highly accurate data can be obtained, and that several samples can be analyzed at the same time.
- A major drawback of this method is that test times can be long compared to mercury injection and centrifuge methods, as the equilibration time for each data point may take several days to reach (depending on nature of the system).

Testing/Sample Requirements

- Reservoir Pressure & Temperature
- Core for Sample Selection & Cutting
- Formation Brine or Water Composition and Oil

Duration

- 5 – 6 weeks*

Deliverables

- Capillary Pressure
- Fractional & Irreducible Water Saturation
- Capillary Pressure vs. Water Saturation Curve

Threshold Pressure

- This analysis is designed primarily for cap or seal rocks, and is used to determine the minimum pressure required to initiate gas production (also known as the breakthrough pressure).
- The test can be performed by one of two different methods:

1. Mercury Injection Method: liquid mercury is injected into the sample at high pressures to evaluate the capillary pressure, and the threshold pressure is estimated from the capillary pressure vs. saturation curve. This method is quick and inexpensive, but only provides an order of magnitude estimate for the threshold pressure.
2. Gas Injection Method: the sample is subject to confining stress and nitrogen gas is injected at a specified intrusion pressure, which is incrementally increased until gas production is observed. This method is more time consuming and expensive, but affords a more accurate determination of the threshold pressure.

Testing/Sample Requirements

- Reservoir Pressure & Temperature
- Core for Sample Selection & Cutting

Duration

- 1 – 2 weeks* for Mercury Injection Method
- 2 – 3 weeks* for Gas Injection Method

Deliverables

- Threshold Pressure or Breakthrough Pressure

Wettability

- Wettability is a measure of the affinity of the reservoir rock surface for either oil or water phases. Wettability represents the tendency of a fluid to spread over (or adhere to) the surface of a solid in the presence of other immiscible fluids.
- Reservoir wettability can be evaluated by one of three different methods:

1. Amott Method: involves spontaneous drainage and imbibition processes, which are used to determine the Amott-Harvey wettability index.
2. USBM Method: involves forced drainage and imbibition processes at a series of different rotational speeds, which are used to determine the USBM wettability index.
3. Amott-USBM Method: involves a combination of the above two methods to determine both the Amott-Harvey and USBM wettability indices.

- It is required that the core sample undergoes a wettability restoration process in order to recreate the in-situ wettability state. This process involves a minimum 40-day aging process at reservoir pressure and temperature conditions, but will ultimately afford more accurate wettability data.

Testing/Sample Requirements
- Reservoir Pressure & Temperature
- Core for Sample Selection & Cutting
- Formation Brine or Water Composition and Oil

Duration
- 7 – 8 weeks* (includes minimum 40 day aging period for restoration process)

Deliverables
- Amott-Harvey Wettability Index (IAH)
- USBM Wettability Index (IU)

Relative Permeability

- Relative permeability data is essential for accurate reservoir simulations, as it can be used to provide important information on displacement efficiency.
- Several different variations of relative permeability experiments exist in which one fluid is used to displace another fluid, such as brine-oil, gas-oil and brine-gas.
- Unsteady state methods are more common and less expensive than steady state methods. Both methods typically involve the use of a core stack comprised of 3 – 4 smaller plug samples.
- It is required that the core samples undergo a wettability restoration process, which involves a minimum 40-day aging process at reservoir pressure and temperature conditions. This restoration will ultimately afford more accurate relative permeability data.

Testing/Sample Requirements
- Reservoir Pressure & Temperature
- Core for Sample Selection & Cutting
- Formation Brine or Water Composition
- Injection Brine or Injection Gas
- Live Reservoir Oil

Duration
- 7 – 8 weeks* (includes minimum 40 day aging period for restoration process)

Deliverables
- Effective & Relative Permeability
- Relative Permeability Exponents
- Recovery Efficiency
- Irreducible Water Saturation & Residual Oil Saturation

Permeability Regain

- This analysis is used to evaluate the extent of formation damage caused by a proposed treatment fluid during a simulated invasion process. Typical treatment fluids include fracturing fluids and acid stimulation fluids.
- A variety of experimental methods can be employed, including gas, brine or oil permeability regain on core samples under various states of saturation and restoration.
- Permeability of the sample is determined to establish a baseline reference value, which is followed by treatment with the fluid of interest and a determination of the regain permeability for comparison against the baseline value.

Testing/Sample Requirements

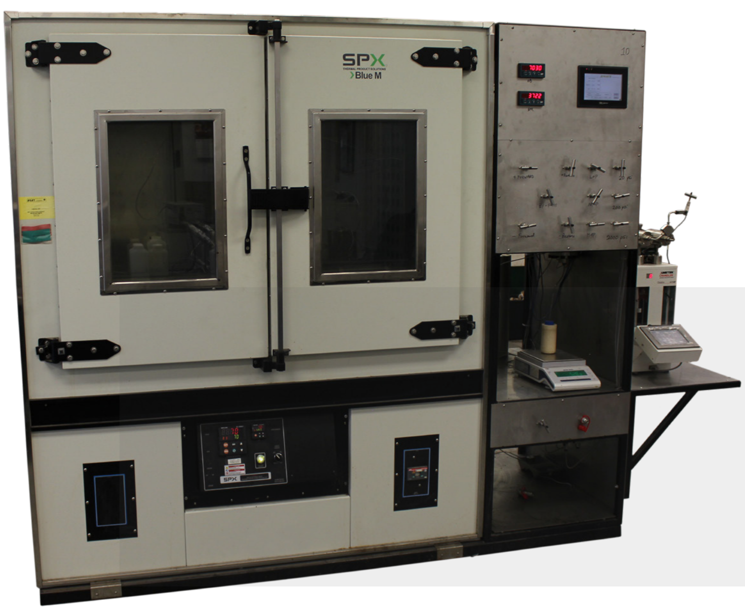
- Reservoir Pressure & Temperature
- Core for Sample Selection & Cutting
- Formation Brine or Water Composition and Oil
- Treatment Fluid

Duration

- 3 – 4 weeks*

Deliverables

- Regain Permeability



Critical Velocity

- This analysis is used to evaluate the interaction between the injection fluid and the reservoir rock in order to identify potential formation damage problems due to the migration of fines such as kaolinite and illite.
- Critical velocity is the minimum flow velocity at which fines become mobile, and this parameter is typically used to establish the maximum well test rate in order to avoid damage of the near wellbore region.
- Permeability of the sample is measured at a series of increasing flow rates, and the critical velocity is identified when a sudden decrease in permeability is observed due to fines mobility and plugging.
- Can be combined with a Critical Sensitivity and a Fluid-Fluid Compatibility (PHREEQC) test for a more thorough investigation.

Testing/Sample Requirements

- Reservoir Pressure & Temperature
- Core for Sample Selection & Cutting
- Formation Brine and Injection Brine or Water Compositions

Duration

- 2 – 3 weeks*

Deliverables

- Critical Velocity
- Permeability vs. Flow Velocity Curve

Our SCAL coreflooding rigs are used in a variety of SCAL experiments, including relative permeability measurements, permeability regain studies, and advanced liquid permeability tests such as Critical Velocity and Critical Sensitivity. These instruments are built with high precision automated injection pumps, in-line differential pressure transducers, and automated data takers, allowing permeability determination in real time throughout the core flood.

Critical Sensitivity

- This analysis is used to evaluate the interaction between formation brine and injection brine in a core sample in order to identify potential formation damage problems due to the formation of insoluble precipitates and scales.
- Permeability of the sample is measured as a function of pore volume throughput at a constant flow rate to identify any decreases in permeability due to incompatible fluids.
- Can be combined with a Critical Velocity test and a Fluid-Fluid Compatibility (PHREEQC) test for a more thorough investigation.

Testing/Sample Requirements

- Reservoir Pressure & Temperature
- Core for Sample Selection & Cutting
- Formation Brine and Injection Brine or Water Compositions

Duration

- 2 – 3 weeks*

Deliverables

- Permeability as a Function of Pore Volume Throughput

Scaling Tendency Evaluation

- This analysis is used to evaluate the compatibility between formation and injection waters in order to identify potential problems during water flood processes.
- Water samples or synthesized samples are mixed under set ratios at desired test temperatures (typically reservoir temperature) and are held at test temperature for 3 days.
- Physical observations are made throughout the hold time to determine onset of precipitation.
- After the hold time is complete, the mixed solutions are filtered to quantify the precipitation as a percentage of the total solution. The filtered scales can also be analyzed by XRD for mineral characterization.
- Data from the physical mixing studies are used to calibrate the scaling tendency model using PHREEQC simulation software.
- Tests can also be conducted with scale inhibitors to evaluate the efficacy of chemical treatments and required loadings.

Testing/Sample Requirements

- Reservoir Pressure & Temperature
- Formation Brine and Injection Brine

Duration

- 1 – 2 weeks*

Deliverables

- Water Composition
- Scaling or Saturation Index

* Please note that all test duration times are estimates, and that actual experimental times will vary according to the number, type and quality of samples received. This test time can be greatly extended if the sample is to undergo a wettability restoration process, which involves sample aging at reservoir pressure and temperature conditions for a minimum of 40 days.

Mud Leak Off

- This analysis is used to evaluate and optimize drilling fluid systems in order to minimize potential formation damage and maximize well performance.
- Invasion of the drilling mud into the formation may cause reduced permeability and limit production if the formation pressure is not great enough to force the invaded fluids out.
- Core sample is treated with the proposed drilling fluid, and the regain permeability, the fluid loss volume and the invasion depth are all determined. The effects of proposed clean-up fluids can also be investigated.

Testing/Sample Requirements

- Reservoir Pressure & Temperature
- Core for Sample Selection & Cutting
- Formation Brine or Water Composition and Oil
- Drilling Fluid

Duration

- 2 – 3 weeks*

Deliverables

- Regain Permeability
- Leak Off Volume
- Linear Invasion Depth

Heavy Oil Extraction

- This procedure is used to extract and clean heavy oil samples from oil sand cores for use in further testing, such as API gravity and viscosity measurements.
- Small sub-samples of core are centrifuged at high speed and at slightly elevated temperatures to separate the oil from the porous matrix without modification of the chemical composition. Extracted samples are spun a second time to further remove trace water and sediment.
- For a moderately rich oil sand core, the centrifuge cleaning of 1 kg of sample will result in the extraction of approximately 50 mL of clean oil.

Testing/Sample Requirements

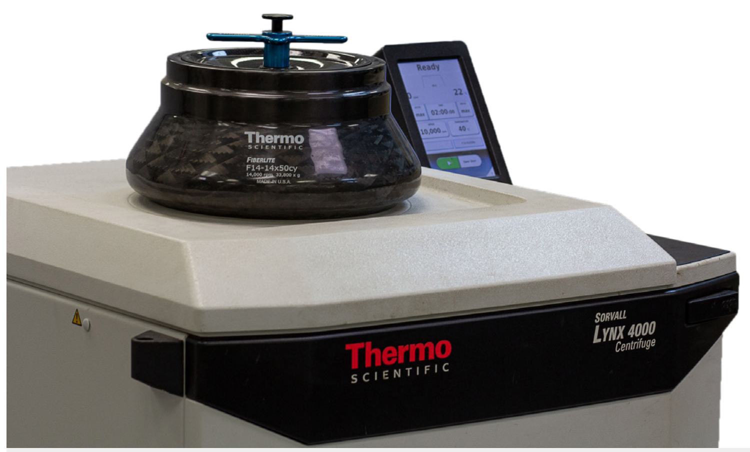
- Oil Sand Core for Sample Selection & Cutting

Duration

- 1 – 2 weeks*

Deliverables

- Clean Oil for Further Testing



Oil or bitumen is extracted from core by high speed centrifuge without the use of solvent, so as to maintain the integrity of the sample. Our centrifuge is run at 10,000 rpm, under low temperature to reduce the risk of losing light end hydrocarbons.

Enhanced Oil Recovery

Water Flood

- A water flood experiment will provide important information on the oil-water relative permeability, which can be used to evaluate the residual oil and irreducible water saturations as well as the recovery efficiency of the flooding procedure.
- As not all reservoirs are amenable to water flooding, it is highly suggested that this analysis be performed in conjunction with Critical Velocity, Critical Sensitivity and Fluid-Fluid Compatibility tests for a more complete investigation.
- It is required that the core samples undergo a wettability restoration process, which involves a minimum 40-day aging process at reservoir pressure and temperature conditions. This restoration will ultimately afford more accurate relative permeability data.

Testing/Sample Requirements

- Reservoir Pressure & Temperature
- Core for Sample Selection & Cutting
- Formation Brine and Injection Brine or Water Compositions
- Live Reservoir Oil

Duration

- 7 – 8 weeks* (includes minimum 40 day aging period for restoration process)

Deliverables

- Effective & Relative Oil & Water Permeability
- Relative Permeability Exponents
- Recovery Efficiency
- Irreducible Water Saturation & Residual Oil Saturation

Gas Flood

- A gas flood experiment will provide important information on the oil-gas relative permeability, which can be used to evaluate the residual oil and irreducible water saturations as well as the recovery efficiency of the flooding procedure.
- Depending on the type of gas and the injection pressure used, gas flooding can involve either miscible or immiscible displacement. For miscible displacement procedures, it is suggested that Miscibility, Swelling and Multi-Contact gas injection studies be performed.
- It is required that the core samples undergo a wettability restoration process, which involves a minimum 40-day aging process at reservoir pressure and temperature conditions. This restoration will ultimately afford more accurate relative permeability data.

Testing/Sample Requirements

- Reservoir Pressure & Temperature
- Core for Sample Selection & Cutting
- Formation Brine or Water Composition
- Live Reservoir Oil
- Injection Gas

Duration

- 7 – 8 weeks* (includes minimum 40 day aging period for restoration process)

Deliverables

- Effective & Relative Oil & Water Permeability
- Relative Permeability Exponents
- Recovery Efficiency
- Irreducible Water Saturation & Residual Oil Saturation

Sample core plugs or full diameter sections are loaded into core barrels (pictured) in our Special Core Analysis rigs for coreflooding experiments. Samples are pressurized and heated to reservoir conditions for Relativer Permeability studies, Formation Damage tests, or for evaluation of EOR strategies.

Steam Flood

- A steam flood experiment is a high-temperature, thermal variation of a water flood experiment, which will provide important information on the oil-water relative permeability and the recovery efficiency.
- After performing a typical water flood procedure, the temperature is incrementally raised and the pressure reduced in order to generate steam inside the core stack. Further determinations of the effective water permeability are made as the temperature is reduced back down to reservoir conditions.
- This analysis requires special equipment and materials that are capable of handling the elevated pressure and temperature conditions.

Testing/Sample Requirements

- Reservoir Pressure & Temperature
- Core for Sample Selection & Cutting
- Formation Brine and Injection Brine or Water Compositions
- Live Reservoir Oil

Duration

- 8 – 9 weeks* (includes minimum 40 day aging period for restoration process)

Deliverables

- Effective & Relative Oil & Water Permeability
- Relative Permeability Exponents
- Recovery Efficiency
- Irreducible Water Saturation & Residual Oil Saturation

Polymer, Surfactant or Caustic Flood

- Polymer, surfactant and caustic floods are all variations on a typical water flooding procedure in which different chemical additives are added to the proposed injection water.
- A polymer additive will help to modify and control the viscosity of the injection water to increase the sweep efficiency to improve oil recovery.
- A surfactant additive will help to modify and control the oil-water interfacial tension, thereby affecting the wettability in an effort to improve oil recovery.
- A caustic additive will promote an in-situ reaction with the reservoir fluids to form natural surfactants, which will again modify the oil-water interfacial tension to improve recovery.

Testing/Sample Requirements

- Core for Sample Selection & Cutting
- Formation Brine and Injection Brine or Water Compositions
- Live Reservoir Oil
- Polymer, Surfactant or Caustic Additive and Desired Injection Concentration

Duration

- 8 – 9 weeks* (includes minimum 40 day aging period for restoration process)

Deliverables

- Effective & Relative Oil & Water Permeability
- Relative Permeability Exponents
- Recovery Efficiency
- Irreducible Water Saturation & Residual Oil Saturation

Water-Alternating-Gas (WAG) Flood

- A water-alternating-gas experiment involves a combination of water and gas flooding processes that help to reduce channeling effects and improve oil recoveries.
- After performing a typical a water flood procedure, a gas flood is performed on the core stack, which is followed by another cycle of water-gas flooding. This iterative process is repeated for any number of cycles using specified water and gas slug volumes.
- With the use of custom built core holders, variability in the core plug stack length can be accommodated up to a maximum length of ca. 65 cm (25").

Testing/Sample Requirements

- Reservoir Pressure & Temperature
- Core for Sample Selection & Cutting
- Formation Brine and Injection Brine or Water Compositions
- Live Reservoir Oil
- Injection Gas

Duration

- 8 – 9 weeks* (includes minimum 40 day aging period for restoration process)

Deliverables

- Effective & Relative Oil & Water Permeability
- Relative Permeability Exponents
- Recovery Efficiency
- Irreducible Water Saturation & Residual Oil Saturation

Pressure-Volume-Temperature (PVT) Analysis

Field Sampling

- AGAT field personnel can visit well sites and processing plants to provide a variety of fluid sampling services and on-site analysis.
- All personnel have proper safety training, including H2S Alive and First Aid, and will provide sampling containers that are suitable for the specific sampling request.
- Typically, there are two different types of fluids that can be sampled for use in PVT analysis:

1. Bottom Hole: live reservoir fluid is collected down hole at reservoir pressure and temperature conditions.
2. Separator: separator gas and liquid samples are collected for recombination in the lab to afford a live reservoir fluid.

Testing/Sample Requirements

- Reservoir Pressure & Temperature
- Separator Pressure & Temperature
- Gas-Oil Ratio
- Saturation Pressure or Bubble Point

Duration

- 1 – 2 days*

Deliverables

- Pressurized or Atmospheric Gas, Oil & Water Samples for PVT Analysis

Bottom Hole Sampling

- In addition to routine fluid sampling services, AGAT can also provide equipment rental and field personnel to acquire bottom hole fluid samples.
- Field personnel will travel to site to operate an Electronic Shut In Tool in order to collect a live fluid sample at reservoir pressure and temperature conditions.
- Bottom hole sampling techniques will afford representative fluids that are suitable for further PVT analysis, provided that appropriate conditioning of the well by the operator has occurred prior to sampling.

Testing/Sample Requirements
- Reservoir Pressure & Temperature
- Wireline Operator & Results of Static Gradient Test
- Gas-Oil Ratio

Duration
- 1 week minimum advance notice, 1 – 2 days* actual sampling time

Deliverables
- Bottom Hole Fluid Sample for PVT Analysis

Constant Composition Expansion (CCE)

- This analysis involves an evaluation of the fluid's pressure-volume relationship at reservoir temperature, in which changes in pressure lead to changes in volume above and below the saturation pressure (bubble point).
- A series of small pressure reductions are performed on the fluid while maintaining the fluid composition constant. The total relative volume of the fluid is measured at each stage, and the saturation pressure is determined.
- A computer and a highly sensitive CCD camera are used to capture images of the fluid phases to help with the visual determination of the bubble point.

Testing/Sample Requirements
- Reservoir Pressure & Temperature
- Live Reservoir Oil (Bottom Hole or Recombination)
- Gas-Oil Ratio or Saturation Pressure

Duration
- 2 – 3 weeks*

Deliverables
- Saturation Pressure
- Y-Function
- Relative Volume & Fluid Compressibility

Differential Liberation (DL)

- This analysis is typically performed on conventional and heavy oil samples that possess an API gravity below 40, and is used to simulate the behaviour of the liquid phase that is not produced during primary pressure depletion.
- A series of small pressure reductions are performed on the fluid from saturation pressure to atmospheric pressure. At each pressure stage, the gas liberated from solution is removed while maintaining a constant pressure.
- Liberated gas and residual oil undergo a multitude of chemical composition and physical property measurements to determine important parameters at each pressure stage.

Testing/Sample Requirements

- Reservoir Pressure & Temperature
- Live Reservoir Oil (Bottom Hole or Recombination)
- Gas-Oil Ratio or Saturation Pressure
- Live Reservoir Oil
- Injection Gas

Duration

- 2 – 3 weeks*

Deliverables

- Gas-Oil Ratio
- Compressibility or Deviation Factor (Z)
- Differential Oil (Bod) & Total Formation Volume Factors (Bt)
- Produced Gas Composition & Composition of Liquids in Place

Constant Volume Depletion (CVD)

- This analysis is typically performed on volatile oil and gas condensate samples that possess an API gravity above 45, and is used to simulate the pressure depletion process that occurs during primary production.
- A series of small pressure reductions are performed on the fluid from saturation pressure to atmospheric pressure. At each pressure stage, a small portion of the produced gas is removed from the system in order to maintain a constant volume.
- Liberated gas and residual oil undergo a multitude of chemical composition and physical property measurements to determine important parameters at each pressure stage.

Testing/Sample Requirements

- Reservoir Pressure & Temperature
- Live Reservoir Oil (Bottom Hole or Recombination)
- Gas-Oil Ratio or Saturation Pressure

Duration

- 2 – 3 weeks*

Deliverables

- Compressibility or Deviation Factor (Z)
- Cumulative Recovery of Gas Phase Products
- Produced Gas Composition & Composition of Liquids in Place

Multi-Stage Flashing

- Multi-stage flash analysis is used to simulate the pressure and temperature changes that the fluid experiences as it is produced from the reservoir to the separator and stock tank.
- The sample fluid is subject to the desired pressure and temperature conditions (e.g. separator, standard), and the volumes of the separated gas and liquid phases are measured in order to determine parameters like the gas-oil ratio and volume factors.
- Any number of flash stages can be performed, and either pressurized oil or pressurized water samples can be tested.

Testing/Sample Requirements
- Reservoir Pressure & Temperature
- Live Reservoir Oil (Bottom Hole or Recombination)
- Separator Pressure & Temperature
- Gas-Oil Ratio or Saturation Pressure

Duration
- 2 – 3 weeks*

Deliverables
- Gas-Oil Ratio
- Formation Volume Factor (FVF) or Separator Volume Factor (SVF)
- Shrinkage Factor

Live Oil Viscosity

- This analysis is used to evaluate changes in viscosity as the pressure of the fluid sample is reduced over several stages from reservoir pressure to atmospheric pressure.
- The viscosity is measured using a magnetic viscometer, which is housed inside a temperature-controlled oven to accurately simulate reservoir temperature conditions.
- Due to expansion of the fluid volume as the pressure decreases, the viscosity will decrease and reach a minimum value at the saturation pressure.

Testing/Sample Requirements
- Reservoir Pressure & Temperature
- Live Reservoir Oil (Bottom Hole or Recombination)
- Gas-Oil Ratio or Saturation Pressure

Duration
- 1 – 2 weeks*

Deliverables
- Live Oil Viscosity at Pressures Above and Below the Saturation Pressure
- Live Oil Viscosity vs. Pressure Curve

* Please note that all test duration times are estimates, and that actual experimental times will vary according to the number, type and quality of samples received. This test time can be greatly extended if the sample is to undergo a wettability restoration process, which involves sample aging at reservoir pressure and temperature conditions for a minimum of 40 days.

Miscibility by Slim Tube

- This analysis is used to evaluate the three factors that govern asphaltene solubility in oil: pressure, temperature and fluid composition. Changes in these parameters may cause precipitation behaviour that can lead to reduced permeability and formation damage.
- Near Infrared Spectrophotometry is used to determine the specific pressure and temperature conditions at which asphaltenes begin to precipitate from the reservoir fluid.
- The effect of fluid composition can be determined through the introduction of an injection gas (e.g. nitrogen, carbon dioxide) at a variety of different ratios.
- It is strongly suggested that a bottom hole sample be collected for this analysis, to ensure that all of the asphaltene components remain in solution prior to testing.

Testing/Sample Requirements
- Reservoir Pressure & Temperature
- Live Reservoir Oil (Bottom Hole or Recombination)
- Gas-Oil Ratio or Saturation Pressure
- Injection Gas & Desired Injection Pressure Range

Duration
- 3 – 4 weeks*

Deliverables
- Asphaltene Precipitation Pressure
- Absorbance vs. Pressure Curve

Swelling

- This analysis is used to evaluate the effects of gas injection on the properties of a reservoir fluid as the pressure is allowed to vary above the saturation pressure.
- After determining the initial properties of the sample fluid, a quantity of injection gas is introduced and the resulting volume change is measured. The properties of the fluid are re-determined, and the process is repeated with the next quantity of injection gas.
- Swelling tests are typically done up to four stages of gas injection, but additional injection stages can be included if required.

Testing/Sample Requirements
- Reservoir Pressure & Temperature
- Live Reservoir Oil (Bottom Hole or Recombination)
- Gas-Oil Ratio or Saturation Pressure
- Injection Gas & Desired Gas Injection Ratios

Duration
- 3 – 4 weeks*

Deliverables
- At each gas injection stage, the following parameters are determined: Saturation Pressure, Swelling Factor, Live Oil Density, Formation Volume Factor & Gas-Oil Ratio
- Oil and Gas Composition at each Gas Injection Ratio

Multi-Contact (Forward & Backward)

- This analysis is used to evaluate the effects of gas injection on the properties of a reservoir fluid as the pressure is held at a constant value below the saturation pressure.
- There are two different methods of performing a multi-contact analysis:

1. Forward Multi-Contact: involves the successive addition of fresh reservoir liquid into the equilibrium gas, and is used to simulate a vapourizing gas drive (VGD).
2. Backward Multi-Contact: involves the successive addition of fresh injection gas into the equilibrium liquid, and is used to simulate a condensing gas drive (CGD).

- Multi-contact tests are typically done up to three stages of gas injection, but additional injection stages can be included if required.

Testing/Sample Requirements

- Reservoir Pressure & Temperature
- Live Reservoir Oil (Bottom Hole or Recombination)
- Gas-Oil Ratio or Saturation Pressure
- Injection Gas & Desired Gas Injection Ratios

Duration

- 3 – 4 weeks*

Deliverables

- The initial and final values of the following parameters are determined before and after the gas injection stages: Saturation Pressure, Density, Formation Volume Factor, Gas-Oil Ratio and Viscosity (@ Bubble Point)
- Gas Composition at each Gas Injection Ratio

Interfacial Tension (IFT), Surface Tension & Contact Angle

- Interfacial tension (IFT) represents the imbalance of molecular attractive and repulsive forces that exists between any two immiscible fluid phases, such as oil and water. Surface tension is a specific case of IFT in which one of the fluid phases is air, while contact angle is the angle a fluid makes with a smooth surface that can be used to estimate the wettability of a core sample.
- The measurement of these three parameters is performed using a highly sensitive camera, which records and analyzes the shape of the fluid drop either on a surface (contact angle) or in the presence of another fluid phase (interfacial and surface tension).
- These measurements can be made at ambient conditions on the bench-top, or at elevated pressure and temperature conditions using a visual pressure cell housed inside a temperature-controlled oven.

Testing/Sample Requirements

- Test Fluids and/or Core Sample
- Desired Test Pressure & Temperature

Duration

- 1 – 2 weeks*

Deliverables

- Interfacial Tension, Surface Tension or Contact Angle

API Gravity & Viscosity

- This analysis is used to provide important information on the physical properties of an oil sample, and is typically used on heavy oil samples with low API gravity values.
- API gravity measurements are performed using a pycnometer and are reported at standard temperature conditions of 15 °C.
- Viscosity measurements are performed using a cross-arm viscometer, which is used to calculate the kinematic and dynamic viscosity values of the sample. Test temperatures of greater than 200°C can be obtained by this method.

Testing/Sample Requirements
- Oil or Oil Sand Core for Extraction & Cleaning
- Desired Test Temperatures

Duration
- 1 – 2 weeks*

Deliverables
- API Gravity
- Kinematic & Dynamic Viscosities at Desired Temperature

Phase Diagram by EOS

- This analysis is used to calculate the phase diagram of the reservoir fluid by Equation of State (EOS) computer simulation.
- Gas and liquid samples are analyzed for composition by chromatography, and the data is used to calculate the wellstream composition of the reservoir fluid.
- Fluid composition, reservoir pressure, reservoir temperature and the gas-oil ratio are then input into the EOS simulation software, which will calculate the corresponding phase diagram of the fluid.

Testing/Sample Requirements
- Reservoir Pressure & Temperature
- Gas-Oil Ratio
- Separator Gas & Liquid Samples for Analysis

Duration
- 1 – 2 weeks*

Deliverables
- Phase Diagram
- Critical Point, Cricondenbar & Cricondentherm

Corporate Overview

Who We Are

AGAT Laboratories' is a highly specialized, Canadian-based company that provides laboratory services worldwide. With 40 years' experience, locations coast-to-coast and 1,200 employees Canada-wide, AGAT Laboratories' is the most geographically and technically diversified commercial testing laboratory in Canada. Committed to local communities, AGAT Laboratories' aims to maintain our mission statement to deliver "Service Beyond Analysis".

Our laboratory operations offer full-service solutions for a wide range of industries, including Mining, Environmental, Energy, Industrial, Transportation, Agriculture and Food, Forensic Science, and the Life Sciences sectors.

AGAT Laboratories' network of laboratory facilities and depots provides extensive geographic coverage in Canada. We are proud to set high standards in the laboratory industry with our mandate to provide timely, accurate and defensible solutions for our clients' analytical needs with services ranging from basic testing to extremely complex technical projects.

When you choose AGAT Laboratories', you will experience "Service Beyond Analysis". We provide quality data and unsurpassed service through our client-focused approach to accomplish and deliver on your specific needs. We understand the importance of providing accurate and timely results with consistently great service. Our methodologies, operating procedures and instrumentation are selected to provide suitable analytical techniques to produce the most precise and accurate analytical results possible. Our cutting edge technical expertise and innovations enable us to provide you with service excellence.

AGAT Laboratories' Ltd.
International Corporate Headquarters
Calgary, Alberta. Canada

"Home-Grown and Proud to be Canadian"

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AGAT Laboratories

Visit us at

www.agatlabs.com

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wide range of laboratory services.