Providing customized engineered solutions to maximize wellbore value is the operating directive for the Baroid Laboratories world-wide. Research and Development, Technical Services, Technical Support, and Quality Assurance are all addressed within the world-wide Baroid Laboratory infrastructure. Dedicated scientists and engineers staff these laboratories which are equipped with standard and state-of-the-art equipment for evaluating drilling, drill-in, and completion fluids and products.

The Baroid Global Laboratories in Houston, Texas and Pune, India provide a complete spectrum of laboratory services. In addition to comprehensive drilling, drill-in, and completion fluids services and support, the facilities have the capacity to address a wide range of operational issues related to well construction, completion, and production. These laboratories perform research and development, provide quality assurance services, and have analytical capabilities. The Houston labs also have bioassay testing capabilities enabling evaluation of aquatic toxicity and aerobic biodegradability of products and fluids systems. The Industrial Drilling Products (IDP) laboratory, supporting the IDP product line, is also included in the Houston labs.

The first line of technical services and quality control is at the well site. Our engineers are trained to perform API and other field tests to monitor fluid properties, to pilot test, and to recommend and implement appropriate treatments to help ensure that the drilling, drill-in, or completion fluids meets operational specifications. In support of the engineers in the field, there is a network of Area and Country labs which can perform more extensive and complex tests that cannot reasonably be performed at well site. When situations arise that cannot be adequately addressed by the Area and Country labs, then the Baroid Regional labs are called on for support and solutions. Additional fluid testing equipment such as FANN® 75 or FANN® iX77 viscometers and particle size analyzers; and shale characterization equipment such as Linear Swell Meters, Slake Durability apparatus and Capillary Suction Time testers can be found in these labs. In cases where very specialized equipment or knowledge is required or the project impact is substantial, the Global Laboratories are called on to help provide customized engineered solutions.

Delivering Solutions

The availability of equipment is clearly important. However, the ability to correctly utilize this equipment and properly interpret the data output to deliver tangible fluid performance improvements to our customers is paramount. Through utilization of this equipment, customized, state-of-the-art fluid solutions are determined, complex drilling problems solved, and cost savings to the operator realized.
The chart below shows the testing capabilities of the Baroid laboratories based on classification. The Global laboratories (Houston and Pune) will have all of the capabilities shown but the Region, Country, and Area lab capabilities are dependent on the technical needs of the region, country, or area. In some cases, area labs can have capabilities almost on par with those of country labs and country labs can have capabilities almost on par with those of the regional labs.

**World-Wide Laboratory Capabilities**

The chart below shows the testing capabilities of the Baroid laboratories based on classification. The Global laboratories (Houston and Pune) will have all of the capabilities shown but the Region, Country, and Area lab capabilities are dependent on the technical needs of the region, country, or area. In some cases, area labs can have capabilities almost on par with those of country labs and country labs can have capabilities almost on par with those of the regional labs.

### GENERAL LABORATORY CAPABILITIES

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<th>Laboratory Classification</th>
<th>Region</th>
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<th>Laboratory Classification</th>
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Baroid has made and continues to make considerable investment in research and engineering facilities as well as laboratories and field-support operations. Recognized as innovators in the industry, Baroid’s Research and Development chemists and engineers are responsible for designing the hundreds of patented technologies applied every day in field locations all over the world.

From maximizing production in unconventional, small, or remote fields to economically drilling and developing deepwater reservoirs, we collaborate with our customers to understand their challenges and then apply the latest advancements in fluids technology to resolve those challenges.

Baroid’s Global Laboratories in Houston, Texas and Pune, India are regarded as the Company’s principal R&D centers. Design work is also conducted in Aberdeen and has resulted in many successful and innovative products. Design planning is completed in accordance with the stringent quality standards of ISO9001:2000 requirements.

Baroid has developed a number of new products, fluid systems and testing equipment capabilities to support the challenges associated with changing well conditions, technology and field/well economics. The Research and Development groups are actively working on projects in a variety of areas in support of our drilling and completions fluids business. Our project portfolio aligns with our knowledge platforms of:

- Wellbore Fluids
- Wellbore Management
- Reservoir Productivity
- Environmental Assurance.

In addition, we have a number of projects that are run in collaboration with universities around the world. These universities have been selected based on their specific technical knowledge and world-class capabilities in support of our knowledge platforms.

Baroid’s R&D efforts support a number of key technology areas relevant to land operations, fluids management, oil based fluid development, water based fluid development, shale stabilization, engineering design, H₂S well drilling, wellbore monitoring/stabilization, and environmental compliance.

**Engineering Services**

The Engineering Services group provides a complementary set of capabilities for fluids R & D. These include development of:

- Engineered solutions for support of fluid design and management.
- Instruments that expand the scope and capabilities of existing testing methods.
- Software for drilling simulation and wellbore pressure management (DFG™ software).
- Leading edge capabilities in well planning and real-time problem solving.

**FANN® Equipment Development**

The Fann Equipment Development group designs and brings to market instruments used across the industry.

- HP/HT Viscometers used in both Drilling Fluids and Production Enhancement – these are used in both the R&D and field operations labs.
- Cement analysis instruments to measure thickening time, static gel strength and compressive strength.

The group provides next generation instrumentation software:

- The new software uses a common platform so that training of operators across product lines becomes more seamless. The use of a test input “wizard” has been implemented to assure all required data has been entered.
- The software will connect to a searchable database providing field engineers access to historical and geographical data to converge on a solution more quickly and will enable remote real-time monitoring of test progress and results.

And, the Fann group supports Baroid lab schools by providing theory of operation and practical application instruction on instruments in current use.
The Baroid Global Laboratories have the equipment and staff needed to conduct all standard and virtually all non-standard testing on drilling, drill-in, and completion fluids. The Baroid Regional Laboratories have equipment and staff to conduct all standard tests and many specialized tests. Baroid Country and Area Labs have equipment required to support the technology being implemented in their country or area. All test equipment that performs measurements is subject to programmed calibration and maintenance in accordance with documented procedures. Technical service laboratory project requests are entered, project status tracked, lab test data logged, and lab reports generated using the “Viking” global database. Every Baroid laboratory utilizes this “Viking” system.

FANN® 50 High Temperature Viscometer
The FANN® 50 HTHP viscometer is used to evaluate rheological properties at up to 500°F (260°C) and 700 psig to determine the temperature stability of a drilling fluid. When the viscosity of the drilling fluid increases or decreases after heating and cooling cycles, the test results can indicate temperature instability.

FANN® 70 and 75 HP/HT Viscometers
Both instruments are concentric cylinder viscometers capable of providing standard oilfield rheology data on fluids subjected to 20,000 psig and 500°F (260°C). The FANN 75 viscometer can also be used sub ambient (to 41°F/5°C) to simulate low fluid temperatures encountered within deepwater risers. FANN 70 and FANN 75 rheometers are used extensively during the planning and drilling of HP/HT wells to measure rheological properties under field conditions. Measurement of fluid rheological properties under downhole conditions is critical to management of equivalent circulating density (ECD) and must always be considered in conjunction with any measured change in sag performance.

FANN® 77 and iX77 HP/HT Viscometer
Fann's newest viscometer will operate at temperatures up to 600°F (315°C) and pressures up to 30,000 psig to allow rheological property measurements on fluids designed for extremely hot, deep wells. The instrument has an improved embedded electronics control module, data acquisition and control software, and pressure, temperature, and speed controllers.

Permeability Plugging Apparatus
The permeability Plugging Apparatus (PPA) measures fluid loss using ceramic discs to simulate a variety of reservoir pore throat diameters (10 to 190 microns). Filter cake is built on the underside of the ceramic disc. This orientation eliminates the effects of settlement during formation of the filter cake. Overbalances to 2500 psig can be reproduced and the cell can be heated to 500°F (260°C).

PPA is used extensively for optimization of pore throat bridging formulations using BARACARB® bridging agent (sized marble). The continued ability of field muds to provide suitable bridging is typically evaluated using a combination of PPA testing and particle size analysis.
FANN 90 Dynamic Filtration Test
The FANN 90 dynamic filtration test builds on the capabilities of the PPA in that it utilizes ceramic cores available in a range of different pore sizes. The FANN 90 dynamic filtration test differs from PPA in three important respects:

- Filter cake is built on the inner surface of a vertically oriented, cylindrical ceramic core to more accurately replicate the wellbore.
- A motor-driven rod inserted through the center of the core simulates the action of drill string rotation and annular fluid velocity on filter cake deposition and attrition.
- Filtrate volume can be measured versus time.

The FANN 90 dynamic filtration test simulates filtration properties downhole and implements unique Baroid filtration models to determine cake deposition index (CDI) and dynamic filtration rate to provide solutions preventing differentially stuck pipe.

Dynamic High Angle Sag Testing (DHAST™) Device
Baroid has developed a dynamic sag testing device that operates under variable temperature and pressure. The device requires a 40 ml mud sample and is used for pilot testing improvements to correct dynamic sag problems. Conventional static sag testing does not yield clear answers since sag is highly impacted by temperature, pressure, and low shear rate.

Linear Swell Meter
The linear swell meter measures dimensional changes of constrained shale pellets exposed to candidate fluids. Measurement is effected by means of a Linear Displacement Transducer probe maintained in contact with the upper face of the shale pellet. Testing may be conducted at ambient or elevated temperature. Results are recorded as plots of swelling or contraction versus time. This test provides a graphical comparison of up to four inhibitive fluids simultaneously. Ideally, comparisons using this technique would involve sections of representative shale cut such that bedding planes lie perpendicular to the direction of measurement. Rarely is it possible to obtain such samples and hence most linear swell testing is conducted using compressed shale pellets formed from powdered shale.

Capillary Suction Time
The Capillary Suction Time instrument measures the water retained by shale/brine slurries. Water retained by the shale will result in shale swelling and loss of mechanical properties. Water retention is measured as the time taken for ‘free’ water from the slurry to travel radially between two electrodes on thick, porous filter paper. This test is used principally to validate increases in brine salinity and cation selection.
Technical Services: Drilling Fluids

Complex Well Support Equipment

**Slake Durability**
Samples of sized test shale are placed into mesh-covered cylindrical cages. The cages are then rotated at a constant 20 rpm while immersed in the drilling fluid. Tests are typically run for four hours at room temperature. However, longer runs at elevated temperature can be conducted where appropriate. The weight of shale recovered as a percentage of the original weight enables the inhibitive qualities of the drilling fluid to be compared. Results obtained using the slake durability test generally follow the same trends as those obtained from shale recovery testing. However, shale samples that are particularly susceptible to mechanical damage will give lower recoveries in this test than those in shale recovery tests. Hence, data from both test methods provide an insight on the effects of candidate fluids on shale hydration/dispersion and attrition.

**Shale Recovery and Shale Erosion Tests**
Both tests are very similar but differ only in the amounts and sizes of shale particles used. A known weight of dry sized shale is hot rolled in the test fluid (mud or brine) for 16 hours. The shale/brine mixture is then passed through the sieve used to size the original particles. The shale retained on the sieve is washed, dried, and weighed. This recovered weight is expressed as a percentage of the original weight. The greater the inhibition qualities of the mud or brine, the higher the shale return weight will be.

**Filter Cake Removal Pressure Apparatus**
This device is essentially a flow loop incorporating a pump, pressure transducer, double-ended cell and valve arrangements. The valves permit control of flow in either direction through the double-ended cell. The cell can accommodate a variety of ‘filter’ media including gravel pack screens and ceramic discs of the type used in the Permeability Plugging Apparatus. Equipment is used during optimization of fluids for gravel packing and minimization of filter cake ‘lift-off’ pressures.

**FANN Lubricity Meter**
Reduction in metal-to-metal friction is measured using a FANN Lubricity Meter. A constant force is applied to a contoured metal test block. The applied force presses the test block against a rotating metal ring. Both metal components are immersed in the test fluid. The motor torque required to maintain rotation of the test ring is measured and used in conjunction with the metal-to-metal contact area to calculate a lubricity coefficient.

Water based mud lubricants are evaluated by measurement of lubricity coefficient reduction following addition of the lubricant to the drilling fluid. The relative performance of lubricants is often dependent upon the fluid type with factors such as solids loading and pH having a marked effect on the performance of certain lubricants. Lubricity coefficient is typically found to reduce with increasing lubricant concentration. However, it is usual to find one concentration at above which the addition of further lubricant is no longer cost effective. Hence, use of the lubricity meter allows identification of the optimum lubricant and lubricant concentration for a particular application.

**Particle Size Analyzer**
Malvern, Microtrac, or Coulter laser diffraction particle size analyzers are used in a majority of the laboratory locations. The analyzers measure the distribution of the sizes of particles in a fluid or powder. The results are presented in a table and graph. The table lists the amount of particles classified by size (microns). The graph shows the concentration in percent by volume of solids in a particular range. A useful value determined by the instruments is the D50, which is the median size of the particles in the sample.
Completion fluids services encompass a wide range of testing capabilities, including, but not limited to: formation damage assessment resulting from exposure to completion and drill-in fluids, shale inhibition properties, determining effects of filter cake breakers, and drill pipe, casing, and tubing corrosion prevention. Proven processes are established for brine evaluation, treatment recommendations for fluid reconditioning, and preventing possible permeability impairment by contaminants.

**Variable Pressure Crystallometer**
Variable Pressure Crystallometer apparatus provides the ability to test crystallization points of brines under elevated pressures for deepwater applications.

**Automated Return Permeameter**
Core samples are tested with the Automated Return Permeameter (ARP) to identify the least damaging drilling/completion fluid for a particular operation. The samples can be tested at elevated temperatures and pressures and under dynamic and actual downhole conditions. The Automated Return Permeameter provides the ability to program remedial steps, such as clean-up with acids and oxidizers.

**Manual Return Permeameter**
The Manual Return Permeameter is similar in use to the ARP; however test fluid exposure is static rather than dynamic. The operation of the permeameter is mostly manual rather than automatic. This machine is very useful in determining damage with solids-free fluids such as displacement pills or completion fluids.

**Screen Tester**
The Screen Tester is used to evaluate sealing capabilities of inside screen pills on screen coupons, with or without gravel packs, under variable temperatures and differential pressures. It is also used as a screen flow-through device to ensure the fluid will pass through the production screen without plugging or hindering flow, such as when running screens in mud before displacement to a completion fluid or gravel pack fluid.
The Baroid Analytical Labs in Houston, Texas (H) and Pune, India (P) offer a broad spectrum of chemical and material characterization capabilities. Analyses ranging from bulk properties down to ultra-trace elemental quantification can be performed in-house via various types of instrumental and wet chemical techniques. The analytical group provides direct support to every technically-oriented function within Baroid and provides the data required to help customize fluid formulations or to identify non-compliant materials.

**X-Ray Diffractometer (H, P)**
The X-Ray Diffractometer helps determine the mineral composition of cores, cuttings, and ores, identification of scales, corrosion by-products, and detection impurities in products.

**Gas Chromatography with Mass Selective Detector (H)**
The Gas Chromatograph is used for the determination of crude oil contamination in synthetic muds and base oil “fingerprinting” identification of volatile organic components of products and drilling fluids.

**X-Ray Fluorescence Spectrometer (H)**
This apparatus is used to determine the elemental components in barites, clays, brines, non-crystalline materials, scales, and corrosion by-products and ore assays.

**Pyrolysis/Gas Chromatography with Mass Selective Detector (H)**
The Pyrolysis/Gas Chromatograph is used for the molecular characterization of non-volatile organic materials such as fluid-loss polymers, and surface-absorbed coating agents.

**Infrared Spectrometer (H, P)**
This test is performed to identify polymer, surfactant, and emulsifier content, and to determine sludge composition.

**Infrared Microscope (H)**
This instrument is used to identify organic coatings on solid surfaces and evaluation of corrosion inhibitor coverage, surfactant coatings, and polymer homogeneity.

**Inductively Coupled Argon Plasma Spectrometer (H, P)**
This test is used to determine the presence of heavy metals in barites, clays, and soil samples, and to identify trace elements in brines, effluents, mud filtrates, acid leachates, and production discharges.
Technical Support: Analytical

**Ion Chromatograph (H, P)**
The Ion Chromatograph is used to determine cations and anions in brines, makeup waters, effluents, and discharges, and ion composition in water leachates from solid products, soils, and ores.

**Laser Diffraction Particle Size Analyzer (H, P)**
The Laser Diffraction Particle Size Analyzer provides grind size analyses of barite, limestone, and hematite, and determination of particle size distribution in drilling fluids and brines.

**Thermo-Gravimetric Analyzer (H)**
The Thermo-Gravimetric Analyzer determines sample weight loss with increase in temperature, moisture content on small sample volumes, and distillation ranges of base oils.

**High Performance Liquid and Gel Permeation Chromatograph (H)**
This specialized chromatograph identifies and quantifies nonvolatile organic components such as surfactants, emulsifiers, rheology modifiers, and filtration control agents.

**Differential Scanning Calorimeter (H, P)**
The Differential Scanning Calorimeter helps determine exothermic and endothermic reactions of samples with increase in temperature and characterization of polymers and clays.

**Flash and Fire Point Tester (H, P)**
This apparatus is used to determine the flash point of base oils, diesel oils, crude oils, oil-base mud, products, and solvents.

**Optical Microscope (H, P)**
The optical microscope helps determine the size and shape of sands and ground products and helps with micro-fracture identification.

**Mercury Analyzer (H)**
The mercury analyzer determines the mercury content in weight materials, clays, reserve pit water, and waste water.

**High-Resolution Densitometer (H)**
This test is used to measure the density of brines, base oils, and liquid products with a very high level of resolution to evaluate contamination, decomposition, evaporation, or alteration. In addition, the Baroid Analytical Laboratory is capable of performing many classical gravimetric and volumetric “wet” chemical analyses utilizing modern automated instrumentation, Kjeldahl Nitrogen analysis, and aniline point determination.
At Baroid, we strive to conduct business without affecting the environment in which we work, to comply with environmental rules and regulations, and to provide our customers with products and services that help them do the same. The Baroid Bioassay Laboratory Group performs aquatic toxicity tests on water, oil, and synthetic-based drilling fluids, stock base fluids, products, brines, effluent discharges and cuttings from land or offshore. Sheen tests are performed on drilling and completion fluids, brines and some products. Biodegradation tests are performed on existing products and research products for North Sea or other international applications.

Aquatic Organisms Cultured and Tested in The Lab

Mysid Shrimp
Primarily to determine aquatic toxicity of both Water-Based and Synthetic-Based drilling fluids and product components for use in the USA NPDES regulated waters.

Leptocheirus Amphipod
To determine sediment toxicity of base synthetic fluids, synthetic drilling fluids and product components for use in the USA NPDES regulated waters.

Sheepshead Minnow/Skeletonema

Algae/Acartia Copepods
For product/ component toxicity tests as required by North Sea and other international regulatory agencies including the EPA, specifying Good Laboratory Practices (GLP) methods.

Daphnia (FW Crustacean)
To determine freshwater aquatic toxicity of product components, inland drilling fluids and effluent discharge to freshwater areas.

Fathead Minnow
To determine freshwater aquatic toxicity of product components, drilling fluids, land-based cutting and effluent discharge to freshwater areas.

Bioassay, biodegradation, and sheen tests specified by State, Federal or International regulations

48 hr Rangefinder and Definitive Acute Toxicity Tests
For International regulatory agencies including the EPA, using many of the cultured species.

96 hr Rangefinder and Definitive Acute Toxicity Tests
For drilling fluids or component products for International regulatory agencies including the EPA, using many of the cultured species.

96 hr Leptocheirus Sediment Toxicity Tests
On synthetic-based drilling fluids for use in the USA NPDES regulated waters.

10 day Leptocheirus Sediment Toxicity Tests
On base synthetic fluids for use in the USA NPDES regulated waters.

28 day OECD 306 and BODIS Seawater Aerobic Biodegradation Tests
On drilling fluids, product and components for North Sea and other International regulatory agencies.

Static Sheen Tests
To indicate the presence of free oil for the use in the USA NPDES regulated waters.

Specific EPA, ASTM, COE, and OECD test protocols are followed to meet state, federal and International discharge monitoring regulations. The Baroid Bioassay Laboratory’s Quality Assurance Program guarantees that the accuracy and precision of reported results from the lab have been thoroughly monitored and exceed minimum reliability requirements for the appropriate protocols. The Program meets NELAC and ISO9001:2008 certification criteria. The lab is also Good Laboratory Practices (GLP) qualified to submit test results acceptable to the EPA, North Sea and other International regulatory agencies.
Quality assurance standards support our goal of ensuring that our internal and external customers receive the quality and on-time delivery needed for successful business and field operations.

There are several "Quality" functions within Halliburton Fluid Systems and within Baroid, including ISO 9001:2000, API registration activities, Service Quality, Operations Support Lab Quality, and Global Quality Assurance. Several direct activities, related primarily to Operations Support Laboratories and Global Quality Laboratories in Houston and Pune, contribute to our Quality Assurance (QA) effort:

- The Product Review Committee (PRC) approves and deletes products. Once the Technology Department has approved the chemistry, formula maintenance and distribution is coordinated by Quality Assurance. Procedures and records are coordinated with the HSE (Health Safety and Environmental) department which reviews toxicity, regulatory compliance, transportation, and Export Compliance issues. When this process is complete, QA issues a draft formula and works with the Global Technical Team to introduce the product.

- Procurement and Quality departments work together to maintain a list of approved suppliers for our trade named products along with the raw materials and selected commodity chemicals which are deemed to have a significant impact to the success of our operation.

- Ore samples for manufacturing operations are evaluated by Quality Assurance.

- Product Quality Complaints are evaluated through the Quality Department. The department employs approximately 250 different test procedures applicable to our trade named products and principle raw materials.

- The QA Laboratory, in conjunction with Technology Department personnel where applicable, evaluates and develops methods applicable for chemical and performance evaluation of our products.

- The manufacturing operations quality testing is monitored by the Global Quality Assurance team.

- Site Quality Surveys are conducted to augment the sample evaluations typically sent to Houston and to provide an additional site quality assay.

- Disposition including reprocessing nonconforming product is a responsibility of the Quality Assurance Department.

- The QA Laboratory is responsible for Quality Testing training for Operations Laboratories.

- Certificates of Analysis and Certificates of Quality are generated by the Quality Assurance Laboratory out of the Houston office.

- A Global Quality Assurance Database (QC DOC) has been implemented in which all Baroid Quality Assurance Lab data and Vendor COA data are input as well as VQCA electronically signed. Alerts are sent out immediately to the Global Quality Assurance team and Procurement if any data input into QC DOC does not meet specifications. The Logistics group also generates Certificates of Quality from QC DOC to send along with shipments of Baroid products. QC DOC globally tracts the quality of Baroid products from the time the material ships from the vendor until the customer receives it.

- All suppliers electronically sign Vendor Quality Compliance Agreements (VQCA) with the Quality and Purchasing department in which the suppliers are directed to input certificates of analysis data into the Global Quality Database (QC DOC) and send samples to the Quality Assurance Department in Houston or Pune. VQCA for all trade-named products are included in QC DOC along with the commodity chemicals such as salt and caustic soda and many others as agreed by stakeholder departments or customer requirements.
Industrial Drilling Products

Since 1958, Baroid Industrial Drilling Products (IDP) has been providing products and services to the industrial drilling industry for non-oil and gas exploration applications. The IDP Laboratory in Houston is committed to product development and technical service to fulfill the industry needs and support the IDP field engineers. The IDP product line includes drilling fluid additives, bentonite grouts, well remediation products and well development products specifically engineered to optimize performance and lower end-user costs. Baroid IDP serves wide-ranging and diverse markets including:

- Water-well drilling
- Mineral exploration
- Horizontal direction drilling (HDD)
- Deep foundation/drilled shaft/slurry trenching
- Pipe bursting/pipe jacking
- Micro-tunneling
- Tunneling
- Construction/micro piles/ auger boring
- Geotechnical investigations
- Geothermal heat loop applications
- Environmental monitoring wells
- Environmental horizontal drainage/recovery wells
- Shot hole drilling
- Water impedance and pond sealing/vertical barriers
- Pipeline river crossings