BAKER HUGHES INTEQ

Drilling Systems

Baker Hughes INTEQ

Headquarters: 17015 Aldine Westfield Road, Houston,Texas 77073, Tel: (713) 625-4200, Fax: (713) 625-5200

North America Business Unit: 17015 Aldine Westfield Road, Houston,Texas 77073, Tel: (713) 625-4800, Fax: (713) 625-5800

Latin America Business Unit: 17015 Aldine Westfield Road, Houston,Texas 77073, Tel: (713) 625-4900, Fax: (713) 625-5900

Asia Pacific/Middle East Business Unit: 273 Jalan Ahmad Ibrahim, Jurong, Singapore 2262, Tel: (65) 861-1855, Fax: (65) 862-5112

Europe/Africa Business Unit: Campus 1, Science & Tech. Park, Balgownie Rd., Bridge of Don, Aberdeen AB22 8GT, Scotland, Tel: (44) 224 226-000, Fax: (44) 224 226-026

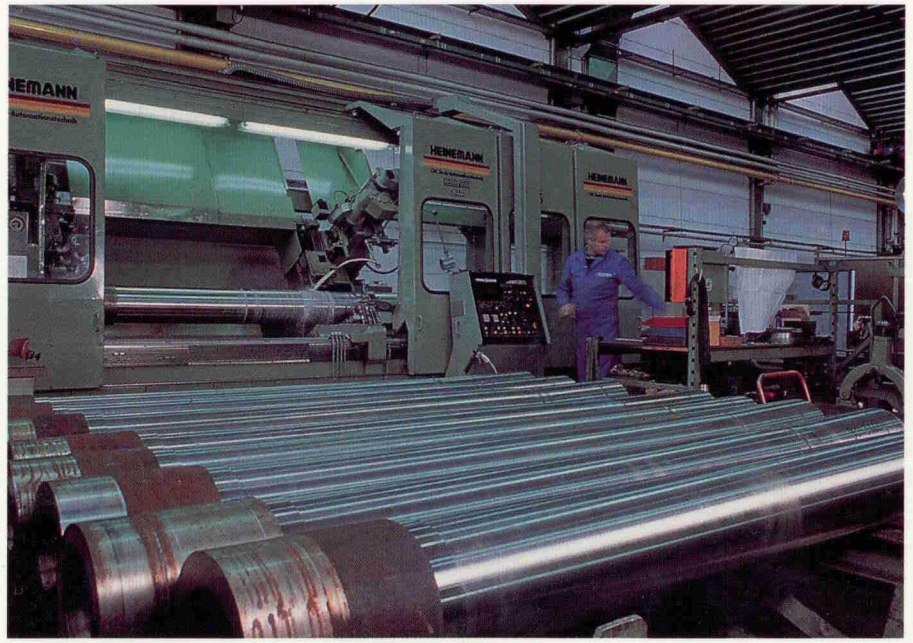
603-002 5/93

A New Service Company to Meet Your Objectives

Baker Hughes INTEQ is a new kind of oilfield service company...dedicated to helping you improve the processes and productivity of wellbore construction.

With our worldwide service network and range of technologies we can provide integrated solutions for efficient drilling, completion and production. We can also give you single point access to other Baker Hughes technologies, as well as to other contractors' products and services, to match the best solution with your project requirements.

Our technical disciplines are championed by an engineering staff that is expert in drilling, evaluation, fluids and completion technologies. This publication focuses on Baker Hughes INTEQ's drilling systems technology and services.



Continuous Improvement

Baker Hughes INTEQ places high priority on dedicated research and engineering efforts. The result is constant improvement to tool design, materials and quality assurance systems. Manufacturing and Operations resources are equally committed to quality. In 1992, the company became one of the first ever to achieve certification to ISO quality standards for its wellpath design techniques as well as its manufacturing and service facilities.

Resources for Continued Technical Improvement

Baker Hughes INTEQ's drilling systems operations are backed by one of the industry's most successful drilling research and development programs. The Drilling Research Center in Celle, Germany developed the Navi-Drill motor line, steerable drilling systems, and specialized systems for medium and short radius horizontal drilling. These efforts continue to result in significant innovations, such as the Slimhole Drilling system and advanced air drilling technology, successful development of a near-bit sensor for improved measurement-while-drilling, and on-going work on coiled tubing drilling.

Celle, Germany, Drilling Research Center

A Baker Hughes Company

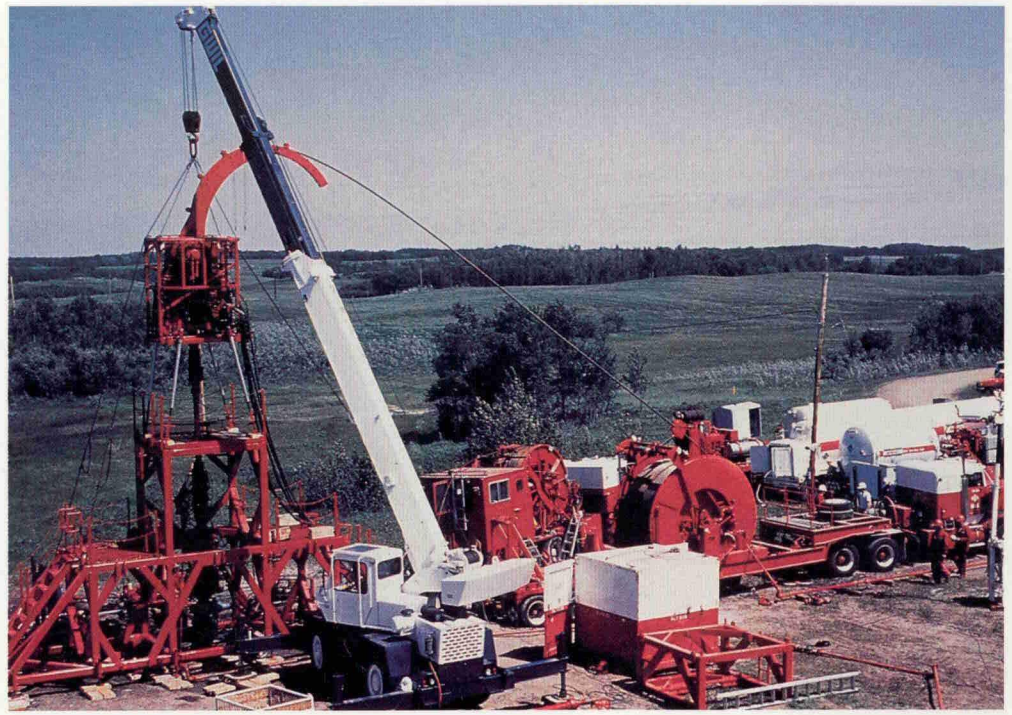
Baker Hughes INTEQ has access to the total resources of other Baker Hughes, Inc. oil service leaders, helping clients in the wellbore construction process. Baker Hughes INTEQ also plays a major role in the Integrated Solutions program, which can combine the technologies and services of any or all Baker Hughes companies with other suppliers to best meet the needs of the project.

Improving the Wellbore Construction Processes

Today, Baker Hughes INTEQ shares the objectives of the operating company: to safely and cost–effectively drill and complete a productive well. This concept of shared objectives encompasses more than low cost-per-foot drilling or high-accuracy geosteering technology. Now the goal is to provide best value.

Baker Hughes INTEQ's emphasis on value involves us in a growing number of partnering arrangements with clients, often involving our engineering staff working as participants in the client's project management team.

For more information on how our advanced drilling systems technology — and our complete capabilities — can improve the economics on your next well, contact your nearest Baker Hughes INTEQ representative.



Baker Hughes is a leading innovator in applying directional drilling technology with coiled tubing shown here.

Air Drilling

Underbalanced drilling — with air or mist as the circulating medium — is often used in low pressure reservoirs to minimize formation damage and avoid lost circulation problems. To provide the benefits of steerable systems in applications where air or mist is the preferred drilling fluid, Baker Hughes INTEQ offers the Eastman Navi-Drill Mach 1/AD air drilling motor. This powerful air drilling motor operates without overspeeding, and incorporates a sealed bearing pack for long service downhole.

With an adjustable kickoff (AKO) sub, the steerable air motor system combines directional and straight hole drilling capabilities to provide precise directional control. When an alignment bent sub (ABS) is fitted to the top of the motor, the Mach 1/AD motor can be used as a fixed–angle build motor, achieving build rates up to 20°/100 ft. A variety of steering and survey options are available to maintain directional control.

Directional Drilling with Coiled Tubing

Baker Hughes INTEQ has been an innovator in directional drilling with coiled tubing in place of a conventional drill string. Using small diameter motors and specially developed orienting equipment, we have drilled underbalanced to make curve and horizontal hole sections during casing-exit and new-well operations. Our development team and operations experts continue to gain experience with this emerging technology.

Drilling Systems Solutions

Baker Hughes INTEQ is the industry leader in a full range of directional and performance drilling applications. Whether your project calls for cost-effective exploratory drilling, development of a multi-well platform, placement of horizontal wells in a complex reservoir, or re-entering existing wells to boost production, Baker Hughes INTEQ is likely to have the drilling systems solution that best meets your needs.

We engineer and provide our drilling systems technology in conjunction with other critical systems — including drilling fluids, drill bits, measurement-while-drilling and completions.

When the project requires it, we engineer and provide our drilling systems technology in conjunction with other critical systems — including drilling fluids, drill bits, measurement-while-drilling and completions. This integrated approach can enhance overall drilling performance and maximize the production potential of each well.

These technologies are delivered through our worldwide service network, which places qualified people, reliable equipment and in-depth support where they can contribute most to the success of your project.

Innovation in Drilling Systems

Baker Hughes INTEQ's experience in drilling technology and service spans over 60 years, from the early developments in controlled directional drilling to the latest advances in horizontal and extended reach technology.

In the 1980's, Baker Hughes INTEQ predecessor company Eastman Christensen introduced the industry's first steerable drilling system. Since then we have combined Navi-Drill steerable motors with Polycrystalline Diamond Compact (PDC) drill bits and measurement-while-drilling technology to help oil companies dramatically improve drilling economics throughout the world.

Today, Baker Hughes INTEQ provides integrated services that combine steerable and horizontal drilling systems, advanced Teleco MWD and formation evaluation technology, Milpark engineered drilling fluid systems, and Baker custom-engineered completions. Baker Hughes INTEQ personnel also work closely with Hughes Christensen experts to engineer the right bit for the formation and drilling assembly.

This technology is expertly applied by an experienced team of directional drilling supervisors, field service engineers and technical service representatives. Rigsite personnel are backed by regional coordinators, drilling engineers and field maintenance personnel.

Baker Hughes INTEQ also operates research and manufacturing facilities in Europe and the United States, with engineering support groups based in Houston, Texas and Celle, Germany. These professionals bring years of experience to each job, helping customers achieve their objectives for efficient, cost-effective performance in a full range of drilling applications.

Baker Hughes INTEQ's strategic presence around the globe ensures timely delivery of tools, unmatched technical support and reliable performance on the rig.

Technology and Experience in Directional Drilling

Baker Hughes INTEQ's drilling systems have been used in thousands of vertical, horizontal and directional wells around the world. Our steerable systems bring speed and accuracy to single and multi-well projects and make it possible to efficiently drill complex well paths that hit multiple targets. They have consistently improved performance and reliability over conventional techniques and competitive steerable systems. This cumulative experience enables us to improve the performance and reliability of our drilling systems components and develop new ones to meet the industry's needs.

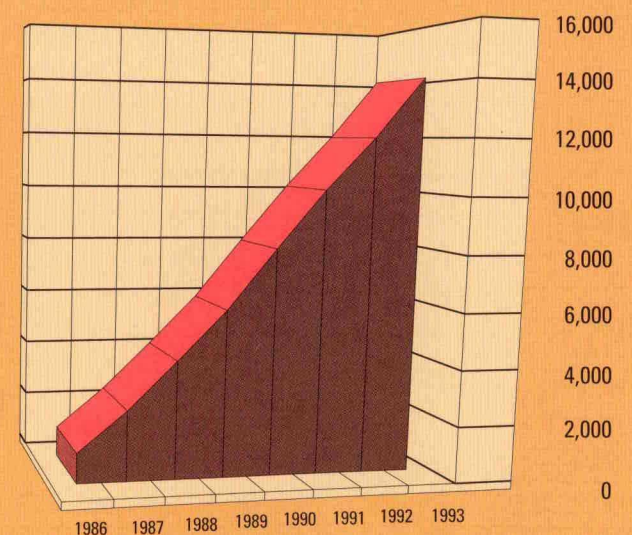
Advanced Steerable Systems Technology

Baker Hughes INTEQ's advanced systems incorporate Eastman Navi-Drill high performance drilling motors in a variety of configurations. Our systems can achieve build rates from 1°/100 ft to 1.5°/foot, making them suitable for a complete range of directional and horizontal drilling applications.

Applications for Baker Hughes INTEQ drilling systems include:

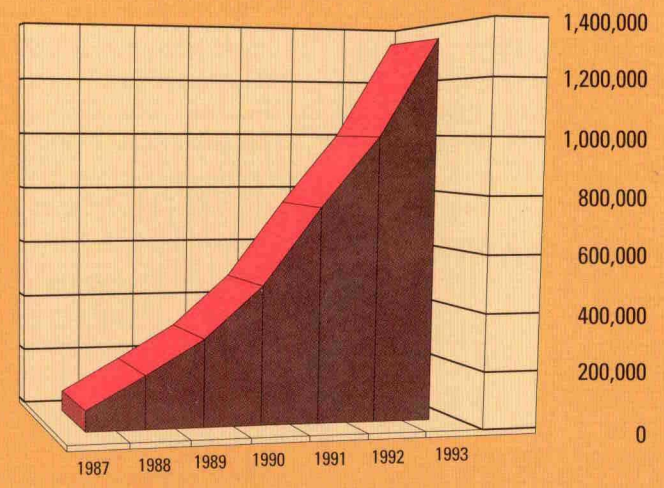
- Offshore development and exploration wells
- Extended reach wells
- Horizontal wells
- Geosteering
- Directional wells and sidetracks
- Peformance-drilled straight holes
- Re-entry wells
- Air-drilled holes
- Relief wells
- Slimhole wells
- High temperature/high pressure formations

Cumulative Directional/Horizontal Wells 1986–1993



Baker Hughes INTEQ has provided services on more directional and horizontal wells than any other company.

Navi-Drill Motor Cumulative Circulating Hours 1987–1993



Since 1986, Navi-Drill motors have logged more than 1.3 million operating hours worldwide.

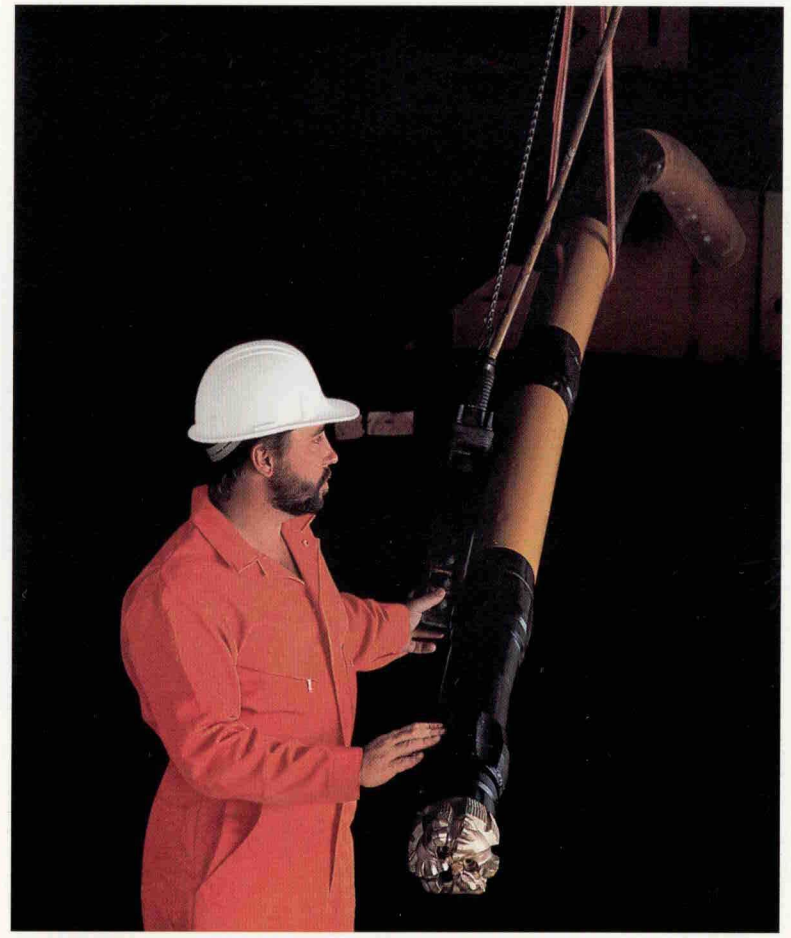
The short radius re-entry systems have had impressive results. In one West Texas field, the system has been used to re-enter wells that were originally drilled over 50 years ago. Initial production has increased ten-fold after recompletion with horizontal extensions averaging 700 ft in length.

Slimhole Drilling

In conjunction with a major operating company, Baker Hughes INTEQ engineers have developed new technology for slimhole drilling. This advanced Slimhole Drilling System (SHD) comprises drilling engineering, downhole tools, fluid systems, operating software and a unique kick detection system. The combination enables oil companies to achieve substantial cost savings by reducing hole and casing sizes.

No longer limited to using mining rigs and continuous coring techniques, slimhole drilling with the Baker Hughes INTEQ SHD system employs conventional oilfield equipment and drilling rigs. The system has been used with success on both development and exploration wells, including holes drilled in high temperature-high pressure formations. In one recent exploratory well in Madagascar, for example, the SHD system helped the operator cut project time in half while achieving cost savings of 40% compared to an offset well drilled in the same region.

The SHD uses proven Eastman Navi-Drill performance motors in conjunction with PDC bits to improve penetration rates in small holes. The slimhole BHA incorporates such features as improved fixed cutter bit designs, high-strength drill pipe and a Thruster device which, combined with the downhole motor, reduces damaging vibrations to improve bit life and reduce stress on the drill string.



Articulated short-radius motor used in short radius re-entries.

Slimhole wells can be monobore completions, in which all remedial and stimulation tools are the same size through the length of the wellbore. Monobore completions allow operations to proceed without pulling production tubing — a significant cost saving over the life of the well.

Advanced Drilling Systems for Special Applications

Re-entry Technology

In mature oil fields around the world, Baker Hughes INTEQ offers the industry's most reliable drilling technology for horizontal re-entry applications. This includes our articulated short radius motor and MWD systems which may be used with conventional rigs, workover rigs or coiled tubing units. Baker Hughes INTEQ also has performed numerous re-entry projects using medium radius systems to improve production of offshore development wells.

Short Radius Motor System

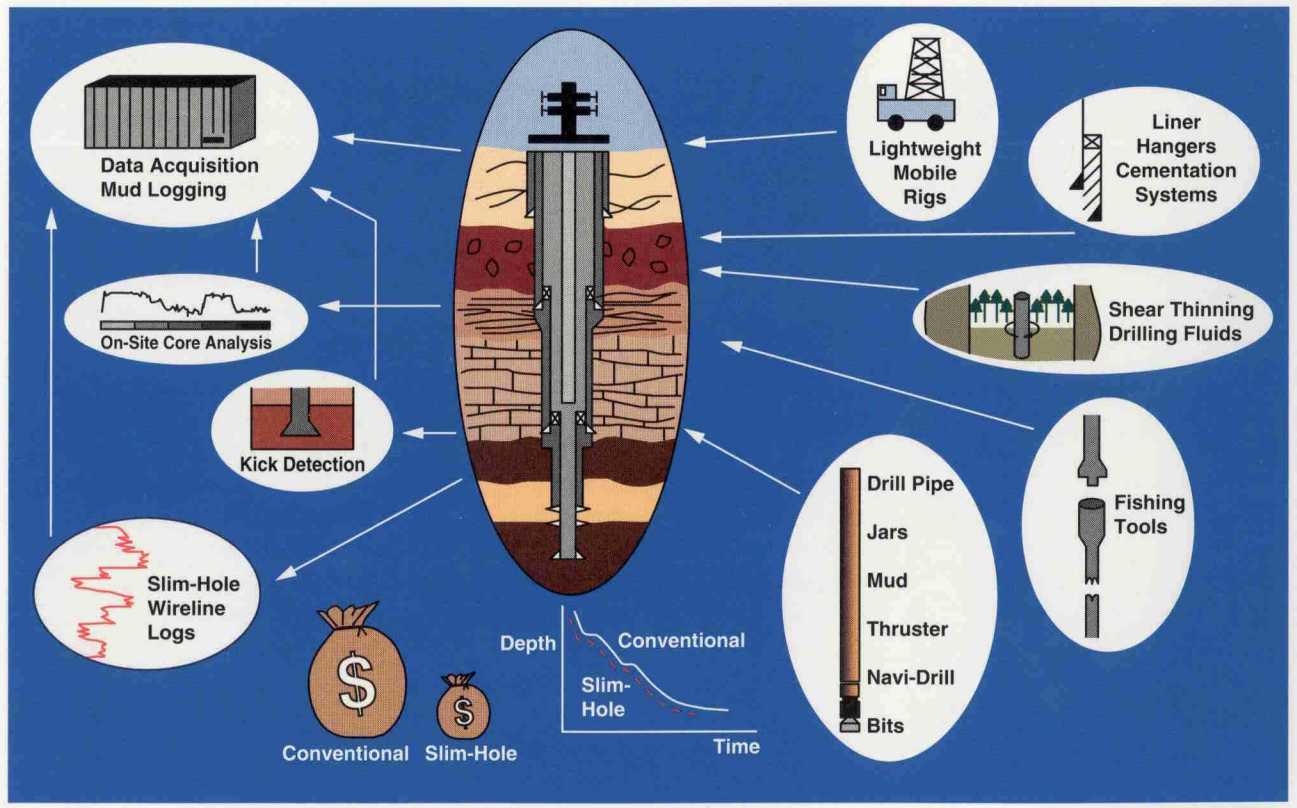
The short radius well profile, which builds from vertical to horizontal along a 40 to 100-foot (12–30m) radius, has been extremely useful in re-entry applications. Short radius wells provide traditional horizontal wellbore benefits, and are ideal for reservoirs underlying unstable zones. Additionally, where lease lines or geology restrict displacement, short radius profiles maximize the productive footage within the reservoir.

Baker Hughes INTEQ's short radius motor system can be applied from existing vertical cased wellbores or open hole intervals, and can drill horizontal sections exceeding 1200 ft. The system uses roller cone or PDC bits for hole sizes from 4 1/8" to 9 7/8".

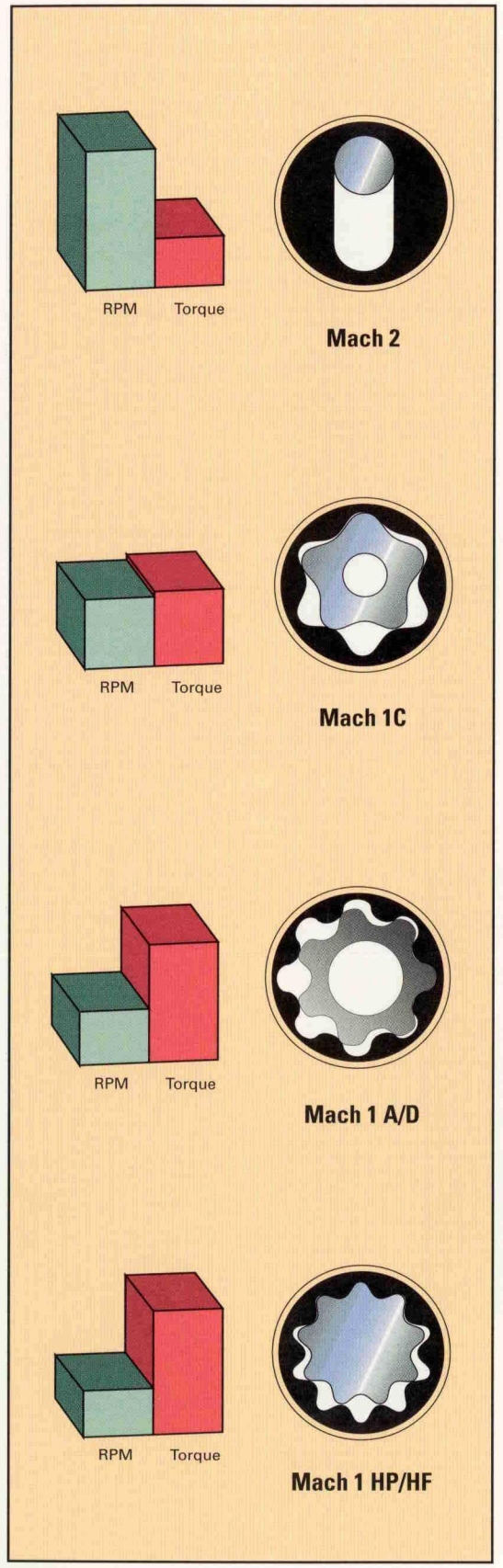
This drilling system affords precise directional control over inclination and azimuth, and surpasses ROP performance of rotary-driven short radius systems. The short radius motor system can be guided using our patented NaviTrak SR MWD system, or by a specialized wireline steering tool.

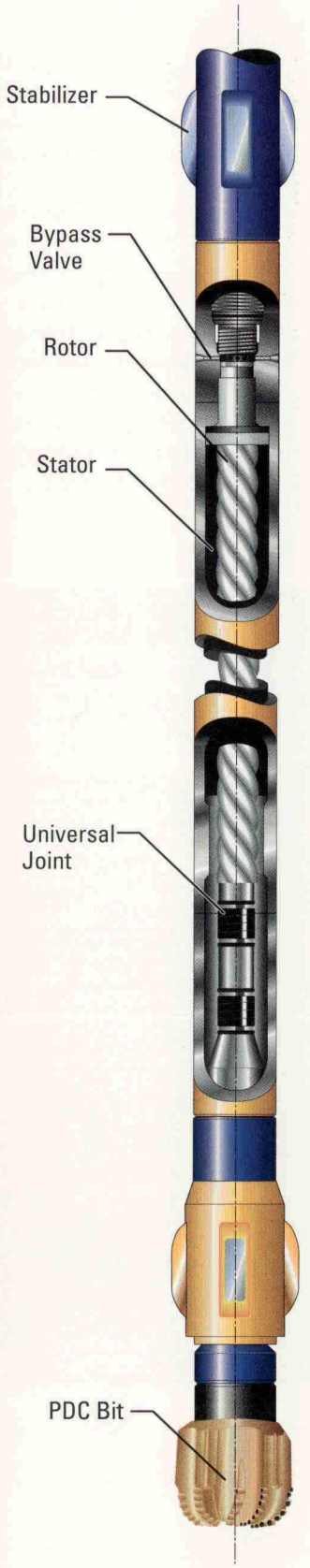
The short radius technique is an excellent redevelopment tool since, in most cases, a window can be cut and the horizontal section drilled within the reservoir. This makes completions less complicated and improves project economics. Prepacked liners, inflatable packers, sliding sleeves and other completion options are now available for short radius wells.

Baker Hughes INTEQ elements of slimhole drilling technology.



Eastman Navi-Drill Motors





Mach 1P/HF

The Power Inside the System

A simple, rugged drilling tool, Navi-Drill provides power to turn the bit at predictable levels of torque and rotating speed. Navi-Drill motors are available for drilling hole sizes from 17/8" to 26" and operate efficiently and reliably in all types of drilling fluids, including air and foam.

To assure ultimate quality, Baker Hughes INTEQ maintains careful control over research, engineering and manufacture of critical motor parts, including rotors, stators, housings, drive shafts and radial bearings.

Navi-Drill designs:

- Mach 2 motor, 1:2 lobe design, for medium speed and torque in straight holes, harder formations and extended reach wells
- Mach 1C, a 5:6 lobe motor, provides high torque at low speeds for directional and performance drilling with roller cone and PDC bits
- Mach 1/AD, for drilling with air, foam and mist
- Mach 1 P/HF, generates high torque at flow rates as high as 1200 gpm for larger sizes

Information Management, Planning through Completion

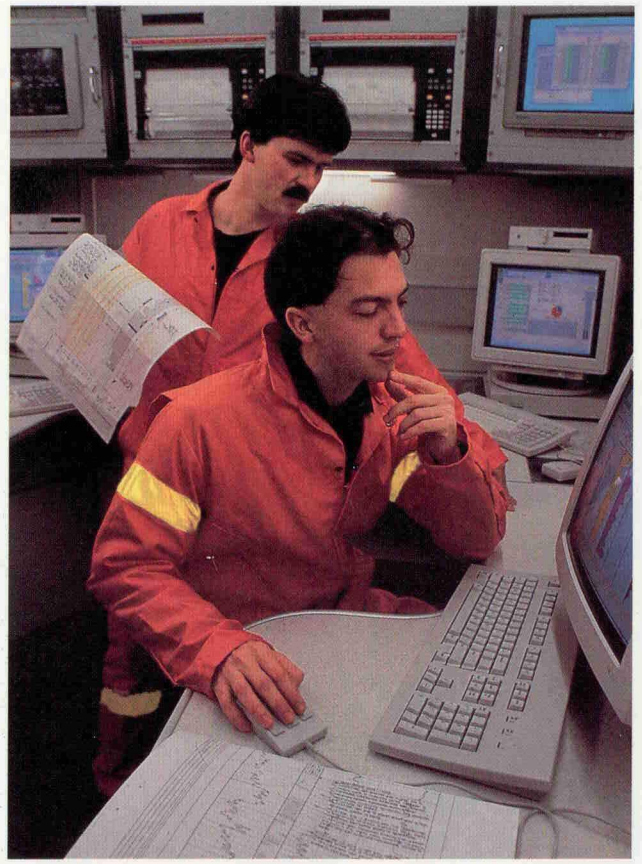
Before operations begin, Baker Hughes INTEQ drilling engineers and directional well planners work with the operator to design the wellpath, bottomhole assemblies and drilling parameters that will reach the target as efficiently as possible.

Our personnel are expert in the full range of drilling and completions disciplines, so we can offer comprehensive wellbore planning that uses extensive applications software and database capabilities to prepare the optimum wellbore design.

At the planning stage, the proposed wellbore geometry is optimized for safety by the comprehensive directional planning facilities within our software systems. These applications allow automated proximity scanning and rapid refinement of geometry to maintain wellbore clearance tolerances. Our systems also can model the well's survey program to ensure that the well path and survey instrument tolerances meet accuracy specifications.

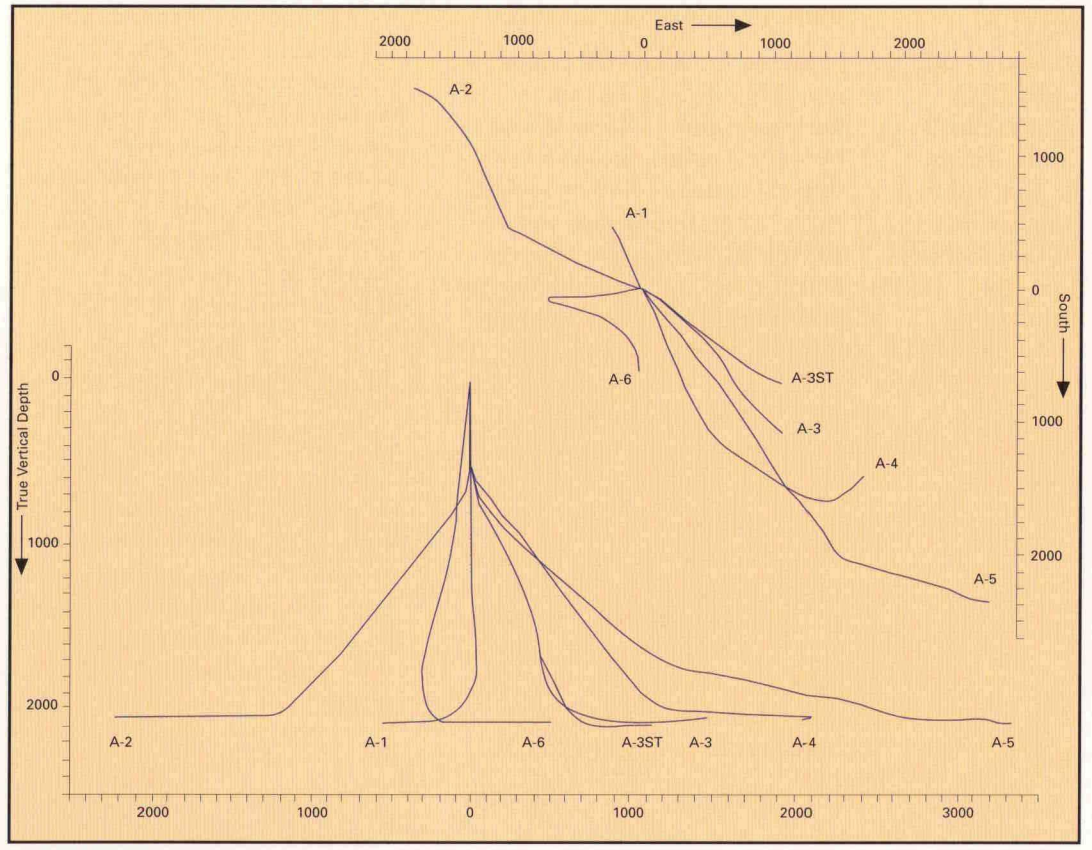
After the initial well geometry is established, drilling engineering software is applied to analyze bit and hole cleaning hydraulics, surface and downhole torque and drag stresses and proposed bottom hole assembly (BHA) designs. Database facilities allow previous drilling experience to be applied to the proposed well. The wellbore is designed within the rig's capability to ensure the well is drilled and completed as efficiently and economically as possible.

During drilling, the same engineering applications are used at the rig site by the directional and survey/MWD specialists to supervise progress. The Baker Hughes INTEQ DrillByte system provides a common data base, real-time mud logging, comprehensive daily reporting and trouble avoidance utilities for complete monitoring of drilling operations.

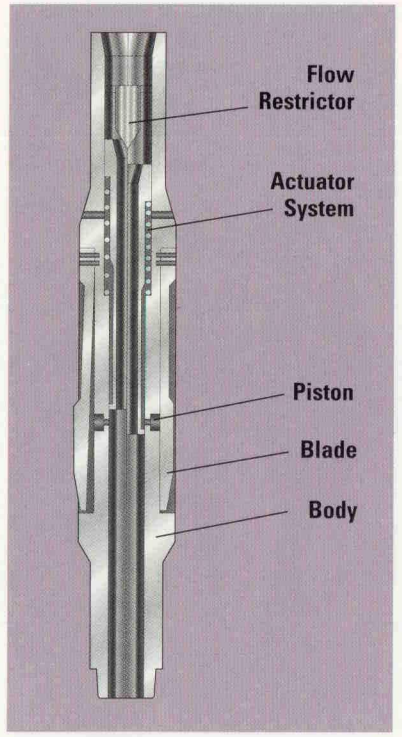


Optimized wellbore geometry starts with computer-based data analysis.

Medium Radius Horizontal Wells



Wellpath map shows elevation and plan views of seven horizontal wells drilled from one platform.



NaviStab℠ downhole-adjustable stabilizer eliminates trips to change BHA.

Medium radius horizontal wells are ideal for producing from naturally fractured and thinly-bedded formations, for placing long sections of horizontal hole in low-permeability zones, and for solving coning problems.

Medium radius drilling systems can be configured with the full range of Teleco MWD systems. Depending on hole size, the bottomhole assembly can be guided to and kept within the pay zone using either directional or formation evaluation MWD systems. Properly configured, they can build hole inclination at rates from 8° to 26° /100ft in hole sizes from 4 1/2" to 12 1/4".

In some development programs, horizontal wells can reduce the number of wells (and platform slots) required to develop a field. In 1990, Baker Hughes INTEQ was the first to drill a dual lateral horizontal wellbore in the Austin Chalk trend. This produced as much as 10,000 ft (3076m) of horizontal pay from a single vertical wellbore.

The multilateral completion technology developed by Baker Oil Tools since those early dual lateral projects extends the benefits of multilateral holes offshore, enabling each lateral to be isolated and completed separately.

Drilling Systems for Development Drilling

Our drilling systems are used most widely in development drilling projects, including directional and horizontal wells both on and offshore.

Baker Hughes INTEQ's steerable systems can drill long-radius horizontal and directional wells with build rates up to 6°/100 ft(30m). The well profiles are suitable for extended reach applications from offshore platforms, pads or environmentally sensitive locations.

For example, on one project offshore Australia, our steerable drilling systems, configured with an MWD system and Drilling Dynamics sensors, achieved extended displacements exceeding 16,250 ft(5000m), compared to 9750 ft(3000m) on previous wells. The further reach meant that substantially greater gas reserves could be produced without tiebacks or additional platforms.

Steerable drilling systems contribute to flexibility in directional drilling.

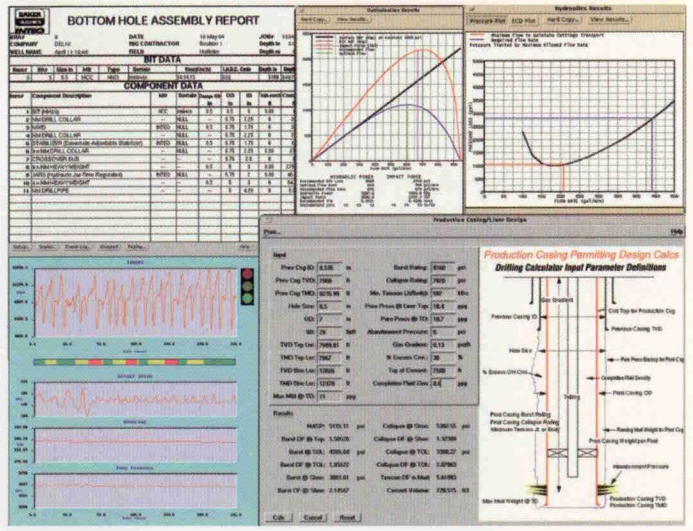
Our steerable assemblies with Formation Evaluation MWD systems also permit operators to drill complex wellpaths that can intersect multiple targets, then geosteer the final horizontal section into the pay. In one recent case, an operator in the Netherlands developed an entire offshore reservoir using horizontal wells drilled with this technology.

Drilling fluid systems are critically important in long sections of horizontal hole. Baker Hughes INTEQ is a leader in providing environmentally safe fluid systems that also minimize drag and formation damage in the horizontal well.

MWD Systems for All Applications

Applications	Directional	DMWD	NaviTrak	NaviGamma	DG	DDG	RGD	DPR II	Triple Combo
Slimhole Drilling		■	■	■					
Short Radius			■	■					
Horizontal Wells	■	■	■	■	■	■	■	■	■
Borehole Location	■	■	■	■	■	■	■	■	■
Directional Control	■	■	■	■	■	■	■	■	■
Relief Well Drilling	■	■	■	■	■	■	■	■	■
Stratigraphic Positioning				■	■	■	■	■	■
Geosteering in Reservoir				■	■	■	■	■	■
Lithology Identification				■	■	■	■	■	■

Depending on the level of MWD service employed, information provided by Baker Hughes INTEQ's measurement systems can be used for a variety of applications.



DrillByte system provides comprehensive monitoring of drilling operations.

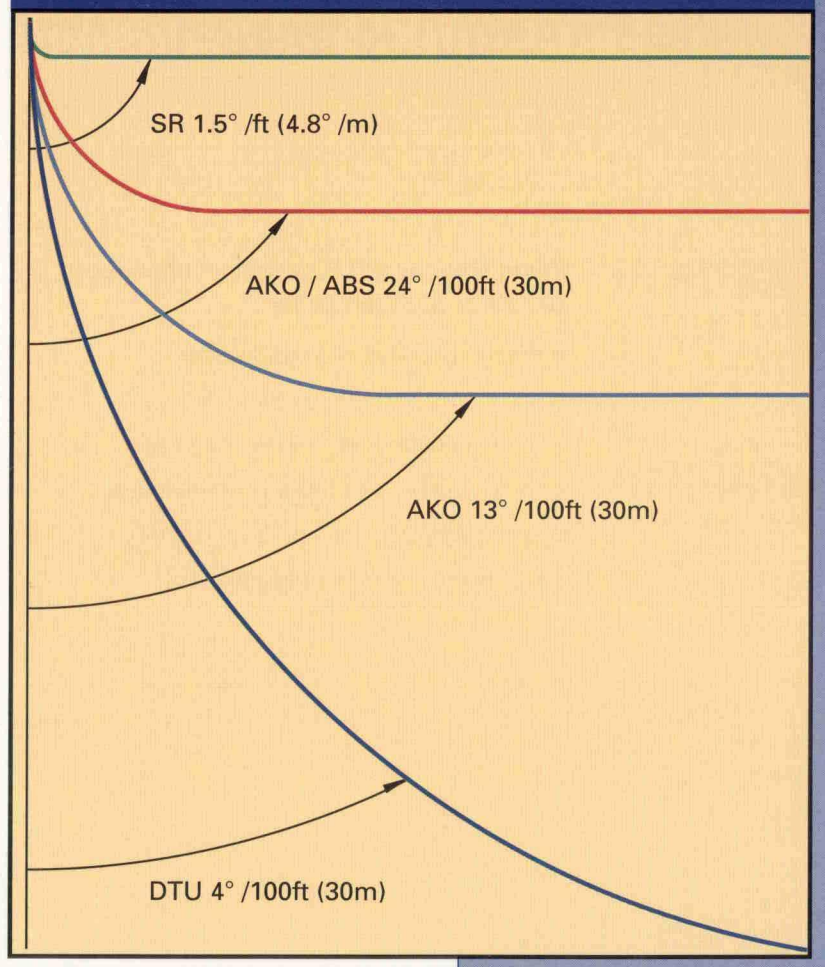
Baker Hughes INTEQ employs advanced computer technology for:

- Wellbore design and optimization
- Survey analysis and program design
- Drilling engineering and BHA analysis
- Measurement and logging while drilling
- Surface Information and Mud Logging
- Fluids and completion engineering solutions

Navi-Drill Motor Configurations

Incorporating Eastman Navi-Drill motors with a variety of adjustable bent housing and stabilizer configurations, Baker Hughes INTEQ steerable systems achieve a range of build rates.

Maximum Build-Up Rates For Navi-Drill Motor Configurations



Short Radius Motor

- Bit Offset Device: Adjustable Kick-Off Sub, Articulated Motor Sections
- Power Section: Modified Navi-Drill Mach 1
- Radius: 40 to 100 ft (12–30m) radius

AKO/ABS Motor

- Bit Offset Device: Adjustable Kick-Off Sub and Adjustable Bent Sub
- Power Section: Navi-Drill Mach 1
- Build Rates: 10° to 24°/100 ft (30 m)

AKO Steerable Motor

- Bit Offset Device: Rigsite Adjustable Kick-Off Sub
- Power Section: Navi-Drill Mach 1 or Mach 2
- Build Rates: 2° to 13°/100 ft (30 m)

DTU Steerable Motor

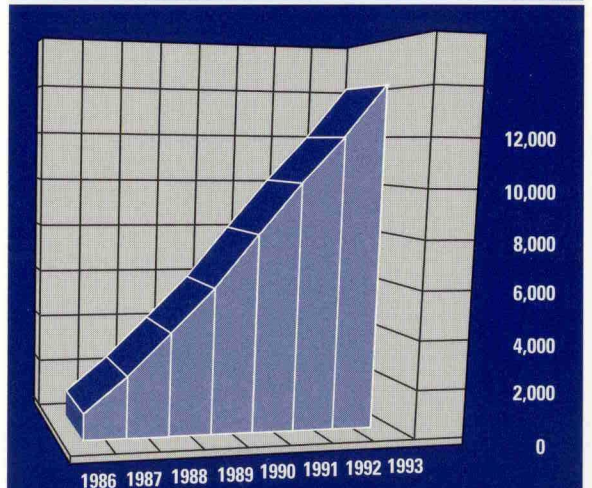
- Bit Offset Device: Double-Tilted U-Joint Housing
- Power Section: Navi-Drill Mach 1 or Mach 2
- Build Rates: 1° to 4°/100 ft (30 m)

Comprehensive Planning

Using their specialized knowledge of Navi-Drill technology, Baker Hughes INTEQ personnel can produce comprehensive wellbore planning that yields superior performance. Baker Hughes INTEQ wellbore planning makes full use of drilling and completion disciplines, employing data base systems and computer software to focus on a wellbore design that will optimize production of the reservoir.

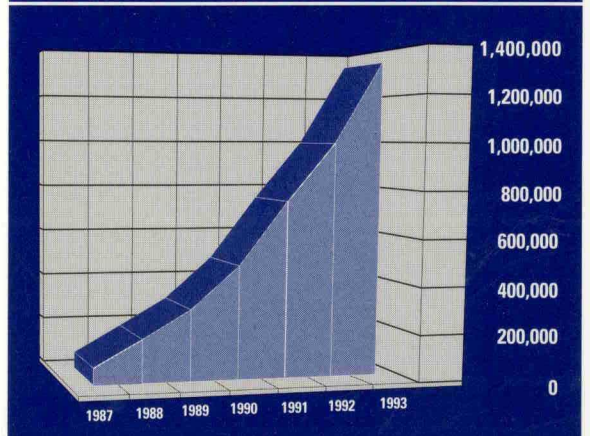
With a Baker Hughes wellbore plan, the operator can use sophisticated software to monitor drilling parameters at the surface. The Navi-Drill technology empowers rigsite engineers to new levels of control over the drilling process, producing drilling efficiencies not possible when using outdated methods.

Cumulative Directional/Horizontal Wells 1986-1993



Baker Hughes INTEQ has provided services on more directional and horizontal wells than any other company.

Navi-Drill Cumulative Directional/Horizontal Wells 1986-1993



Since 1986, Navi-Drill motors have logged more than 1.3 million operating hours worldwide.

Industry Standard

Through a continuous process of improvement and innovation, the Navi-Drill motor has achieved unprecedented levels of performance. It is the most widely used motor in the industry.

Baker Hughes INTEQ

Headquarters: 17015 Aldine Westfield Road, Houston, Texas 77073, Tel: (713) 625-4200, Fax: (713) 625-5200

North America Business Unit: 17015 Aldine Westfield Road, Houston, Texas 77073, Tel: (713) 625-4800, Fax: (713) 625-5800

Latin America Business Unit: 17015 Aldine Westfield Road, Houston, Texas 77073, Tel: (713) 625-4900, Fax: (713) 625-5900

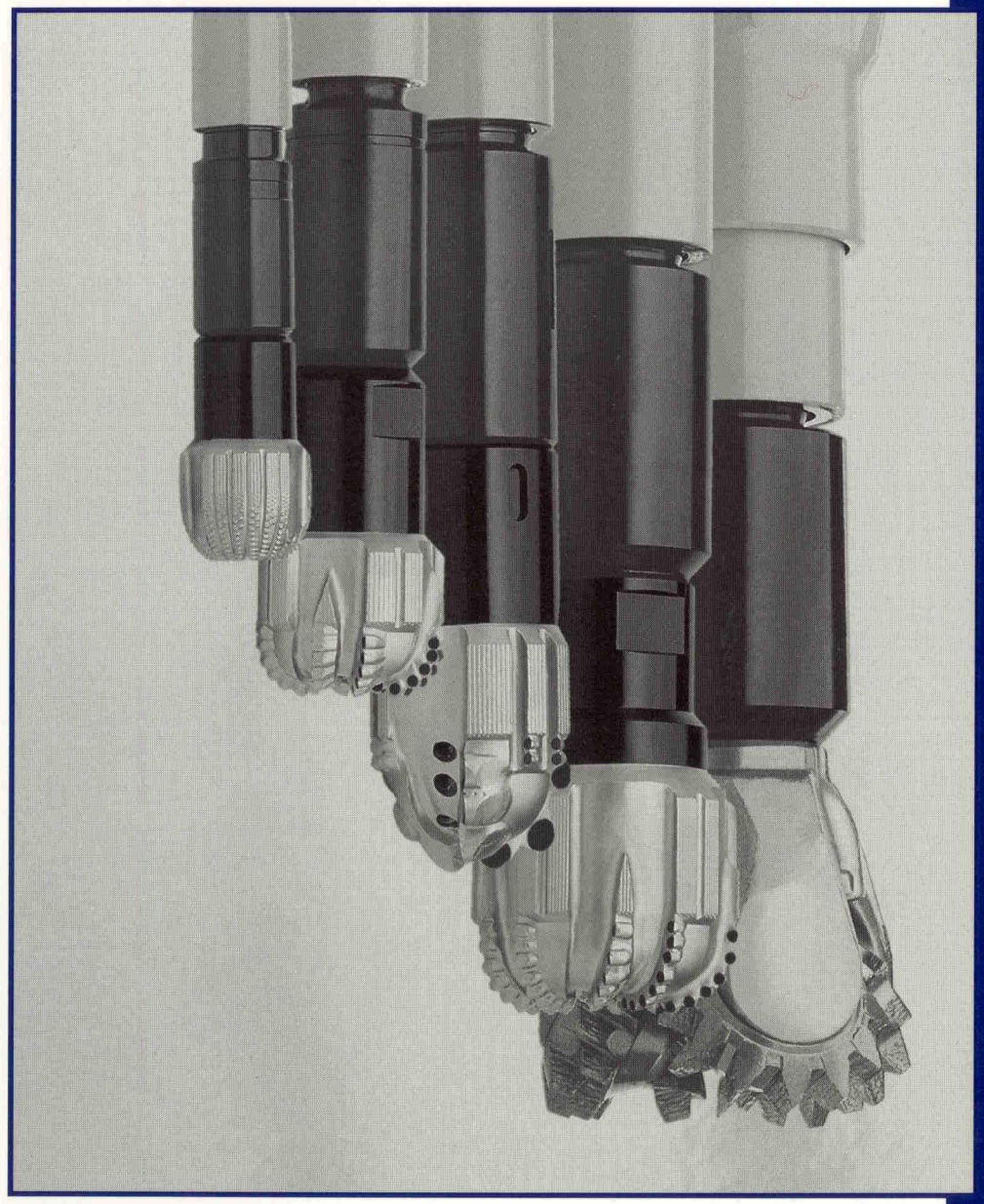
Asia Pacific/Middle East Business Unit: 273 Jalan Ahmad Ibrahim, Jurong, Singapore 2262, Tel: (65) 861-1855, Fax: (65) 862-5112

Europe/Africa Business Unit: Campus 1, Science & Tech. Park, Balgownie Rd., Bridge of Don, Aberdeen AB22 8GT, Scotland, Tel: (44) 224 226-000, Fax: (44) 224 226-026

 603-003 2/94

BAKER HUGHES INTEQ

Navi-Drill™ Downhole Motors

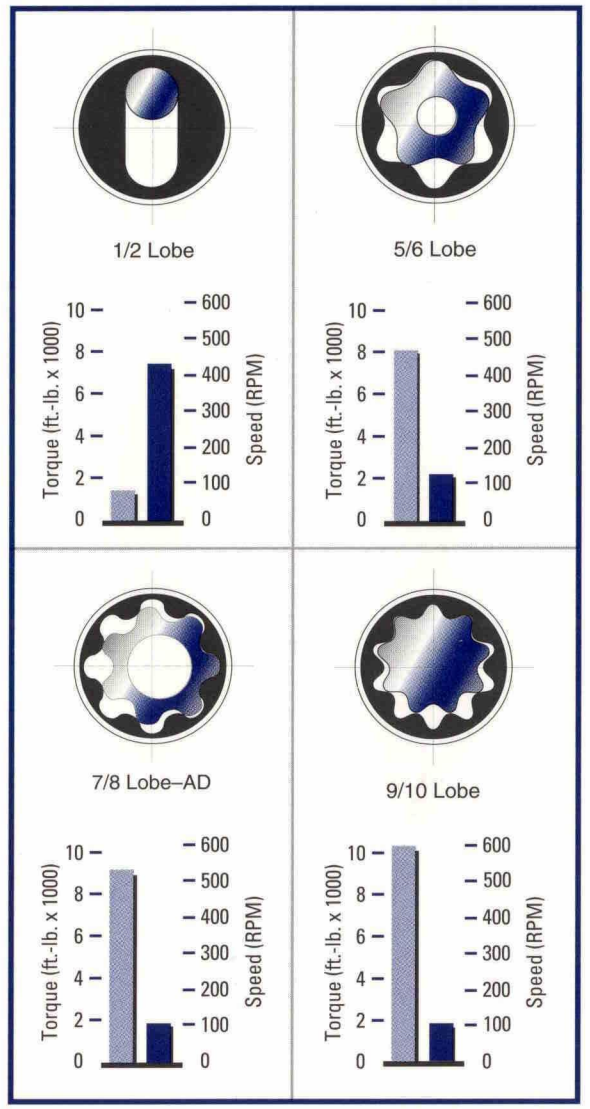


Navi-Drill™ Downhole Motors

"... the advanced Baker Hughes downhole technology has made drilling with downhole motors more cost effective than conventional rotary drilling."

Baker Hughes INTEQ offers a complete line of proven, high-performance Navi-Drill™ downhole motors. Since their introduction in 1976, Navi-Drill motors have undergone continuous development, extending the range of downhole motor applications to new areas.

Once used only during kickoff of a directional well, downhole motors are now employed extensively in all types of applications: straight hole drilling, slim hole drilling, short and medium radius horizontal drilling and extended reach drilling. In many cases, the advanced Baker Hughes downhole technology has made drilling with down-hole motors more cost effective than conventional rotary drilling.



Each generation in the Navi-Drill series develops increasing torque at rated fluid pressures.

Motor Design Principles

Positive displacement mud motors (PDMs) convert the force of the mud flow into rotational power that drives the bit without turning the drill string. This fundamental motor design criterion is based upon the Moineau "progressive cavity" principle.

As the mud is pumped through the motor, it fills the cavity between the dissimilar shapes of the rotor and stator, displacing the rotor. The resulting motion is transferred through the bearing assembly to the drive sub, delivering rotation and torque at the bit. Baker Hughes INTEQ motors optimize this design principle to produce maximum power at the bit, achieving high penetration rates.

Speed vs. Torque

The rotational speed (angular velocity) of the rotor is proportional to the mud flow rate through the motor's progressive cavity. The torque generated is proportional to the mud pressure drop across the motor section, and is a function of the weight-on-bit.

Increasing weight-on-bit will create more torque and also increase differential pressure across the motor section until the motor stalls. By controlling the bit speed and torque, the operator can enhance bit life and optimize penetration rates. At the correct balance of motor speed and torque (mud pressure and weight-on-bit), optimum penetration and reliability are obtained.

Steerable System

The steerable system employs a Navi-Drill motor configured with either a double-tilted universal-joint (DTU) housing or an adjustable kick-off (AKO) sub. This geometry allows effective use of the motor in several drilling techniques, including long and medium radius horizontal drilling, slim hole and coiled tubing drilling, underbalanced drilling and performance drilling.

Horizontal Drilling

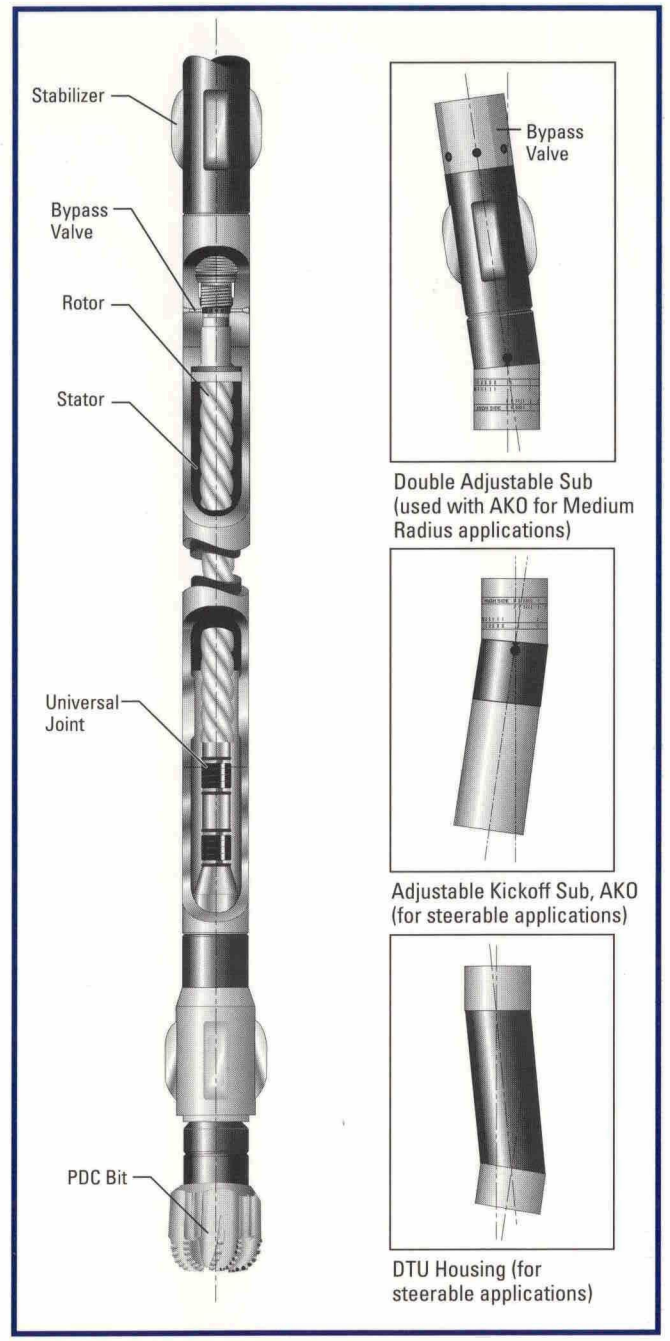
Baker Hughes INTEQ motors can drill a smooth horizontal wellbore along a specified radius from 40 ft (12m) to 1,000 ft (300m) or more, depending upon the application. The full line of Navi-Drill steerable motors is available with adjustable kick-off subs and adjustable bent subs that allow rigsite adjustment of build rates. For short radius applications, the motors feature articulated housings and multiple power sections.

Slim Hole Drilling

Slim hole, steerable motors ($1^{11}/_{16}$"OD to $4^{3}/_{4}$"OD) with specialized kick detection systems, thrusters, bits and other downhole equipment have all of the economic advantages of small hole rotary drilling.

Underbalanced Drilling

The innovative air drilling motor for underbalanced drilling uses a modified multi-lobe design that can be driven by compressible fluids (air, nitrogen, CO_2, or natural gas). With this motor, it is now feasible to drill directional, high-angle, or horizontal wells in depleted zones. The approach can be especially attractive in wells with low pressure and in lost circulation areas of damaged formations.



Navi-Drill motors can be used with various adjustable subs and steering systems to achieve improved capabilities in a wide range of drilling applications.

Performance Drilling

Navi-Drill downhole motors and selected drill bits often can achieve faster penetration rates than rotary methods. Thus, they can improve performance in straight hole drilling.