This presentation has been prepared to give you a better understanding of slim-hole well technology.

We want to disseminate this knowledge because of a resurgent interest in this technology, from several operators around the world, and our current involvement in Australia through the SMART1 program.

Recommendations presented here should be applied within operational needs.
During the past years, the oil industry has undergone a series of drastic changes that are irreversibly altering the way in which business is conducted in domestic and international oil exploration.

1. Stringent environmental regulations have forced oil companies to restructure their spending capital in order to align themselves—sometimes with cost being no object—with the protection of the environment.

2. In the same way, the increasing cost of drilling related materials and services, together with flat oil prices, are influencing the allocation of money for drilling exploratory wells.

3. A special drilling technology has regained some popularity among companies trying to achieve explorationist goals while keeping costs down—slim-hole drilling offers attractive advantages in the areas of geological information, environmental protection and cost reduction. Drilling a slim hole in an unknown region, provides great amounts of geological information (through continuous coring) that will help design a better seismic program for subsequent evaluations of the area. Also, due to the reduced size of the equipment needed, locations are significantly smaller than those built for conventional drilling and access roads can be eliminated by using helicopters to transport the drilling rig.

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Based on hole size, oil & gas wells can be generally categorized as:

- conventional wells
- reduced-diameter wells

A reduced-diameter well is one in which 90 percent or more of the length of the well is drilled with bits smaller than 7 inches in diameter (e.g., micro-hole and slim-hole wells). As far as drilling technology is concerned, the main difference between micro holes and slim holes lays in their annular geometry—a slim-hole’s annular area is approximately 30 percent (or less) of the total hole area. This characteristic is very important when determining flow behavior of circulating fluids during drilling and when designing preventive and/or corrective procedures for well control operations.
This slide illustrates the differences in well geometry between conventional and slim-hole wells.
The main goal of a slim-hole well is to reduce total drilling costs. Even though instantaneous rates of penetration for slim holes have so far proven to be not as high as those found in conventional drilling, field trials should continue until rates of penetration are comparable. Also, progress in rig equipment materials and construction should aid in reducing lost time and number of drilling days.

The following can be said about the slim-hole wells drilled during the last three years throughout the world:

- A large majority were located on land
- A high percent were development wells
- Many within the United States and Canada were redrills
- Motor drilling was the most frequently used system
- The predominant hole size was 4 3/4"
- Most wells were single completions
- While more than half the wells were vertical, a number of directional and horizontal wells were also drilled.

NEXT SLIDE
A recent survey, conducted among 146 operators and service companies around the world, has identified several advantages of slim-hole wells.
The same survey also identified specific problems and concerns regarding this technology, as presented in this slide.
As in conventional drilling, the most important aspect of any slim-hole project is the execution.

1) Approximately 80 percent of the slim-hole wells drilled during the last four years have been deemed a mechanical success.

2) Sixty-five percent of them were considered as an economic success. Not surprisingly, it was determined that low production problems were due to the formation and not to a limitation in the production string. Regarding the cases of not reaching TD, problems occurred with tubulars, motors and bits, as well as directional control difficulties.

3) These findings underscore the fact that reliability continues to improve in the construction of small-diameter wellbores and that technology has solved most of the problems which resulted in the original demise of slim-hole drilling in the past.
This slide shows the percent savings —with respect to conventional methods— which occurred in drilling slim-hole wells, for specific components involved in the overall process.

As can be seen, the most significant savings are related to site preparation, transportation and logistics. This is particularly true for slim-hole, exploratory wells located in remote areas (such as mountainous regions or jungles). As mentioned previously, it is not uncommon in areas of remote exploration to spend a substantial amount of capital before even spudding the well.
The highest percentage of pressure losses for a slim-hole well is experienced in the annulus (approximately 90%). This characteristic makes wellbore hydraulics an important factor in both drilling fluid circulation and well control operations. Equivalent circulating density becomes of primary importance when deciding what type of drilling fluid and flow rates will be utilized when drilling a certain hole interval.

Reduced annular clearance increases annular pressure losses.

Annular pressure losses decrease with increasing eccentricity. This is due to the increase in effective flow area (effective diameter) which governs the transition from laminar to turbulent flow on the wide side of the annulus.

Drillpipe rotation has a significant effect on annular pressure losses in slim annuli. When drillpipe rotates, it disturbs the drilling fluid’s original axial flow path and imposes a helical motion (can also induce turbulence), thus increasing the effective distance that the drilling fluid must travel in order to move up the annulus.

Accurate static and dynamic monitoring of wellbore hydraulics is the single most important factor of a successful well control program in slim-hole drilling and the use of an adequate wellbore-hydraulics monitoring system will significantly increase the response time available to the Driller in a well-control situation.
Santos Ltd. (the largest land operator in Australia) has a majority interest in several oil and gas fields in the Cooper/Eromanga basins. Starting in 1996, they embarked on a four-year, accelerated exploration program that includes the drilling of 140 slim-hole wells in order to meet their financial objectives —Santos has a target to achieve 20% to 30% savings after a reasonable learning stage is completed. This is the first long-term program of this nature in the world since typical slim-hole projects have lasted only four or five wells.

Defining a suitable drilling rig was extremely important for the success of the project and Santos decided from the beginning to use a hybrid system —originated in the South African mining industry— as the basis for their slim-hole drilling program. The system in question was originally developed by British Petroleum to drill exploration wells down to 16,000 ft and is a combination of mining and oilfield technology. It includes a drill string (RSA 6K), used for either full-bore drilling or continuous coring at very high rotary speeds, extensively tested at BP’s Tubular Research Department by imposing internal pressures up to 10,000 psi, while rotating through a 15-degree dogleg at an axial loading equal to 250 kips. Overall, the hybrid nature of the system makes it more compatible with conventional oilfield technology and in turn facilitates maintenance and helps reduce cost.
Due to the nature of the project, a three-year contract was deemed necessary to justify the capital investment for specific slim-hole equipment. This has been started on a “cost plus” basis before establishing an operational benchmark and possibly moving into an “integrated services” performance arrangement.

After initial discussions it was decided that since Sedco Forex was to be the Company in charge of managing the rig, it made more sense to use a rig of their own. Once the initial financial details were worked out, it was necessary to develop a solid reactivation plan that included adequate timing and resources. When the AD 9 proposal was given to Santos, in April 1996, Sedco Forex were given the option to use either Rig Design Services Ltd. or SF-ENG for engineering and construction management (RDS is a firm based in London and was involved in the original engineering design of the slim-hole rig). A proposal submitted to SF by RDS, for engineering and construction management of the rig, was used as the basis for a Contract between the two companies.
Several equipment modifications were necessary before the rig was ready for drilling operations:

1. Probably the single most important piece of hardware installed on the SMART1 was its top drive. Since the drilling program called for rotary speeds up to 600 rpm, it was necessary to fit the rig with an efficient yet light and preferably fully portable top-drive system. The right solution was found through a Canadian company specializing in this type of equipment. After initial calculations it was determined that the use of a fully portable top drive was not possible due to structural restrictions on the rig; therefore, it was decided to install a semi-portable top drive which still required several modifications to some upper-mast sections. In the process, the entire racking board was also re-designed for added functionality.

2. Another equally important system was installed to improve feed-control sensitivity over the conventional method of releasing the brake. This mechanism plays a unique role in the optimization of the bit program, as past experience indicates a potential 200% increase in bit performance when accurate control of specific energy, through weight-on-bit control, is maintained. After evaluating total costs as well as performance and functionality indicators, it was decided to use a system that provided good flexibility at a reasonable price.

NEXT SLIDE
SMART1 (cont.)

Drilling Equipment (cont.)
- RSA 6K Drill String
- Micro-Grip™ Slips
- Early Kick Detection System (Smart Alarms™)

1. A non-API drill string (RSA 6K) was chosen for this particular application. A hybrid between API and standard mineral drilling systems, it was designed to allow full-bore drilling and continuous coring, down to 16000 ft.

2. Seventy-five percent of all drill pipe failures in SF rigs occur due to fatigue — slip marks rank among the main stress concentrators that originate this costly problem. Due to the required high rotary speeds this was of great concern and a decision was made to fit the SMART1 with a novel product, marketed by Weatherford: the Micro-Grip™ slips. This setup significantly reduces permanent marking on the drill pipe by distributing the tensile load around its periphery in a more effective way than conventional slips, as confirmed by laboratory experiments carried out at the University of New South Wales, in Sydney.

3. Early kick detection plays a paramount role in slim-hole drilling — reduced annular clearance causes a relatively small kick to occupy a significant length of annular space. It is for this reason that monitoring of dynamic variances in well volumes has to be carried out at all times and allow the Driller a prompt response in case of a well control event. Developed by SCR (Schlumberger Cambridge Research), Smart Alarms™ is a software package that provides real-time analysis of critical events during drilling and facilitates early kick detection.

NEXT SLIDE
Progress in total well cost for the complete project is illustrated in this slide.

1 A total of six slim-hole wells had been drilled at the time this document was written (final costs available only for five of them). Overall, the project is near the end of its learning curve and significant improvements regarding drilling efficiency are still possible. Much progress has been made in the mob/demob aspects of the rig, as well as in the preparation of BOPs and other time consuming activities.

NEXT SLIDE
Shown in this slide is the progress made regarding the time required to finish a well, throughout the project. Except for one well (Lambdina 2) where a major stuck-pipe incident was experienced, the graph shows a clear tendency in the reduction of total number of days to drill and complete a well. Looking at the last two graphs simultaneously, it is possible to see the potential for additional drilling performance improvements and their positive effects on further cost reduction.
As in any other enterprise of this type, it is important to capture all the lessons learned at all levels of the operation including the areas of logistics, well construction, HSE, equipment and others. The following is a non-ranked, categorized list of the different elements considered of significant influence in the overall well construction efficiency:

1. Safety (HSE): STOP Program, Safety Videos, HSE Approach/Representative, Gas Detection
3. Contracting: Contractor/Client Relationship, Non-Oilfield Suppliers, Competition/Entry Threat, Open-Book Contract
The SMART1 rig will continue its drilling operations for Santos Ltd. in search of a much optimized performance that will bring with it reduced operating costs. At this time, talks have begun to make the second SMART rig a reality and accelerate the development program.

Significant amounts of data, related to slim-hole drilling operations, have been compiled throughout this project and can be accessed by contacting the Sedco Forex office, in Adelaide.
It is necessary to evaluate the slim-hole drilling arena can become more than just a niche market. Because the impact of slim-hole acceptance can vary widely, it is important that a long-term market-trend analysis be conducted for each product line to be used on these wells.

Some suppliers should also expect a lower base of revenues from certain downsized products. In particular, this includes tubing and casing, drilling fluids and a number of other consumables which are hole-size dependent. Profitability can be best ensured by limiting the development effort to address hole sizes having high activity. Operators have developed a habit (which has been encouraged by the suppliers) of requesting a large number of sizes for various products used in drilling, completion and production applications. Also, there is a need for a slim-hole rig fleet to meet market demands —few rigs exist in the world which were designed specifically for drilling slim holes. Whether through the retrofit of conventional rigs with slim-hole technology (as in the case of SMART1) or the development of entirely new rigs, the establishment of this fleet is the foundation upon which the market for slim-hole technology will be based in the coming years.
Once slim-hole technology has been satisfactorily proven and optimized, Santos Ltd. is planning on using it in the exploration of some of their other leases in the region (i.e., Australia, Indonesia and Papua-New Guinea). Others, like Shell, are also observing with interest the progression of this venture with the probable intent to use slim-hole technology on their own operations.

All the characteristics discussed throughout this presentation make slim-hole drilling a viable candidate for exploration and development efforts in environmentally and/or inaccessible areas of Latin America (i.e., Peru, Bolivia, Costa Rica and Ecuador) — during the last three years Mobil has used this technology to effectively explore and delineate one of their plays in the northern part of Bolivia. In addition, preliminary contact with Shell has already been established to discuss the availability of a mobile, environmentally sound and highly efficient drilling rig for their upcoming exploration program in Peru.
SUPPLEMENTARY SLIDE

This slide shows the characteristics of the RSA 6K drill pipe
SUPPLEMENTARY SLIDE

This slide shows the marks left by the Micro-Grip™ Slips on a joint of RSA 6K drill pipe. Note the relatively minor size of the mark themselves and the arrangement pattern.