The traditional method of drilling oil and gas wells has been in use for almost 100 years. It continues to be used all around the world, regardless of oil company or location. However, as oil and gas reserves are found at ever greater depths, often in deep waters offshore, the costs of the traditional approach rise rapidly. If a way could be found to reduce the size of rigs, increase the depth that rigs could drill and regulate the size of drills and piping, a drilling revolution could begin.

**TRADITIONAL BORING**

Conventional drilling for oil and gas begins using a drill bit with a large diameter, typically 20 to 30 inches (the oil industry uses the American/Imperial measurement system). Drilling continues until the well must be cased to stop the hole from caving in. At this point the drill bit is removed and a steel pipe, known as a casing, is run into the hole. The pipe is smaller than the hole in order to leave space between the casing and the rock around the borehole. This ensures that the pipe does not get stuck while being put in place.

Once the pipe is in position, the gap, known as the annulus, is filled with cement. This is to give structural support to the well, and to isolate the different zones of rock, water and gas. Drilling continues using a smaller drill bit that fits inside the first casing. Eventually, the bit again reaches an unstable depth. The drilling team has to repeat the procedure, this time running a smaller pipe inside the first pipe and repeating the cementing process.

This sequence of drill, run and cement continues with an ever-decreasing diameter size of drill and pipe until the rig reaches the required depth. At this point, the rig team runs a completion tubing so that production can begin. After all this, a conventional well looks, in cross section, like a giant telescope in reverse that begins large in size and finishes small. Any size up to a 26-inch drill can be used at the top, yet at the bottom the casing that reaches the goal may only be 5 inches wide (Figure 1).

**DRAWBACKS OF THE TRADITIONAL APPROACH**

Conventional drilling has many disadvantages. It requires a large drilling rig, plus casings of several different sizes and considerable quantities of drilling fluid and cement. It also produces substantial amounts of waste drill cuttings. Moreover, hole problems (e.g. possible collapse or rock that is too hard to drill through) can sometimes cause premature casing setting. This means that the well may end up with a casing that is too small to produce oil or gas at economic rates.

Another significant disadvantage of the conventional approach is that the deeper the oil and gas reserves, the larger the starting holes required. This has a dramatic consequence for drilling offshore in deep water (500–2300 m) requiring ever bigger, and more expensive, semi-submersible drilling rigs. Overcoming the tapering effect could bring about substantial savings in cost, time and scale of searching for oil and gas sources.

One of the most significant investments in the oil industry is the cost of developing a well. Any technology that reduces drilling costs, digs deeper, and improves the probability of reaching oil or gas resources would have enormous value. Myles Burke outlines how the recent development of expandable tubular technology has the potential to revolutionise energy production.
SEEDS ARE SOWN
In the early 1990s, engineers at Shell’s Research Laboratories conceived the idea of an expandable well tubular. The initial concept was similar to traditional well drilling but posed many new technical challenges. The idea was that the hole would be drilled and the pipe inserted into the hole. As soon as the casing was in position, but before the cement had set, an oversized hardened steel cone would be pushed or pulled through the pipe, irreversibly expanding the diameter of the casing by some 10–15%. The expansion would be selected so that the expanded casing fitted snugly into the previous casing at the overlap. At the same time the annulus between the pipe and the rock would also be reduced.

If this system could be realised it would mean that smaller casing sizes could be used at the outer of the well (14” compared to 26”) yet still give the same production diameter (5”) in the reservoir as used in conventional drilling. The gains for the industry of this slimmer well design were obvious: deeper wells, a smaller diameter hole on the surface, less cement and less sophisticated drilling rig could be used for a monodiameter well. Operating in the Gulf of Mexico a smaller rig and substantial savings on well costs (Figure 3).

A BOTTOMLESS WELL?
The Shell engineers saw this slimmer well as merely the first step towards their ultimate goal of a ‘monodiameter well’. This would be a well that used only one size of drill bit and one size of casing. Every casing run into the well would be expanded by the same amount to provide a continuous flow area through the entire depth of the well, with no telescoping effect.

Technically, this is only possible if the expansion is large enough to allow the unexpanded pipe to be run through the same, but expanded pipe, requiring expansion ratios of up to 30%. Theoretically there would be no limit to the number of casing sections that could be used and therefore no limit on the depth of the well.

The reduction in costs would be significant for example in a typical drilling operation in the Gulf of Mexico a smaller and less sophisticated drilling rig could be used for a monodiameter well. Operating in 1524 m of water with 10 casing strings to 8899 m a saving of 366.5 million could be achieved just by reducing the size of the drilling vessel.

The selected strategy involved a single trip system, whereby in one single run the following functions were performed:

• run the unexpanded casing to the desired depth
• create an overlap section by expanding the bottom of the casing by 30% (this would form the overlap with the next Monodiameter casing string)

pump cement down the casing and into the annulus
• expand the entire casing some 25%, all the way into the overlap section of the previous casing
• cut the casing at the top of the overlap and remove the excess casing.

The tool stringing that performed all these functions was built as a modular system, operated by standard mechanical methods used on drilling rigs (Figure 3).

Developing a MONODIAMETER WELL
There were obvious engineering challenges embedded in the concept, one of the first being to come up with a pipe material that would allow cold expansion in diameter of 25–30% without fracturing. In addition, the expansion process had to be sufficiently robust to take pipe tolerances into consideration (e.g. wall thickness variations) that could be avoided in practice.

To address the required conditions and variable ratios best, a 9 5/8” pipe was used in the prototype Shell MonoDiameter system development to comply with current drilling practices, pressure casings and production capacity. This relatively large size would also provide the internal space for robust expansion tools. Slimmer systems could be developed later building on the experiences with the 9 5/8” system.

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EXPANDABLE TECHNOLOGY FUNDAMENTALS

The application of monodiameter technology required careful assessment of pipe size formability and practicality. Although there were great advantages to using the smallest pipe size available, the laws of physics dictated otherwise. The amount of expansion applied to the solid expandable casing is controlled by the size of the expansion cone. The cone stresses the pipe above the yield limit and into the plastic region rendering a permanent deformation. Successful expansion occurs when the applied stresses are above the yield point but less than the ultimate strength limit of the material. Figure 4: Stress Diagram. Successful expansion occurs when the applied stresses are above the yield point but less than the ultimate strength limit of the material.

The ultimate tensile strength and its relationship to the yield point controls both the range of expansion and the limit of expansion applied to the pipe. The formability (accumulated plastic deformation) of pipe material used can only withstand an expansion ratio of 30%. Exceeding this ratio results in fracture.

Shell laboratory engineers also conducted extensive testing on the properties of the Martensitic Stainless Steel used in downhole expandable tubulars, evaluating the effects of expansion on their mechanical properties, defects and cracking. The results were used to qualify and select the stainless steel for use in expandable applications.

A STEP BY STEP APPROACH

Another significant challenge concerned the creation of a casing connection that would provide pressure integrity before, during and after expansion. Moreover, this needed to be achieved without locally increasing wall thickness - as customary with standard casing connectors - because that would require an even larger expansion ratio. By pushing the limits of what the laws of physics would allow and specific expansion cone design would permit, a step-wise construction process was developed that allowed for overlapping sections to be constructed with the required strength and sealing capability.

Achieving the dream of a MonoDiameter well had to come in stages, as there were considerable technical challenges to be overcome before any ‘solid pipe’ system could be developed. However, in pursuing that dream many other innovative developments were discovered along the way. Pipes with slots cut into them were the first to be expanded. They were developed in conjunction with other materials to become effective ‘expandable sand screens’ in wells where there was a problem with sand getting into the well. Over 10 000m of sand screens have been successfully installed to date and expanded in situ, enabling better reservoir management and higher production rates.

It was discovered that the expandable option was also an excellent solution for repairing pipe casings that had been damaged. A new expandable pipe casing was run down through the damaged section of pipe and then expanded to form a completely new section of pipe (clad), nearly the same diameter as the old one.

Figure 4: Stress Diagram. Successful expansion occurs when the applied stresses are above the yield point but less than the ultimate strength limit of the material. (Diagram by Royal Dutch Shell plc)

EXPANDABLE TUBULARS – ENGINEERING A PIPE DREAM

“Moving a technology from innovation to field use in the well and gas industry normally takes up to 20 years… in comparison, expandable technology has taken off very quickly.”

ABSORBENT RUBBER

With a specially developed swellable elastomer, rubberised covering wrapped around it, an expandable casing was found to be an elegant solution in wells where there was water penetration from fractures in the surrounding rock. When the pipe was expanded, the annulus was reduced, forcing the rubber against the water fracture. The swellable rubber would then swell up in contact with the water and seal off the fracture. Close to 1000 of these swellable packers have been successfully installed. Although the 9¾” MonoDiameter well has been demonstrated in the field, the development towards a robust and field-proven system is still being actively pursued.

NO LONGER A PIPE DREAM

According to a McKinsey business survey, moving a technology from innovation to field use in the oil and gas industry normally takes up to 20 years; it is in fact a very conservative industry. In comparison, expandable technology has taken off very quickly. Despite only being launched into the industry in 1998, there have now been many hundreds of applications in all parts of the world in offshore and onshore sites, generating savings of hundreds of millions of dollars.

John Dewar (Programme Manager for Wells R&D) has worked extensively with the expandable tubular concept since its early inception. He summarised, “We have already shown the value of this game-changing technology in a wide spectrum of applications across all regions of the world. The next step is to take the technology from a contingency application to becoming the basis for design for well engineers who are planning challenging wells. Small automated drilling rigs with mono-diameter technology are one of the ways we believe this could be achieved in the years ahead.”

Myles Burke is a professional Communication Consultant who has been working in The Netherlands based Technology division of Shell Exploration and Production since 1999.

NO LONGER A PIPE DREAM

Under testing conditions the casing is slowly expanded as the cone is pushed or pulled and pumped along the length © Royal Dutch Shell plc

ABSORBENT RUBBER

The absorbent rubber is a specially developed swellable rubberised covering wrapped around the casing © Royal Dutch Shell plc

NO LONGER A PIPE DREAM

Expansible tubulars have also been effectively used to repair damaged pipe sections © Royal Dutch Shell plc

WEALTH CREATION

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