Shell E&P has deployed swelling elastomers in a variety of applications: as a means to establish zonal isolation in liner completions, as a production separation packer, and as an integral part of expandable openhole clad tubulars. In these applications, the elastomers were run in various openhole, casing, and tubing sizes. Approximately 60 deployments have been recorded, all of which were successful.

Introduction
In most areas where Shell operates, especially in the more mature oilfield environments, there is a high focus on well-cost reduction. Various technology applications have been identified to meet this business need and allow the operator to drill wells cheaper and smarter, making the most of existing infrastructure. One technology that is experiencing a rapid uptake is the application of swelling-elastomer packers. These packers, which swell naturally when exposed to the appropriate swelling agent, have been used successfully as a replacement for traditional mechanical packers and cement. The business case for using swelling-elastomer packers is different for each application and can include time savings as well as direct tool-cost savings. Shell used swelling elastomers in combination with a solid-expandable-tubular (SET) system called openhole clad (OHC) in July 2002. First application of swelling packers for zonal isolation was in the South Furious field in Malaysia in June 2003. Since then, more than 60 deployments have taken place in Malaysia, Brunei, Nigeria, Gabon, Oman, and the U.K.

Applications
Liner Completion. In the last 2 years, swelling packers have been used in various parts of the world as part of an openhole completion to provide zonal isolation. Shell E&P has recorded six applications in Africa, two in the Far East, and one in the North Sea, with (at the time this paper was written) an additional five global implementations expected before the end of 2004. All of the applications used oil-swellable packers because of the operating parameters. The business case for the use of swelling-elastomer packers for zonal isolation is the elimination of traditional cementation and a potential perforation run.

Case Study. In December 2003, the last well in a five-well through-tubing rotary drilling (TTRD) campaign was drilled in the North Cormorant field in the U.K. North Sea. The North Cormorant field is highly compartmentalized, and the reservoir is characterized by many interbedded shale sections, isolating the various oil and water sands. The main challenge in completing the North Cormorant wells was isolating the more dominant water-producing sands while selectively producing from the oil-bearing sands.

The first four wells of the campaign were completed by running 27/8-in. liners, cementing them in place, and perforating them across the oil-bearing sands. Cementation in a slimhole reservoir section through a small-sized liner has always been difficult and was the main cause of nonproductive time (NPT) during the 2003 North Cormorant campaign. It was for this reason that the alternative of using swelling packers in combination with a preperforated liner was considered. In addition to the direct cost savings associated with leaving out cementation, additional time and cost were saved by eliminating a cleanout run and a coiled-tubing (CT) perforating operation. Use of the swelling packers in combination with a preperforated liner mitigated the NPT incurred during the completion operations in the first four wells. After successfully drilling the reservoir with a 2,424-ft 41/2-in. sidetrack, the last well was completed with a selection of preperforated and blank liner joints and 12 swelling packers spaced out to seal against the various interbedded shales. The packers were 10 ft and 16 ft in length and had an original outer diameter (OD) of 4.2 in. The top packer was set inside the original production tubing. Above it was a separate liner-top packer.

The swelling packers all were run with a thin diffusion barrier and a low-swelling outer layer to prevent premature swelling. Typical swelling times for oil swellables are approximately 15 to 20 days. The well was brought on line more than 20 days after running the liner because of operational circumstances.
Wells can be brought on line before the packers are fully swollen, but this introduces the risk that the formation around the packer will wash out. Nevertheless, this approach was taken in Malaysia in the South Furious field.

The last North Cormorant campaign well was the first ever TTRD well to run swelling-elastomer packers in the completion; almost a year after bringing the well on line, the well is producing better than expected, and the water cut is similar to the other wells in the field that were completed conventionally. Differential pressures held by the packers are estimated to be approximately 2,300 psi below the 3,000 psi, for which they were tested.

When modeling the production from a well with a wellbore damage of 50%, a perforated well will see a somewhat accelerated profile compared to a well with a predrilled liner because of perforating past the damage. However, both completions still will enable the well to produce the same amount of reserves, and the acceleration does not generate enough net present value to offset the cost of cementing and perforating.

The cost benefit became even more apparent when it was demonstrated during the TTRD campaign that the mud system actually caused much less damage to the formation than previously expected. This neutralized the positive effect of the deep perforations, and the production profiles of the cemented liner and the predrilled liner became virtually identical.

Production Isolation. Packers that swell by themselves can be used logically as an alternative to mechanically or hydraulically set packers. The main drivers for this are a straight cost saving on the packer as well as elimination of any extra running or setting trips, with their associated risks. Although the use as a production packer is a relatively simple concept, there are still a few considerations to keep in mind. Thermal effects and subsequent relative movement of the completion strings will exert significant stresses on the packers. Furthermore, it may be necessary to run a cable past the packer. Swelling packers allow for cables to be run physically through the rubber element, but the forces on the cable need to be modeled.

So far, the only applications of swelling packers for production isolation in Shell E&P have been in the Saint Joseph and Barton fields in Malaysia. The packers all have been oil swellables, although water swellables have been considered for this application and likely are to be used in the near future.

Case Study. In the Barton field in Sabah, Malaysia, a swelling packer was run successfully as a production-isolation packer. The well was completed with a 7-in. liner across the reservoir. The liner was perforated underbalanced across the two pay zones, after which the 3½-in. completion tubing was run. The completion contained a sliding side door (SSD) across the perforated zones and a conventional packer above the reservoir. The swelling packer was set between the pay zones to isolate the production.

The swelling time in this particular application was approximately 4 to 5 days. The sealing capacity of the packer is more difficult to measure than in the zonal-isolation application, but the well is producing as expected, and all indications are that the deployment was successful. Thermal effects were not expected to cause any adverse consequences in this well.

The main reason for deploying a swelling-elastomer packer between the reservoir sections is that the well inclination builds rapidly through the reservoir section. Inclination at the swelling-packer setting depth of 2,545 ft was 83°. Setting a conventional plug-and-prong system would mean running the lower SSD closed, and an extra CT run would be required to open it afterward.

The extra CT work and the associated operational cost make a strong business case for using swelling packers. There is a drive to reduce the cost of these relatively shallow wells in Malaysia, and the use of swelling packers in both production isolation inside the casing and zonal isolation outside the casing has been a strong contributor to the cost-saving initiative.

Expandable OHC. To seal off a water-producing openhole section without significantly sacrificing hole size, the use of an expandable OHC or an openhole liner (OHL) should be considered. When a water-bearing sand or a water-producing fracture is identified, it is critical that the cladding create a proper seal against the borehole wall. A long annular seal is provided, with as much as 70% of the pipe covered with elastomer. Chances of success can be improved by lining the expandable cladding with swelling elastomers. Fig. 1 shows SETs with swelling-elastomer elements.

Application of expandable clads in combination with swelling elastomers has proved to be highly successful in operations in Oman, where some of the main reservoirs are highly fractured carbonate formations with increasing water production. Water-swelling elastomers were developed for this application to swell when contacting reservoir water.

Case Study. The Yibal field in Oman is characterized by highly fractured and faulted carbonate formations. Over the life of the field, the water cut from the producing wells has increased significantly, and it has become difficult to predict in the planning phase of a well which fractures will produce water. It is almost impossible in a fractured (and depleted) carbonate reservoir to achieve zonal isolation with cemented horizontal liners. A solution is to drill long horizontal wells and provide zonal isolation by expanding SETs in combination with swelling elastomers. One such well would replace five vertical wells at the cost of only two vertical wells.

The elastomer provides the seal after pipe expansion and, if necessary, will swell to fill any voids. Because swelling elastomers are self-healing and form themselves to fill any wellbore shape or cavity, they are ideal for this sealing application. The swelling effect is, however, seen only as a backup to the mechanical expansion of the pipe/elastomer combination.

Adding a rubber element to the outside of an expandable liner increases its OD and its friction coefficient when running in the hole. Because of this, significant planning and modeling time went into the selection of the appropriate cladding lengths to be run in the well. After successfully drilling the Yibal well, a caliper was run. The caliper showed the hole diameter to be between 6¾ and 6½ in., with some spots at just under 7 in. After thoroughly cleaning the wellbore, the decision was made to run a 1,033-ft-long OHC for the first section. It was run and expanded successfully. The next section was even more ambitious, running a 2,323-ft-long OHL (tied back to the previous casing shoe), again successfully. This achievement established a record as being the world’s longest OHL with swelling elastomer as a seal.

Both cladddings were 5½ in. OD when running in and were covered with 0.2 in. of swelling elastomer except for the top 328 ft of the second clad, which had only 0.16 in. of elastomer. In both expansions, the observed overpressures indicated a good elastomer seal against the formation. This was confirmed by production-logging-tool readings.

Swelling elastomers on expandable tubulars have been used in more than 40 installations. The main issues to consider when running the expandable OHC with elastomer elements are the dogleg severity limitation of 14°/100 ft and the risk of the wellbore being overgauge.