Varel bit design enhances hydraulic flow to improve ROP in Barnett Shale lateral drilling

By Jerry Greenberg, contributing editor

CHESAPEAKE ENERGY operated four rigs in the Barnett Shale field when it entered the region in 2002. Today, the company has 36 rigs in the play, which are among its more than 150 operated rigs nationwide—more than double the next closest operator. During the spring of 2007, Chesapeake became the US’s largest independent producer of natural gas.

The operator also is the most active driller and the largest leasehold owner in the Core and Tier 1 sweet spot of Tarrant, Johnson and western Dallas counties, committing $1 billion to the play in its 2007-08 drilling budget. Chesapeake’s reserves have reached a record 10 Tcfe, and the operator is achieving a reserve replacement rate of 41.6%. Average second quarter 2007 production was 187 Bcfe/day.

The company said it expects to use 35-38 operated rigs during the second half of this year, and to complete, on average, one new Barnett Shale well approximately every 15 hrs, a very quick rate, to be sure. However, that rate could increase due to the tenacity of one of Chesapeake’s drilling superintendents and the willingness of privately owned global drill bit company Varel International to listen to its customer when calculations indicated otherwise.

The operator had been drilling the lateral production section of its Johnson County wells in the Shale with 8 ½-in. PDC bits, realizing good success with rates of penetration (ROP) of around 45 ft/hr.

Drilling superintendent Wilson Glass believed that by enhancing the total hydraulic flow, weight on bit (WOB) and ROP could increase significantly. Several bit manufacturers that Mr Glass had approached, including Varel, said that hydraulic calculations indicated only a slight improvement would be noticeable. Mr Glass was adamant that his idea would work, and Varel agreed to design a bit with better hydraulics.

“We were drilling and getting good rates,” Mr Glass said, “I knew we could do more, but we were pressed out on our drill string. I kept thinking, can’t we open up the jets or add one? I cornered Russ England (Varel’s district manager-North Texas) and told him what I wanted.”

Varel agreed to work with Chesapeake to design a bit with more and larger nozzles to increase the total hydraulic flow and reduce pressure. Two weeks later, Varel’s engineers, using the company’s proprietary design process, including

<table>
<thead>
<tr>
<th>WELL #1</th>
<th>BIT</th>
<th>DEPTH IN</th>
<th>DEPTH OUT</th>
<th>FOOTAGE</th>
<th>HOURS</th>
<th>ROP</th>
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</thead>
<tbody>
<tr>
<td>Varel Bit</td>
<td>6,912</td>
<td>10,930</td>
<td>4,018</td>
<td>72.5</td>
<td>55.42</td>
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<tr>
<td>Comp #1</td>
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<td>3,754</td>
<td>78</td>
<td>48.13</td>
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<tr>
<td>Comp #2</td>
<td>6,900</td>
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<td>2,825</td>
<td>68</td>
<td>41.54</td>
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</tbody>
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The new bit increased ROP by 13.07% and drilled 7.03% longer than best given offset.

<table>
<thead>
<tr>
<th>WELL #2</th>
<th>BIT</th>
<th>DEPTH IN</th>
<th>DEPTH OUT</th>
<th>FOOTAGE</th>
<th>HOURS</th>
<th>ROP</th>
</tr>
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<tbody>
<tr>
<td>Varel Bit</td>
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<td>9,398</td>
<td>1,661</td>
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<td>61.52</td>
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<tr>
<td>Comp #1</td>
<td>6,991</td>
<td>10,745</td>
<td>1,704</td>
<td>37.5</td>
<td>45.55</td>
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In the second well, ROP was 35.38% faster than best given offset.
SPOT and computational fluid dynamics (CFD) program, designed and manufactured an 8 ½-in. VM519HU, a five-blade, 7-nozzle PDC bit with ¾-in. cutters. “Varel had the new 8½ in.-bit designed and to the field in two weeks,” said Mr Glass, the consummate driller who needs equipment now. “I thought that was impressive.”

“We field-tested the bit,” he continued, “and it brought our pressures down even though the hydraulic programs said it wouldn’t. We are cutting off a day, maybe two, in some cases. We were drilling about 1,000 to 1,200 ft/day, and now it’s up to 1,800 ft/day.

“Most of our wells are around 4,000-ft laterals, so the new bit design is cutting our lateral time down to two days from four.”

The first run with the bit proved Mr Glass’ hypothesis. ROP increased by more than 13%, drilling a 4,018-ft lateral section in 72.5 hrs with an ROP of 55.42 ft/hr. Offset data from two wells illustrates the success of the new bit.

SKEPTICISM, THEN SUCCESS

Like most other bit manufacturers working in the Shale that Mr Glass had approached for a possible solution to the hydraulics situation, Varel was skeptical that improving bit hydraulics would result in better ROP. Varel’s calculations were essentially the same as the other bit manufacturers’ calculations, resulting in a pressure differential of only 7-10 psi, not large enough for the drillers to notice a difference at the rig.

“I calculated the hydraulic numbers, and it didn’t show that there would be a significant gain in pressure reduction,” said Cary Maurstad, PDC product manager for Varel. “But Wilson said let’s try it on just one bit, so we put the design together. It was tough to get the sixth and seventh nozzles on the bit, but we finally placed them according to CFD and then proceeded to manufacture the bit and got it to the field.

“It stood to reason that we could get more weight on bit because we didn’t have the hydraulic jet force we had before with the smaller nozzles, and the change would also increase bottomhole cleaning at the bit face,” Mr Maurstad explained.

The primary reason for hydraulic calculations indicating low pressure gains is that the software utilized for the calcula-
tions is predicated upon a vertical well, he noted. “When you look at a horizontal well, it changes,” he said. “To my knowledge, nobody has been able to model that correctly yet.”

Varel was aided by the fact that the cutting structure design was already optimized for the formation and the “only” thing to do was to figure how to place extra larger nozzles in the bit. “We didn’t change anything on the bit design since it has been the most consistent performer (in the Barnett Shale),” Mr England explained.

Since the bit’s cutting structure was already optimized for the application, Varel’s engineers were constrained somewhat in how and where to place two extra, plus five larger nozzles into the bit in a layout that made sense from a hydraulic standpoint in cleaning and cooling the bit’s cutters.

Neither the blades nor the cutting structure were moved, although the total configuration of the hydraulics was changed, increasing the nozzles from five to seven. The nozzle orifice size was also increased from $18/32$-in. to a $22/32$-in., changing the flow pattern across the face of the bit.

This image is an example of the format and type of information a Varel GeoScience report shows. GeoScience is Varel’s proprietary mechanical rock properties model that utilizes well logs. Output information from GeoScience is fed into the design process through SPOT, Varel’s proprietary product simulation tool, allowing bit designers to accurately model bit dynamics.
To accomplish this, the bit face was essentially wiped clean of nozzles, allowing engineers to begin from scratch to determine the optimal hydraulic layout. Varel used its proprietary SPOT software to determine how the bit would react in the formation and to learn if the bit’s torque was reduced to make the bit drill more effectively.

**SPOT Design**

SPOT software was developed by Crystal Profor, a French-based PDC bit company that Varel purchased in 2000 shortly after the company was sold and led by current president and CEO Jim Nixon. That company had developed the software over a period of about 10 years, utilizing proprietary algorithms to model forces acting on the bit behavior and assuring maximum bit performance.

The software uses laboratory and field data, with the lab data containing full bit and single cutter test data and field data. SPOT is essentially a drilling simulator utilized for determining optimal bit designs for a specific application. It allows Varel to examine different cutting structures for a given area to develop the optimal design. Several different designs can be viewed simultaneously as well as enabling the engineers to work with one particular design to compare it with other potential designs.

When the bit’s profile is determined and the cutting structure is laid on the bit, Varel engineers will use computational fluid dynamics (CFD) to determine the best nozzle orientation and the best fluid flow for the bit design. When the hydraulic design is finalized, the information is combined with information from SPOT, and it is loaded into a solid modeling program from which programs for milling the bit’s molds are produced.

When designing bits for directional wells, such as Chesapeake’s Barnett Shale development wells, SPOT can predict a PDC bit’s directional behavior to match the operator’s needs in term of the bit’s directional signature.

“SPOT allows us to virtually test a bit,” Mr. Maurstad explained. “For an 8 ½-in. bit drilling a simulated 2,000-ft interval, SPOT would take about 10 seconds to generate the (informational) output. It would provide certain parameters, including weight on bit required to drill, torque required to rotate the bit, lateral aggressivity, axial aggressivity, cutter wear and many other drilling parameters.”

Offset electric well logs from a field can also be entered into SPOT through the use of a program called GeoScience, Varel’s in-house lithology software and trade name for a log analysis method for improving bit selection and optimization. GeoScience will develop information on formation type, abrasivity, porosity, drillability and many other formation data parameters. This information can then be fed into SPOT to help design a bit specific to the formation that will be drilled.

With GeoScience and SPOT, pre-well planning can aid in optimal bit selection and customized design. GeoScience and SPOT additionally are used in post-well analysis to improve bit performance through modification to various design parameters, bit design and cutter technology.

In this cooperative effort, Chesapeake’s Wilson Glass and his drilling knowledge, aided by Varel’s customer-oriented business attitude resulted in a win-win situation for Chesapeake and Varel in the Barnett Shale.