

Horizontal oriented perforating stabilizes formation

RECENT ADVANCES IN perforating in long horizontal sections have helped to optimize perforation efficiency and production. While these new techniques are applicable to any horizontal or highly deviated well, they are especially important where orientation of charges is critical to maintain wellbore stability and control sand production.

Perforating with oriented charges in horizontal sections will play a key role in the future to assist operators optimize production from new or declining fields. Significant contributions to perforation technology resulted with the advent of these new techniques and systems designed to navigate through severe doglegs while maintaining orientation.

Baker Atlas utilized these technology advances to successfully perforate a 2,246 m horizontal section in a North Sea well for a major operator. The company set a world record by perforating a total of 1,496 m of the horizontal section in a single trip, with orientation successfully verified. Baker Atlas launched the new Horizontal Oriented Perforating System (HOPS) after completing field tests with over 50 runs.

RESEARCH AND DEVELOPMENT

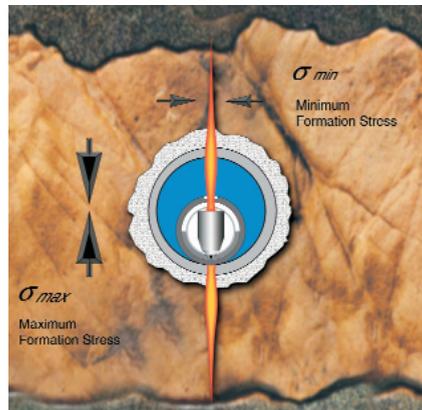
In order to come up with a solution to the concerns associated with perforating a cased horizontal section, research needed to be performed to develop a Horizontal Oriented Perforating System (HOPS). Criteria for the system were that it be able to navigate through severe doglegs, orient the shaped charges and provide verification that the charges were fired in the desired orientation direction.

These criteria required a system with a swiveling mechanism that could allow orientation of charges even while the system is being subjected to the arduous navigation demands of severe doglegs within the horizontal sections.

The system had to be simple and rugged enough to withstand the torque and drag forces imposed on it while traveling to the desired perforating intervals in horizontal sections. Verification of perforation orientation also had to be incorporated into the system.

HOPS SYSTEM

HOPS was developed to address the needs and requirements of oriented perforating in extremely long sections. The system was developed by removing the deficiencies of prior methods and by developing new technologies to address the identified gaps. By utilizing specially designed perforating guns that



To maintain wellbore and perforation tunnel stability, perforations should ideally be oriented in the direction of the maximum formation stress. The charges should be shot in directions that will subject the perforation tunnel to the least amount of collapse stress.

include internal eccentric weights, the need for kickover lugs is removed. Another benefit in utilizing internally mounted weights within the perforating gun is the increased coverage for perforated interval. Since the weights are included within the perforating gun, no dedicated blank weighted gun spacers are required.

A special swivel gun connector is included at the top of each gun section, eliminating the need to orient gun sections to each other, thereby minimizing make-up time at the job site. Additionally, since each gun is now independently free to rotate, the problems associated with orienting long, rigidly connected gun sections is eliminated.

When swivel gun connectors are used, the torque generated by the weights begins to orient the gun as it enters the lateral section. The combination of the weights and the lateral motion during trip-in orient the guns. The gun swivel

connectors and internal weights eliminate the need for kickover lugs and provide a more reliable orienting system.

A new technology required was the ability to verify that the perforating guns were properly oriented at the time of detonation. To address this requirement, Shot Detection Indicator Devices (SDID) were developed. First deployed in early 2002, SDIDs are located within the gun swivels and determine the gun's exact positions when fired. These indicators provide valuable information on the gun's position upon detonation, which verify either the gun's successful orientation, or lack of total orientation.

Two types of swivels are available for use depending on the severity of the well's doglegs. Standard swivels allow for up to 2½°/100 ft while Severe Dogleg (SDL) swivels can be used on wells with dogleg build angles up to 10°/100 ft.

NORTH SEA APPLICATION

A major North Sea operator wanted to optimize production from a horizontal well section by reducing the risk of future sand production. Horizontal oriented perforating in long horizontal sections was critical to optimizing production from the well. Minimizing perforating debris to ensure future completion and production operations was another key objective. The operator also wanted to minimize rig time by perforating a net 1,490 m of a 2,246 m horizontal section in a single trip.

To minimize the risk of perforation tunnel collapse and sand production, the operator wanted to orient the charges in the horizontal section in the direction of maximum formation stress. Maximizing effective perforation coverage was another key issue that would require deployment of the longest guns available to minimize the dead space created by gun connectors.

In performing the job to meet the operator's objectives, a world record for perforating the longest oriented horizontal section in a single trip was set. A total of 2,246m of 28-ft, 4 ½-in. guns with low debris deep penetrating charges were run. This included a 1,490m section of 5 spf, 0°-180° oriented perforating charges and a 756m blank gun spacer.

This feat was accomplished in a single trip using the Horizontal Oriented Perforating System. This world record run used 188 regular swivel connectors and 23,180 charges. All shots detonated successfully and five shot detection indicator devices placed strategically in the gun string verified the gun's orientation.

The operator's goal was to perforate within $\pm 10^\circ$ of the direction of maximum formation stress to minimize the risk of sand production and perforation tunnel collapse. Three of the five SDIDs indicated that the guns fired within 5° of the desired orientation. The three SDIDs that indicated positive results were in a section of the horizontal lateral with local doglegs between 0.3° - $0.4^\circ/100$ ft. The other two SDIDs were located in sections with localized doglegs between 2° - $5^\circ/100$ ft.

Regular swivels are recommended for doglegs up to $2\frac{1}{2}^\circ/100$ ft while SDL swivels are recommended for doglegs over $2\frac{1}{2}^\circ/100$ ft and up to $10^\circ/100$ ft. At

the time of this job, SDL swivels were not commercially available and regular swivels had to be used. Shot orientation in these sections indicated that orientation was acceptable, but not within the $\pm 10^\circ$ target of the direction of maximum formation stress which reinforces the need for the SDL swivels and selecting gun lengths based on dogleg severity.

By using 28-ft guns, the operator was able to optimize production, effectively covering 6% more of the reservoir and decreasing the total area not effectively perforated by more than 100% compared to other conventional guns. The use of 28-ft guns and speed lifting clamps resulted in a minimum savings of seven hours of rig time. Perforating the entire section in a single trip saved an estimated 45 hours that would have been required for a second trip. Low debris deep penetrating charges produced the minimum amount of debris compared to steel charges to ensure future wellbore operations.

CONCLUSIONS

The HOPS perforating system will play a key role to increase production and minimize sand production. The new perforating system will enable operators to optimize production by allowing perforating systems to navigate through arduous well paths and effectively perforate long horizontal intervals in a single trip. Oriented guns minimize the potential of perforation tunnel collapse and sand production by perforating in the direction of maximum formation stress. SDIDs provide verification of orientation.

REFERENCES

Based on SPE Paper 80929 prepared by **Simon P Benavides, William D Myers, Edgar W Van Sickle, Baker Atlas**; and **Kristian Vargervik, Baker Oil Tools**, to be presented at the 2003 SPE Production and Operations Symposium in Oklahoma City, OK on 25 March 2003. ■