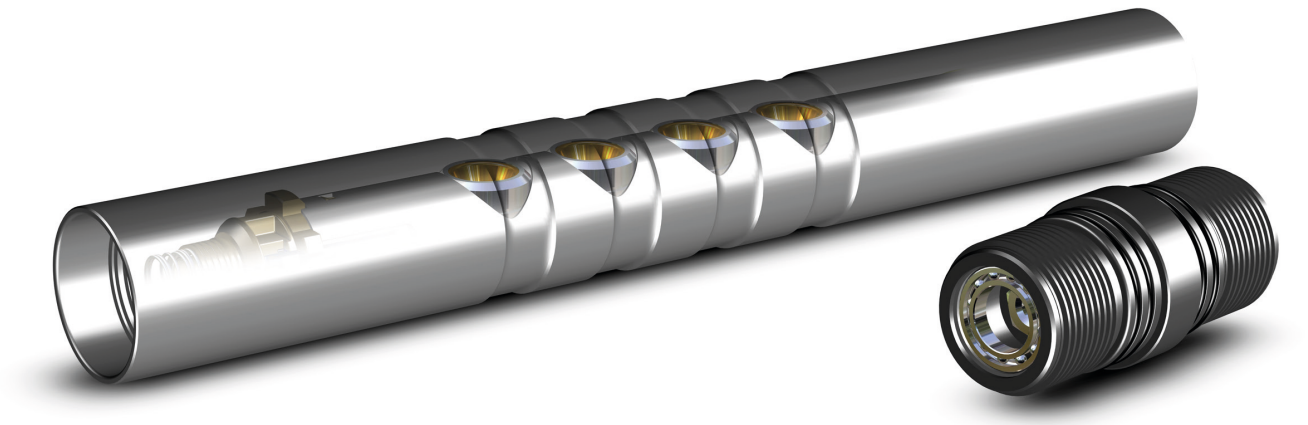
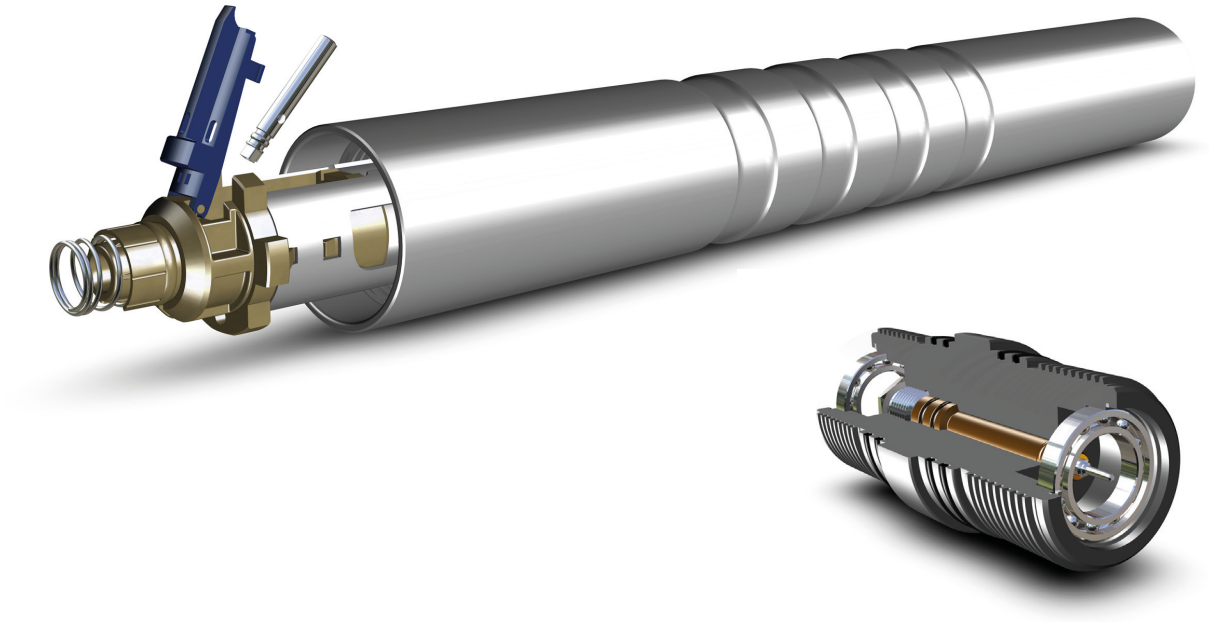
H-4 Oriented Perforating System Case Study



HUNTING

H-4 Oriented Perforating System Accuracy

H-4 Oriented Perforating System



Executive Summary

This report presents the results of a recent field trial in West Texas, where Hunting Titan's H-4 internal orienting perforating system was compared to the H-3 guns utilizing conventional lock collar guns with eccentric weight bars. The H-4 system features fully modular guns connected by patented orientation tandems that support gravity rotation of the charge tube assembly. The primary objective was to assess the accuracy of casing perforations created by these two systems. The trial consisted of 20 total completion stages followed by post frac camera work to determine the positioning of each casing entry hole. The results show that H-4's internal orientation system is significantly more accurate with 91% of H-4 perforations within 5% of the target direction, while only 30% were within 5% of target when running a mechanically oriented system with conventional orienting hardware. The customer plans to run H-4 over H-3 for any subsequent oriented perforating operations.

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H-4 Oriented Perforating System

Field Trial Summary

Hunting Titan recently introduced the H-4 internal orienting perforating system to improve oriented perf operations by eliminating less reliable eccentric weight bars and lock collars associated with conventional guns. On a recent field trial in West Texas, shot data from 20 stages on a new well completion was analyzed to determine H-4 shot accuracy. The customer ran Hunting's H-4 internal orienting guns on 12 stages and ran mechanically oriented guns with eccentric weight bars on 8 stages. Each gun cluster contained two shots positioned 180 degrees apart in the 90/270-degree direction. Each stage contained 15 guns and a setting tool with plug. The target casing was 5-1/2" 20#.

Once the frac stimulation was completed for all stages, the customer ran an EV downhole camera to determine the angle of each perforation entry hole in the casing. A total of 378 H-4 data points and 240 H-3 data points were analyzed. The video-based measurements showed a significant increase in entry hole accuracy when using the H-4 system. Frac data and post perf erosion data were also collected but were not made available for this report. This report will focus solely on the accuracy of H-4 in terms of shooting in the intended direction.

Data Analysis

The EV camera captured each casing entry hole, and its data was processed to provide shot orientation in respect to true north (0-degrees). A sample EV perforation image is given in Figure 1 below. Each gun cluster consisted of 2 opposing shots. Gun configuration in the casing was decentralized with 180-degree phase against the casing wall. The centralized EV camera target angles (110 / 250-degrees) correspond with the 90/270-degree gun phase angle, as shown in Figure 2 below. The angle measurements were corrected to account for variable gun clearance resulting from the larger diameter setting tool. The frac plug setting sleeve was 4.37" diameter, resulting in a tilt in the gun string as illustrated in Figure 3.

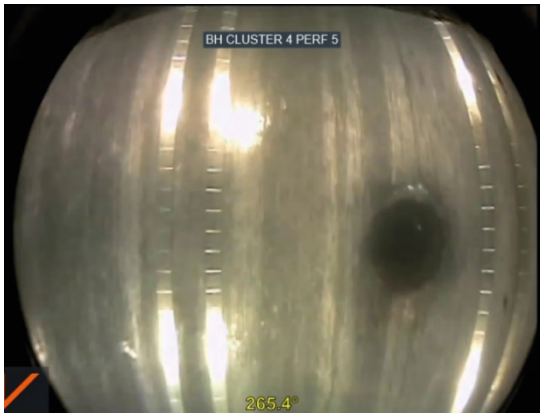

Figure 1 – EV camera perforation

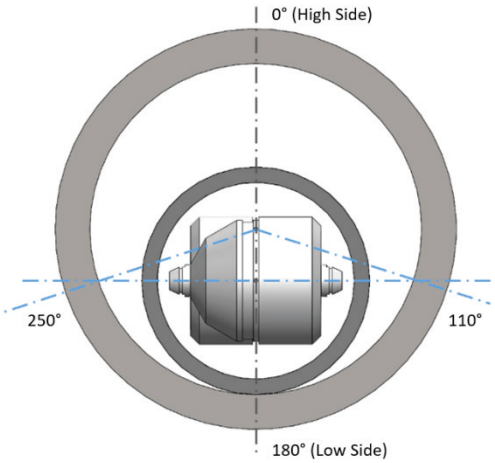

Figure 2 – H-4 Gun Decentralized in Casing

After analyzing the measurement data set, some anomalies were found and corrected, resulting in a normalized data set. As seen in Figure 4 below, the angle between shots of the same 2 shot gun should be 180 ± 3 degrees, which accounts for manufacturing tolerances for clearance and fitment of perforation charge in the charge carrier. Some of the EV data points showed shots from the same gun being oriented apart more than physically possible. Hunting took a conservative approach to cull the questionable data and removed all same gun shots measuring 180 ± 18 degrees (±10%) apart instead of using ± 3-degree manufacturing tolerance. A total of eight guns (16 data points) were removed based on these criteria. Hunting also removed an additional 12 outlier data points (exceeded 30 degrees from target) representing six H-4 guns which failed to orient properly due to known sticking issues that have since been remedied.

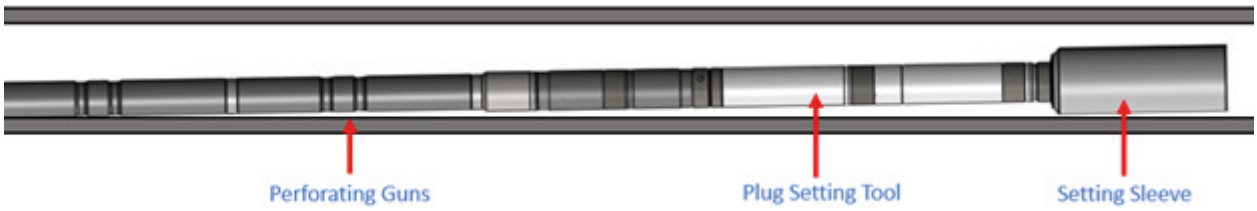

Figure 3 – H-4 Gun string tilt

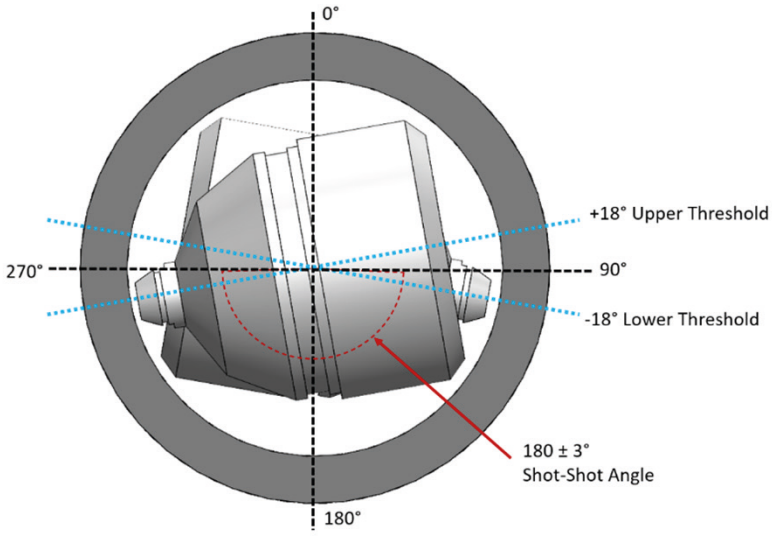

Figure 4 – Possible gun shot-to-shot angles

Trial Results

The results of the normalized data set are shown in Table 1. H-4 guns resulted in 91% of the entry holes being within +/- 5% of the target and 98% of entry holes within +/- 7% of target. In comparison, only 30% and 38% of the entry holes were within 5% and 7%, respectively, of the target when running mechanically oriented guns with eccentric weight bars. Note that accuracy on runs utilizing mechanically oriented guns with eccentric weight bars could be improved by incorporating a swivel and additional weight bar(s) to the lower section of the gun string. A shot accuracy bell curve comparison of H-4 versus mechanically oriented with eccentric weights is given in Figure 5. The entry hole distribution for each H-4 perforation is shown in Figure 6 below.

Table 1 – Entry Hole EV Summary Results - Normalized

Gun Type	H-4	Mechanically Oriented
Sample Size	350	240
Calculated Target Angles	110°/250°	110°/250°
Mean (Degrees from Target)	-0.06	-0.86
Standard Deviation	10 deg	44 deg
Entry Holes within 5 degrees (1%) of target	35%	9%
Entry Holes within 10 degrees (3%) of target	68%	16%
Entry Holes within 15 degrees (4%) of target	84%	24%
Entry Holes within 18 degrees (5%) of target	91%	30%
Entry Holes within 20 degrees (6%) of target	95%	30%
Entry Holes within 25 degrees (7%) of target	98%	38%

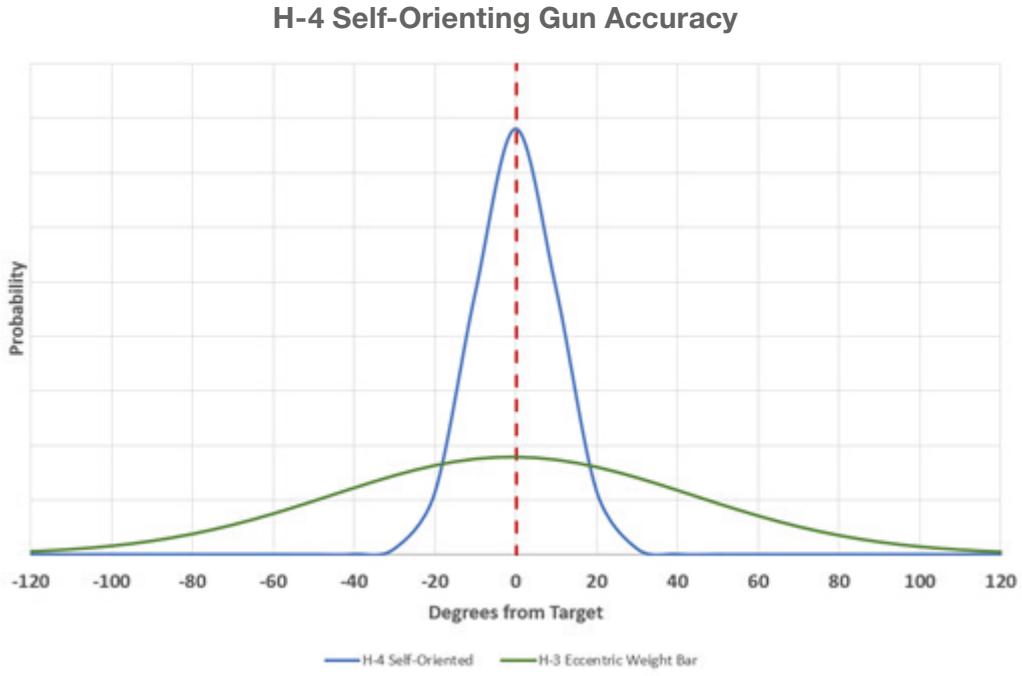

Figure 5 – H-4 vs H-3 Eccentric Weight Bar Accuracy

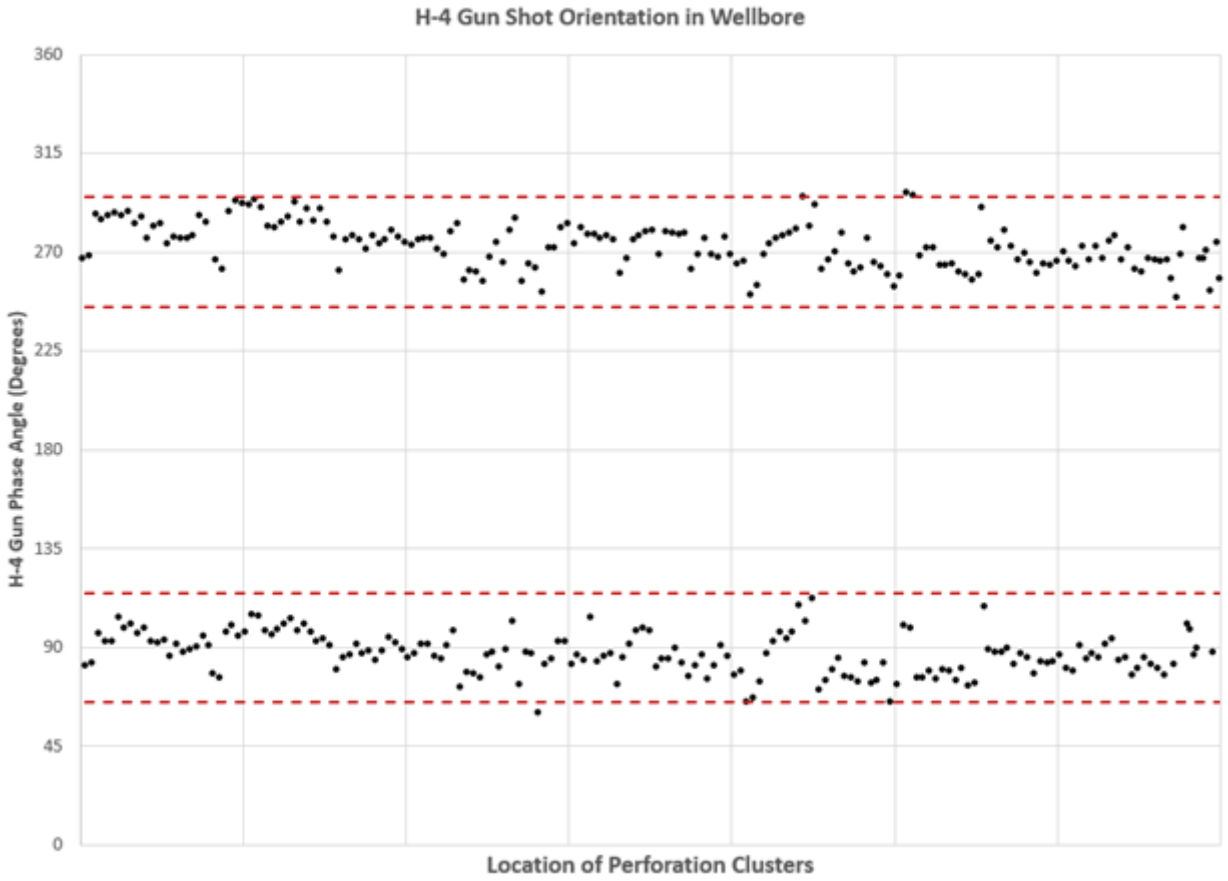

Figure 6 – H-4 Shot Location Plot

Conclusion

Overall, the first full scale H-4 field trial resulted in very reliable perforation accuracy. Since this trial, Hunting has made charge fitment improvements to eliminate any movement that could result in the charge contacting the gun carrier and preventing rotation (outlier data points). Higher accuracy results are also expected in zero phase (true north shot) orientation H-4 guns. The H-4 internal orienting guns are a significant improvement to guns reliant on lock collars, or other means of mechanical orientation, and eccentric weight bars.

Further Information

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