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A New Technique for the Development and Quality Control of Flow-Optimized Shaped Charges

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Abstract

For nearly two decades, shaped charge optimization has focused on increasing entry hole – for "big hole" gravel-pack style charges – and depth of penetration into standardized cement targets – for deep-penetrating charges. However, it has been acknowledged for some time that the latter approach, which is based on the misguided use of a test protocol described in API Recommended Practice 19B, Section 1, for perforator performance benchmarking, does not necessarily lead to perforations that deliver optimum flow performance. On the contrary, perforators optimized for maximum cement penetration are highly unlikely to be optimized for maximum rock penetration, let alone to create perforation geometry conducive to maximum flow.

A technically superior approach is to optimize both geometry and flow performance by benchmarking into natural rock, stressed to representative levels, as described in Sections 2 and 4 of the aforementioned Recommended Practice. The downside of such an approach is the time and cost associated with repeated test shots into stressed natural rock media, which must first be characterized in order to normalize the results for target variations. Furthermore, production quality control of charges optimized for natural rock perforation should also be conducted using natural rock targets; this adds another significant cost as a result of performing frequent test shots during production.

GEODynamics designed and built the 'Quick Development Cell' to facilitate the rapid development and production quality control of charges optimized for flow performance in natural rock. The cell allows for rapid loading of the core, setup of test fixture, pressurization of the core vessel, shot execution, and extraction of the perforated core for evaluation. This facility significantly reduces the time and overhead associated with stressed rock tests; GEODynamics is now able to conduct a significant number of tests each day, compared to only two shots using a conventional arrangement. Such rapid turnaround allows the company to progress efficiently through design iterations and lowers the barrier to using stressed rock testing as a primary production quality control method.

The paper describes in detail the need for such a capability, development of the vessel, initial applications, and the significance of this development to the future of shaped charge design and performance.

Introduction

Since their introduction by Welex Jet Perforators in the early 1950's, perforating systems utilizing shaped explosive charges have become the dominant method for connecting a cased-and-cemented completion to the desired reservoir interval. During the ensuing five decades of development and deployment, shaped charge performance has advanced considerably as the result of more potent explosives, tighter manufacturing tolerances, improved quality control, and overall design enhancements. However, it has also been recognized that the flow path created by perforation with shaped charges is seldom ideal. Researchers acknowledged early on that extensive testing would be required under "*…the various conditions which may occur in a well*" in order to satisfy the industry's need to predict perforator effectiveness (Allen & Atterbury, 1953).

The Performance Benchmark Problem

In recent times, industry standardization has been applied in order to effectively benchmark alternative perforating systems. The American Petroleum Institute issued its first recommended practice on the evaluation of wellbore perforators in the 1980's, and the revised version (Recommended Practice 19B, API, 2001) is the accepted guideline for perforator