ROCKY MOUNTAIN OILFIELD TESTING CENTER

PROJECT TEST RESULTS

ALLIED OIL & TOOL POWERJET SLOTTING TOOL

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Prepared for:

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Prepared by:

RALPH SCHULTE
RMOTC Project Engineer

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Rocky Mountain Oilfield Testing Center
Technical Report: Allied Oil & Tool

SUMMARY

The following article describes some recent work performed at the Naval Petroleum Reserve No. 3 (NPR-3), comprising the Teapot Dome oil field and located 35 miles north of Casper, Wyoming by the Rocky Mountain Oilfield Testing Center (RMOTC) and an industry partner, Allied Oil & Tool, of Phoenix, Arizona. RMOTC is operated by Fluor Daniel, the management and operating contractor for the Department of Energy's Naval Petroleum Oil Shale Reserves in Colorado, Utah, and Wyoming.

As part of RMOTC's continuing mission to support and strengthen the domestic oil and gas industry by allowing testing by individual inventors and commercial companies to evaluate their products and technology, RMOTC has completed a test of a Power Jet Formation Stimulation (PJFS) tool developed by Allied Oil & Tool. The objective of the tool is to create opposing slots or cuts in well casing as an alternative to jet perforating. The tool was tested on two separate occasions in the dual-zone Shannon formation of the NPR-3. A downhole video camera was utilized to confirm the slotting action of the casing, cement sheath, and the formation. The downhole video camera confirmed the potential for creating a vertical slot in the production casing, erosion of the cement behind pipe and access to the formation face.

INTRODUCTION

Naval Petroleum Reserve No. 3 is a federally owned oil field 35 miles north of Casper, Wyoming. NPR-3, also known as the Teapot Dome field, lies along the southeastern portion of the larger Salt Creek anticlinal structure. The field was originally developed in the early part of the century and became well known through the Teapot Dome scandal of the 1920's. After the oil crisis of the 1970's, the field was developed on a large scale basis. During the late 1970's and early 1980's, hundreds of new producing and injection wells were drilled for primary and secondary recovery. In addition, a large scale, light oil steamdrive was developed in the shallow, heterogeneous Shannon formation in the late 1980's to supplement the projected low recovery (-5% of OOIP).

More recently, the Department of Energy has authorized the oil field to be used as a testing center for inventors and commercial companies. Access to an active oil field with complete production, injection and EOR facilities is now possible in accordance with DOE's, "Domestic Natural Gas and Oil Initiative", which allows, "new applications that lead to increased production, lower operating costs, and improved environmental compliance costs to be tested at Naval Petroleum Reserve No. 3 .

The test of the PJFS tool developed by Allied Oil & Tool is an example of the type of support that RMOTC offers to the individual inventors and commercial businesses. Typically, in consolidated formations in the Rocky Mountain Region, the normal practice is to run casing, cement, jet perforate, and stimulate the oil or gas well. The intent of the PJFS tool is to provide an alternative to conventional perforating, and possibly stimulation of the near wellbore with an abrasive jet to create opposing slots in the casing at 180' phasing.

The tool is partly based on the application of Russian technology in the design of the perforating system. The Former Soviet Union (FSU) has a more extensive experience with the use of abrasive jet perforating with the technology being applied on a wide scale. Allied Oil & Tool has utilized this technology along with further operational improvements to develop a prototype test tool.

DESCRIPTION OF OPERATIONS

The initial test of the slotting tool was the slotting of the Lower Shannon in Well 23-1-SX-2 with the prototype tool on March 29, 1995. The tool was raised slowly from the bottom of the zone to the top of the zone using a hydraulic lift assembly consisting of three large hydraulic cylinders. The cylinders are operated from a remote control panel located approximately 50 ft away from the wellhead. The hydraulic cylinders are moved at approximately 1" per minute over a 4 - ft available stroke length. The hydraulic lift assembly is then reset, and the tubing can be rotated to create offsetting slotted perforations.

The abrasive cutting action of the PJFS is accomplished by pumping a 20 ppt gel solution with a sand density of 0.5-1 ppg down the tubing, through the tool, up and the tubing/casing annulus. The injection rates typically varied from 3 to 5 BPM at 3000 - 5000 psi surface pressure. No lost returns were evident during the operation even with the low reservoir pressure of the Shannon formation (< 50 psi).

The fluid returns from the tubing/casing annulus contained slightly pulverized sand with small pieces of cement and formation cuttings. The cuttings were the first indication that the tool had penetrated the casing and eroded the cement sheath and formation face.

Well 23-1-SX-2 was originally drilled as a fractured shale producer, but was uneconomic. The decision was made to plug the well back to the Shannon formation and test the PJFS tool by slotting the Lower Shannon bench for approximately 22 ft (562 - 584 ft). This early test of the tool resulted in the tool face and retaining rings being eroded by the ricochet blast of the sand/slurry mixture from the casing wall after 6 ft of the casing was slotted. The tool was repaired and modified overnight, and the second day resulted in the remaining 16 ft being slotted.

Halliburton's downhole video camera was then utilized to determine the actual physical effects of the PJFS tool. The casing was circulated with clean produced water, but the downhole video was unable to obtain a clean picture of the casing wall due to a large amount of suspended debris. The well was then swabbed down several times and the water cleared out of the wellbore, to allow the downhole video camera to run in air filled casing. Very detailed pictures were obtained by this method.

At several depths, the video of the casing indicated opposing slots (180' phase difference) of 1/2"-3/4' in width. The erosion of the cement sheath was also detected with some inferred formation erosion which was confirmed by the surface returns. At other depths, the slots are

often narrower and the depth of penetration based on the video was more difficult to determine. There were several places where the tool was held stationary producing two opposing round holes in the casing similar to conventional perforating.

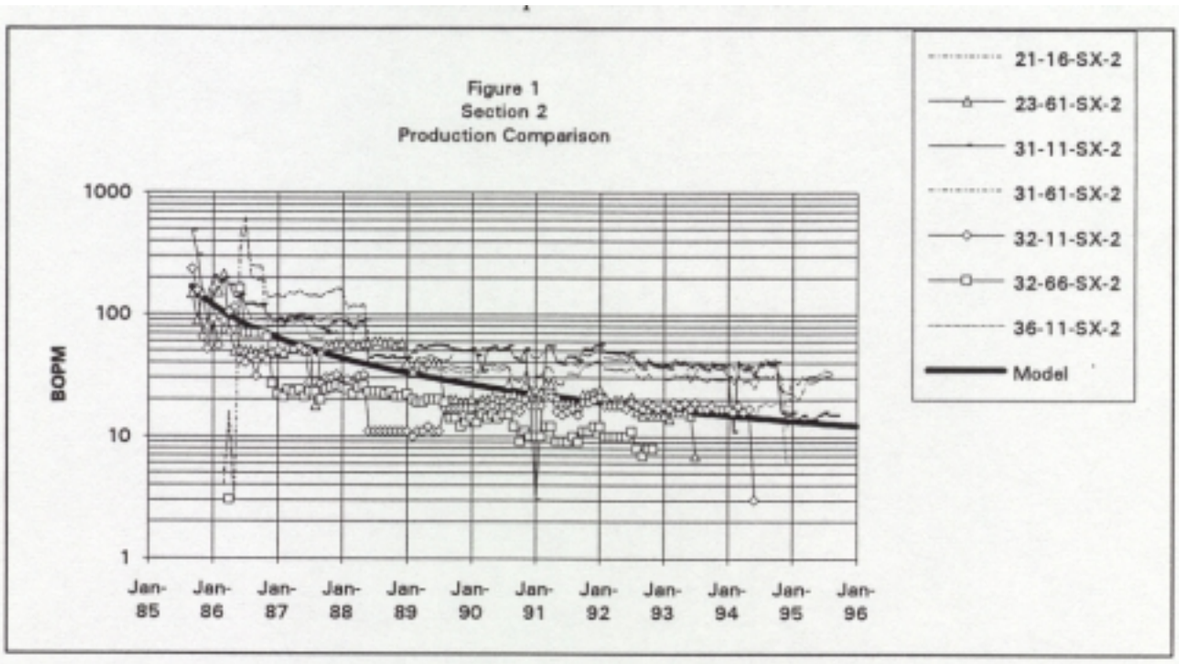
The images of the downhole video were striking and very useful in determining, in a qualitative sense, the effects of the downhole slotting tool. Production data, however, reflected limited inflow from the Lower Shannon bench. This limited inflow is common in the Shannon outside the EOR patterns, due to low reservoir pressure (< 50 psi), low permeability (< 50 md), and severe heterogeneity of the formation. The Shannon formation normally requires fracture stimulation to be productive, and this was also the case with Well 23-1-SX-2.
The well was stimulated during June 1995 with a conventional fracture treatment. The initial breakdown pressure for the well was 370 psi, which was significantly lower than similar wells in the area indicating a possible additional benefit of the slotting operation over conventional perforating. The lower breakdown pressure is assumed to be the result of better communication between the wellbore and the formation.

The slotting tool was again utilized in July 1995 to treat the Upper Shannon over a 27 ft interval. The tool performed better this time, losing only one port during the operation after slotting approximately 10 ft. A second tool was able to complete the remaining interval. Similar rates and pressures were present during the Upper Shannon treatment from 479 to 506 ft.

The Upper Shannon was then fracture stimulated and both zones were cleaned out and placed **on production.** No downhole video camera was run for the second zone. Initial production tests indicated an IP of 13 BOPD which is above the average of surrounding wells; however, production quickly declined to 4 BOPD which is below the production model for the area.

Initial production rates and cumulative oil production are quite variable in the Shannon reservoir due to its severe heterogeneity. See Figure 1. For example, seven infill wells which were completed during the 1985-86 time frame have a 5:1 contrast in cumulative production ranging from 1,600 BO to 8,000 BO. An expected production model was derived from the historical recompletion response and is shown in Figure 2 along with the production of Well 23-1-SX-2.

The low production rate of 4 BOPD, as shown in Figure 2, is not necessarily considered to be an effect of the slotting tool, but may reflect the difficult geologic setting, the late stage of reservoir depletion, and the large natural variation in well productivity.



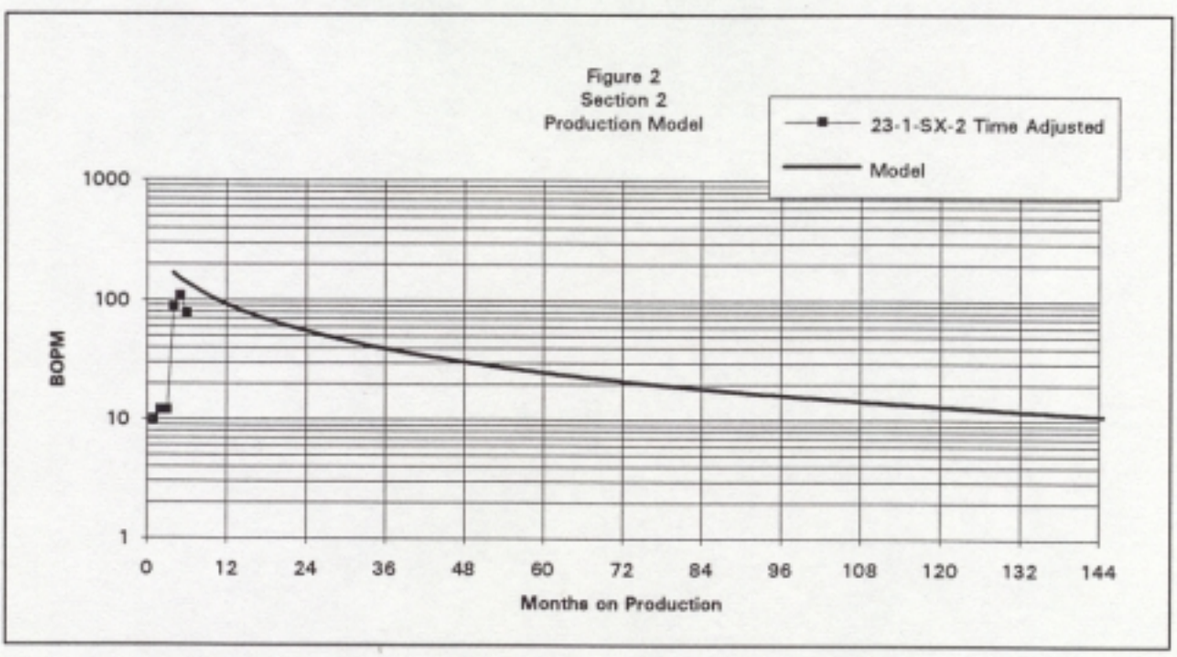


Figure 1

CONCLUDING REMARKS

No quantitative comparison is possible but the overall judgment, based on the downhole video, surface returns, breakdown pressures, and initial production rates is that the casing slotting was comparable to conventional perforating. The video confirmed that the casing was eroded by

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the high velocity of the sand/slurry mixture, and surface returns indicated small pieces of cement and formation cuttings were present.

RMOTC offers the opportunity for field testing of petroleum and environmental processes in an active oil field with workover and drilling rigs, hundreds of producing and injection wells, and technical expertise onsite. The extent of commercialization of Allied's PJFS tool has been advanced with experienced gained in a real oil field situation. The design of the tool has been modified to account for unforeseen difficulties. RMOTC is continuing the testing of other devices and drilling techniques to aid the domestic oil and gas industry.

To receive an information packet, or discuss a testing project or new proposal, please contact RMOTC at, 907 Poplar, Suite 100, Casper, Wyoming 82601, phone (307)-261-5000, ext. 5060.