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TITLE: GEOFRAC™ -- AN EXPLOSIVES STIMULATION TECHNIQUE FOR A GEOTHERMAL WELL

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GEOFRAC™--AN EXPLOSIVES STIMULATION TECHNIQUE FOR A GEOTHERMAL WELL

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ABSTRACT

The first known use of explosives for stimulating a geothermal well was successfully conducted in December 1981 with a process called GEOFRAC™. The 260°C well was located at the Union Oil Company's Geysers Field in Northern California. For the initial test, 364 kg of a new explosive called HITEX™ II was placed at a depth of 2256 meters and detonated to verify techniques. The explosive was contained in an aluminum canister to separate it from the well fluids. In the second test, 5000 kg of explosive was used representing a column length of approximately 191 meters. The explosive was detonated at a depth of 1697 meters in the same well. The results of these tests show that HITEX™ II can be safely emplaced and successfully detonated in a hot geothermal well without causing damage to the well bore or casing.

INTRODUCTION

Using explosives to stimulate a geothermal well has long been considered an attractive method by many researchers to enhance production (Ref. 1-3). However, no known field demonstrations have been carried out prior to this time because of the high cost and limited availability of heat resistant explosives. This paper describes a process called GEOFRAC™ in which a new, low-cost heat-resistant explosive called HITEX™ II was used in a field demonstration to show that it could be safely emplaced and detonated in a geothermal well.

HITEX II™

Rocket Research Company recently developed a new heat-resistant explosive called HITEX™ II* for use in geothermal well stimulation (Ref. 4). This explosive consists of a mixture of sodium nitrate, potassium nitrate, and calcium nitrate as oxidizers with guanidinium nitrate as the fuel. When compounded as solid grains, it has an off-white color and cannot be detonated at room temperature. It melts at a temperature near 185°C and becomes an almost colorless liquid that can be detonated. Further heating to 260°C shows no occurrence of incipient exotherms. Weight loss for a 24-hour period at 260°C was less than 1%. The detonation velocity at this temperature was measured as 6394 m/s. The properties of HITEX™ II are summarized in Table 1.

Table 1. Physical and chemical characteristics of HITEX II.

Composition	
Calcium Nitrate	16.5%
Potassium Nitrate	16.4%
Sodium Nitrate	4.1%
Guanidinium Nitrate	62.9%
Density	
Solid Grain (21°C)	1.63 g/cm^3
Liquid (185° to 205°C)	1.53 g/cm^3
Liquid (232° to 260°C)	1.50 g/cm^3 (contains bubbles)
Melting Temperature	~ 177°C (350°F)
Color	
Solid (21°C)	White
Liquid (260°C)	Clear
Detonation Velocity	6349 m/s (measured) 6459 m/s (calculated)
Heat of Explosion	-2844 J/g
Energy Release	864 J/mol gas
Critical Diameter for Sustained Detonation in an Aluminum Pipe	> 6.35 cm, < 14.92 cm

GEOFRAC™ TECHNIQUE

GEOFRAC™ involves the process of loading solid cylindrical grains of HITEX™ II explosive into a container and emplacing the container in a geothermal well with a detonator package; the HITEX™ II melts when heated by the hot well temperature and can then be detonated to create additional fractures around the well bore. This explosive stimulation concept was evaluated in a dry steam well provided by Union Oil Company at their Geysers Field in Northern California. Two tests were planned. The initial test was designed to use a small amount of explosive at the bottom of the well to verify the operational techniques prior to conducting a full stimulation test in a higher section of the well with a large amount of explosive. The two configurations tested are described below.

*U.S. Patent No. 4,274,893

INITIAL TEST

For the initial test, 367 kg of explosive was placed in sections of aluminum pipe joined with steel couplings coated with Teflon™. This canister was then lowered into the well on X-line casing and a detonator package placed on top of the explosive by wireline. After sealing the canister with a bridge plug, the casing was retrieved by disconnecting it from the canister at a releasing tool joint.

To ensure that the explosive did not melt during emplacement, the steam production was curtailed by injecting water into the well, thus lowering the temperature of the well below the melt temperature of HITEX™ II. When all equipment was safely secured, the water flow was turned off, the well was pressurized with air to drive the water into the surrounding formation, and the well was allowed to produce steam, thus heating the HITEX™ II to liquid form. This sequence of operations for this test is shown in Figure 1.

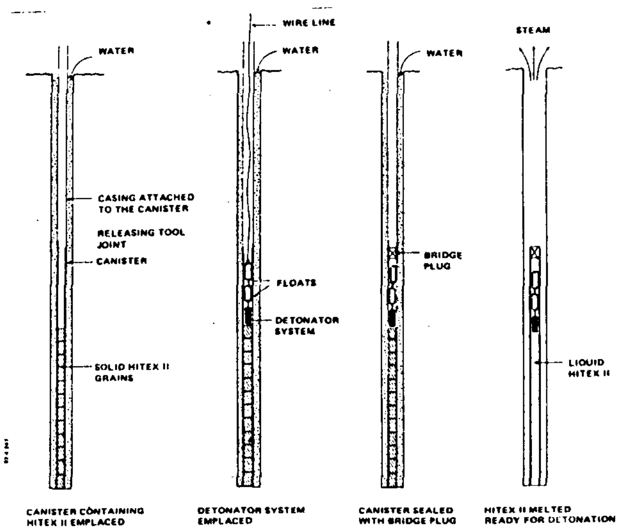

Figure 1. GEOFRAC emplacement concept: detonating the top of the HITEX II explosive column.

The specially designed detonator package consisted of a shaped charge with electronic timing and firing circuits. These elements were protected from the hostile environment of the well by placing them inside a protective pressure vessel with a thermal shield. These components are illustrated in Figure 2. Buoyancy floats were attached to the detonator package so it would remain at the top of the liquid explosive column after melt occurred. The well and canister configuration after emplacement are shown in Figure 3. The explosives were successfully detonated at the preset time of 48 hours after emplacement.

Cleaning out the well proved to be extremely difficult. A short piece of X-line, the canister lengths above the liquid explosive level, and the remains of the detonator/float package were lodged at various locations in the well. A solid debris plug was located at a depth of 1698 meters; consequently, further cleanout of the well was discontinued. This plug unfortunately shut off the lower two steam entries in the well.

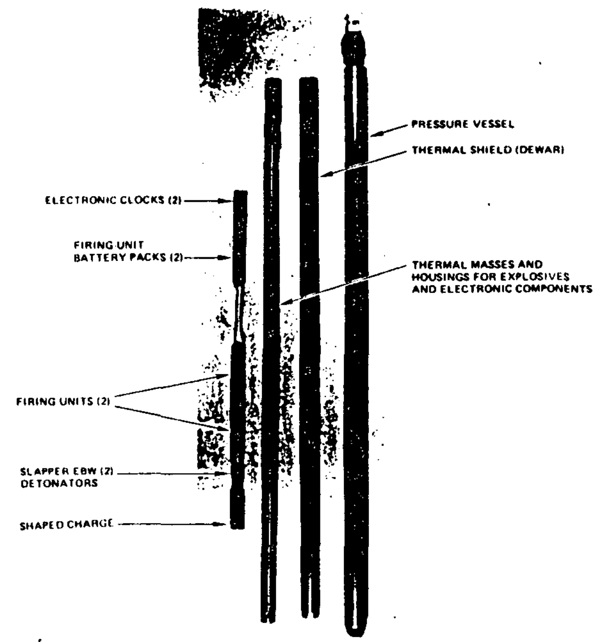

Figure 2. Photograph of the detonator-system components.

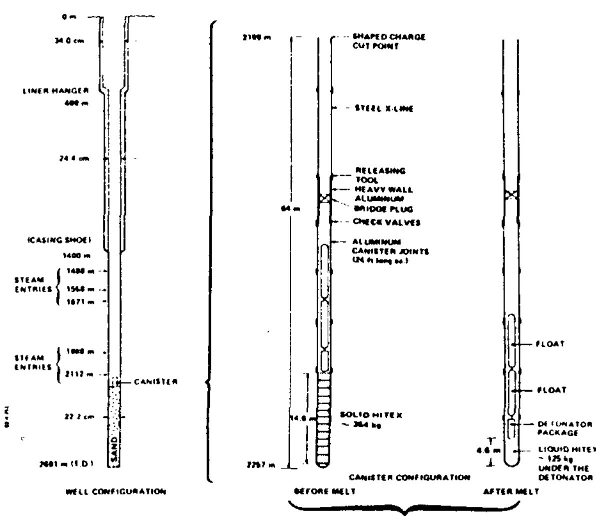

Figure 3. Configuration of the canister emplaced in the LF-30 well for the initial test. (Fired on December 4, 1981 at 3:00 a.m.).

STIMULATION TEST

To prevent a similar problem of well plugging during the 5000 kg stimulation test, an alternate emplacement configuration was selected. In this configuration, the detonator package was placed at the bottom of the canister, eliminating the need for the floats and void space for the detonator package. A left-hand safety joint was selected as a substitute method for improving the canister disconnect. The main operational difference using this technique was that the detonator package was placed close to the bottom of the explosive column, the top of the canister was sealed at the well head, thus eliminating the need for a bridge plug, and the canister could be lowered into the hole in a shorter time on drill pipe. The configuration of the well and canister for this test is shown in Figure 4.

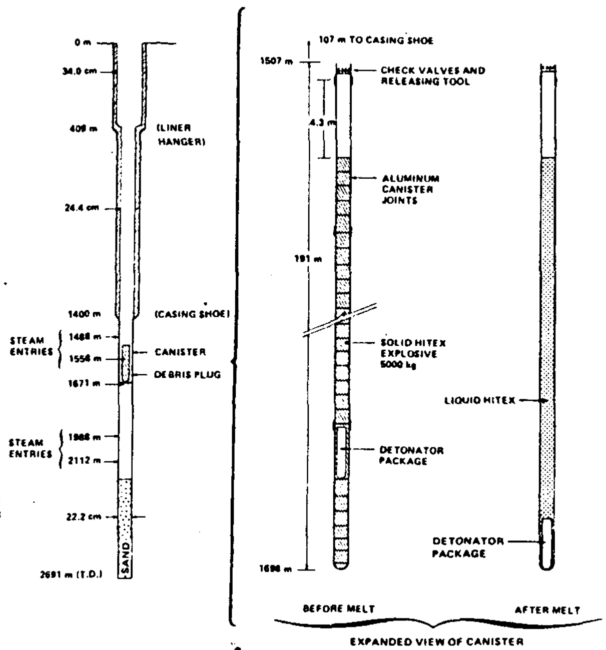

Figure 4. Configuration of the canister emplaced in the LF-30 well for the simulation test. (Fired at 9:45 p.m. on December 14, 1981).

No operational problems were encountered during the emplacement of the explosives. The total column length of explosives was 168 meters. The detonator system caused the explosives to detonate again on schedule 48 hours after emplacement. The well vented rocks and small pieces of metal for a short time after the detonation. Well cleanup proved to be quite minimal and, in fact, the solid debris plug on which the canister assembly was placed was driven 202 meters deeper in the well, where again it became solidly lodged. Complete clean-out of the well below this point was not attempted.

PRODUCTION TEST RESULTS

Production test results from the well prior to, between, and after the two explosive tests are shown in Figure 5. The data show that the steam production decreased from about 22,200 kg/hr before the tests to 14,100 kg/hr afterwards. This decrease is probably a result of the debris plug that formed after the initial

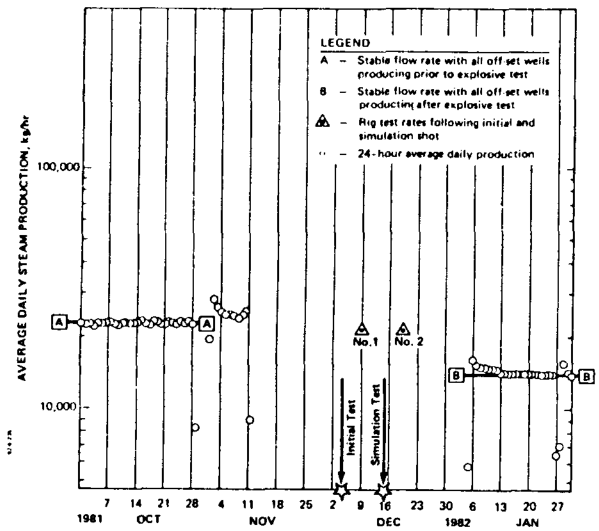

Figure 5. Production data (LF-30).

test, effectively sealing off the lower two steam entries. Although the measured skin factor showed improvement from a -0.6 to -2.4, we suspect it was also caused by the loss of the lower section of the well by the debris plug. There does not however appear to have been any damage to the well bore caused by the creation of a residual "stress cage," compaction of the formation, or damage to well casing.

CONCLUSIONS

It was demonstrated that the unique properties of HITEX™ II can be used in the explosives stimulation of geothermal wells. A shaped-charge detonator package was developed that can survive temperatures of 260°C and pressures of 1000 psi for 48 hours, and then cause molten HITEX™ II to detonate at a preset time.

A successful technique was developed to place the explosives and detonator package in a geothermal well so that personnel hazards were minimized during emplacement and well cleanup after detonation was not a big problem. The primary objective of developing the GEOFRAC™ technique was met; however, no improvement in well productivity was observed over the well-bore interval that was treated. A number of additional wells will need to be tested before the full economic utility of the concept can be developed and demonstrated.

ACKNOWLEDGEMENTS

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