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SHAPED-CHARGE TESTS IN SUPPORT OF THE COAL-GASIFICATION PROGRAM

R. F. Scheloske

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SHAPED CHARGE TESTS IN SUPPORT OF THE COAL GASIFICATION PROGRAM

By

R. F. Scheloske

Lawrence Livermore National Laboratory
University of California

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ABSTRACT

The LLNL concept for in-situ coal gasification requires forming horizontal holes in deep coal beds to connect vertical bore shafts. These lateral holes are required to provide a passage for the gases between the vertical shafts.¹ Shaped charges are being considered for producing these horizontal bore holes. This report describes a test method for evaluating new shaped charge designs and presents the results for three designs.

I. INTRODUCTION

The Non Nuclear Ordnance group has provided limited support directed toward developing a conventinal shaped charge that will produce maximum penetration into coal. Since it would be very expensive to actually use coal for these experiments at Site 300, we used water to mock up the coal. Test results indicate that water is a valid target for evaluating shaped charge designs for this program.

II. TEST SETUP

Figure 1 shows the general configuration for the first two experiments described in this report. The water (coal mock) was contained in a steel pipe that had an outside diameter of 24 inches and an overall length of 18.5 feet. The test tanks for the third and fourth experiments were fabricated from wood and were lined with plastic sheet stock. Sensor plates, containing copper/kapton/copper switches, were installed in the water at approximately 24 inch intervals along the length of the test tanks. These switches were closed by the shaped charge jet and provided a means for determining the approximate jet velocity and penetration. A blast shield, consisting of two 4 inch thick armor plates and a one inch thick plywood sheet, was used to protect the test tanks from the shaped charge blasts.

III. WATER AS A TEST MEDIUM

Most of the properties of coal are very much different than water; however, the density of coal (approx. 1.30 g/cc) is very similar to water. It is generally agreed that density is the controlling factor affecting shaped charge jets for velocities greater than about 2.0 mm/ μ s. Our main interest is in jet velocities greater than 2.0 mm/ μ s.

A Shillelagh shaped charge was used to evaluate using water as a test medium since we have data on its performance in coal. Shillelagh shaped charges were fired into coal in Wyoming. The average penetration from three vertical shots into coal was 2157 mm (ranged from 1828 to 2446 mm). Based on the density difference between water and coal, we expected the Shillelagh penetration in water to be approximately 2459 mm.

Copper/kapton/copper switches positioned 609.6 mm (24 inches) apart in the water indicated that the jet traveled between 2438.4 mm and 3048 mm. The switch located at 2438.4 mm was closed by the jet; the switch located at 3048 mm was not.

Figure 2 shows a plot of the test data. The velocity curve is a plot of the average velocity between each pair of switches. The closure times for the switches are shown on the time curve.

IV. SHAPED CHARGE DESIGNS

LLNL issued a purchase order to The Firestone Fire and Rubber Company in March 1977 to design, test and analyze the performance of conventionally developed shaped charges for use in boring holes in coal. Firestone evaluated five scaled (3.3" and 4" diameter) shaped charge warhead designs.² These designs were tested for radiographic data in Ohio and for penetration into coal beds in Wyoming. These early studies showed that 30⁰ aluminum liners and 20/42⁰ copper tandem liners gave the best penetration into coal.

Based on Firestone's experience, we designed and tested three shaped charges; all with 30⁰ liners. the liners were 0.200" and 0.300" thick aluminum and 0.090" thick nickel. The assembly designs are shown in Fig. 3. These shaped charges were ring initiated whereas the designs evaluated by Firestone were point initiated. Ring initiation permits a shorter overall design and a more efficient use of the high explosive.

For a given design, the larger the shaped charge assembly the greater the jet penetration. For the coal gasification program, the shaped charge size must be limited because of the cost for drilling the vertical holes into the coal beds. We chose to evaluate six inch diameter assemblies since this size appeared to be a reasonable compromise for performance and drilling costs.

V. TEST RESULTS

A. 0.200" Thick 30⁰ Aluminum Liner

Figure 4 shows the test results for the shaped charge containing a 0.200" thick 30⁰ aluminum liner. The jet velocity in air was approximately 12 mm/ μ s. The jet appears to have travelled about 3658 mm (12 feet) into the water.

This shot destroyed the steel test tank. We used plywood water troughs, lined with sheet plastic, for testing our other two designs.

B. 0.300" Thick 30⁰ Aluminum Liner

Figure 5 shows the results of testing the 0.300" thick 30⁰ aluminum liner in water. The switch located at 3581 mm (approx. 12') in the water closed at 7612 μ s. The switch located at 4267 mm (14') closed at 62 ms. This indicates that the jet penetrated about 12' into the water. This liner performed approximately the same as the 0.200" thick aluminum liner.

C. 0.090" Thick 30⁰ Nickel Liner

It appears that the jet from this shaped charge only traveled about 1219 mm (4') into the water. The recovered shaped charge slug indicated that the high explosive in the assembly did not detonate uniformly. The slug was shaped very much like a trout. The reason for this non-uniform detonation is not clear. The jet velocity in air was approximately 10.5 mm/ μ s.

VI. SUMMARY

In the Firestone study, the Shillelagh warhead (5.8" dia.) had a comparable performance with a 4.0" diameter shaped charge having a 0.145" thick 30⁰ aluminum liner. We assumed that we could improved the performance of the 30⁰ aluminum liner by scaling it up to six inches in diameter and by ring initiating the high explosive. Our test results from the Shillelagh, the 0.200" thick aluminum liner and the 0.300" thick aluminum look very similar. The designs with the aluminum liners appear to have penetrated, at the most, 20Δ further in the water than the Shillelagh.

Further work needs to be done to develop a small diameter shaped charge that will produce maximum penetration into coal. The test method, using water to mock coal, described in this report should provide a relatively inexpensive means for evaluating new designs.

VII. ACKNOWLEDGEMENTS

The author wishes to acknowledge the contributions of project team members John Brenkwitz and Jim Morrison who provided the electronics support for these experiments.

VIII. REFERENCES

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SHILLELAGH SHAPED CHARGE

JET VELOCITY VERSUS DISTANCE
(SWITCH CLOSURE TIMES ARE ALSO SHOWN)

FIGURE X2

[illegible]

LET.	DWN.	CN	DATE	ZCME	CHARGE

[illegible]

1. LNL SHAPED CHARGE WITH 0.200" THICK 30° AL. LINER

TEST NO.: COAL 2

JET VELOCITY VERSUS DISTANCE
(SWITCH CLOSURE TIMES ARE ALSO SHOWN)

FIGURE X4

LLNL SHAPED CHARGE WITH 0.300" THICK AL. LINER

TEST NO. 15509-A3

JET VELOCITY VERSUS DISTANCE
(SWITCH CLOSURE TIMES ARE ALSO SHOWN)

FIG. 5

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