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1 OF 1

QUARTERLY REPORT

NNC-Q-3

Contract DAI-19-020-501-ORD-(P)-58

NATIONAL NORTHERN CORPORATION
West Hanover, Massachusetts

THE EFFECT OF ALTITUDE ON DETONATION AND FRAGMENT VELOCITY

QUARTERLY PROGRESS REPORT 2005-3

Contract DAI-19-020-501-ORD-(P)-58

TENTH QUARTERLY REPORT

NNC-Q-3

September, October, November 1957

Copy No. 07

NATIONAL NORTHERN CORPORATION

West Hanover, Massachusetts

A Subsidiary of American Potash and Chemical Corporation

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Contract DAI-19-020-501-ORD-(P)-58

TENTH QUARTERLY REPORT

NNC-Q-3

September, October, November 1957

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A Subsidiary of American Potash and Chemical Corporation

1.0 INTRODUCTION

This is a Quarterly Report of testing accomplished during the period 10 September 1957 through 9 December 1957 for Picatinny Arsenal under supplemented Contract DAI-19-020-501-ORD-(P)-58 and is designated NNC-Q-3.

The first four Quarterly Reports under this contract, NN-Q-1 through NN-Q-4, are concerned with free-air blast testing, and the results are summarized in National's Summary Report NN-P-34. The fifth and sixth Quarterly Reports describe the work on various RDX systems. The seventh and eighth Quarterly Reports describe preliminary determinations for National's current investigation of detonation and fragment velocity of various explosive systems at several simulated altitudes. The ninth Quarterly Report includes the initial results of National's work on velocity of detonation at various simulated altitudes. The results of National's work to date are summarized in the present report.

National Northern Corporation gratefully acknowledges the guidance and assistance of Picatinny Arsenal personnel in this investigation.

2.0 OBJECT OF TESTS

The task assigned under this contract, as supplemented, is a survey of various explosive systems for the purpose of determining any change in detonation and and fragment velocity with changes in simulated altitude, charge diameter, and degree of confinement of the explosive.

The study of detonation velocity is described in Paragraphs 3.0, 4.0, 5.0 and 6.0 of this Report. The investigation of fragment velocity is detailed in Paragraph 7.0, 8.0, 9.0 and 10.0.

STUDY OF DETONATION VELOCITY

3.0 CHARGE DATA

3.1 In order to survey possible changes in behavior of various explosive systems with changes in simulated altitude, charge diameter, and degree of confinement of the explosive, a number of specific conditions have been taken as starting points. In each combination of conditions, five measurements of the detonation velocity of the explosive system are made.

3.2 The explosive systems included in these tests are TNT, H-6, 70/30-RDX/TNT, 70/30-HMX/TNT, and MOX-2B.

3.3 These systems are studied at pressures of 760, 226, 60, and 13 millimeters of mercury, corresponding to simulated altitudes of ground, 30,000, 60,000, and 90,000 feet.

3.4 These systems are tested in cylindrical columns, one and two inches in diameter by eighteen and seven inches long, respectively. These represent estimates of the maximum explosive load that can be tolerated in National's altitude chamber.

3.5 These explosives, with the exception of MOX-2B, are measured for detonation velocity in two conditions of confinement. In one case, bare charges are used; and, in the other, the explosive is loaded in one-quarter-inch-thick steel tubing of appropriate inside diameter. MOX-2B will not sustain detonation in unconfined columns of the selected diameters and an increase in diameter would require reduction in the length of column to maintain the maximum charge weight allowed in National's chamber. Columns shorter than those now used would cause the experimental error to be too large.

3.6 Subsequent to initiation of the firing program, some difficulty was experienced in detonating TNT columns, unconfined, in these diameters. This difficulty has since been ascribed to the method of casting, in which the molten TNT was poured into heavy paper sleeves. The TNT was finally cast in steel sleeves and removed from the sleeves for testing. These columns were found to detonate completely.

4.0 TEST EQUIPMENT

4.1 The detonation velocity is measured by timing the passage of the detonation zone over a known column distance. This distance is measured between two electrical probes, each consisting of open-end wire pairs. The passage of the detonation zone closes the open-end pairs and, with associated circuits, generates a sharp pulse. The pulses generated are applied to the start-stop circuits of an electronic counter-chronograph. The counter is the Potter Model 471 operating at 8 megacycles.

4.2 Tests at simulated altitudes are accomplished in National's largest altitude chamber. The chamber has approximate inside dimensions of 12x14x9 feet and may be evacuated to a simulated altitude of 120,000 feet (3 mm. Hg) by a Kinney KD-780 vacuum pump run by a forty horsepower electric motor. Those tests run at "ground" (760 mm. Hg) are accomplished at National's Halifax Testing Range.

5.0 TEST RESULTS

5.1 The tables following include all of the data obtained to date. In these tables, charge density is determined by geometry and net charge weight. The eighteen-inch by one-inch cylinder is calculated to have a volume of 232 cubic centimeters and the seven-inch by two-inch cylinder a volume of 360 cubic centimeters.

Altitude (feet mm Hg.)	Average Charge Density (gm/cc)	Measured Segment (meters)	Measured Time (microseconds)	Velocity of Detonation (meter/seconds)
H-6, unconfined, in one-inch diameter columns				
Ground	1.80	.302	41.1	7350
(760-764 mm Hg.)	1.78	.295	41.1	7180
	1.78	.303	40.9	7410
	1.81	.305	40.9	7460
	1.79	.303	41.1	7370
30,000	1.81	.305	40.6	7510
(226 mm Hg.	1.79	.302	41.2	7330
	1.79	.302	40.9	7380
	1.81	.305	40.9	7460
	1.80	.305	40.9	7460
60,000	1.80	.302	39.2	7700
(60 mm Hg.)	1.79	.305	40.6	7510
	1.79	.302	40.4	7480
	1.80	.303	41.1	7370
	1.79	.300	40.5	7410
90,000	1.78	.302	41.0	7360
(13 mm Hg.)	1.78	.302	41.0	7360
	1.79	302	42.1	7170
	1.78	.303	40.6	7470
	1.79	290	41.4	7000
H-6, unconfined, in two-inch diameter columns				
Ground	1.83	.099	14.0	7070
(760-764 mm Hg.)	1.77	.100	14.5	6900
	1.84	.102	14.8	6890
	1.75	.102	15.1	6750
	1.81	.100	14.8	6760
30,000	1.77	.099	14.0	7070
(226 mm Hg.)	1.78	.099	14.2	6970
	1.84	.102	15.0	6800
	1.81	.102	14.7	6940
60,000	1.87	.102	14.4	7080
(60 mm Hg.)	1.78	.099	14.1	7020

Altitude (feet) (mm Hg.)	Average Charge Density (gm/cc)	Measured Segment (meters)	Measured Time (microseconds)	Velocity of Detonation (meter/seconds)
H-6, unconfined, in two-inch diameter columns (Cont'd)				
60,000	1.78	.102	14.9	6840
(60 mm Hg.)	1.80	.102	14.5	7030
	1.83	.102	14.4	7080
90,000	1.78	.099	14.2	6970
(13 mm Hg.)	1.84	.102	14.6	6990
	1.76	.099	14.9	6640
	1.84	.102	14.1	7230
	1.81	.102	14.2	7180
H-6, confined in 1/4-inch wall steel tubing, one inch diameter columns				
Ground	1.72	.305	42.0	7260
(760-764 mm Hg.)	1.72	.305	42.0	7260
	1.72	.303	42.0	7210
	1.66	.305	43.3	7050
	1.71	.303	42.3	7180
H-6, confined in 1/4-inch-wall steel tubing, two-inch diameter columns				
Ground	1.78	.102	13.9	7340
(760-764 mm Hg.)	1.78	.102	13.9	7340
	1.77	.102	14.4	7080
	1.78	.102	13.6	7500
	1.78	.102	13.7	7450
30,000	1.77	.103	13.8	7500
(226 mm Hg.)	1.78	.102	14.0	7260
	1.79	.103	13.9	7430
	1.79	.102	14.0	7260
	1.77	.103	14.0	7370
60,000	1.78	.103	12.4	8330
(60 mm Hg.)	1.78	.103	13.8	7500
	1.79	.103	14.1	7300
	1.79	.103	14.1	7300
	1.77	.103	14.1	7300
90,000	1.78	.103	14.0	7370
(13 mm Hg.)	1.78	.102	13.6	7460
	1.78	.102	13.8	7390
	1.78	.103	13.1	7860
	1.78	.103	13.9	7430

Altitude (feet) (mm Hg.)	Average Charge Density (gm/cc)	Measured Segment (meters)	Measured Time (microseconds)	Velocity of Detonation (meter/seconds)
HMX/TNT, - 70/30, unconfined in two-inch diameter columns				
Ground (760-764 mm Hg.)	1.75	.098	13.5	7290
	1.76	.100	14.6	6840
	1.79	.100	13.1	7620
	1.74	.102	12.9	7890
	1.80	.102	13.1	7740
30,000 (225 mm Hg.)	1.80	.102	13.2	7730
	1.81	.102	13.5	7560
	1.83	.102	13.1	7790
	1.78	.102	13.2	7730
	1.85	102	13.2	7730
60,000 (60 mm Hg.)	1.82	.099	13.1	7560
	1.76	102	13.6	7500
	1.76	.099	13.2	7500
	1.78	102	13.1	7790
	1.81	.102	12.9	7910
90,000 (13 mm Hg.)	1.74	.102	14.9	7240
	1.80	.102	12.9	7910
	1.79	102	13.0	7850
	1.75	.102	12.8	7970
	1.77	.099	13.6	7280
HMX/TNT-70/30, unconfined in one-inch diameter columns				
30 000 (226 mm Hg.)	1.63	305	38.1	7990
	1.60	.305	38.0	8020
	1.61	.303	38.1	7950
60,000 (60 mm Hg.)	1.71	302	38.4	7860
	1.73	305	38.0	8020
	1.65	.306	38.5	8540
	1.68	.305	38.4	7940
90,000 (13 mm Hg.)	1.69	.305	38.4	7940

HMX/TNT, - 70/30, confined in 1/4 inch-wall steel tubing, two-inch diameter columns

Altitude (feet) (mm Hg.)	Average Charge Density (gm/cc)	Measured Segment (meters)	Measured Time (microseconds)	Velocity of Detonation (meter/seconds)
Ground (760-764 mm Hg.)	1.75	.102	12.8	7970
	1.59	.102	13.1	7790
	1.63	.102	13.2	7730
	1.73	.103	13.1	7860
	1.73	.103	12.9	8010
30 000 (226 mm Hg.)	1.72	.102	13.1	7790
	1.74	.102	12.6	8100
	1.74	.102	12.8	7970
	1.74	.102	13.0	7850
	1.68	.127	16.0	7940
60,000 (60 mm Hg.)	1.73	.102	13.1	7790
	1.74	.103	12.6	8170
	1.76	.102	12.8	7970
	1.65	.102	13.1	7790
	1.75	.102	13.2	7730
90 000 (13 mm Hg.)	1.72	.127	16.0	7940
	1.73	.103	12.6	3170
	1.73	.102	13.2	7730
	1.74	.102	12.7	8030
	1.75	.102	13.0	7850
	1.59	.102	13.3	7670

RDX/TNT - 70/30, unconfined, in one-inch diameter columns

Altitude (feet) (mm Hg.)	Average Charge Density (gm/cc)	Measured Segment (meters)	Measured Time (microseconds)	Velocity of Detonation (meter/seconds)
Ground (760-764)	1.78	.305	38 1	8000
	1.72	.302	36.1	8360
	1.58	.305	37.6	8110
	1.75	.302	38.0	7950
	1.76	.303	37.6	8060
30,000 (226 mm Hg.)	1.68	.306	37.9	8070
	1.66	.305	36.0	8470
	1.74	.302	38.0	7950
60,000 (60 mm Hg.)	1.70	302	37.5	8050
	1.72	.305	37.8	8070
	1.61	.302	37.2	8120
	1 62	.305	36.5	8360
	1.44	305	37.7	8090
90,000 (13 mm Hg.)	1.72	305	38.1	8000
	1.71	.305	38.0	8030
	1.62	302	37.9	7970

Altitude (feet) (mm Hg.)	Average Charge Density (gm/cc)	Measured Segment (meters)	Measured Time (microseconds)	Velocity of Detonation (meter/seconds)
RDX/TNT, - 70/30, unconfined, in one-inch diameter columns (Cont'd)				
90,000 (13 mm Hg.)	1.62	.305	38.4	7940
	1.73	.302	37.9	7970
RDX/TNT, - 70/30, unconfined, in two-inch diameter columns				
Ground (760-764 mm Hg.)	1.82	.102	12.6	8050
30,000 (226 mm Hg.)	1.81	.103	13.0	7920
	1.81	.099	13.2	7500
	1.76	.099	12.2	8110
	1.83	.102	13.0	7850
	1.78	.102	13.4	7610
60,000 (60 mm Hg.)	1.82	.099	12.6	7860
	1.82	.103	12.9	7980
	1.77	.102	12.8	7960
	1.84	.102	12.6	8010
	1.78	.099	12.5	7920
90,000 (13 mm Hg.)	1.82	.102	13.2	7730
	1.84	.099	12.5	7920
	1.84	.099	12.6	7860
	1.76	.099	12.6	7860
	1.80	.096	13.4	7160
RDX/TNT, - 70/30, confined in 1/4-inch-wall steel tubing, one-inch diameter columns				
Ground (760-764 mm Hg.)	1.72	.305	38.3	7960
	1.74	.305	38.5	7920
	1.57	.305	38.0	8030
	1.71	.305	38.5	7920
	1.73	.305	38.4	7940
	1.61	.305	38.1	8010
	1.62	.305	38.0	8030
30,000 (226 mm Hg.)	1.64	.302	37.9	7960
60,000 (60 mm Hg.)	1.64	.305	37.9	8050
	1.63	.305	38.0	8020
90,000 (13 mm Hg.)	1.66	.307	37.9	8100
	1.62	.306	37.9	8070
	1.64	.305	37.9	8050

Altitude feet (mm Hg.)	Average Charge Density (gm/cc)	Measured Segment (meters)	Measured Time (microseconds)	Velocity of Detonation (meter/seconds)
RDX/TNT, - 70/30, confined in 1/4-inch-wall steel tubing, one-inch diameter columns (Cont'd)				
90,000 (13 mm Hg.)	1.63	.305	38.0	8020
	1.64	.305	37.9	8050
	1.63	.305	37.9	8050
RDX/TNT, - 70/30, confined in 1/4-inch-wall steel tubing, two-inch diameter columns				
Ground (760-764 mm Hg.)	1.70	.102	13.2	7730
	1.72	.102	13.1	7790
	1.72	.101	13.0	7770
	1.72	.102	13.9	7340
30,000 (226 mm Hg.)	1.72	.102	12.8	7970
	1.72	.102	12.6	8100
	1.72	.102	13.5	7560
	1.72	.102	12.8	7970
	1.72	.102	15.1	6750
60,000 (60 mm Hg.)	1.70	.102	12.6	8090
	1.74	.102	12.5	8160
	1.73	.102	12.6	8090
	1.72	.102	12.9	7910
	1.71	.102	13.1	7790
90,000 (13 mm Hg.)	1.71	.102	12.8	7970
	1.70	.102	12.6	8100
	1.67	.102	12.6	8100
	1.70	.102	13.0	7850
	1.70	.102	12.7	8030
MOX-2B, confined in 1/4-inch-wall steel tubing, two-inch diameter columns				
Ground (760-764 mm Hg.)	2.12	.103	22.3	4630
	2.12	.103	20.9	4940
	2.12	.102	22.1	4590
	2.12	.103	22.1	4660
	2.12	.103	21.4	4820
TNT, unconfined, in two-inch diameter columns				
Ground (760-764 mm Hg.)	1.74	.100	19.5	5130
	1.76	.102	19.9	5110

Altitude feet (mm Hg.)	Average Charge Density (gm/cc)	Measured Segment meters	Measured Time (microseconds)	Velocity of Detonation (meter/seconds)
TNT, unconfined, in two inch diameter colomns (Cont'd)				
Ground	1.78	.102	18.5	5500
(760-764 mm Hg.)	1.76	.100	19.3	5200
	1.73	.103	19.0	5430
TNT, confined in 1/4-inch-wall steel tubing, one-inch diameter columns				
Ground	1.56	.305	44.7	6820
(760-764 mm Hg.)	1.59	.305	45.5	6850
	1.61	.303	44.7	6780
	1.60	.304	44.7	6800
	1.62	.305	44.5	6850
	1.61	.305	44.4	6870
30,000	1.00	.305	46.9	6500
(226 mm Hg.)	1.01	.305	46.9	6500
	1.59	.305	45.4	6720
	1.53	.305	45.4	6720
60,000 (60 mm Hg.)	1.58	.305	44.8	6810
90,000	1.56	.305	44.8	6810
(13 mm Hg.)	1.59	.305	44.7	6820
	1.59	.305	44.7	6820
	1.58	.305	44.8	6810
	1.55	.305	44.8	6810
	1.64	.305	44.3	6880
	1.62	.305	41.5	7350
	1.57	.305	42.3	7210
TNT, confined in 1/4-inch-wall steel tubing, two-inch diameter columns				
Ground	1.57	.102	15.4	6620
(760-764 mm Hg.)	1.57	.103	15.2	6780
	1.61	.102	15.2	6710
	1.58	.102	15.2	6710
60,000	1.58	.102	15.8	6460
(60 mm Hg.)	1.59	.102	15.9	6420
	1.58	.102	15.6	6540
	1.58	.102	15.4	6620
	1.60	.102	15.5	6580

Altitude (feet) mm Hg.	Average Charge Density (gm/cc)	Measured Segment (meters)	Measured Time (microseconds)	Velocity of Detonation (meter/seconds)
TNT, confined in 1/4-inch-wall steel tubing, two-inch diameter columns (Cont'd)				
90,000	1.61	.102	15.6	6540
(13 mm Hg.)	1.60	.102	15.6	6540
	1.59	.102	15.6	6540
	1.58	.102	15.6	6540
	1.59	.102	15.6	6580

6.0 DISCUSSION OF RESULTS

6.1 National has estimated the experimental error to be ≠ 3%, maximum, due to three major sources of error:

(a) Non-uniform density in the charges

(b) Non-linear velocities over the measured segment

(c) Precision of measurement in both time and distance

6.2 Density variations within a single column are not readily detected. The test charges have been inspected by X-ray photography to eliminate any with major flaws.

6.3 Non-linear velocities of detonation occur where steady-state detonation reaction is not established. This is corrected by allowing ample "run-up" explosive column ahead of the segment to be measured. The weight limit and diameter requirements of the test charges determine the length of the charges and restrict the "run-up" column.

6.4 The error in measurement has been estimated to be less than 1%, maximum. Linear distance is accurate within one millimeter and time within one-tenth microsecond.

STUDY OF FRAGMENT VELOCITY AT SIMULATED ALTITUDE

7.0 OBJECTIVE

7.1 The object of this phase of the program is the investigation of the effect of altitude on the velocity fragments produced from steel cylinders by charges of the following explosives:

TNT
H-6
MOX-2B
70/30 - RDX/TNT
70/30 - HMX/TNT

The four altitudes under investigation are ground, 30,000, 60,000, and 90,000 feet.

8.0 Test Items

8.1 Steel cylinders of two configurations are used. Both sizes are fabricated from A1S1 1015 steel. One is 1" I.D. x 18" long with a 1/4" wall thickness. The other is 2" I.D. x 7" long with a 1/4" wall thickness.

9.0 TESTS

9.1 The major portion of the test program has been completed and velocities obtained on a 6-foot radial distance by counter-chronograph. Accuracy difficulties were encountered at the higher altitudes. Causes are being traced in order to obtain reliable data. Data obtained by the electrical method have been checked by high-speed photography and the two methods found to be compatible at ground level.

10.0 COMPUTATIONS

10.1 Theoretical velocities are being computed with known Guerney constants for ground level velocities for H-6, TNT, and MOX-2B. New values of Guerney constants of the 70/30 mixtures will be obtained by computation from observed velocities.

11.0 FUTURE WORK

The major part of this program has been completed. The entire program with the results of the remaining tests and fragment calculations will be reviewed and summarized in a final report.

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