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August 1970

**AEROSPACE
NUCLEAR
SAFETY**

PIONEER RTG HEAT SOURCE DROP TESTS

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PIONEER RTG HEAT SOURCE DROP TESTS

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Albuquerque, New Mexico

August 1970

Approved by:

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ABSTRACT

Eighteen simulated pioneer heat sources representing four different heat source shapes were drop-tested at Tonopah Test Range to obtain terminal velocity data and reduced trajectory data. A secondary objective was the acquisition of data related to impact crater and soil characteristics. Photographs of the samples before impact and reduced trajectory data are presented.

Key words: safety, aerospace, nuclear, reentry

The cutoff date for information
in this report is August 1970.

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SUMMARY

Eighteen simulated pioneer heat sources representing four different reentry ablation profiles were drop-tested at Tonopah Test Range. The primary objective of the tests was to obtain terminal velocities and reduced trajectory data for the different shapes. A secondary objective was to obtain data related to impact craters and soil characteristics at the impact points. All drops were made from a helicopter (UH-1F) at an altitude of approximately 15,000 ft MSL.

Free-fall flight was predominately in a tumbling-spinning mode. Average impact velocities, measured at 6,500 ft MSL, were 308 fps for the earth orbital side-on-stable reentry shape, 312 fps for the multi-orbit side-on-stable reentry shape, 405 fps for the superorbital side-on-spinning reentry shape, and 268 fps for the unablated sharp-cornered hexagonal shape. The specimens were impacted in the Yucca target area which is firm, dry, sandy soil impregnated with small rocks. Impact craters ranged from under 0.5 ft² and 5-inches deep to 1.5 ft² and 1-foot deep.

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PIONEER RTG HEAT SOURCE DROP TESTS

General

These drop tests were conducted for the mutual benefit of Sandia Laboratories and Isotopes, Inc. Sandia performed the tests and data reduction; Isotopes supplied the test specimens.

Test Objectives

The primary objective of the drop tests was to obtain the terminal velocities and reduced trajectory data for the four differently ablated Pioneer shapes. A secondary objective was to obtain photographic coverage of the impact craters, measurement of crater depths, and brief general information about soil conditions at the impact points.

Test Specimens

The drop test specimens consisted of four different reentry configurations: a typical earth orbit side-on-stable reentry shape (Figure 1), a typical multiple orbit side-on-stable reentry shape (Figure 2), a typical superorbital side-on-spinning reentry shape (Figure 3), and an unablated sharp-cornered hexagonal control shape (Figure 4). The specimens were made from graphite and lead; they were constructed to simulate the size, shape, weight, center-of-gravity, and moments of inertia of the actual heat source. The specimens are described in detail in Table I.

Test Details and Results

Test data were obtained by radar and movie camera. An MPS-25 C-band radar was used to gather the trajectory data, and a Mitchell camera was used to obtain documentary films and backup trajectory data. Two Contraves cameras were used as a second backup for trajectory data. Meteorological data were obtained by radiosonde for the test day; the data included atmospheric conditions up to and including the drop altitude.

All drops were made from a helicopter (UH-1F) at an altitude of 15,000 ft MSL at a forward speed of approximately 40 mph. The units were dropped onto the Yucca target at the Tonopah Test Range. A summary of the test results is presented in Table I. Appendix A contains computed meteorological data for the test. Complete trajectory data showing altitude, velocity, deceleration, dynamic pressure, and mach number as a function of time and drag coefficient as a function of mach number are presented in Appendix B.

Soil Penetration

The secondary objective of obtaining photographic coverage of the impact craters, measurement of the craters, and a general definition of the soil at the impact point was achieved. Results are presented in Table II. Generally the soil in this area is constituted of sand mixed with a little clay and small rocks.

TABLE I

Test Specimen Details and Test Results

<u>Test Unit No.</u>	<u>Reentry Configuration*</u>	<u>Weight (lbs)</u>	<u>Velocity (fps) (6500 ft MSL)</u>
1	Orbital decay, Side-on-Stable	10.398	297
2	Orbital decay, Side-on-Stable	10.422	292
3	Orbital decay, Side-on-Stable	10.273	313
4	Orbital decay, Side-on-Stable	10.219	298
5	Multi-orbit, Side-on-Stable	10.086	319
6	Multi-orbit, Side-on-Stable	9.969	295
7	Multi-orbit, Side-on-Stable	10.121	325
8	Multi-orbit, Side-on-Stable	10.156	305
9	Multi-orbit, Side-on-Stable	10.211	302
10	Multi-orbit, Side-on-Stable	10.086	323
11	Superorbit, Side-on-Spinning	9.973	407
12	Superorbit, Side-on-Spinning	9.965	405
13	Superorbit, Side-on-Spinning	10.188	403
14	Superorbit, Side-on-Spinning	9.957	401
15	Superorbit, Side-on-Spinning	10.109	412
16	Superorbit, Side-on-Spinning	9.898	402
17	Control	10.531	270
18	Control	10.391	265

*Reentry Configurations:

Orbital decay, Side-on-Stable--6.50 inches long, ablated 0.20 inch on one face of the hexagon with a 0.406-inch radius on all adjacent corners and edges (Figure 1).

Multi-orbit, Side-on-Stable--6.50 inches long, ablated 0.40 inch on one face of the hexagon with a 0.625-inch radius on all adjacent corners and edges (Figure 2).

Superorbit, Side-on-Spinning--6.50 inches long, ablated 0.050 inch on all sides of the hexagon with a 0.875-inch radius on all edges and corners (Figure 3).

Control--6.50 inches long, 3.50 inches across the flats, edges and corners sharp (Figure 4).

TABLE II

Soil Penetration Results

<u>Unit No.</u>	<u>Soil Hardness</u>	<u>Crater Cross Section (in.)</u>	<u>Crater Depth (in.)</u>
1	Hard	15 x 17	4
2	Firm	6 x 9	5.5
3	(Not recovered)	-	-
4	Medium	6.5 x 8	6
5	(Not recovered)	-	-
6	Soft	8 x 10	8
7	Firm	6 x 9	5
8	Soft	9 x 10	9.25
9	(Not recovered)	-	-
10	Soft	8 x 9	-
11	Soft	9 x 9	9
12	Soft	10 x 12	10
13	Soft	4 x 4	12
14	Soft	6.25 x 9	8
15	Firm	8 x 9	8.5
16	Firm	8 x 12	5
17	Hard	9 x 10	3
18	(Not recovered)	-	-

Figure 1. Earth orbit side-on-stable
reentry shape

Figure 2. Multiple orbit side-on-stable
reentry shape

Figure 3. Superorbital side-on-spinning reentry shape

Figure 4. Unablated sharp-cornered hexagonal control shape

APPENDIX A

Computed Meteorological Data

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APPENDIX A

COMPUTED METEOROLOGICAL DATA							PAGE 1
TEST 418012	SITE 22	DATE 032070	RUN 1	RADIOSONDE LAUNCHED 1534 MST			
PSL ALT FEET	PRESS IN HG	TEMP DEG F	SOUND FT/SEC	DENSITY LB/CU FT	XWIND FT/SEC	YWIND FT/SEC	ALT DIF FEET
5331	24.752	54.0	1111.6	0.06382	16.9	0.0	-175
5875	24.254	47.8	1104.9	0.06332	18.6	-1.2	-188
6404	23.794	44.5	1101.3	0.06250	20.3	-2.5	-197
6886	23.371	41.4	1097.9	0.06177	16.4	-3.9	-205
7438	22.893	38.5	1094.7	0.06066	11.2	-7.4	-212
7856	22.502	36.0	1091.6	0.06014	12.3	-8.0	-217
8254	22.166	33.9	1089.6	0.05948	9.3	-8.1	-221
8638	21.876	32.3	1087.8	0.05891	4.2	-10.3	-224
8983	21.609	30.9	1086.3	0.05835	4.3	-10.9	-226
9315	21.321	30.1	1085.3	0.05767	5.9	-9.7	-229
9643	21.043	28.8	1083.9	0.05712	2.1	-12.8	-232
9947	20.811	27.4	1082.4	0.05661	-0.4	-14.0	-234
10254	20.559	25.6	1080.5	0.05611	0.8	-12.0	-237
10555	20.298	24.2	1078.7	0.05558	2.4	-15.7	-239
10939	20.029	23.1	1077.4	0.05497	5.1	-17.9	-241
11254	19.756	22.0	1076.2	0.05434	8.0	-25.2	-243
11667	19.472	21.1	1075.2	0.05364	11.3	-30.5	-245
12065	19.172	20.7	1074.6	0.05288	8.9	-32.9	-248
12460	18.880	20.3	1074.4	0.05211	2.6	-37.2	-252
12822	18.615	19.3	1073.1	0.05150	3.9	-42.6	-257
13182	18.369	17.8	1071.5	0.05098	7.1	-43.3	-261
13526	18.108	15.9	1069.4	0.05045	8.9	-40.8	-264
13857	17.846	14.2	1067.5	0.04990	13.2	-40.7	-268
14288	17.572	12.8	1065.8	0.04929	13.4	-40.3	-272
14643	17.327	11.4	1064.2	0.04874	11.3	-40.8	-275
14967	17.105	10.1	1062.7	0.04825	13.0	-40.5	-277
15287	16.885	8.8	1061.3	0.04777	14.8	-44.2	-280
15670	16.632	7.5	1059.7	0.04716	12.6	-53.8	-283
16052	16.379	6.2	1058.3	0.04659	25.9	-60.1	-286
16486	16.096	4.4	1056.3	0.04596	31.4	-54.0	-290
16821	15.800	3.5	1055.2	0.04543	17.2	-56.4	-293
17119	15.690	2.6	1054.4	0.04497	14.1	-52.7	-295
17430	15.493	1.2	1052.6	0.04455	19.4	-51.9	-298
17741	15.299	0.1	1051.3	0.04410	21.4	-52.9	-300
18065	15.099	-0.9	1050.1	0.04362	17.7	-51.7	-303
18410	14.888	-1.7	1049.3	0.04308	17.9	-48.1	-306
18743	14.687	-1.3	1049.7	0.04247	21.6	-46.8	-310
19098	14.476	-2.1	1048.8	0.04193	21.3	-43.8	-314
19462	14.262	-3.4	1047.2	0.04143	21.5	-44.0	-319
19835	14.045	-5.2	1045.2	0.04096	27.0	-49.5	-324
20216	13.826	-7.1	1042.9	0.04050	30.5	-47.2	-329
20549	13.637	-8.8	1041.0	0.04009	29.4	-40.1	-332
20866	13.458	-10.6	1038.9	0.03973	31.8	-36.0	-335
21211	13.266	-12.5	1036.6	0.03933	31.8	-35.0	-338

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APPENDIX B

Reduced Trajectory Data

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DYNAMIC PRESSURE VS TIME

CDRAD 1

TEST 418012 01 DATE 032070 SITE YTR
CARRIER MP8 25 DATA

NACH NUMBER VS TIME

CORAD 1

TEST 418012 01 DATE 032070 SITE TTR
CARRIER MP8 25 DATA

CDS VS MACH NUMBER

CDRAD 1

TEST 418012 01 DATE 032070 SITE TTR
CARRIER MPS 25 DATA

CROSS SECTIONAL AREA OF 0.164 SQUARE FEET WAS USED TO COMPUTE CDS

DYNAMIC PRESSURE VS TIME

CORAD 1

TEST 418012 02 DATE 032070 SITE YTR
CARRIER MPS 25 DATA

CDS VS MACH NUMBER

CDRAD 1

TEST 418012 02 DATE 032070 SITE YTR
CARRIER MP8 25 DATA

CROSS SECTIONAL AREA OF 0.164 SQUARE FEET WAS USED TO COMPUTE CDS

DYNAMIC PRESSURE VS TIME

CORAD 1

TEST 418012 03 DATE 032070 SITE TTR
CARRIER MP8 25 DATA

CDS VS MACH NUMBER

CDRAD 1

TEST 410012 03 DATE 032070 SITE YTR
CARRIER MPS 25 DATA

CROSS SECTIONAL AREA OF 0.164 SQUARE FEET WAS USED TO COMPUTE CDS

VELOCITY VS TIME

CDRAD 1

TEST 418012 04 DATE 032070 SITE TTR
CARRIER MP8 25 DATA

DYNAMIC PRESSURE VS TIME

CORAD 1

TEST 418012 04 DATE 032070 SITE TTR
CARRIER WPS 25 DATA

MACH NUMBER VS TIME

CDRAD 1

TEST 418012 04 DATE 032070 SITE YTR
CARRIER MP8 25 DATA

CDS VS MACH NUMBER

CORAD 1

TEST 418012 04 DATE 032070 SITE YTR
CARRIER MP8 25 DATA

CROSS SECTIONAL AREA OF 0.164 SQUARE FEET WAS USED TO COMPUTE CDS

DYNAMIC PRESSURE VS TIME

CDRAD 1

TEST 418012 05 DATE 032070 SITE TTR
CARRIER MPS 25 DATA

MACH NUMBER VS TIME

CDRAD 1

TEST 418012 03 DATE 032070 SITE YTR
CARRIER MPS 25 DATA

CDS VS MACH NUMBER

CORAD 1

TEST 410012 DS DATE 032070 SITE TTR
CARRIER HP8 25 DATA

CROSS SECTIONAL AREA OF 0.164 SQUARE FEET WAS USED TO COMPUTE CDS

DECELERATION VS TIME

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TEST 418012 06 DATE 032070 SITE YTR
CARRIER MPB 25 DATA

DYNAMIC PRESSURE VS TIME

CDRAD 1

TEST 418012 06 DATE 032070 SITE YTR
CARRIER MPB 25 DATA

CDS VS MACH NUMBER

CDRAD 1

TEST 418012 06 DATE 032070 SITE TTR
CARRIER MPS 25 DATA

CROSS SECTIONAL AREA OF 0.164 SQUARE FEET WAS USED TO COMPUTE CDS

DECELERATION VS TIME

CONRAD 1

TEST 418012 07 DATE 032070 SITE YTR
CARRIER MPS 25 DATA

DYNAMIC PRESSURE VS TIME

CDRAD 1

TEST 418012 07 DATE 032070 SITE TTR
CARRIER MP8 25 DATA

CDS VS MACH NUMBER

CDRAD 1

TEST 418012 07 DATE 032070 SITE TTR
CARRIER MP8 25 DATA

CROSS SECTIONAL AREA OF 0.164 SQUARE FEET WAS USED TO COMPUTE CDS

DYNAMIC PRESSURE VS TIME

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TEST 418012 08 DATE 032070 SITE YTR
CARRIER MPS 25 DATA

MACH NUMBER VS TIME

CDRAD 1

TEST 418012 08 DATE 032070 SITE TTR
CARRIER MPS 25 DATA

CDS VS MACH NUMBER

CONRAD 1

TEST 410012 00 DATE 032070 SITE TTR
CARRIER MPB 25 DATA

CROSS SECTIONAL AREA OF 0.164 SQUARE FEET WAS USED TO COMPUTE CDS

VELOCITY VS TIME

CDRAD 1

TEST 418012 09 DATE 032070 SITE YTR
CARRIER MP8 25 DATA

DYNAMIC PRESSURE VS TIME

CONRAD 1

TEST 418012 09 DATE 032070 SITE YTR
CARRIER NPS 25 DATA

MACH NUMBER VS TIME

CDRAD 1

TEST 418012 09 DATE 032070 SITE YTR
CARRIER MPS 25 DATA

DYNAMIC PRESSURE VS TIME

CORAD 1

TEST 418012 10 DATE 032070 SITE TTR
CARRIER MPS 25 DATA

CDS VS MACH NUMBER

CORAD 1

TEST 418012 10 DATE 032070 SITE YTR
CARRIER NPS 25 DATA

CROSS SECTIONAL AREA OF 0.164 SQUARE FEET WAS USED TO COMPUTE CDS

DECELERATION VS TIME

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TEST 418012 11 DATE 032070 SITE TYR
CARRIER MPS 25 DATA

DYNAMIC PRESSURE VS TIME

CORAD 1

TEST 410012 11 DATE 032070 SITE YTR
CARRIER MPS 25 DATA

CDS VS MACH NUMBER

TEST 418012 12 DATE 032070 SITE YTR
CARRIER MPS 25 DATA

CROSS SECTIONAL AREA OF 0.164 SQUARE FEET WAS USED TO COMPUTE CDS

CDS VS MACH NUMBER

CDRAD 1

TEST 418012 14 DATE 032070 SITE TTR
CARRIER MPS 25 DATA

CROSS SECTIONAL AREA OF 0.164 SQUARE FEET WAS USED TO COMPUTE CDS

CDS VS MACH NUMBER

TEST 418012 15 DATE 032070 SITE TTR
CARRIER MPS 25 DATA

CROSS SECTIONAL AREA OF 0.164 SQUARE FEET WAS USED TO COMPUTE CDS

MACH NUMBER VS TIME

CDRAD 3

TEST 418012 15 DATE 032070 SITE TTR
CARRIER MFS 25 DATA

VELOCITY VS TIME

CDRAD 3

TEST 418012 15 DATE 032070 SITE TTR
CARRIER MPS 25 DATA

CDS VS MACH NUMBER

CDRAD 1

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TEST 418012 16 DATE 032070 SITE TTR
CARRIER MPS 25 DATA

CROSS SECTIONAL AREA OF 0.164 SQUARE FEET WAS USED TO COMPUTE CDS

DYNAMIC PRESSURE VS TIME

CORAD 1

TEST 418012 18 DATE 032070 SITE TYR
CARRIER MP8 25 DATA

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