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SNAP RADIOISOTOPE SPACE PROGRAMS
QUARTERLY PROGRESS REPORT NO. 9

TASK 7

October 1 through December 31, 1961

MND-P-3017-I

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FOREWORD

This quarterly report has been prepared to describe the progress of the radioisotope safety programs conducted by the Martin Marietta Corporation Nuclear Division. It covers the work performed on Task 7 from October 1 through December 31, 1961, under Contract AT(30-3)-217 with the U. S. Atomic Energy Commission.

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SUMMARY

SUBTASK 7.1--SAFETY STUDY OF A TYPICAL CAPE CANAVERAL LAUNCH

A preliminary safety analysis report (MND-P-2612) on the Surveyor generator was submitted during the reporting period. This submittal terminates the effort under this subtask.

SUBTASK 7.3--UPPER ATMOSPHERE EXPERIMENTAL RE-ENTRY STUDY

All Phase I and Phase II testing was completed. Both launches of Phase I were successful, neither Phase II launches were successful. Test data recovered on Phase I launchings included optical coverage of re-entry and the trajectory and weather data; no telemetry canister temperature data were obtained. No test data were obtained on Phase II experiments.

Reduction of Phase I test data was begun at Air Force Special Weapons Center (AFSWC). The Phase II (Sub-subtask 7.3.2) was terminated December 20, 1961, when no test data were recovered for comparison with the analytically predicted results.

The Sub-subtask 7.3.3 program (Generator Re-entry Burnup Study) was completed and terminated December 29, 1961. The study objectives were met.

The Sub-subtask 7.3.4 program (High Altitude Sampling) was terminated when it was completed November 30, 1961. All study objectives were met.

Topical reports were prepared on Sub-subtasks 7.3.1, 7.3.2, 7.3.3 and 7.3.4 in December 1961. They will be published and distributed in February 1962. This quarterly contains information on the work performed in the reporting period that was not included in the topical reports in compliance with the statement of work. It is the work that pertains specifically to test results.

SUBTASK 7.4--RADIOISOTOPE SHIELDING CODE

Checkout and troubleshooting operations on the last two subroutines and main code were completed. Results from several runs of a simple check problem compared well with published data.

I. SUBTASK 7.1--SAFETY STUDY OF TYPICAL CAPE CANAVERAL LAUNCH *

A. OBJECTIVES

The objectives of the safety study conducted during the quarter discussed in this report were:

- (1) To analyze the launch of Surveyor generator units on the Atlantic Missile Range (AMR) as to launch ascent and intermediate or final stage failure.
- (2) To define the following factors for each type of failure.
 - (a) Altitude, velocity and range.
 - (b) Forces imposed on the generator as a result of the conditions determined under Item (a).
 - (c) Final disposition of the isotope as a result of the forces determined under Item (b).

B. SCOPE AND EVALUATION

Efforts under this subtask were successfully concluded during the reporting period with the submittal of a preliminary safety analysis report (Ref. 1).

Plans were formulated for the test phase of this program in support of the Surveyor Program.

*R. J. Wilson

II. SUBTASK 7.3--UPPER ATMOSPHERE EXPERIMENTAL RE-ENTRY STUDY*

The Sub-subtask 7.3.2, 7.3.3 and 7.3.4 programs were completed and terminated this quarter. Sub-subtask 7.3.2, Fuel Core Ablation, was terminated on December 20, 1961, when, as a result of launch vehicle failure, no test data were recovered for analysis. Sub-subtask 7.3.3, Generator Burnup, was terminated when engineering and analysis of re-entry testing of isotopic and reactor mockup generators were completed December 29, 1961. Sub-subtask 7.3.4, High Altitude Sampling, was terminated as complete on November 30, 1961, when study objectives requiring definition of feasible experimental programs to determine the particle size of re-entry burnup residue and its ultimate fate were met.

The work completed on these studies is not reported here, but rather in topical reports which are nearing completion. They will be distributed in February 1962.

Only the work performed in this period that pertains to Phase I and Phase II testing, exempted by the statement of work (Ref. 2) from inclusion in the topical reports, is reported in this Quarterly. It is presented under the following subtitles:

- (1) Sub-subtask 7.3.1--Fuel Core Heating Re-entry Tests.
- (2) Sub-subtask 7.3.2--Fuel Core Ablation Re-entry Tests.
- (3) Sub-subtask 7.3.5--Project Direction and Reporting.

A. SUB-SUBTASK 7.3.1--FUEL CORE HEATING

1. Objectives

The objective of this portion of the program is to determine the heating phenomena experienced by cores during re-entry into the earth's atmosphere following an ICBM trajectory. Specific detailed objectives are as follows:

- (1) To determine the heating rate to which a fuel core of known drag factor will be subjected when placed in an Atlas ballistic trajectory. The drag factor used in this case will be representative of the re-entry samples to be used in SNAP cores.

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- (2) To investigate suitable dye markers or flare materials to be used in these cores.
- (3) To design and manufacture burnable fuel cores with four different ballistic coefficients.
- (4) To design and manufacture cores having identical aerodynamic parameters to those in Item (3), but having larger actual dimensions. The cores used in this case will be fitted with transmitters (supplied by Air Force Special Weapons Center (AFSWC)) which will sense the wall temperature of the re-entry sample and transmit the information back to ground receiving stations. Martin Marietta will provide the recorder/reproducers.
- (5) To coordinate the core designs with AFSWC for incorporation in their core ejection mechanism.
- (6) To determine, using an IBM 7090 code, the exact position and altitude at which the cores will burn up.
- (7) To compare analytical and experimental results.
- (8) To revise the IBM 7090 heating code and redetermine the altitude and position of core burnup.

2. Phase I Testing

This testing was to determine experimentally the influence of fuel capsule aerodynamic configurations on the re-entry heating rate. A total of 32 test specimens per launch was used, eight each of four different length-to-diameter ratios. During two launches, an instrumented telemetry canister accompanied the test specimens to obtain time-temperature history.

All test articles excepting the telemetry canisters were ready for test at the beginning of this quarter. Analysis of telemetry data received on the 100-pound pod test conducted by the Air Force Special Weapons Center indicated that the telemetry system could have failed to operate throughout the entire re-entry because the antenna did not withstand the re-entry heat pulse. To avoid repeating this on Phase I and II tests, a design change was made. The AVCO Corporation was retained by Galton Industries, supplier of the antenna, to apply a protective ablative coating to the ceramic antenna covers at both ends of the canisters. The modified canisters were ready for Phase I testing in early November.

a. Test 1

A fit check of the test specimens and telemetry canister to the ejection mechanism was carried out one week prior to firing. A Martin Marietta representative provided technical support at Cape Canaveral. Four days prior to firing, the FACT test was carried out. This proved the compatibility of the squib-operated devices with the missile RF radiation environment. Fitting of the ejection device to the scientific pod took place two days prior to firing; some of the wooden positioning devices had to be reworked because of dimensional changes that occurred in the humid Florida weather. On firing day, the scientific pod was attached to the missile. During the installation, a mismatch of electrical connectors was discovered and corrected. A successful launch took place November 22, 1961.

Technical support was provided downrange at Ascension Island by a Martin Marietta representative. The personnel responsible for recovering test data were briefed in such specifics as camera train and elevation angles, aircraft position requirements, assignments of precedence in radar coverage to specific radars and the manner and frequency of recording aircraft position fixes.

The test specimens re-entered at the precise time, elevation and azimuth from the various optical data collection stations as predicted by Martin Marietta. Four aircraft obtained photographic data. Three were positioned generally northeast of the re-entry zone while the fourth was 90 degrees to them and looking uprange. AVCO Everett Corporation personnel operated cameras on two aircraft, Barnes Engineering Corporation on a third and AFSWC personnel on a fourth. The AFSWC aircraft was the most completely instrumented and had the preferred viewing position and prime radar coverage. Photographic coverage also was obtained from two land sites at Ascension Island, one instrumented by AMR, the other by AFSWC. Viewing conditions were perfect from the ground (no cloud cover) and both stations obtained good data.

Visual observation from all stations reported that the test specimens did burn at the approximate altitudes previously predicted analytically. AFSWC, AVCO Everett and Barnes Engineering are presently reducing their respective photographic data to more precisely pinpoint the burnup altitudes. Photographic plates which recorded a chopped light streak of the re-entry are being used to establish the test specimen velocities during burnup. The Barnes cinespectrometer camera that was to have recorded spectral data to positively identify the characteristic sodium, cesium, rubidium and potassium flare materials of the test specimens obtained data on only the sodium flare and the lead-silver test specimens. It was hoped that the Barnes-operated photometer would record the time of test specimen penetration (flare material release). This instrument

failed to obtain satisfactory data because of the narrow field of view (two to four degrees) of the instrument. It is believed, however, sufficient redundancy in other photographic coverage was obtained to fulfill test objectives.

The telemetry canister system did not operate so the time-temperature history of the re-entry was not obtained. The cause of the failure was not determined.

The radar which was to have provided trajectory data on re-entry failed to operate. The trajectory data used in data reduction will be extrapolated from radar coverage obtained in midcourse flight and from ballistic camera data obtained in the vicinity of the nose cone impact. These data are only slightly less reliable than that which would have been obtained had the radar in the impact area operated.

b. Test 2

A thorough check of the telemetry canister ejection system used in Test 2 did not reveal the reason the identical system in Test 1 failed. However, it was not possible to check the internal electronics of the telemetry canister because access to this equipment was prevented by the AVCO ablative coating protecting the antennas. This equipment was last checked at AFSWC approximately one month prior to firing.

A successful launch took place December 1, 1961; it was intended to measure the repeatability of experimental results obtained on Test 1. Essentially the identical coverage was obtained photographically. The radar did obtain re-entry trajectory data; however, the telemetry canister again failed to operate. Reduction of scientific pod telemetry (different from canister telemetry) indicated that the telemetry canister may have been ejected at liftoff plus 40 seconds. This is approximately 1700 seconds early. The signal indicating this is believed to have been false. However, events which would have caused such a signal would also have prevented operation of the canister in the terminal phase of the test flight.

Test data obtained are presently being reduced; no measure of repeatability excepting that obtained visually is available yet. Test specimens were observed to burn up at approximately the same altitude as in Test 1.

To date, no reduced experimental data have been received from AFSWC by Martin Marietta Corporation for correlation with analytically predicted results or improvement of analytic techniques.

B. SUB-SUBTASK 7.3.2--FUEL CORE ABLATION

1. Objectives

This portion of the program is to determine analytically, and verify experimentally, the ablation effects experienced by simulated fuel cores of nuclear auxiliary power systems during re-entry into the earth's atmosphere. In the analytical procedure used to determine the burnup of SNAP fuel cores, a mathematical model which divides the core into a series of concentric shells has been constructed. This experimental re-entry study is devoted to the verification of the accuracy of this model. Specific objectives are:

- (1) To design and manufacture four fuel cores having the same external dimensions but different wall thicknesses. All cores will be designed to burn up on the basis of an ICBM trajectory.
- (2) To design and manufacture a similar core in which a transmitter is placed. This transmitter will be coupled to a temperature sensing device and will indicate the wall temperature as a function of time during the re-entry of the core into the earth's atmosphere. The AFSWC will supply the sensing device and transmitter, and Martin Marietta will provide recorder/reproducers.
- (3) To coordinate with AFSWC on the design of their ejection system to accommodate these core configurations.
- (4) To determine analytically the exact position and altitude of burnup through the use of the IBM 7090 ablation rate code.
- (5) To compare analytical and experimental results.
- (6) The concentric shell ablation code will be revised according to the experimental results, such that it corresponds with actual observed values of core burnup.

2. Phase II Testing

This testing was to provide experimentally information pertaining to ablation rates. A total of 28 capsules per launch were used, seven each of four different wall thicknesses but all of identical external dimensions. A telemetry canister instrumented to obtain the time-temperature history of re-entry accompanied test specimens on each of two launches.

All test articles were ready for test in early December. When the telemetry canister failed to operate on the second shot of Phase I, additional checking to determine the cause was undertaken. The ablative

coating techniques used on the antenna were revised to permit a final checkout of internal electronics at the launch site. These tests did not reveal the cause of the telemetry failure. However, further analysis to determine what caused the early canister eject signal on the second Phase I launch proved fruitful. This signal is a positive indication of the breaking of the electrical connection between the scientific test pod and the canister. It is through this connection that the pod programmer signals start of transmitter and recorder operation. It was discovered that this electrical connection was partially disengaged when the telemetry canister was installed in the ejection mechanism. Launch vibrations could easily cause disengagement of this electrical connector. Under this condition, the transmitter and recorder/reproducer would never receive a signal to begin operation. The situation was corrected by redesigning retractable fingers in the ejection mechanism so the canister is firmly positioned, thus preventing inadvertent open circuiting of the plug by launch vibrations.

a. Tests 1 and 2

Phase II Test Shot 1 occurred December 12, 1961, and Shot Number 2 occurred December 20, 1961. The launch vehicle failed to provide the intended trajectory in each instance. Test specimens re-entered 500 and 3000 miles short of the prescribed test area; neither telemetry nor photographic test data were obtained.

It was not learned if the fix to the telemetry canister system had proved adequate. No early eject signal was received so this condition was relieved; however, re-entry occurred on both flights before programmed eject and operation could occur.

All work on Phase II was terminated December 20, 1961.

C. SUB-SUBTASK 7.3.5--PROJECT DIRECTION AND REPORTING

1. Objectives

The effort required to administer the total Subtask 7.3 is included in this sub-subtask. Specifically, the following work is to be accomplished:

- (1) A literature search of high altitude flare materials.
- (2) Project direction of the analytical, design, manufacturing (when applicable) and report phases of Sub-subtasks 7.3.1, 7.3.2, 7.3.3 and 7.3.4.

- (3) Technical liaison and coordination with the various Government agencies involved in this program; specifically, the agencies to be contacted are NASA, AFSWC, Headquarters ARDC, Convair, AFEMD, AMR and AEC.
- (4) All reports prepared in the execution of the Subtask 7.3 program will be charged to this sub-subtask.

2. Status of Work

Reporting in this quarter has included monthly letters (Refs. 3, 4 and 5) and a quarterly report (Ref. 6).

Technical support was provided at AMR for all four launches and downrange for the first of the series. A sufficient understanding of the test objectives and methods of data acquisition was achieved by downrange personnel to make followup downrange trips on Tests 2, 3 and 4 unnecessary.

As noted previously, topical reports on Sub-subtasks 7.3.1 and 7.3.4 have been prepared.

Documentary films are being prepared; Martin Marietta film exposed downrange by AFSWC personnel has not been received for editing and use.

Coordination and liaison work with various agencies involved in the program has been initiated to determine possible additional action required to successfully complete Sub-subtask 7.3.2, Phase II testing.

III. SUBTASK 7.4--RADIOISOTOPE SHIELDING CODE*

A. OBJECTIVES

The objectives of this program are:

- (1) To develop a machine calculation code using the Monte Carlo technique to:
 - (a) Determine the gamma flux in photons/cm²-sec or dose rates in mr/hr for a given shield configuration.
 - (b) Determine through an iterative process the shielding necessary to reduce radiation dosage to any selected value (between the range of maximum emission and one photon/cm²-sec) when measured at any selected distance from 2.5 centimeters to 30 meters from the external surface of the shield.
- (2) Utilize the code to calculate the dose rate of one fueled generator for comparison with actual measurements.

B. SCOPE AND EVALUATION

Checkout of the last two subroutines, COORDA and COORDX, was completed successfully. First attempts to run the overall program using the main code were unsuccessful. Trouble shooting operations uncovered malfunction causes ranging from duplication of storage points in the machine to simple errors in signs. Unfortunately, many errors of this type are not detectable until the subroutines are used in combination as directed by the main code. Malfunctions of this type are unavoidable in a calculation program of this complexity. After many correction iterations, successful operation was achieved. A simple check problem was devised to determine the number of particles that must be followed to obtain consistent results. In this problem, a point source of 3 mev gammas in an infinite homogeneous iron medium was assumed. Samples of photon distribution and dose rate were taken at five locations. Code results in which 3000 particle histories were followed compared well with calculated values using the moments method (Ref. 7).

Some revision of the generator input data was required due to code corrections since its preparation. These data are currently being used

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as an input for final code verification. Results will be analyzed and incorporated in a final report currently being prepared.

IV. REFERENCES

1. "Preliminary Safety Analysis of the Surveyor Generator--Subtask 7.1," MND-P-2612, The Martin Company, September 1961, Secret Defense Information.
2. "Statement of Work for Study of Upper Atmosphere Re-entry of Nuclear Devices, Ref. 3," MN-SW-1007, The Martin Company, Nuclear Division, Baltimore 3, Maryland, September 19, 1961.
3. "Task 7--Radiological Safety Studies for Space Power, Monthly Progress Letter No. 10," MND-P-2472-10, The Martin Company, October 1961.
4. "Task 7--Radiological Safety Studies for Space Power, Monthly Progress Letter No. 11," MND-P-2472-11, The Martin Company, November 1961.
5. "Task 7--Radiological Safety Studies for Space Power, Monthly Progress Letter No. 12," MND-P-2472-12, The Martin Company, December 1961.
6. "SNAP Radioisotope Space Programs, Quarterly Progress Report No. 8," MND-P-3016-I, The Martin Company, September 30, 1961.
7. "Calculations of the Penetration of Gamma Rays," USAEC Report, NYO-3075, June 1954.