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SNAP RADIOISOTOPE SPACE PROGRAMS
QUARTERLY PROGRESS REPORT NO. 8

TASK 7

July 1 through September 30, 1961

MND-P-3016-I

Approved by
Douglas G. Harvey

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FOREWORD

This quarterly report has been prepared to describe the progress of the radioisotope safety programs conducted by the Martin Company. It covers the work on Task 7 performed from July 1 through September 30, 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

An informal technical report summarizing the results of a preliminary generator design study was submitted. A preliminary report of the safety analysis of the Surveyor Program generator is in the final phases of preparation for submittal.

SUBTASK 7.2--STUDY OF LUNAR IMPACT OF A RADIO- ISOTOPE-FUELED THERMOELECTRIC GENERATOR

Efforts under this subtask were terminated upon submittal of a final report early in the reporting period.

SUBTASK 7.3--UPPER ATMOSPHERE EXPERIMENTAL RE-ENTRY STUDY

Flare and telemetry test capsules have been completed for two of the four re-entry tests which are currently scheduled for November and December of this year. Of the 92 flare capsules and 2 telemetry capsules delivered to AMR, 32 flare capsules and a telemetry capsule will be loaded into Passenger Pod No. 22. The AEC pods, Nos. 22, 23, 24 and 25, will be carried aloft by Atlas missiles.

The altitude of re-entry burnthrough for all Phase I and II test capsules and nose cone-vehicle-pod relative position data has been determined. Using these data, Martin determined the optimum positions and headings for the optical and optical-telemetry aircraft (2-C54). The test capsule dispersion data will also be used as an acquisition aid downrange for Ascension Island and DAMP ship optical, radar and telemetry equipments.

Coordination of the Phase III program has continued between AEC, Atomics International (AI) and the Martin Company. Reactor reflector and fuel rod separation test requirements and drawings are expected from AI during the next period.

An AFSWC 100-pound test pod was shot into space on July 31, 1961 via an Atlas missile. Three simulated SNAP fuel cores were ejected from that pod. Two of these were flare capsules, containing sodium and potassium, and one was a telemetry capsule containing a transmitter only. Preliminary information received from Ascension Island indicated that the flares were sighted and the telemetry signal was received. Later comments from AFSWC indicated that the telemetry signal strength was erratic due to assumed equipment (antenna and voltage control oscillator) difficulties; however, final reported data are still forthcoming from AFSWC and AVCO.

Calibration data have been obtained on telemetry canister wiring and thermistors for use in reducing telemetered data.

The high altitude sampling diffusion and dispersion study effort was concluded with the writing of equations which account for cloud growth due to turbulence, translational motion due to the mean wind and vertical motion due to gravitational force. Equations are presented for particulate concentration at a point as a function of time and for time of maximum concentration at any given point.

Results of the numerical program for predicting fuel particle size as a function of initial size, re-entry velocity and altitude are presented.

SUBTASK 7.4--RADIOISOTOPE SHIELDING CODE

Routine coding, assembly and checkout operations were continued and all subroutines except two are checked out. Dose rates of the Strontium-90 fueled weather station generator were obtained by a survey prior to shipment of the unit.

I. INTRODUCTION

This Task 7 quarterly progress report is specifically devoted to the safety evaluation of isotopic power systems in space applications. Task 7 is a continuing program and deals with radioisotope flight safety analyses and tests currently under contract.

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

A. OBJECTIVES

The objectives of this safety study 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 failures.
- (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

A design study to better define generator configuration and performance beyond that data developed through an earlier conceptual study was completed. An informal technical report summarizing the design details was submitted (Ref. 1).

A preliminary safety analysis of the Surveyor generator was completed. Criteria defining acceptability from a safety standpoint, are satisfied during the ascent-to-orbit phase by the initial generator configuration. Guidance failures of the Centaur stage could result in land release on the more southerly launch azimuths. To avoid this, it is recommended that an active destruct system be incorporated in the Centaur and the launch azimuth range be restricted to 90 to 96 degrees. The consequences of vehicle guidance failure during injection into the lunar transfer trajectory cannot be defined beyond the limiting conditions at this time. A more extensive study of the trajectory, vehicle control system characteristics and statistical analysis of failure will be conducted under the Surveyor program currently proposed to the AEC.

*R. J. Wilson

With the revised generator configuration, more accurate data on oxidation and penetration rates of the shield material are required to determine safety criteria compliance. An alternate approach would be to segment the shield material and restrain it during normal operations by bands or connectors made of material with a lower melting point. With this arrangement, partial or complete burnup areas would conform to those defined for the initial configuration.

A report on this is being prepared for submittal during the next reporting period (Ref. 2).

III. SUBTASK 7.2--STUDY OF LUNAR IMPACT OF A RADIO-ISOTOPE-FUELED THERMOELECTRIC GENERATOR*

A. OBJECTIVES

The objectives for Subtask 7.2 were:

- (1) To conduct a literature search to aid in defining the lunar surface and environment.
- (2) To determine the results of impacting a generator similar to that proposed for the Surveyor program at velocities of 500 and 9000 fps normal to the lunar surface.
- (3) To determine the consequences of fuel capsule rupture and radioactive material release following high velocity impact on the moon's surface.
- (4) To outline a test program to verify the analytical results determined under Items (2) and (3) and evaluate the facilities available for conducting such a test program.

B. SCOPE AND EVALUATION

Efforts under this subtask were successfully concluded early in the reporting period. A final informal topical report was submitted (Ref. 3).

Plans are being formulated for continuing this program into the test phase in support of the Surveyor program.

*R. J. Wilson

IV. SUBTASK 7.3--UPPER ATMOSPHERE EXPERIMENTAL RE-ENTRY STUDY

Progress on Subtask 7.3 is presented in the following sections under sub-subtask designations as follows:

- (1) Fuel core heating and ablation (7.3.1 and 7.3.2, Phases I and II).
- (2) Generator burnup (7.3.3, Phase III).
- (3) High altitude sampling (7.3.4).
- (4) Project direction and reporting (7.3.5).

A. SUB-SUBTASKS 7.3.1 AND 7.3.2--FUEL CORE HEATING AND ABLATION

1. Sub-Subtask 7.3.1--Fuel Core Heating 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.
- (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 AFSWC) which will sense the wall temperature of the re-entry sample and transmit the information back to ground receiving stations. Martin will provide 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. Sub-Subtask 7.3.2--Fuel Core Ablation 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 Air Force Special Weapons Center (AFSWC) will supply the sensing device and transmitter, and Martin 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.

In accordance with the test plan issued by the coordinating agency, AFSWC, Martin responsibilities with respect to the study include:

- (1) Design of the experiment.
- (2) Determination of initial data requirements.
- (3) Design of test capsules.
- (4) Fabrication and delivery of test packages.
- (5) Provision of ejection requirements to AFSWC.
- (6) Analysis and interpretation of data.
- (7) Provision of technical support to the Atlantic Missile Range during launch.

3. Design of Experiment

a. Delivery status

In August, 64 Phase I and 28 Phase II flare capsules were delivered to the Solid Propellant Storage Area No. 2 at Cape Canaveral. A Martin Nuclear representative observed the uncrating, handling and storage of that shipment. Flare capsules typical of those shipped to the Cape are shown in Fig. 1.

Two recorders, produced by Consolidated Electrodynamics Corporation (CEC), successfully passed the environmental tests which were conducted by AFSWC at Kirtland Air Force Base (KAFB), New Mexico. These recorders, coupled to AFSWC transmitter system packages, were installed by AFSWC into Martin canisters to make the first two telemetry capsules which are now ready for re-entry testing.

A summary of the delivery status for flare capsules, telemetry canisters and recorders is shown in Table 1.

Spheroid Capsules, Na loaded--one set
required per launch

Cylindrical Capsules, Cs, K, and Rb loaded--three sets
required per launch

Fig. 1. Phase I Capsule Loadings

TABLE 1
Delivery Status

<u>Flare Capsules</u>		<u>Shipping Dates to AMR</u>
Phase I--64 capsules		8-18-61 (completed)
Phase II--28 capsules		8-18-61 (completed)
Phase II--56 capsules		11-1-61
<u>Telemetry Canisters</u>		<u>Shipping Dates to AFSWC</u>
Phase I--No. 1		7-17-61 (completed)
Phase I--No. 2		7-21-61 (completed)
Phase II--No. 3		9-15-61 (completed)
Phase II--No. 4		9-20-61 (completed)
Backup--No. 5		10-11-61 (completed)
Backup--No. 6		11-8-61
<u>Recorder/Reproducers</u>	<u>Estimated CEC Shipping to AFSWC</u>	<u>Complete Acceptance Tests at AFSWC</u>
Phase I--No. 1	10-31-61	--
Phase I--No. 2	9-18-61	10-2-61
Phase II--No. 3	10-19-61	--
Phase II--No. 4	10-19-61	--
Backup--No. 5	7-15-61	7-31-61
Backup--No. 6	10-10-61	--

b. Telemetry canister data

In addition to the shipment of the completed telemetry canisters, Fig. 2a, the following transducer data reduction information has been prepared by Martin and submitted to AFSWC.

a. Instrumented and insulated canister

b. Transducers installed showing lead wires

Fig. 2. Telemetry Canister

Type 64-3 thermistors have been calibrated to 1450° F and installed on Canisters 1 through 4. Twenty-gage, silver coated, copper wire has been calibrated to 900° F. Similar tests are underway on Type 64-8 thermistors for Canisters 5 and 6, and on 24-gage wire which is used on Canisters 4, 5 and 6.

The 20-gage wire used on Canisters 1, 2 and 3 was found to retain a constant slope equal to 0.0001683 ohm/ft-° R. Installed Type 64-3 thermistors were found to exhibit a similar consistency of slope. This slope was equal to the resistance quoted by Transonic, divided by the absolute temperature at which this resistance was measured. Information had been submitted previously giving:

- (1) The resistances of individual thermistors at 492° R for Canisters 1, 2 and 3.
- (2) Transducer lead wire lengths.

Figure 2b shows the assembly technique used on transducers and lead wires. The resistance of the transducer lead wire must be calculated and subtracted from the total circuit resistance, measured on re-entry, to determine the actual resistance (temperature) of the thermistor (canister). Analysis has indicated that the wire temperature used to determine the resistance of the wire can be calculated with sufficient accuracy to preclude significant error in the reduced data. Failure to correct for the wire will induce an error in measured temperature up to 4% at low temperatures and 3% at high temperatures. These errors can be readily reduced to less than 1% if wire resistance is accounted for by even a very crude estimate of its temperature.

It is assumed that data will be reduced in the following manner. Raw data will consist of a voltage reading for a specific thermistor. At a known temperature (resistance), AFSWC will have noted the ohms/mv for each thermistor circuit prior to launch. An example of what data are required, and how the canister temperature at Transducer 1 (of 26) is determined, are shown.

$$\begin{array}{lll}
 V_1 & = & \text{raw data voltage, mv, Thermistor 1} \\
 K_1 & = & \text{ohms/mv as determined by AFSWC for} \\
 & & \text{Thermistor 1} \\
 R_T & = & \text{resistance of thermistor at time of } V_1, \text{ ohms}
 \end{array}$$

R_C	=	total resistance of thermistor circuit as determined on reduction of raw data, ohms
R_W	=	resistance of lead wire at time of V_1 , ohms
K_2	=	0.0001683 ohm/°R-ft, lead wire characteristic
T_W	=	calculated temperature of lead wire at time of V_1 , °R
L_1	=	length of lead wire to Thermistor 1, ft
T_C	=	temperature of canister at Location 1, °R
K_3	=	°R/ohm (from Transonics data for Thermistor 1)
T_C	=	$K_3 R_T$
R_T	=	$R_C - R_W$
R_C	=	$K_1 V_1$
R_W	=	$T_W (L_1) K_2$
T_C	=	$K_3 (K_1 V_1 - T_W L_1 K_2)$

The value of K_2 for Canisters 4, 5 and 6 will be forwarded with information regarding K_3 for Type 64-8 thermistors when testing is completed in October.

c. Recorder/Reproducers

The Martin Company was authorized by the AEC to procure for and provide to AFSWC the necessary recorder/reproducers for test and installation. Consolidated Electrodynamics Corporation was selected as the subcontractor for the development and manufacture of six units in accordance with Ref. 4.

The first two recorders (Nos. 3 and 5) passed their functional tests at CEC and were delivered to AFSWC (Albuquerque, New Mexico) for acceptance testing in July. Shock and vibration phases of the acceptance tests, which were witnessed by a Martin representative, were carried out at AFSWC during the same month.

Recorder Unit 5 passed the Ref. 4 acceptance test requirements; however, Unit 3 did not pass the tests and, subsequently, was returned to CEC for repairs.

Shortly after the receipt of the first two units, all remaining recorders were delivered. Six recorders were tested at AFSWC and, to date, only Units 2 and 5 have been accepted. The units which malfunctioned during testing were returned to CEC for refurbishing and redelivery.

A summary of the status of the six recorders follows.

Unit 1. Had excessive flutter of 31% during g testing, which exceeded the 1-1/2% peak-to-peak requirement. This unit also had an incorrect tape speed of 3.5 in. /sec instead of the specified 5 in. /sec. In addition, an apparent gear interference or grinding noise occurred during bench testing. (Received in July, returned to CEC; received in September, returned to CEC.)

Unit 2. Center frequency held at 5440 cps and was not capable of returning to specified 3600 cps. This unit also had a high flutter of 12 to 15% during 50 g testing. (Received in July, returned to CEC; received in September and accepted.)

Unit 3. Power regulator failed and the output was reduced to zero. (Received in August, returned to CEC.)

Unit 4. Failed to function properly because the output was approximately 0.02 volt rms instead of the specified 1.5 volts rms. (Received in August, returned to CEC.)

Unit 5. Accepted. (Received in July.)

Unit 6. Had a static (bench) flutter of 5.9% and an output rms voltage of 0.3 instead of 1.5 volts. (Received in July, returned to CEC.)

On August 30, Martin was notified by CEC that they would stop work due to an estimated overrun which was attributed primarily to increased overhead and "general and administrative" rates. This

matter was reviewed by Martin and immediately reported to AEC-NYOO. On September 15, after many ensuing discussions, the recorder contract (1E0702) CPFF price limit was adjusted upward and CEC resumed work. However, in accordance with the recorder contract requirements, all costs incurred by CEC on the design and manufacture of the six recorders will only be acknowledged after receipt of a concurring Government-approved audited statement.

4. Aerodynamic Re-Entry Analysis

The study to determine the methods to compute aerodynamic heating on arbitrary bodies during re-entry into the earth's atmosphere has been completed. As reported in Ref. 8, the use of the stagnation point heating equations, derived by Detra, Kemp and Riddell to estimate the heat flux to the capsules, was verified. This information is now being compiled and prepared for the first topical report.

The rough draft of the topical report for the fuel core heating and ablation phases of Task 7.3 is approximately 70% complete. The sections which are completed cover aerodynamic heating calculations, heat transfer digital code, the physics of a re-entering body and detail descriptions of the telemetry and flare capsules.

This topical report will include the prediction of burnup positions for all flare capsules. Summary curves are being drawn to show the aerothermodynamic performance of all test specimens. A typical stagnation heating graph for one of the Phase I capsules is shown in Fig. 3. This figure shows the effects of re-entry flight path angles on the heating of a spherical test core.

a. Phases I and II flare capsule burnup altitudes

The altitudes of burnthrough expected for each capsule were completed. Briefly, the expected maximum and minimum altitudes of burnthrough are as follows. (The minimum altitudes were calculated by assuming spinning and tumbling bodies during re-entry. The maximum altitudes are for spinning but nontumbling bodies. Thus, the sphere can have only one calculated altitude of burnthrough. In all cases, laminar air flow was assumed when calculating aerodynamic heating. The spread in altitude within the maximum and minimum category is due to the expected variations in the initial re-entry flight path angle).

Fig. 3. Stagnation Heating Rates for 3-Inch Diameter Sphere

		Altitude	
	<u>Body (in.)</u>	<u>Maximum (ft x 10³)</u>	<u>Minimum (ft x 10³)</u>
Phase I			
	3 x 3/8 t sphere	209 to 187	--
	3 x 4 x 3/8 t cylinder	199 to 165	172 to 154
	2-1/2 x 5 x 3/8 t cylinder	199 to 176	178 to 159
	2 x 5 x 3/8 t cylinder	204 to 185	188 to 167
Phase II			
	2-1/2 x 5 x 5/8 t cylinder	175 to 155	160 to 135
	2-1/2 x 5 x 1/2 t cylinder	185 to 164	169 to 147
	2-1/2 x 5 x 3/8 t cylinder	199 to 176	178 to 159
	2-1/2 x 5 x 1/4 t cylinder	188 to 166	172 to 149

t = wall thickness.

b. Flare release error analysis

A study was completed showing the effects of error in measuring the altitude of flare release versus the accuracies in predicting aerodynamic heating experienced by the re-entering body. It was shown that errors of ± 2000 feet or greater will invalidate the results of the proposed test program, if the flare ignition point is the only available data. At altitudes of approximately 180,000 feet, accuracies of positioning the flare burst must be in the order of ± 500 feet, as shown in Fig. 4. This independent study of flare burst position limits versus re-entry trajectory altitude and heating rate, as summarized in Fig. 4, substantiated the information previously presented to AFSWC and AEC at the Task 7.3 Coordination Meeting on March 15, 1961.

The normal procedures used in data reduction will suffice to define the re-entry trajectory, since it is expected that sufficient

Fig. 4. Single Point Data Position Limits--Flare Burst

trajectory data (chopped capsule streaks) will be available prior to flare burst. An example of this type of data would be obtaining time-indexed and chopped photographic coverage of the re-entering test capsules. With this information, it would be possible to obtain fairly exact trajectory data of each small flare capsule. It will be possible to relax the requirement of ± 500 feet previously requested if the time-indexed trajectory data are obtained.

To avoid placing absolute dependence on the flare release error analysis, camera data shall be time-indexed and include nose cone and flare bursts on a single frame.

As a result of a second independent study completed during this period, it was determined that optical nose cone data can be compared to results normally obtained from radar. Therefore, it was requested that Martin and AFSWC data reduction personnel be supplied with optical and radar tracking data on the re-entering nose cone. The information derived from optical data reduction can be compared to that obtained via radar data reduction (with its known accuracy).

By photographing flare burst and nose cone streaks on a single photographic plate, the method described can be used to determine the position of the burst within ± 500 feet. The streak expected from the re-entering flare capsules can then be reduced to give trajectory data on the capsule to the same accuracy as that of the nose cone.

c. Re-entry dispersion data

Martin analyzed and prepared test capsule dispersion data to provide the following re-entry information to AFSWC and Convair.

- (1) Distance between nose cone, Atlas tankage and re-entering scientific passenger pod as a function of time.
- (2) Dispersion distances of capsules due to ejection from the pod.
- (3) Altitude and range of nose cone.

The Convair Astronautics Division Aerodynamic Group also performed a study to determine the position and distances of the test specimens from the nose cone. This work was done at the requests of AFSWC and BSD. The analysis completed by Convair considered the exact separation velocity, momentum and separation angle of the pod from the Atlas tankage. Their dispersion analysis includes the

exact aerodynamic coefficients of each re-entering unit. The coefficients of the nose cone are highly classified and were unavailable to Martin. Martin results were within 5% of those numbers developed by Convair.

5. Optical Data Reduction

An effort was initiated to study optical data reduction. Several reports were requested and received from the RCA Missile Test Project, AFMTC, Florida. A review of these reports indicates the complexity of obtaining accurate position and velocity information on re-entry bodies.

Two areas were investigated initially. They were the central projection and photogrammetric triangulation. The first involves the relationship of space coordinates to camera coordinates. This method requires the use of matrices. Sufficient knowledge was gained to become somewhat aware of the techniques of data reduction. Photogrammetric triangulation describes the method whereby three or more cameras are focused on a common screen, and the intersection of the rays is the theoretical location of the event during the flight test. Normally, a clean intersection is not achieved and thus, an error analysis is required. This procedure alone is one of the most important factors in obtaining reliable postflight data.

Based on these findings, Martin has requested AFSWC to supply them with the methods used for, and expected accuracies of, optical and telemetry data reduction techniques.

6. Aircraft Equipments and Flight Plan

Two aircraft (C-54) will be available to monitor the re-entry of the capsules. One, denoted the primary aircraft, is used to contain the majority of the photographic equipment. It is to be placed in a flight profile so as to have an optimum viewing angle for observation of the flare capsules. The other, designated the secondary aircraft, will contain some photographic equipment, but is primarily used to carry telemetry receivers and a photometric device. The two-barrel photometer has only a five-degree viewing angle which necessitates manual aiming during flight. It was estimated by Barnes Engineering Company, the manufacturers and principal users of this instrument, that a man can aim the unit to within $\pm 1/2$ degree. Later, they estimated that the aiming accuracy is, in reality, $\pm 1-1/2$ degree, which is in full agreement with comments previously made by the representative of the Geophysics Corporation of America. The flight plans were completed and submitted to AFSWC. These plans include aircraft positioning data for all possible flight dates from September 1 through December 31.

Block diagrams of the equipments which are planned for use in the AFSWC primary and the AMR telemetry aircraft are shown in Appendix A.

7. Preliminary 100-Pound Pod Test Flight

On July 31, three SNAP-3 test cores were successfully launched into space by the advanced Atlas E missile.

The objectives of the preliminary test were to determine the effects of the ionization sheath buildup on the telemetry capsules (temperature) transmission signal (247.3 mc); and to optically and visually observe the ablation penetration point of the two simulated SNAP-3 flare capsules.

The three simulated SNAP cores were installed in an AFSWC 100-pound scientific pod which was attached to the side of the Atlas missile. The specimens consist of a telemetry capsule with an 8-1/8-inch diameter and a 12-5/8-inch length (43 lb); and two flare capsules (10 lb)--one a 3-3/4-inch diameter sphere containing 1/4 pound of sodium, and the other, a 2-inch diameter, 4-1/2-inch long cylinder containing 1/8 pound of potassium. During re-entry, the sodium burns yellow and the potassium burns orange and violet when observed directly, or violet when observed through an appropriate filter.

a. Results of the re-entry test launch

The Atlas E missile was successfully launched on July 31 at 2132 Greenwich Civil Time. This launch is cataloged by AMR as "Operations No. 1360."

The telemetry capsule signal was received at Cape Canaveral at $T_0 + 12$ minutes, 46 seconds. This indicated that the ejection of three SNAP capsules occurred.

Telemetry signals (time versus temperature) were received at Ascension Island. However, the received signal strength was erratic. The Data Reduction Group of AFSWC has looked into this and believes that the antenna and the VCO (voltage control oscillator) components could be the cause of the poor signals received.

Downrange DC-6 aircraft reported seeing three objects near the glowing re-entering tankage. Two of the three objects emitted a yellow glow and soon disappeared.

The BC-4 camera crews on Ascension Island reported the re-entry vehicle glowing blue-white, surrounded by a star burst of orange and yellow which lingered for several seconds.

8. Conclusions

The flare capsule information is based primarily on visual observations made in the Ascension Island area. Comments on the telemetry capsule performances were received verbally from AFSWC. Actual raw data and/or 100-pound pod test reports have not been received by Martin.

Receipt of these data by Martin for the 100-pound shot (No. 1360) was not required as a contractual requirement. However, it was hoped that AVCO and Barnes Engineering spectral and colored documentary films, and AFSWC telemetry data and reports would be available for Martin perusal prior to the first 500-pound pod test flight. Martin has requested data from AFSWC, Barnes Engineering and AVCO.

B. SUB-SUBTASK 7.3.3--GENERATOR BURNUP STUDY

1. Objectives

This phase of the program is designed to determine the susceptibility of heterogeneous exterior construction of auxiliary power units to burnup during re-entry. The detailed steps of the program are as follows:

- (1) To design generator mockups of a typical radioisotope SNAP device and a reactor SNAP device. These mockups, with flare materials contained in their centers, will be designed to burnup on re-entry from an ICBM trajectory. Investigations will be made to use the backup transmitter and recorder units from Phases I and II for reactor beryllium reflector separation testing.
- (2) To analytically determine the exact position and altitude of burnup of these generator mockups through the use of the digital IBM 7090 code.
- (3) To prepare a "primary AEC mission" test program for followon testing.

2. Status of Work

The objectives of this program have been revised and resubmitted in MN-SW-1007, Revision 3, dated September 19, 1961. This revised program now includes the design, analysis and test program preparation for isotope and reactor generator test devices.

The mockup isotopic test configuration described in Ref. 2 is presently being analyzed for flare alkali metal determination and altitude of burnthrough for both the external shell slough-off and flare ignition. These data will be completed, and the report furnished early next period.

Work has continued on the design, coordination and planning of the isotope and reactor component re-entry test program. Several meetings have been held between AEC Headquarters, Atomics International and Martin representatives on the reactor test part of the program and the following has resulted.

Atomics International stated that a reactor re-entry test program should include the following areas:

- (1) Beryllium reflector separation.
- (2) NaK release.
- (3) Fuel rod separation.
- (4) Fuel rod burnup.

Martin and AI agree that component testing is a sound test program approach to obtain flight test data early in the program. This would also permit the use of lower cost, highly reliable, lighter payload capability re-entry test missiles.

Atomics International has been cooperative and indicated they were anxious to assist Martin in the test program. During one of the three coordination meetings, Martin received an unclassified general reactor design drawing (L141-07002) and a weights list. Design concepts were discussed and the following preliminary schedule established:

	<u>1961</u>			<u>1962</u>			<u>1963</u>		
	O	N	D	J	F	M	A	M	J
AI test requirements									
AI design drawings									
AI environmental and creep test drawing modifications									
MND design test devices									
MND submit drawings to AI									
MND manufacturing test devices									
MND environmental test and checkout									
MND flight tests (3 shots)									

C. SUB-SUBTASK 7.3.4--HIGH ALTITUDE SAMPLING

1. Objectives

The principal objectives of this portion of the Task 7 program are:

- (1) The investigation of suitable simulated fuel materials to use in an experimental study.
- (2) A review of available high altitude sampling techniques for determining the particle size and concentration of simulated fuel after burnup has occurred.
- (3) An investigation of the feasibility of applying such methods to a program restricted to an ICBM trajectory.
- (4) The analytical determination of the limitations of such a test program in terms of concentration and amount of fuel that must be introduced into the atmosphere.
- (5) The examination of the feasibility of measuring the actual fallout of simulated fuel.
- (6) Recommendation of a test program at the end of this phase,

which will enable the empirical determination of fuel particle size and dispersion in the upper atmosphere during re-entry.

2. Scope

In this period, studies continued on analytical determination of particulate size resulting during re-entry burnup of isotopic fuel and on its subsequent dispersion. The dispersion studies were concluded about midquarter when the equations reported in the last quarterly, Ref. 5, were modified to account for the effects of gravity and cloud movement due to bulk air transport. Emphasis was shifted to the selection of materials for use as tracers in meteorological research, samplers and sample analysis techniques applicable to a program which would improve accuracy in predicting the fate of re-entry residue.

3. Particulate Cloud Diffusion and Dispersion

To reach valid conclusions with respect to Objectives 4, 5 and 6 it was considered necessary to investigate the feasibility of predicting cloud location, size and particulate concentration as a function of spatial origin and time. The principal sources of information relied upon were Refs. 6, 7 and 8. The model analyzed is pictured in Fig. 5.

The release of fuel from a generator, in instances where the fuel is in liquid form prior to release, can be considered to produce an instantaneous point source cloud. Since the expected release is between 100 and 200,000 feet, it can be considered to have occurred in an infinite volume. The particulate concentration at a general point is by Ref. 6:

$$C(x, y, z, t) = \frac{M}{(4\pi t)^{3/2} (K_x K_y K_z)^{1/2}} \exp \left[-\frac{1}{4t} \left(\frac{x^2}{K_x} + \frac{y^2}{K_y} + \frac{z^2}{K_z} \right) \right] \quad (1)$$

where the coordinates x, y, z are as shown in Fig. 5 and

$C(x, y, z, t)$ = concentration in gm/cm³ at x, y, z at time t

M = amount of material released, gm

K_x, K_y, K_z = diffusion coefficients in the direction of the mean wind, laterally crosswind and vertically, respectively, cm²/sec.

Fig. 5. Diffusion--Dispersion Model

Reference 7 calculates from HASP data, a K_y of between 5×10^8 and $5 \times 10^9 \text{ cm}^2/\text{sec}$ in the stratosphere. Because of the normally greater stability of the tropical stratosphere (30° N to 30° S latitude) as compared to the polar stratosphere, it is felt that the lower value should be applied to a source originating here; the higher value would apply for a cloud of origin in the polar stratosphere. K_z is calculated to be of the order of $10^3 \text{ cm}^2/\text{sec}$ in the tropical stratosphere and $10^4 \text{ cm}^2/\text{sec}$ in the polar stratosphere. These values for K_z are generally confirmed by H. Lettau in Ref. 8, but are considered applicable in the first instance to the altitude range of 82,000 to 115,000 feet, and in the latter to 33,000 to 82,000 feet and 115,000 to 145,000 feet. From 145,000 to 260,000 feet, Lettau predicts a K_z equal to $10^6 \text{ cm}^2/\text{sec}$. Since HASP data are available to only 115,000 feet, this latter figure is neither confirmed nor contradicted by Ref. 7. A value for K_x of $10^{11} \text{ cm}^2/\text{sec}$ is predicted by H. Lettau in Ref. 8. Reference 7 does not evaluate K_x from the available HASP data.

a. Method to estimate K_x

Reference 7 states that bomb debris clouds are distributed in a band around the earth in a "few" months; it is also stated that they have lost their identity. This latter statement can be interpreted to mean that the "hot" spot is indistinguishable, and that the hottest spot, presumably the origin of the cloud, has a concentration no greater than twice that of any point along the axis of the banded cloud. The origin, $x = 0$, is taken to be the point of maximum concentration, $C_{\max}$, and a point diametrically opposed to this as the point of minimum concentration, $C_{\min}$. In accordance with the definition of loss of identity given, $C_{\max} = 2 C_{\min}$. Also, for purposes of this analysis, a "few" months will be assumed as 90 days, ($7.68 \times 10^6 \text{ sec}$)--the time necessary for K_x to act and result in $C_{\max} = 2 C_{\min}$. The positive direction of x is taken toward the east from the point of origin. Unique values of x , P , range from 0 to S where S is the circumference of the cloud along the parallel of latitude. Again, for purposes of this analysis, let the parallel of latitude of interest be 30° N ; therefore, $S = 3.48 \times 10^9$ centimeters.

Equation (1) is now modified to apply where the x direction is a closed path. This means that eventually as the cloud diffuses east

and west, the tails of the diffusing cloud will overlap. Concentrations in the regions of overlap are considered additive, the diffusion being essentially turbulent. Since concern is chiefly with concentrations on the axis of the cloud, Eq. (1) for $y = z = 0$ is rewritten as:

$$C(x, t) = \frac{M}{(4\pi t)^{3/2} (K_x K_y K_z)^{1/2}} \exp \frac{-x^2}{4tK_x}$$

The form of this equation is such that a finite value of $C(x, t)$ exists for any x if $t > 0$. The concentration at any unique point, P , where $0 < P < \hat{S}$ is a function of time and the number of overlaps, n , of the diffusing cloud. The overlaps of x form the series

$$X_n = P + nS$$

where

$$n = 0, 1, 2, 3 \dots$$

The contribution to the concentration at P due to an overlap proceeding from west to east is

$$C_{W-E}(x_n, t) = \frac{M}{(4\pi t)^{3/2} (K_x K_y K_z)^{1/2}} \exp \left(\frac{-(P + nS)^2}{4tK_x} \right)$$

Since the cloud also diffuses east to west from the origin, the contribution due to overlap from this source is

$$C_{E-W}(x_n, t) = \frac{M}{(4\pi t)^{3/2} (K_x K_y K_z)^{1/2}} \exp \left(- \frac{(S - P + nS)^2}{4tK_x} \right)$$

The sum of contributions from these sources yields the total concentration increase due to the n th overlap:

$$C_n(x_n, t) = \frac{M}{(4\pi t)^{3/2} (K_x K_y K_z)^{1/2}} \left\{ \exp \left[- \frac{(P + nS)^2}{K_x} \right] + \exp \left[- \frac{(S - P + nS)^2}{K_x} \right] \right\} \quad (2)$$

The concentration at the unique point, P , due to all such overlaps is

$$C(P, t) = \sum_{n=0}^{n=\infty} C_n(x_n, t) \quad (3)$$

By expansion and regrouping of Eq (2) the value for the concentration at $x = 0$ can be more simply written as

$$C_n(0, t) = \frac{M}{(4\pi t)^{3/2} (K_x K_y K_z)^{1/2}} \left[1 + 2 \exp \left(\frac{-n^2 S^2}{4t K_x} \right) \right] \quad (4)$$

for $n = 1, 2, 3$

and

$$C(0, t) = \sum_{n=1}^{n=\infty} C_n(0, t)$$

At $n = 0$, the value for $P = x = 0$ is given by

$$C(0, t) = \frac{M}{(4\pi t)^{3/2} (K_x K_y K_z)^{1/2}} \quad (5)$$

Use of $n > 1$ does not appear reasonable. When $n = 1$ the twin tails of the diffusing cloud have met for the first time at the origin; it seems reasonable to assume that the relative concentrations, point to point on the x -axis of the cloud, will not be changed appreciably by the very low concentration tails that contribute to the 2, 3 and 4 overlaps. Recalling that

$$C_{\max} = 2 C_{\min} \quad (6)$$

the simultaneous solution of Eqs (3) for $C_{\min}$, (4) for $C_{\max}$ and (6) gives a value for K_x of $0.7 \times 10^{11} \text{ cm}^2/\text{sec}$. A solution derived where $0.5 > n > 1$ also gives an estimate of $K_x = 0.7 \times 10^{11} \text{ cm}^2/\text{sec}$. These values correlate closely with Lettau's estimate of $10^{11} \text{ cm}^2/\text{sec}$ in Ref. 8.

To fully evaluate this technique for estimating K_x , raw sampling data should be used to specify a specific altitude and latitude:

- (1) The actual time, t , required for banding to occur.
- (2) The actual ratio, $C_{\max}/C_{\min}$, which permits identification of the cloud center.
- (3) An estimate, by study of the wind velocity distribution in the cross sectional area swept by the cloud, of the most reasonable number of times, n , that overlapping can occur in time, t .

b. Mean wind and fall velocity effects.

The diffusion coefficients discussed relate specifically to cloud growth. It is also necessary that cloud location be predicted. Account must be taken of the translational and vertical forces, the mean effective wind and gravity, respectively. In attacking this problem, the cloud is assumed to be either of a single particle size so that a single terminal value of V_m is applicable or that the cloud is in fact an aggregate of several clouds, each of single particle sizes characterized by their respective fall velocities. Equation (1) is modified to account for mean wind, $\bar{u}$, and cloud terminal fall velocity, V_m , as shown in Fig. 5.

To modify Eq (1)

$$\bar{u} = a \bar{i} + b \bar{j} + c \bar{k}$$

where

a, b, c = components of wind in x, y, z directions

$\bar{i}, \bar{j}, \bar{k}$ = unit vectors in the x, y, z directions

and

$$\bar{V}_m = -V_m \bar{k}$$

where

$\bar{V}_m$ = terminal velocity vector quantity

$-V_m$ = scalar terminal velocity in negative z direction

$\bar{k}$ = unit vector in z direction

From Fig. 5

$$\bar{r}' = \bar{r} - \bar{R}$$

and

$$\dot{\bar{R}} = \bar{u} + \bar{V}_m = a \bar{i} + b \bar{j} + (c - V_m) \bar{k} \quad (7)$$

and since $\bar{R} = 0$ when $t = 0$

$$\bar{R} = at \bar{i} + bt \bar{j} + (c - V_m) t \bar{k} \quad (8)$$

also

$$\vec{r} = x \vec{i} + y \vec{j} + z \vec{k} \quad (9)$$

where

x, y, z = coordinates of point for which concentration will be determined.

Substituting Eqs (8) and (9) into Eq (7), then taking the dot product with respect to itself, gives

$$(r')^2 = (x - at)^2 + (y - bt)^2 + (z - ct + V_m t)^2$$

which is used to modify Eq (1) to obtain the equation which predicts concentration (gm/cm^3) at a specific point in a cloud of single particle size, diffusion and dispersion accounted for:

$$C(r', t) = \frac{M}{(4\pi t)^{3/2} (K_x K_y K_z)^{1/2}} \exp - \frac{1}{4t} \left[\frac{(x - at)^2}{K_x} + \frac{(y - bt)^2}{K_y} + \frac{(z - ct + V_m t)^2}{K_z} \right]$$

To obtain the concentration in spherical particles/ cm^3

$$C(r', t) = \frac{(1.214 \times 10^3) M}{\rho d^3 t^{3/2} (K_x K_y K_z)^{1/2}} \exp - \frac{1}{4t} \left[\frac{(x - at)^2}{K_x} + \frac{(y - bt)^2}{K_y} + \frac{(z - ct + V_m t)^2}{K_z} \right] \quad (10)$$

where

ρ = density of particle (gm/cm^3)

d = diameter of particle (cm).

To obtain the time of maximum concentration at x, y, z , Eq (5) is differentiated and set equal to zero. A quadratic equation results for which the solution is:

$$t_{C(r') \max} = \frac{-A \pm \sqrt{B^2 - 4AC}}{2A} \quad (11)$$

where

$$A = K_y K_z a^2 + K_x K_z b^2 + K_x K_y c^2 - 2 K_x K_y c V_m + K_x K_y V_m^2$$

$$B = 6 K_x K_y K_z$$

$$C = - K_y K_z x^2 + K_x K_z y^2 + K_x K_y z^2$$

c. Conclusions on dispersion and diffusion

The analysis has assumed a homogeneous infinite volume. The variability of the atmosphere with time is such that the programming of Eqs (10) and (11) for particular solutions does not seem warranted. They would appear to be of greatest value in predicting in a general way, the hazards associated with the cloud resulting from burnup of fuel in a specific generator design, not the hazards resulting on any actual re-entry of a specific generator. The effective wind over given altitude increments needs to be known to handle specific cases; the diffusion coefficients K_x , K_y , K_z should be the effective values for the particle size under consideration, it being obvious that a 10-micron particle will not be as affected by a given eddy current as a 0.1-micron particle.

4. Particle Ablation

It has become evident, in attempting to predict analytically the fuel particle size resulting on re-entry burnup of fueled generators, that the final size is very dependent on the generator design, re-entry conditions and the fuel form. The results obtained for plutonium will differ from those obtained for polonium. Results will differ for plutonium if, in one instance, the re-entry velocity at which the fuel cladding is penetrated is five kilometers per second and in another design, three kilometers per second. Results will differ if cladding is penetrated in both instances at five kilometers per second but at different altitudes-- in one instance, 200,000 feet, and in another, 150,000. Understanding this, it is apparent that an experiment to recover particulate in the wake of a re-entering test specimen will give results applicable only to that design and set of re-entry conditions. Such an experiment could only be a test of the analytical procedures for predicting size distribution of particulate generated on re-entry of a specific device. An experiment for this purpose could be better performed in a laboratory where conditions can be precisely known and results precisely measured.

Recognizing this, it was decided to develop a parametric picture of the results that might be expected for a single fuel form, plutonium.

Equations describing the phenomena controlling ablation rates of particles of small initial size (those in free molecule flow) were written, programmed and solved. Heating phenomena considered included drag, radioactive decay, combustion and radiant heat loss. From previous analysis, it had been determined that for a specific generator of Martin design, the plutonium would be at about 3000° R when the fuel cladding fails. The initial particle size can vary from very small to quite large--approximately 1 to 1400 microns. Initial size is dependent on the method of release. Small particles will result if the release is by spewing from a localized rupture of the fuel element; an instantaneous general failure of the element could result in some very large particles. The largest particle size was determined as that at which surface tension in the molten plutonium droplet equals drag forces attempting to tear it apart. Results are available only on those particles whose initial size is equal to or less than the molecular mean free path at the penetration altitude (Fig. 6). Work in the next quarter will be concentrated on the larger particles. Figures 7 through 13 show ablated plutonium particle size as a function of initial particle size, exposure altitude and velocity, until such time as the heat input is no longer sufficient to drive off additional molecules.

Concurrent with this effort, information was collected on other isotopic fuel forms, including polonium, curium, cerium and cesium. Chemical and thermal properties were tabulated for use in a possible extension of the work to these elements. In addition, nonradioactive elements and compounds were selected whose properties closely parallel those of radioactive materials; this was done to determine whether or not the analytical model of the ablation process can be verified experimentally without using the actual fuel. Tentatively, it is concluded that nonradioactive materials can be used.

5. Test Materials, Sample Collection and Analysis

Late in the quarter, studies were initiated in three areas:

- (1) Test materials for possible use in particulate ablation laboratory experiments and in experiments to develop empirical data on atmospheric dispersion and diffusion of particulate clouds.
- (2) Sample collectors.
- (3) Sample analysis techniques.

To supplement the efforts of the Martin group, other commercial organizations possessing unique capabilities in these specialties were contacted. Recommendations were sought on materials, collectors, analysis techniques and launch vehicles. In addition, such cost data

Fig. 6. Molecular Mean Free Path Versus Altitude

Fig. 7. Plutonium Particle Ablation, 100 μ Radius

Fig. 8. Plutonium Particle Ablation, 100μ Radius Fig. 9. Plutonium Particle Ablation, 20μ Radius

Fig. 10. Plutonium Particle Ablation, 20μ Radius Fig. 11. Plutonium Particle Ablation, 10μ Radius

Fig. 12. Plutonium Particle Ablation, 10 μ Radius Fig. 13. Plutonium Particle Ablation, 2 μ Radius

Fig. 14. Plutonium Particle Ablation, 2μ Radius

and delivery information as will prove useful in program planning were requested. Replies to these requests for information are due early in the next quarter. The organizations contacted include:

Howard School of Public Health, Cambridge, Massachusetts
 General Mills, Inc., Minneapolis, Minnesota
 Raven Industries, Inc., Sioux Falls, South Dakota
 Industrial Emulsions Co., Nutley, New Jersey
 Union Carbide Chemical Co., New York, New York
 Algin Corp. of America, New York, New York
 Acheson Colloids Co., Port Huron, Michigan
 Kahlenberg Tabs, Sarasota, Florida
 Stein Hall and Co., New York, New York
 Tracerlab, Inc., Washington, D. C.
 Atlantic Research Corp., Alexandria, Virginia
 Del Electronics Corp., Mount Vernon, New York
 Isotopes, Incorporated, Westwood, New Jersey
 Nuclear Science and Engineering Corp., Pittsburgh, Pennsylvania

6. Plans for Next Quarter

All work underway at present will be concluded in the next quarter. Results of these studies, coupled with the data submitted by organizations listed in paragraph 5, will form the basis for the recommendations in the final topical report. It will be prepared and submitted late next quarter.

D. 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 during this quarter has consisted of monthly letters (Refs. 9, 10, 11) and a quarterly progress report (Ref. 5).

Project effort has been devoted to keeping the various tasks on schedule and assuring proper coordination of contractor efforts with those of affected Government agencies. All test hardware is ready for the first launching in November. In addition, Martin is ready to provide technical support at both AMR and at Ascension Island prior to and during the first test launching.

A documentary movie for Sub-subtasks 7.3.1 and 7.3.2 is in progress. Twenty-six slides, showing various flare and telemetry capsule manufacturing phases, were submitted to AEC-Hq. and NYOO. A Plasma Arc Test Photo report (in color) was also submitted to both AEC branches and NYOO of the AEC during this period.

Martin coordinated and attended the preparations for and the launching of the first preliminary 100-pound pod test at AMR. Previously, all technical discussions and hardware deliveries had been coordinated through the AFSWC project office.

Just prior to launch it was found that another representative of AFSWC who was not familiar with the Martin-AEC portion, was in charge of the 100-pound pod at AMR. He was briefed accordingly.

In general, all phases of the Task 7.3 are progressing satisfactorily, with the exception of the design drawing preparation for the Sub-subtask 7.3.3 reactor test unit. Reactor test unit drawings are held up pending the receipt of AI reactor fuse link test designs.

During this period Martin was requested by AEC-Hq. to present a preliminary review of the expected Task 7.3 increased scope of work. The generator re-entry followon test program and the high altitude sampling testing program were presented. Martin stated that primary AEC test missiles could be designed, built and launched in eight months after contract go-ahead.

Martin representatives also attended two conferences with Goodyear Rubber Company representatives at the request of AEC. The primary purpose of these meetings was to acquire data and determine whether or not the Goodyear orbital decay (ballute) and recovery systems could be used in future AEC SNAP programs. It is felt that there are two areas where the Goodyear systems could be used in future AEC SNAP programs. They are:

- (1) Orbital decay system--to command a predictable impact location on earth for an orbiting radioactive space generator after an operational life of 5 to 10 years.
- (2) Recoverable system--this system, which includes balloon, radio beacon, dye marker, etc., could possibly be used for recovery of radioactive generators for the conditions of launch pad to near injection into orbit aborts and for recovery after orbital decay.

V. 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 accomplish the following:
 - (a) To determine the gamma flux in photons/cm²-sec or dose rates in mr/hr for a given shield configuration.
 - (b) To 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) To utilize the code to calculate the dose rate of one fueled generator for comparison with actual measurements.

B. SCOPE AND EVALUATION

Efforts under this subtask, during this period, have consisted primarily of routine coding, assembly and checkout operations. All subroutines except COORDA and COORDX have been completed and checked out. In the process of checking these subroutines, several minor errors affecting other routines were discovered. Although minor, correction of these errors required rechecks of several of the other routines. Delays of this type must be expected in the final checkout phase of complex calculation programs.

Final flow diagrams have been completed and are ready for processing pending correction of errors that may be discovered in the final check.

A survey of dose rates of the weather station generator developed under Task 1 of Contract AT(30-1)-2519 was completed prior to shipment of the unit to its installation site. These data will be used to verify results of a sample calculation using the completed code. Code input data based on this generator configuration have been prepared.

Difficulty in obtaining a satisfactory checkout of the last two subroutines has caused the program to fall behind schedule. The total efforts of manpower available to this subtask are being concentrated on this program to accelerate final checkout operations.

*R. J. Wilson

APPENDIX A

EQUIPMENT BLOCK DIAGRAMS FOR PRIMARY AND SECONDARY AIRCRAFT

Primary Aircraft--AFSWC-C-54

Secondary Aircraft--AMR C54

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9. "Task 7 Monthly Progress Letter, " MND-P-2472-7, Martin Nuclear Division, July 1961.
10. "Task 7 Monthly Progress Letter, " MND-P-2472-8, Martin Nuclear Division, August 1961.
11. "Task 7 Monthly Progress Letter, " MND-P-2472-9, Martin Nuclear Division, September 1961.