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AEROSPACE NUCLEAR SAFETY GROUND TEST PROGRAM

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MASTER

Introduction

Increasingly complex satellites and spacecraft developed by the U. S. in recent years have created demands for larger amounts of auxiliary electrical power than can be economically supplied by batteries, solar cells, and other means. Longer-lived orbital vehicles, especially the manned versions now being developed, have increased these demands for power.

Since nuclear powered sources are the obvious solution to these requirements, development work was begun several years ago under contracts from the AEC and DOD. This work is now resulting in operative nuclear systems which produce power for these new applications. Designated Systems for Nuclear Auxiliary Power (SNAP), these power sources can be divided into two general categories: those using radioisotopes for heat generation, and those using operating nuclear reactors.

Each of these nuclear power systems presents radiation hazards whenever it or its debris is within the earth's atmosphere. Considerable effort has been expended in studying and determining the extent of this radiation hazard.

In the latter half of 1961, Sandia Corporation was approached by the AEC Division of Reactor Development to consider serving as their technical

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contractor for the purpose of examining the safety of aerospace nuclear power sources and performing needed basic research and development work in that field. At the present time, four distinct work areas have been delineated by AEC/DRD as follows:

1. A Basic Aerospace Safety Research and Development Program
2. An Aerospace Safety Ground Test Program
3. An Aerospace Safety Flight Test Program
4. An Independent Assessment of the Safety of all Aerospace Nuclear Power Sources

The Aerospace Safety Ground Test Program will be described in this paper. A paper by Mr. A. J. Clark, Jr. which will be presented in Session V of this meeting will describe the Aerospace Safety Flight Test Program.

Sandia Corporation, under a prime contract with the Atomic Energy Commission, operated two laboratories and a test range, all of which are engaged in weapon work for the AEC, capabilities have been developed that are directly applicable and highly valuable to work in the Aerospace Nuclear Safety Program. Some of these capabilities are:

1. A research organization with scientific fields of interest including physical electronics, plasma physics, high temperature physics, solid state physics, radiation effects, theoretical mechanics, molecular and crystal structure studies, high rate chemical kinetics, and nuclear burst phenomena.

2. An environmental testing organization equipped with complete facilities to perform many types of environmental tests including rocket sled impacts, drop tower, radiant heat, vibration, shock, chemical interaction, acoustical, explosion, etc.

3. A materials and processes organization that develops new materials, keeps abreast of research and development in its fields, evaluates commercially available materials, and operates its own analytical and material properties laboratories.

4. A field testing organization that performs and supports Sandia test programs at its own ranges and at other locations around the world.

The Aerospace Nuclear Safety Organization at Sandia Corporation is under the Director of Aerospace Programs, Don B. Shuster, reporting to the Vice President of Development, Mr. G. A. Fowler. The Department Manager in direct charge is Mr. V. E. Blake, Jr. The Aerospace Nuclear Safety Department, 7410, is divided into three divisions whose responsibilities follow:

1. Division 7411, under H. E. Hansen, is to perform the Basic Aerospace Safety Research and Development Program.

2. Division 7412, under A. J. Clark, Jr., has full responsibility for the Aerospace Safety Ground Test Program and partial responsibility for the Aerospace Safety Test Program. In the latter program, this division is responsible for the mechanical and thermal design of flight test hardware as well as fabrication, environmental and development testing, compatibility with nuclear test articles, launch vehicles, etc. Nuclear and thermal studies and analyses are included in the work of this division.

3. Division 7413, under A. E. Bentz, is responsible for the design, development, test, and operation of the telemetry systems used in the flight tests, and all range instrumentation, both electronic and optical. This division is the contact with the ranges used for flights and makes all arrangements with the launch agencies.

In addition to the work done on the Aerospace Nuclear Safety Program in Department 7410, many other groups within Sandia Corporation make sizeable contributions.

Ground Test Program Description

The Aerospace Safety Ground Test Program at Sandia is broadly defined as that effort to independently assess the effects of mechanical actions, thermal and chemical interactions, and nuclear reactions upon the safety of nuclear power sources which are intended for aerospace applications. This program is responsible for assessing all effects resulting from conceivable accident conditions from the time of factory shipment until terrestrial re-entry.

Work underway in this program is listed on Figure 1 and will be briefly described under the titles shown.

Project Engineering - This task includes planning the work to be performed in this program. It includes necessary liaison work with the various governmental agencies concerned with aerospace nuclear safety, especially in those fields which are not specifically concerned with an existing or already programmed nuclear power source. Also included in this task is the preparation of reports, budgets, and other administrative details necessary to the successful performance of the over-all program.

Mechanical Actions - Present efforts under mechanical actions can be divided into three general areas. As experience is gained in this field, and as additional programs are instituted, it may be necessary to add additional studies in this category.

Impact Tests - The first task in this category is planning, performing, analyzing and reporting impact tests upon complete power units and their individual component parts. These impact tests are performed under conditions that might exist under any conceivable accident situation which the unit being tested might encounter. These tests are run using non-radioactive or inert simulations of radioactive materials. Various methods using different types of test equipment (such as rocket sled tracks, recoilless rifles, centrifuges, and drop towers) are used to perform impact testing.

Associated with this task is a generalized study to develop a method of specifying the design of an impact target fabricated from soil that simulates the earth's surface. This study consists of both: (1) analytical work to set up a mathematical model of the mechanisms that occur in soil upon impact; and (2) experimental work to empirically determine the relationships that result from impact.

A study will be begun to determine the extent to which craters are formed by impacting bodies and the extent to which the crater will contain the projectile. The objective of this study is the definition of crater formation and retention of projectiles in the form of reactor core vessels impacting at various velocities into a variety of soil types and conditions.

Dynamic Analysis Studies - The second task is dynamic analysis studies to predict the effects of mechanical actions on nuclear power units and their individual components. These studies are performed by specially trained personnel using the latest available types of computers for problem solutions. Improved computer codes permit analysis of the effects of dynamic loading on such items. Dynamic analysis studies are performed as soon as design information is available in order to provide information for planning an impact testing series on the design.

Terminal Velocity Studies - The third task under this effort is terminal velocity studies, conducted both by calculation and by experimentation. These studies are performed for entire nuclear power units as well as certain of their components. The velocity determined could result from accidental conditions imposed upon the power unit at various periods during its factory shipment to re-entry sequence.

Thermal and Chemical Interactions - At the present time this area encompasses five separate tasks. Addition of further tasks will be made as conditions warrant.

Chemical Interaction Tests - The first task under this effort is the performance of chemical interaction tests. With certain designs of nuclear power units it is necessary to experimentally determine the interactions that may occur between various chemicals associated with the design of the unit. These tests are non-nuclear (any nuclear items in the design are simulated by inert or non-nuclear substitutes).

Beryllium Compound Formation and Dispersal Studies - The second task in this effort is an extensive study of the formation and dispersal of beryllium compounds. Of particular concern is the toxicity hazards that exist in the formation and dispersal of this material. Sandia Corporation is using the services of other laboratories under contract for experimental work in this task. However, experimental work is being performed under this task by Sandia using its own laboratory facilities in order to be able to evaluate clearly and completely work done by other contractors in this specialized field.

Launch Pad Abort Pressure and Temperature Studies - The third task in this effort is launch pad abort pressure and temperature studies. These studies are both analytical and experimental. The services of other laboratories under contract to Sandia Corporation will also be used in this task. Design and development of specialized instrumentation to obtain necessary pressures and temperatures required for this task is being done by Sandia Corporation. Calibration, fabrication, and installation of such devices is included under the scope of this task.

Self-Welding Design Analysis and Studies - The fourth task under this effort is vacuum self-welding design analysis and studies of those materials that are specifically used in existing designs of nuclear power units. This task supplements similar work being done in the Sandia Aerospace Research and Development Program but is limited to specific applications.

Thermal Analysis - The fifth task in this effort consists of thermal analyses. These analyses are performed on specific nuclear power units and their components. The work consists of analytical studies with experimental determinations being performed when needed.

Nuclear Reactions - This effort presently consists of five individual tasks. Additional tasks will be added as warranted.

Nuclear Power Unit Safety Design Reviews - The first task under this effort is nuclear power unit safety design reviews. These reviews are conducted on the design of specific nuclear power units during all stages of design from their conception to their final configuration. This task is performed with the design group of the nuclear power unit designer-fabricator organization. The object of this task is to acquaint Sandia Corporation with new designs and to provide the designer-fabricator with specialized information which may be incorporated in the design at an early stage to insure adequate nuclear safety.

Hazardous Conditions Analysis - The second task in this effort is the preparation of hazardous conditions analyses. The entire life cycle, from factory shipment to terrestrial re-entry, of each nuclear power unit is closely studied to determine the existence of potentially hazardous conditions. These conditions are set forth in chart form so that they can be recognized at an early stage of the system design. With information gained in the nuclear power unit safety design review described immediately above, probability figures for the occurrence of any hazardous conditions are assigned. From this hazardous condition analysis, it then becomes apparent where special emphasis on safety devices and/or designs should be placed.

Reactor Transient and Excursion Tests - The third task in this effort is reactor transient and excursion testing. In this task the experimental work is performed by others but the planning, execution, and evaluation of these tests are monitored by Sandia Corporation. The objective of this task is to thoroughly acquaint Sandia Corporation with the design and experimental performance of safety devices included in the nuclear design of the power unit.

Critical Configuration Testing - The fourth task under this effort is critical configuration testing. Again, the experimental work is performed by others but the planning, execution, and evaluation of results are monitored by Sandia Corporation.

Fission Product Release Tests - The fifth task under this effort is fission product release testing and studies. As with the two tasks immediately above, the experimental work is performed by others but the planning, execution, and evaluation of results are monitored by Sandia Corporation.

Current Reactor Safety Ground Test Program

The safety assessment of any nuclear power supply that is to be used in aerospace applications must be as complete and factual as it is possible to make it. Unlike a ground-based nuclear power facility, it becomes imperative that all possible effort must be exerted to insure the safety of the general public regardless of the location and condition of the aerospace unit.

The safety ground test task is charged with providing the factual, engineering information (to the extent that it can be obtained from ground-based tests) needed to fully assess the safety of the nuclear aerospace power unit during its entire lifetime, including shipment from the factory, launch, flight, terrestrial re-entry, and impact on the earth. At present, some of the environments which the unit will face cannot be duplicated or simulated in ground-based facilities. For that reason, sub-orbital and orbital flight tests are being planned and performed. However, many environments seen during the entire lifespan of the unit can now be duplicated or simulated in existing ground-based laboratories and test facilities.

A fully comprehensive safety ground test program must be based on a thorough analysis of all of the hazardous conditions to which a nuclear power unit can be subjected during its lifespan. All possible consequences of failures affecting safety during any of the hazardous conditions postulated must be fully assessed. A complete engineering analysis of those aspects of the design of the reactor that are of concern to the safey of the system will be necessary to insure that all possible consequences have been accurately stated. A thorough understanding of all of the system design data is required to fully complete such an analysis.

A study of the probability of the occurrence of a sequence of consequences resulting from all hazardous conditions is required. From the results of this study, a comprehensive ground test program for a specific design can be formulated.

The current safety ground test program for reactor-type power units can be broadly divided into two parts. One, a general studies program includes those efforts whose results can be applied to the safety assessment of many types of nuclear power units. The other, a program of testing to evaluate the safety of specific nuclear power unit designs and hardware. Each of these parts will be described.

General Studies

Launch Pad Abort Environment Study -- One of the more severe environments to which a SNAP power supply can be subjected is that resulting from the explosion and fire from the accidental abort of a rocket vehicle on its launch pad. The overpressures and temperatures of this environment are known to be extreme but quantative values have not been fully defined by close-in measurements within the fireball itself.

The general study embarked upon under this program consists of the following phases:

1. A survey of available information, analytical studies and experimentation on the subject of massive fireballs to attempt to understand in better detail their hydrodynamics and related effects.

2. Participation and cooperation with other governmental agencies in planning and designing instrumentation for installation on certain existing missile launch pads to measure pressures and temperatures existing within fireballs that may result from future launch aborts. Sandia Corporation will utilize previous experience in instrumentation gathered from years of participation in weapon testing activities.

3. Development of a previously designed Sandia passive thermal sensor device to extend its range to a lower level to permit its use in recording the close-in temperatures of fireballs that may occur from missile aborts on any launch pad.

4. Design and development of a passive pressure sensor to be used in conjunction with the thermal sensor described above.

5. Participation and cooperation with other governmental agencies in future scheduled missile launch abort fireball studies and experiments.

The objective of this effort is to obtain a reliable, quantitative definition of the environment resulting from a launch pad abort of a rocket vehicle to be used for the transportation of a SNAP power supply. Based on this definition, laboratory and field tests can be performed to simulate the environment on SNAP hardware to determine the extent of the hazard that might result.

Beryllium Compound Formation and Dispersal Study -- Many present and proposed SNAP reactor type power supplies (as well as other nuclear propulsion reactors) use quantities of beryllium in their design. The high temperatures and pressures from launch pad aborts ~~(See IIA)~~ to which these units might accidentally be subjected could cause the formation and dispersal of highly toxic compounds of beryllium. The fundamental mechanisms causing the formation and dispersal of beryllium compounds is not well understood. This study is intended to clarify the understanding of these mechanisms and to quanitatively define the amount, type, and particle size of beryllium compounds released under various conditions of pressure, temperature, atmosphere, etc.

The study will be conducted along two paths: One, by means of a sub-contract from Sandia to a qualified laboratory. The other, by means of a laboratory investigation conducted at Sandia.

<u>Earth Target Simulation Study</u> -- There is reason to believe that targets commonly used for earth impact tests do not actually simulate a condition of the surface of the earth to a point sufficient to conclude that the effect on a projectile of impacting into such a target duplicates the effect that would be gotten from an actual earth impact. This study has been undertaken to determine if the present earth impact tests do simulate impact into the surface of the earth; and, if found not to do so, to develop a method of specifying the design of an earth target that does indeed simulate the earth's surface.

No statement can be made about what any item will do when it impacts the surface of the earth unless some specific point is defined since the earth's surface is not homogeneous and isotropic. In the space of a very few feet the properties of the soil can vary considerably both horizontally and vertically. This study will set up certain boundary conditions for a limited number of surface soil types so that earth impact tests can be run on a limited number of simulated earth targets that will encompass the range of surface soil conditions upon which a falling test item might impact.

The study will consist of both (1) analytical work to attempt to set up a mathematical model of the mechanisms that occur upon impact and (2) experimental work to empirically determine the relationships that result from impact. The experimental work will consist of laboratory model work, field model tests, and fullscale field tests.

Earth Cratering Studies -- An environment which might, in certain SNAP reactor designs, lead to a critical configuration could result from water gathering in a crater caused by and containing a non-dispersed core following accidental impact into a soil. The extent to which craters are formed and to which the crater will retain the original projectile is not quantitatively known for projectiles in the configuration of reactor core vessels impacting at various velocities into a variety of soil types and conditions.

The objectives of this effort are:

1. To perform an analytical study of the mechanisms of crater formation from projectiles impacting at various attitudes and velocities.

2. To perform a series of impact cratering tests to gather empirical data on the formation of craters and their retention of the impacting projectile under various impact attitudes and velocities. The test series will be of a generalized nature. Simulated test items will be used that will resemble in size, weight, and configuration the core vessels of presently conceived SNAP reactor type power supplies. The impacting velocities and attitudes used in this series will be selected to include those that could reasonably be expected from the presently conceived SNAP reactor designs. The soil types tested in the cratering studies will be as nearly those selected in the earth target simulation study as is reasonable.

Terminal Velocity and Attitude Study -- The terminal velocity and its accompanying aerodynamic attitude achieved by a free-falling SNAP power supply or its components is necessary to completely define the environment for a test series intended to determine the effects of impact. The experimental determination of the terminal velocity and attitude of a free-falling configuration is necessary to supplement aerodynamic calculations of these values.

The objective of this effort is to perform a series of tests to experimentally determine the terminal velocity and accompanying aerodynamic attitude of different configurations of test items simulating generalized SNAP reactor power supplies and core vessels. Simulated test items will be used that will resemble in size, weight, and aerodynamic characteristics (1) presently conceived complete SNAP reactor power supplies less shield and (2) presently conceived SNAP core vessels.

Core Vessel Impact Survival Study -- The structural effects sustained by a reactor core vessel upon impact with a variety of target materials at various velocities must be known to evaluate its safety under all possible conditions.

Demonstrations of the resulting structural effects is necessary to supplement and verify calculations of the core vessels structural integrity.

The objective of this effort is to calculate the structural integrity and to experimentally determine the structural effects on test items simulating generalized SNAP reactor core vessels impacting against a variety of targets at various attitudes and velocities. Simulated test items will be used that will resemble in size, weight, shape, and structural strength a range of generalized examples of presently conceived SNAP reactor core vessels.

The experimental portion of this effort will include several series of tests to determine the following:

1. The effect of impact attitude versus velocity

2. The effect of target materials versus velocity

The impact velocities and attitudes to be examined will be selected from the results of the study described in "Terminal Velocity and Attitude Study" above.

The target materials to be used will be concrete, water, and earth simulations selected from the study described in "Earth Target Simulation Study" above.

<u>SNAP 10A Specific Studies</u>

Phase I Mechanical and Thermochemical Test Series on the SNAP 10A was conducted by Atomics International with the Air Force Special Weapons Center at Holloman Air Force Base, New Mexico as one of the projects in the SNAP Aerospace Safety Program. The principal objective of the tests was to obtain data and information which could be analyzed for evaluating the hazards that may occur before, during, and after the flight of a SNAP 10A reactor.

~~The test series and the results obtained are described in Reference 1.~~ Phase II of the SNAP 10A Safety Ground Test Program was performed by Sandia Corporation. ~~Reference 2 describes this part of the program.~~ Part A of the Phase II plan consisted of several impact tests, a series of fire tests, an explosion test, and a chemical interaction test.

~~The results of the beryllium oxide formation test series were reported in Reference 3. Reference 4 describes the chemical interaction test and its results. The results of the squib temperature test were reported in Reference 5.~~

The explosion test was postponed from Part A and will be performed when the overpressure environment of a launch pad abort is more clearly defined.

Part B of the Phase II program consisted of a complete analysis of hazardous conditions and possible consequences, dynamic analyses of impact configurations, impact tests required to verify calculations, and laboratory tests to determine beryllium compound formation and dispersal. The latter series of laboratory tests has been removed from Part B and is being continued as part of the General Studies Program described earlier.

Presently planned tests on the SNAP 10A reactor include the following:

1. Terminal Velocity and Attitude Study

The objectives of the terminal velocity and attitude test series are:

a. To experimentally determine the terminal velocity achieved by four specific configurations of the SNAP 10A system during free fall in the atmosphere.

b. To experimentally determine the aerodynamic attitude of four specific configurations of the SNAP 10A system at terminal velocity during free fall in the atmosphere.

2. Impact Survival Study

a. Terminal Velocity Impact Series

The objectives of the terminal velocity impact test series are:

(1) To experimentally determine the structural integrity of three specific configurations of the reactor system at sea level terminal velocity under various impact attitude angles and temperatures when these configurations are impacted against a simulated earth target.

(2) To experimentally determine the fuel rod dispersion characteristics under the same conditions as in (1) above.

(3) To experimentally determine the structural integrity of the reactor system under the same conditions as in (1) above, except when the system is impacted against an infinite water target.

(4) To experimentally determine the fuel rod dispersion characteristics under the same conditions as (3) above.

b. Reflector Separation Velocity Impact Series

The objective of the reflector separation drop test series is to determine the minimum impact velocity at which the reactor reflector will separate from the reactor assembly.

3. Explosion Survival Studies

a. Launch Pad Abort Overpressure Series

A series of tests will be conducted to determine the structural damage sustained by specific configurations of the SNAP 10A reactor system at the launch pad overpressure. The earlier explosion test run as part of SNAP 10A Phase I series is believed to have provided little data useful for fully assessing the safety under this environment. Further explosion tests must be performed when evaluation and definition of the overpressures in a launch pad abort environment are completed. Work on this definition is being performed as described earlier in this report. Details on the explosion testing of SNAP 10A hardware will be decided when adequate information becomes available from the launch pad abort environment study.

~~b. Reflector Separation Overpressure Series~~

~~Determination of the explosive overpressure level at which the reactor reflectors separate from the core vessel is necessary as a reference for evaluating the extent of possible hazard during a launch pad abort accident. This specific overpressure value would establish the power limit for values of abort explosion overpressure. This lower limit would be a basis for a reactor design likely to reach criticality with minimum submergence in water.~~

Current Isotopic Power Supply Safety Ground Test Program

This program is divided into two parts as is the program for reactor power units.

General Studies

Fuel Capsule Impact Testing Program -- A fuel capsule impact testing program is underway to statistically determine the effects of impact loading upon the structural integrity of fuel capsules (similar to those of the SNAP 9A series) when fuel configurations, fuel materials, operating temperatures, capsule designs, and impact attitudes are changed for various targets. Test item materials have been carefully selected to simulate at ambient temperature the properties of the actual materials when they are used at their operating temperatures. The test items are specially designed to permit fabrication at a modest cost to allow extensive testing. It is expected that sufficient tests will be performed to permit statistical analysis of the results.

Concurrently, with the performance of the above impact testing program, a dynamic analysis study of the performance of the fuel capsule test items will be pursued. This testing program will be modified according to the results obtained from the dynamic analysis study.

Although the impact testing series will test items similar to SNAP 9A fuel capsules, the results obtained from the tests and the accompanying dynamic analysis will be sufficiently broad that they can be applied to designing and testing fuel capsules which will be used in subsequent isotopic SNAP units.

SNAP 9A Specific Studies

THE OBJECTIVES OF THE SNAP 9A GROUND TEST SERIES WERE:
~~Reference 6 describes the series of SNAP 9A ground tests undertaken on this system. It states the objectives as follows~~:

1. To verify aerodynamic calculations by experimentally determining the terminal velocity and its accompanying attitude of: (a) the SNAP-9A generator, with and without radiator fins; and (b) the SNAP-9A fuel capsules both with the CG located where it would be when the fuel is in the as-installed configuration and with the CG located where it would be when the fuel has melted and run into one end of the fuel rod.

2. To analyze the structural and dynamic effects on the SNAP-9A fuel capsule and generator of impact loading under the determined terminal velocity conditions and under the most adverse conditions of impact attitude and loading conditions.

3. To perform impact tests on the fuel capsule and generator required to verify the structural and dynamic effects analyses.

The following tests on SNAP 9A hardware have been completed and the results have been used in the independent safety assessment of this system. This assessment has been forwarded to the AEC/DRD.

Drop Tests -- ~~The drop tests were completed and the results were published in Reference 7.~~ The test units listed in the table below were dropped from aircraft at altitudes of 10,000 and 15,000 feet above the Tonopah Test Range and were tracked by cinematic theodolites. All units tumbled randomly and evidenced reasonable agreement with theoretical data.

SNAP-9A Generator and Capsule Drop Tests

Test unit	No.	Maximum velocity (ft/sec, corrected to sea level)
Simulated generator with fins	2	118
Simulated generator without fins	2	230
Full-scale simulated fuel capsule	22	253
Scaled-up simulated fuel capsule	12	301

Structural and Dynamic Effect Analyses

Structural and dynamic effect analyses on the SNAP 9A generator and fuel capsules were started in December 1962. Work to date has provided test conditions for a series of impact tests. ~~Results of these analyses are reported in Reference 8.~~

Impact Tests -- Eleven simulated SNAP-9A fuel capsules were impacted against granite and angle-iron targets. This test series was reported in Reference 8. The object of the impact tests was to determine whether the fuel capsule would contain the radionuclide fuel under the most severe predicted impact conditions. Granite and steel angle-iron targets were propelled into the suspended fuel capsules by a 155-mm recoilless rifle for five of the tests and by a rocket-powered sled for the remaining six tests. All capsules were stabilized at a nominal 1150°F before impact.

The results of this test series indicated that the flight quality capsules did not rupture when impacted end-on or side-on against a flat granite target and when impacted side-on against a steel angle iron target at velocities appreciably greater than the predicted impact velocity. However, when impacted at a 45° angle against a flat granite target, the capsule ruptured at a velocity of 276 feet per second, which is near the predicted impact velocity.

~~Nine additional samples were obtained for further investigation of the 45-degree impact attitude against a granite target because of the failure experienced during the first series of tests. This latter test series was halted, however, after six capsules had been tested because the capsule failure threshold appeared to be within or lower than the predicted terminal velocity range of 238 to 260 feet per second at 2000 feet above mean sea level. A preliminary report of this abbreviated test was submitted to DRD (AEC) for review.~~

REFERENCES

1. NAA-SR-8304, "Phase I Mechanical and Thermochemical Test Series Snap Aerospace Safety Program," Atomics International, July 1963.

2. SCDR 336-62, "Snap 10A Ground Test Plan - Phase II" Sandia Corporation, November 1962.

3. SCDR 401-62, "BEO Formation Test Series, Test F-2-D Snap 10A Ground Test Phase II-Part A," Sandia Corporation, January 1963.

4. SCDR 415-62, "Chemical Interaction Test C-I-E Snap 10A Ground Test Phase II - Part A," Sandia Corporation, January 1963.

5. SCDR 107-63 "Squib Temperature Test F-I-C Snap 10A Ground Test Phase II - Part A," Sandia Corporation, June 1963.

6. SCDR 412-62, "Proposed SNAP 9A Ground Test Plan - Phase I," Sandia Corporation, December 1962.

7. SCDR 63-63, "Drop Tests of SNAP 9A Generator and Fuel Capsules," CRD, Sandia Corporation, March 1963.

8. SCDR 64-63, "Impact Tests of SNAP 9A Fuel Capsules, First Progress Report," Sandia Corporation, June 1963.

TABLE 1

SANDIA AEROSPACE SAFETY GROUND TEST PROGRAM

- Project Engineering
  - Planning
  - Report preparation
- Mechanical Actions
  - Impact tests
    - Earth target study
    - Earth cratering study
  - Dynamic analysis studies
  - Terminal velocity studies
- Thermal & Chemical Interactions
  - Chemical interaction tests
  - BE compound formation and dispersal studies
  - Launch pad abort pressure and temperature studies
  - Self-welding design analysis and studies
  - Thermal analysis
- Nuclear Reactions
  - Nuclear safety design review
  - Hazardous conditions analysis
  - *Reactor transient and excursion tests
  - *Critical configuration tests
  - *Fission product release tests and studies

*Indicates experimental work performed by others, but planning, execution, and evaluation is monitored by Sandia.