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SNAP SUPPORTING R & D
DECEMBER 1960 - MARCH 1961
(Title Unclassified)

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PROGRESS REPORT FOR
SNAP SUPPORTING R&D
DECEMBER 1960 - MARCH 1961
(Title Unclassified)

By
M. V. DAVIS

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THE TWO PREVIOUS BI-MONTHLY PROGRESS REPORTS ARE:

NAA-SR-5932	August-September 1960	Issued: January 15, 1960
NAA-SR-6024	October-November 1960	Issued: March 1, 1961

Other Reports Issued:

NAA-SR-5896	SNAP Shield Test Experiment Final Hazards Summary	Issued: March 17, 1961
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PROJECT ENGINEER'S REPORT

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Program: SNAP supporting R&D
Project Engineer: M. V. Davis
Reporting Period: December 1960-March 1961

I. PROJECT OBJECTIVES

The objective of the Supporting Research and Development Program is to give basic and general assistance to the SNAP programs under development and to supply the information necessary for their successful application. In this respect, basic work is underway in developing mathematical techniques appropriate to compact nuclear power systems for reactor core and shielding calculations. These mathematical techniques are augmented by experiments to determine the validity of the methods and to furnish basic data to the calculations. Currently, studies of ballistic re-entry are underway with both analysis and experiments being used to aid in the design of SNAP systems to insure that radiological hazards may be eliminated in the case that the satellite carrying the reactor re-enters the earth's atmosphere. Finally, advanced studies are in progress to insure that full use is made of SNAP technology and that applications of SNAP reactors in space be determined in order to ascertain where more detailed work in development areas must be initiated. As an assist in extending the knowledge to higher powered and more efficient power systems, work is underway in developing thermionic power converters and in utilizing this technology in the design power systems to be used in space applications.

II. PROJECT ENGINEER'S SUMMARY EVALUATION OF PROGRESS TO DATE

The Sigma Corporation, under subcontract to Atomics International, performed preliminary studies of application of SNAP 2, 8, and 10.

A Schedule 44 construction data sheet has been presented to the AEC for a generalized critical facility to support the SNAP technology.

Liaison work has been performed between AI and AVCO Rad to specify design considerations on SNAP 2 and 10 as they affect re-entry safety.

Overall thermionic converter efficiencies greater than 14% have been measured. This number is uncorrected for extraneous heater losses. Thus actual efficiency of the converter would be about 20%.

The dynamic analysis of SNAP type reactors has been extended to include delayed photoneutrons from beryllium and the change of the quantized neutron energy spectrum with temperature.

The Monte Carlo calculations for multitrajectory direct shield calculations and for scattering from plane and conical surfaces are completed and in use.

Empirical formulas are being derived from experiments performed in the SCA-2 to determine the relative worth of reflector materials in order that shields may be calculated.

Thermal radiation from finned radiators has been coded for various fin geometries.

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PROJECT ENGINEER'S REPORT

A shield shaping code (FARSE-1B) has been put in production. This code calculates the number and the angular distribution of neutrons emerging from a shield.

A referenced design of a 300 kwe thermionic reactor system has been completed. The unshielded system specific weight is 4 lb/kwe.

A nuclear reactor kinetics code has been completed. The code, TEAR, yields reactivities from experimental power transients.

The assumed separability of the equations describing the neutron behavior in a reactor has been experimentally verified for the SNAP type reactor cores.

The average neutron generation time was measured in a nickel reflected SNAP reactor. The results were $5 \pm (10)^{-6}$ seconds.

The Shield Test Experiment facility is under construction, is on schedule, and is planned for completion on May 5, 1961.

A permanently sealed thermionic diode operated for 118 hours with no observed degradation of operation.

The following reports have been issued:

NAA-SR-5610, "An Enriched UO_2 -ZrH Critical Assembly."

NAA-SR-5619, "Physics Measurements on the SNAP Experimental Reactor (SER)."

NAA-SR-5650, "Nuclear Space Power Systems."

A paper entitled, "The SNAP Reactor Program" was presented at the Nucleonics in Flight Symposium of the American Nuclear Society.

NAA-SR-5317, "SNAP 2 Radiative Condenser Analysis."

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Program: SNAP Supporting R&D	
Project: Advanced Space Power Plants	
Responsible Engineer: R. A. Stone	Project Engineer: M. V. Davis
Reporting Period: December 1960-March 1961	AEC Category: 04-10-02-01
General Order: 7590	Subaccount: 2004

I. PROJECT OBJECTIVES

A continuing need for long life, reliable, lightweight power sources exists in the United States space program. As boosters become larger, payloads will demand more power, so that power levels into the electrical megawatt region are of interest. Potential electric propulsion applications will require lower and lower specific weights. This project will investigate logical outgrowths from the SNAP 2, 8, and 10 programs with respect to these space objectives. Higher powers will be investigated. Dynamic vs static power conversion systems will be evaluated. Space application studies will be made. Vehicle and mission integration will be considered.

II. MAJOR ACCOMPLISHMENTS TO DATE

A generalized design procedure for the optimization of space radiator-condensers was published in NAA-SR-5317, "SNAP 2 Radiative Condenser Analysis." The method presented has been programmed and run on a digital computer, and minimum weights have been determined for radiator-condensers over wide ranges of power levels, working fluids, and condensing temperatures. The results obtained were presented in a briefing to representatives of NASA and AEC, the contents of which were summarized in NAA-SR-MEMO-5474, "Advanced Nuclear Space Power Systems Briefing for AEC-NASA, July 14, 1960."

The study of the applications of SNAP 2, 8, and 10, prepared by the Sigma Corporation under subcontract to Atomics International, has been completed. The report was in two volumes: LA-3301, "Application of Nuclear Power Supplies to Space Systems," and LA-3302, "An Analysis of the Use of Satellites in Commercial Communications."

Three papers on SNAP systems were presented to the American Rocket Society Meeting on Space Power Systems, and a paper on radiator-condenser analysis was presented to the Winter Annual Meeting of the ASME.

A paper was presented to the International Astronautics Congress entitled "The Practical Application of Space Nuclear Power in the 1960's."

The AI contribution to the ARPA handbook has been published as an AEC topical report, NAA-SR-5650, "Nuclear Space Power Systems."

III. PROGRESS DURING REPORT PERIOD

The ARPA handbook was revised to cover SNAP 10A, and revised chapters on shielding and thermionic reactors were included.

The code for weight optimization of noncondensing space radiators was completed.

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A paper entitled "The SNAP Reactor Program" by J. R. Wetch and M. G. Coombs was presented to the Nucleonics in Flight Symposium of the American Nuclear Society.

A study was made of the integration of SNAP 2 in a manned space vehicle and the results summarized in NAA-SR-MEMO-6187. The weight of the power supply for a two-week mission, with 5 rem integrated dose, and 50-ft reactor-payload separation, was 1800 lb. A study of the integration of SNAP 8 in a manned vehicle has been initiated.

A study of the application of SNAP 2 and SNAP 8 to electrical propulsion missions was initiated.

IV. EVALUATION OF EFFORT TO DATE

Methods and approaches to meet the objectives stated in Par. I have been established. Work has been initiated in all the listed areas.

V. NEXT REPORT PERIOD ACTIVITIES

Work will continue on the electrical propulsion and high temperature hydride reactor studies up to 150 kwe. The generalized radiator codes will be published. A preliminary design study of the installation of an operating SNAP reactor at the 1964 World's Fair will be initiated.

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PROJECT PROGRESS REPORT

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Program: SNAP Supporting R&D

Project: Thermionic Reactor

Responsible Engineer: C. K. Smith

Project Engineer: M. V. Davis

Reporting Period: December 1960-March 1961

AEC Category: 04-10-02-01

General Order: 7590

Subaccount: 2006

I. PROJECT OBJECTIVES

The purpose of this project is to analytically investigate and evaluate the advantages and problems associated with compact reactor thermionic power systems. Particular attention will be given the following:

Space power plants with outputs in the kilowatt to megawatt range.

Terrestrial systems of all power levels with particular emphasis on sea water rejection temperatures.

Compact systems utilizing both thermionic conversion only and coupled to more conventional schemes.

Analyzing and establishing the usefulness of reactor tests with thermionic fuel elements.

Emphasis will be on nuclear, heat transfer, mass transfer and diffusion, and mechanical design of reactor converters. Full advantage will be taken of research in converters and materials in these areas so that the major questions of feasibility will be resolved at the earliest possible date.

II. MAJOR ACCOMPLISHMENTS TO DATE

A reference design of a thermionic reactor system for 300 kwe-1000 v output has been completed. Weight to power ratio is 4 lb/kwe unshielded. A report describing this system has been prepared.

III. PROGRESS DURING REPORT PERIOD

The 300 kwe reference design thermionic reactor system has been further refined.

A study of thermionic reactor weight vs output power is being made using the AIM-6 code with normalization factors from existing experimental results. In addition, coolant pump and radiator codes are being combined and sections to include piping are being added so that minimum weight heat rejection systems can be determined. This work will result in a method for total system weight minimization which will be used in future design studies.

A brief investigation of a converter-fuel element that employs an external cathode and internal anode was made. This arrangement would possess some structural and fabrication advantages and result in a substantial decrease in fuel temperature drop; however, for the same core and fuel volumes the required specific cathode power is about 25% greater than for the cylindrical arrangement using an internal cathode.

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PROJECT PROGRESS REPORT

Work on a research and future development plan for the thermionic reactor has been initiated.

IV. EVALUATION OF EFFORT TO DATE

Design work to date indicates that thermionic reactor systems will offer considerable weight advantage for space applications. Design of the 300 kwe reference system revealed many of the important problem areas which will be subjected to further study.

V. NEXT REPORT PERIOD ACTIVITIES

The technical report NAA-SR-6077, "Design Study of a Thermionic Reactor Power Plant for Space Applications" will be issued.

The development plan will be completed.

Work now in progress will be continued. Systems at other power output levels will be studied. The external cathode concept will be investigated further.

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Program: SNAP Supporting R&D	
Project: Compact Reactor Analysis	
Responsible Engineer: W. J. Roberts	Project Engineer: M. V. Davis
Reporting Period: December 1960-March 1961	AEC Category: 4404.1
General Order: 7590	Subaccount: 2030

I. PROJECT OBJECTIVES

This project will develop basic mathematical techniques for the static and dynamic analysis of compact reactor cores. Analysis of selected experiments will be made to verify and improve the theoretical approaches in order to extend the engineering of compact reactor systems. Analyses of advanced compact reactor concepts will be performed using the developed techniques. The study of reflector geometry and material will be extended and types of reactor controls will be analyzed. The determination of detailed neutron spectrums in SNAP cores is required to evaluate the use of burnable poisons for control minimization. The information will be utilized in the design of more appropriate reactor systems.

II. MAJOR ACCOMPLISHMENTS TO DATE

A kinetics program which allows mother-daughter delayed neutron precursors has been programmed to allow study of beryllium photoneutron effects on SNAP reactors. Determination of effective yields and mean lives of eight photoneutron groups has been made.

A program to compute heat energy radiated from complex finned geometries has been completed.

The spectral coefficient computed by ZOOM has checked SER transient experiments.

A Monte Carlo code to correlate N_H of fuel rods with scattered neutron intensity has been completed.

Transfer cross sections for water have been obtained by reduction of experimental scattering data and have been checked against experimentally determined spectra.

III. PROGRESS DURING REPORT PERIOD

HAMBONE, a Monte Carlo code to calculate scattered neutron intensity from fuel rods, has been completed.

ZOOM transfer cross sections for water were generated from cold neutron scattering data.

A kinetics code, TEAR, to obtain reactivities from experimental flux transients was completed.

A forty-group upscattering diffusion theory code was formulated.

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PROJECT PROGRESS REPORT

IV. EVALUATION OF EFFORT TO DATE

The extension of the Placzek thermal scattering energy transfer mode to water has been shown to be reasonably valid through check of experimental spectra. This is a significant step in assisting in further understanding of neutron thermalization phenomena and the concomitant reactor kinetics.

V. NEXT REPORT PERIOD ACTIVITIES

The forty-group diffusion code will be programmed and "debugging" begun. HAMBONE will be used to study bias techniques.

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PROJECT PROGRESS REPORT

Program: SNAP Supporting R&D

Project: Critical Experiments

Responsible Engineer: L. I. Moss

Project Engineer: M. V. Davis

Reporting Period: December 1960-March 1961 AEC Category: 4404.1

General Order: 7590

Subaccount: 2031

I. PROJECT OBJECTIVES

This project will check out and operate the SNAP Critical Facility. Critical assemblies of idealized cores will be made to provide normalization for theoretical analyses and to obtain basic information for further development of the core concepts necessary to extend the range of compact reactor utilization. The work will further include water immersion and transient effects to insure always-safe reactors.

II. MAJOR ACCOMPLISHMENTS TO DATE

The detailed drawings of a critical assembly machine designed for unusual flexibility with regard to core diameters and lengths and reflector control element parameters have been completed.

The "Basis for Design" of the proposed SNAP Critical Facility was completed. This, along with the Schedule 44 Construction Data Sheet, was submitted to the AEC for approval and authorization of funds.

The neutron counting instrumentation at the critical facility has been overhauled to increase reliability and decrease the number of false scrams arising primarily from switch noise. A determination of the linearity of the various information channels has been made and operating limits defined.

A topical report summarizing the results of the SCA-1 experimental program, NAA-SR-5610, was issued. A topical report summarizing experiments performed with the SER core, NAA-SR-5619, was issued.

III. PROGRESS DURING REPORT PERIOD

A summary of the critical configuration determined for the SCA-2 (cylindrical) geometry is given in Table I. In all cases the core (fuel region) diameter is 7.00 in. and the radial reflector thickness is 2.50 in. A stainless steel sheet 0.062 in. thick separates the assembly at approximately the midplane. The average fuel composition is given in Table II.

Experiments examining the statistical time variation of neutron density have been performed on the nickel reflected assembly with detectors adjacent to the upper core boundary, using both pulse-train and ion-current spectrum techniques. The apparent -3 db point, without refined instrument corrections, is 230 ± 25 cps. This yields a value for the prompt neutron lifetime of approximately 5×10^{-6} sec. Refinement of results is currently in process. The above parameters are important to safety studies of this type of reactor.

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PROJECT PROGRESS REPORTTABLE I
SCA-2 CRITICAL CONFIGURATIONS

Reflector Material	Core Length	Upper End Reflector	Lower End Reflector, Including Control Cap	k_{eff}
	(in.)	(in.)	(in.)	
Nickel	8.85	2.49	1.46	1.000
Nickel	9.00	1.62	1.46	1.002
Beryllium	6.75	2.35	2.50	1.003
Beryllium	7.50	0.80	2.50	1.001

TABLE II
SCA-2 AVERAGE FUEL COMPOSITIONS

Element	Concentration ($\times 10^{-24}$ atoms/cm ³)
Hydrogen	0.0611
Zirconium	0.0353
Uranium-235	0.001414
-238	0.000105

The void coefficient of reactivity has been measured for both lucite and NaK along the axis of the assembly. For lucite the void coefficient is $-2.5\text{¢}/\text{cm}^3$ at the core center and $-0.8\text{¢}/\text{cm}^3$ at the core-reflector interface. The corresponding values for NaK are $+0.21$ and -0.03 . The estimated error of these measurements is $\pm 0.05\text{¢}/\text{cm}^3$.

Activation of U^{235} foils throughout the SCA-2 has been performed. Off-axis points were sampled in both the core and reflector. The activation was found to be separable in the radial and axial directions to within 7% in the core and within 10% over most of the reflector. This verification of separability over almost the entire assembly lends added confidence to the calculational techniques employed by the project, since the validity of separability has heretofore been assumed in criticality calculations.

Various reactivity measurements have been completed. These include the effect of cadmium sheet at the core-upper end reflector interface and at the core midplane, and the effects of 347 stainless steel and Hastelloy B at the core-reflector interface. These measurements have been used to estimate the reactivity effects to be expected from some possible designs of future SNAP reactors.

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The neutron flux decay following a 6-hr run at steady-state operating level has been used to estimate the effective photoneutron constants for beryllium.

Fabrication of the SCA-3 reactor has begun. The feasibility report for the fuel element fabrication has been written

IV. EVALUATION OF EFFORT TO DATE

The submission of Schedule 44 Construction Data Sheet to the AEC was made at the scheduled time. If prompt action is undertaken by the AEC, there will be no delay in attaining the objectives of this project.

The experiments being performed are meeting the above objectives of the project and are providing the input data needed for an estimate of the accuracy and for continuing refinement of calculational techniques. Measurements are yielding estimates of the effects of various design features proposed for future SNAP reactors when these effects are not amenable to accurate calculation. Data are being generated that allow the design of safe reactors.

V. NEXT REPORT PERIOD ACTIVITIES

Further effort on the proposed SNAP Critical Facility will await authorization from the AEC.

Rare earth reactivity measurements in SCA-2 will be made in order to estimate the near-thermal neutron spectrum. Reactivity measurements of reflector materials will continue. The effect of voids at the core-reflector interface will be determined. SCA-2 will be assembled with a lucite reflector.

Fabrication of the SCA-3 critical assembly and of the core loading will be completed. The machine will be installed and checked out.

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Program: SNAP Supporting R&D

Project: Shield Analysis

Responsible Engineer: F. H. Clark

Project Engineer: M. V. Davis

Reporting Period: December 1960-March 1961

AEC Category: 04-10-02-01

General Order: 7590

Subaccount: 2032

I. PROJECT OBJECTIVES

This project will provide analytical tools necessary to design a shield for an engineered satellite system to evaluate the effects of modifications placed in that design by the realities of fabrication, and to evaluate performance of the final designed system. It will further serve to guide the shield experimental program, analyze experiments in that program, and interpret measurements in a way to make them useful in actual shield design.

The overall objective of all shielding accounts is the design of lightweight efficient shields for satellite systems.

II. MAJOR ACCOMPLISHMENTS TO DATE

Two Monte Carlo Programs, upon which work was carried on during FY 1960 under subaccount 2232, have been completed. One is for determining reactor neutron leakage spectrum. Runs are now being made to test the adequacy of its importance sampling. The other program computes - as a function of position - the deposit of gamma ray energy in the shield. This program is used in conjunction with shield cooling calculations.

Two multitrajectory ray tracing codes (FARSE 1A and 1B) are complete and in production. These codes permit tracing of neutron paths from many source locations to the shield surface, angular dispersion of the shield surface, and subsequent tracing to target. They enable shaping of shield.

III. PROGRESS DURING REPORT PERIOD

LEMON-1, the neutron Monte Carlo, has been checked in all its separate parts. It has further been checked in assembly. Difficulties in assembly for curved boundary cases are now being investigated.

SCARF, neutron scattering from a flat surface, is complete and in production.

CORPSE, neutron scattering from a conical surface, is complete and in production.

TIGER-2, a heat conduction code written by GE, has been studied and interpreted. Some modification was made because of convergence difficulties.

A number of "random number" generators have been studied statistically, i.e., frequency distributions, sequential correlations, and chi-square deviations from

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true randomness. This study is intended to lead ultimately to the most economical random number generator with sufficient randomness to be suitable for Monte Carlo.

The assembly of pertinent Monte Carlo cross sections is more than half complete.

IV. EVALUATION OF EFFORT TO DATE

We have substantial confidence in the rough and rapid methods now developed for the shaping and evaluation of shields. These methods remain questionable at shield corners, but we expect nothing short of a full blown Monte Carlo to provide significant improvement. We are also confident of our abilities to determine temperature profiles in our shields. Such determinations are limited by our knowledge of effective cross-sections and effective thermal conductivity of shield structures, not by our ability to compute.

V. NEXT REPORT PERIOD ACTIVITIES

Principal effort will be placed on completing random number studies and Monte Carlo cross sections and in bringing LEMON-1 into production.

Need for supplementary shielding to protect the payload from radiation scattered from control drums, their supports, and other ancillary equipment will be studied.

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PROJECT PROGRESS REPORT

Program: SNAP Supporting R&D

Project: Shield Experiments

Responsible Engineer: R. L. Tomlinson

Project Engineer: M. V. Davis

Reporting Period: December 1960-March 1961

AEC Category: 4404.1

General Order: 7590

Subaccount: 2033

I. PROJECT OBJECTIVES

The purpose of this project is to provide basic measured parameters required in shield design for compact systems. Particular emphasis will be placed upon the following items: (1) attenuation of intermediate energy (0.1 to 4 Mev) neutrons through thin shields, (2) differential energy and angular distribution of neutrons as a function of shield composition and thickness, (3) heat generation distribution within the shield for the neutron and photon spectra emitted by the SNAP 2 reactor, (4) effects of changes in reactor spectra upon shield configuration, (5) effects of voids and penetrations through the shield, (6) effects of shadow shielding and shield splitting on overall system weight, and (7) effects of structural scatter upon system weight.

Approximate mockup shields will be studied. Primary emphasis will be placed on neutron shielding and secondary emphasis will be placed upon photon penetration and secondary photon generation due to the high photon resistance of the probable payload composition.

The overall objective of all SNAP shielding efforts is the design of light-weight efficient shields for compact reactor applications.

Because of the unique requirements of the SNAP program, it becomes necessary to investigate the differential energy and directional behavior of neutrons emerging from their shields. To satisfy this requirement, a shield testing facility has been proposed that allows experiments to be performed which can be integrated to yield the input data necessary to the exact calculations required for satellite APU shielding.

II. MAJOR ACCOMPLISHMENTS TO DATE

A shield test facility has been designed and is currently under construction. Test equipment for use in the facility has been designed and fabricated and is awaiting completion of the building for installation and checkout. Fuel for the reactor has been machined and is now being clad. The safety report for the facility has been prepared, approved by the division safety committee, and submitted to the AEC for final approval.

III. PROGRESS DURING REPORT PERIOD

The construction contract for the Shield Test Facility was awarded to the Southern Engineering and Construction Company of Los Angeles, Calif. Construction of the facility was started late in December.

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Completion of construction is estimated for early in May. At the end of the report period the construction was on schedule.

NAA-SR-5896, "SNAP Shield Test Experiment Final Hazards Summary," was issued during the report period. The fuel for the reactor was about 50% completed at the end of the report period with no difficulties in the fabrication encountered to date.

IV. EVALUATION OF EFFORT TO DATE

The design of the Shield Test Facility and associated test equipment encountered no major technical difficulties. The bids received for the construction of the facility were within budgeting estimates. No major difficulties are envisioned with the remaining construction of the facility or the associated test equipment. Difficulties with test equipment funding have been overcome, and the facility should be activated on or before June 30, 1961.

V. NEXT REPORT PERIOD ACTIVITIES

An operations manual for the Shield Test Facility is in preparation and should be completed and approved by the local safety committee. The Shield Test Facility construction should be completed. The initial criticality of the facility is possible late in the report period.

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ATOMICS INTERNATIONAL

A Division of North American Aviation, Inc.

PROJECT PROGRESS REPORT

Program: SNAP Supporting R&D

Project: Thermionic Conversion Research

Responsible Engineer: N. S. Rasor

Project Engineer: M. V. Davis

Reporting Period: December 1960-March 1961

AEC Category: 04-10-02-01

General Order: 7590

Subaccount: 2036

I. PROJECT OBJECTIVES

This project is directed toward achieving high efficiency and high power density thermionic energy conversion through understanding and applying the fundamental principles of operation. The ultimate objective is extension of this technology to permit integration of thermionic conversion into long life compact nuclear power plants having great superiority over more conventional systems.

II. MAJOR ACCOMPLISHMENTS TO DATE

The thermionic converter technology has progressed to power densities of 20 w/cm² and to efficiencies greater than 15%.

Volt-ampere curves have been determined from the emission limited region for close spacings to the almost constant internal resistance region for large spacings.

A technique for inert gas welding of commercial ceramic insulators into converters has eliminated the unreliable traying procedures.

New converters were designed that allow better access and are more reliable.

III. PROGRESS DURING REPORT PERIOD

Lifetime Studies — As previously reported, serious sputtering of the cathode has been observed during operation of tungsten and molybdenum cathodes for long times at high output power densities. This sputtering is not observed for tantalum cathodes, however. Since molybdenum has otherwise desirable properties as a converter cathode, attempts have been made to eliminate the sputtering effects and thus achieve the inherent long lifetime of the molybdenum cathode. It appears likely that the sputtering has resulted from impurities in the dismantlable analytical converter atmosphere. Therefore, a series of permanently sealed converters is being constructed in which considerable attention is being given to ensure that impurities are maintained at a very low level. Pre-treatment of all components, the use of getters and high purity cesium, and rigidly controlled procedures for assembly and charging are being employed. In a life test, the first diode of this series operated for 118 hr without significant degradation of performance, at which time an internal short circuit occurred. During the test the observed overall conversion efficiency (ratio of converter electrical output to total heater input power) was maintained between 12.8 and 14.7%. The average output power density was 7.5 w/cm², cathode temperature was in the vicinity of 1650 to 1700°C, and the spacing was 0.008 in. Failure occurred as a result of a flake of molybdenum shorting the anode to the cathode.

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Experimental comparison of the relative optimum performance parameters of the four refractory metals Ta, Mo, W, and Re under identical conditions in a dismountable cylindrical diode is continuing. To date, data for molybdenum and tungsten have been obtained. The efficiency using Mo is observed to rise more rapidly with cathode temperature than for W, leveling off above 1650°C. The efficiency for W levels off at about 1800°C at an efficiency about 20% lower than for Mo at that temperature. The optimum cesium pressure for W is substantially lower than that for Mo. These data, and data obtained previously for Ta in a different diode, are thus far in qualitative agreement with the theoretically predicted effect of base metal properties on converter performance. Cathodes with Ta and Re surfaces have been prepared for the standard diode to obtain data for further comparison.

IV. EVALUATION OF EFFORT TO DATE

The analyses and experimental data obtained to date continue to confirm the initial premise that thermionic conversion has the capability, with established technology and materials, of achieving the converter performance required for attractive space-power reactors. Even though advances have been made in the state of the art, the achievement of this performance for acceptable lifetimes with materials suitable to the reactor environment has yet to be demonstrated. Detailed theoretical understanding of converter operation has not yet been achieved, but important facts and relations have been developed which indicate such understanding will be rapidly evolved in the near future.

V. NEXT REPORT PERIOD ACTIVITIES

Further lifetime tests will be performed at different temperatures and performance levels, and with different electrode materials. Causes of failure will be determined and remedial action taken.

Performance data will be obtained for Ta and Re cathodes in the standard diode.

The variable spacing diode will be used to further explore the low temperature, large spacing region. Explanation for previously observed anomalous effects will be sought.

Program: SNAP Supporting R&D

Project: SNAP Re-entry Studies

Responsible Engineer: V. D. Sanders

Project Engineer: M. V. Davis

Reporting Period: December 1960-March 1961

AEC Category: 04-10-02-01

General Order: 7590

Subaccount: 2037

I. PROJECT OBJECTIVES

The purpose of this project is to determine through experimental and analytical studies the properties inherent in a SNAP vehicle re-entering the earth's atmosphere and to make such recommendations as are necessary to insure that no hazard to people will exist. The areas to be investigated for technological information are: (1) emissivity of ZrH from solid to vapor; (2) oxidation and ignition properties of ZrH; (3) ablation rates, temperatures and melting and vaporization points for materials such as aluminum, steel, beryllium, zirconium, and other possible SNAP APU metals; (4) possible separation methods for SNAP vehicles to insure fuel element burnup and fission product high-altitude dispersal; (5) actual burnup, vaporization, and dispersal properties of fuel-moderator (U-ZrH) fuel elements such as particle size, method and state (liquid, vapor, or solid) of ablation, and altitudes of occurrence; and (6) develop a computer code that will predict the data needed to analyze a re-entry SNAP vehicle.

II. MAJOR ACCOMPLISHMENTS TO DATE

Since the initiation of this project, the following major work has been completed.

- 1) Preliminary analyses of SNAP separation and burnup were made on the basis of conversion of kinetic energy to thermal energy during re-entry.
- 2) Two experimental programs were carried out by the Plasmadyne Corporation under subcontract with AI. The ablation characteristics of zirconium hydride in a 1-in. arc-heated gas jet were studied. A proposal for a third program, using a 3-in. jet and full-sized zirconium hydride fuel elements, was prepared. (See Plasmadyne reports TRO30-330000 and TR030-330012.)
- 3) There has been comprehensive review of program and calculations and active cooperation with AVCO-RAD on their comprehensive study of several phases of SNAP re-entry. This work was for AFSWC. Their investigations include:
 - a) Separation studies to suggest methods of insuring release of fuel elements from the reactor early in the re-entry period.
 - b) Experimental aerodynamic stability studies to predict the tumbling or oscillation of SNAP assemblies and components.
 - c) Experimental and theoretical studies in heat transfer, liquid layer stability, and ablation of reactor fuel particles.

Results of the AVCO-RAD investigations are being integrated into SNAP reactor designs.

III. PROGRESS DURING REPORT PERIOD

Close liaison with AVCO-RAD has been maintained by telephone. In addition, a visit to their facility was made in February. It was learned that their computer code for re-entry was not specifically written for SNAP studies, but consists of several codes for trajectory, heat transfer, and liquid-layer runback calculations.

Work at AI has been along the direction of digesting and correlating the theories and data from previous experimental programs. Progress has been made toward the development of a computer code for calculation of the trajectories of tumbling ablating bodies re-entering from satellite orbits. Preliminary results indicate that the assurance of complete burnup of 1.25 in. fuel rods is marginal. These findings are in agreement with those of AVCO-RAD. However, further research on zirconium combustion is necessary for final conclusions.

The subcontract for a third series of arc-jet tests at Plasmadyne is now awaiting final approval by the AEC, and is expected to be released shortly.

The subcontract for oxidation and ignition studies of zirconium hydride is being negotiated with Stanford Research Institute, and is expected to be released immediately.

IV. EVALUATION OF EFFORT TO DATE

The studies to date have pointed up the need for early breakup of the reactor can and release of the fuel elements. The lack of experimental data has delayed progress by several months. Thus, it is not possible at this time to predict whether the fuel rods will be burned and dispersed upon re-entry.

V. NEXT REPORT PERIOD ACTIVITIES

Work during the next quarterly period will proceed along the following lines:

- 1) Continued contact will be maintained with AVCO-RAD, and the results of their analyses will be reviewed for application to our re-entry safety program.
- 2) It is expected that contracts for experimental work will be awarded to Plasmadyne and to the Stanford Research Institute within the next few weeks. These tests will be monitored and the data will be interpreted for use in re-entry studies.
- 3) Calculation methods, including digital computer codes, will be developed for analysis of transient heating and ablation of bodies in re-entry flight and in laboratory tests. Results of the experimental programs will be used to provide physical theory and material property values for these methods. The codes will be used as tools in the analysis of our designs for SNAP reactor separation devices.
- 4) Support will be given the design and development units in the evaluation of thermal effects in devices related to SNAP re-entry safety.
- 5) Recommendations will be made for a flight-test program to provide data on SNAP system separation and burnup.