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LOS ALAMOS SCIENTIFIC LABORATORY
of the
University of California
LOS ALAMOS • NEW MEXICO

Quarterly Status Report on
Advanced Reactor Technology (ART)
for Period Ending April 30, 1967

Part II

(Title Unclassified)

UNITED STATES
ATOMIC ENERGY COMMISSION
CONTRACT W-7405-ENG. 36

AEC RESEARCH AND DEVELOPMENT REPORT

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LOS ALAMOS SCIENTIFIC LABORATORY
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PLASMA THERMOCOUPLE PROGRAM

Thermionic Element Test Facility

Because of the cancellation of the liquid Pu fuel element development program at the LASL, the Fast Reactor Core Test Facility (FRCTF) is being considered for use in conjunction with other programs. With adequate support, the thermionic energy conversion program could make efficient use of this facility. The development of thermionic conversion has been carried out, in this country, to the point that a relatively large test reactor is urgently needed.

A feasibility study has been carried out of the adequacy of the FRCTF as a thermionic element test facility. The main objective was to determine whether or not a reactor could be designed which would utilize the FRCTF buildings and equipment and which would simultaneously satisfy the testing requirements of all AEC contractors in thermionics. Technical advice and supplementary data regarding testing requirements were made available for this study through the cooperation of representatives of General Atomic, General Electric, and Thermo Electron Engineering Corp.

It was found that a mixed spectrum thermionic test reactor could be designed which satisfies current testing requirements and which could be conveniently placed in one of the FRCTF reactor pits. Preliminary designs were completed of the reactor, fuel element and test element handling equipment, fission gas disposal equipment, and Cs reservoir coolant systems. The proposed reactor would utilize the 15-MW Na cooling loop now in existence, and, moreover, the thermionic test program envisioned would make efficient use of essentially all of the buildings and other equipment which currently exist.

The feasibility study culminated in a proposal, which was submitted to the AEC, for further consideration of and subsequent construction of the reactor and related equipment.

Small Thermionic Power Supplies

The AEC has recently indicated considerable interest in the possibility of obtaining small amounts of electrical power by replacing part of the core of the SNAP 8 reactor with fueled thermionic diodes. The electrical power range of interest is from 5 to 25 kW. A preliminary study has been carried out to investigate the feasibility of such designs.

For this study, it was assumed that no radical alterations of the "flight qualified" SNAP 8 reactor, as described in NAA-SR-9592, would be permitted. This reactor has 211 fuel rods 0.53-in. diam. and 17-in. long. The core is approximately 9-in. in diameter. The only modifications of the reference design reactor which were considered involve the grid plates, the top head, and possible relocation of some components at the top of the reactor.

The results of this study show that it is not feasible, because of loss in reactivity, to consider replacing SNAP-8 fuel rods with ^{235}U fueled thermionic fuel rods. Moreover, if the replacement is made with ^{233}U , there is still a reactivity deficit. The use of ^{233}U in the thermionic fuel rods and in part of the remaining SNAP reactor is very sensitive to changes in the radius of the core and to the radial reflector thickness. Such variations may provide the most reasonable method of regaining the reactivity loss resulting from the inclusion of thermionic fuel rods.

The magnitudes of electric power output and the overall efficiencies which have been determined could be improved considerably by power flattening within the thermionic fuel rods and by allowing variable emitter lengths.

This study does indicate that the concept of driven thermionic reactors could be useful to provide electric power in the few kilowatt range.

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These results have been submitted informally to the AEC. It is anticipated that the AEC will provide ground rules for continued investigation.

Low-Power Heat Pipe Cooled Thermionic Reactors

One of the most significant advantages of thermionic reactors over other proposed systems for providing electric power in space is that such reactors require very few moving parts. The number is further decreased if heat pipes are used for cooling. Reactors cooled by heat pipes have been designed for the power range of a few megawatts electrical. There is some current interest in thermionic reactors in the power range of a few hundred kilowatts electrical. Thus, an investigation is now in progress to determine the lower limit in size for thermionic reactors with heat-pipe cooling.

The conceptual reactor design being studied is Be moderated and reflected and contains a double row of fuel elements in a ring surrounding a central moderating region. This concept circumvents the problem of radial power flattening encountered in the design of thermionic reactors.

Preliminary results of neutronics calculations indicate that reactors with heat-pipe cooling can be designed in the power range of 150 to 200 kW electrical in the mass region of 10 kg/kW. These calculations do not include the effects of axial power flattening nor are they necessarily for the optimum geometry.

Irradiation of Tungsten Clad Mo-UO₂ Cermet

A fourth fueled emitter irradiation unit has been added to the three currently undergoing irradiation in the MTR. The latest unit includes Mo-40 v/o UO₂ samples clad with CVD tungsten produced by the following techniques: (1) reduction of WF₆ by H₂, (2) pyrolytic decomposition of WCl₆, and (3) reduction of WCl₆ by H₂. The last method has been found to yield a cladding with a high degree of exposure of the (110) plane on the emitter surface -- an orientation highly desirable for

thermionic conversion applications. Another fuel sample clad by this process has been fired at 1800°C for 748 h, and x-ray diffraction measurements have shown the following changes in diffraction peak intensities:

	<u>110</u>	<u>200</u>	<u>211</u>	<u>220</u>	<u>310</u>
As deposited	110	1	7	27	5
747.6 h	100	0	37	13	0

The irradiation times accumulated by fueled emitter tests currently in the MTR as of May 8, 1967 are given below.

Test No.	Irradiation Times (Average)		
	MW-days	Hours	Goal Time (hours)
MTR-6	3690	2218	7500-10000
MTR-7	3075	1848	1500-2000
MTR-8	2460	1478	5000-6500
MTR-9	615	370	3000-3500

Mo-UO₂ Fuel Pin Development

Several parameters associated with the fabrication of Mo-UO₂ fuel pins are being evaluated. These include particle size of the Mo and UO₂, Y₂O₃ additions and the method of adding the Y₂O₃, the density of the UO₂ particles, and UO₂ loading.

A series of specimens has been completed and evaluated. Variables in this series were particle size of the Mo and UO₂ powders and composition. Twelve mixtures were lubricated with paraffin pressed hydrostatically at 15 tsi, presintered at 1050°C, and sintered at 1700°C. Metallography indicated a strong tendency for the dense spherical particles of UO₂ to block uniform shrinkage of the Mo matrix. This resulted in extensive cracking of the matrix and the Mo shrinking away from the UO₂. Factors aggravating these tendencies were finer Mo powder, coarser UO₂ spheres, and higher UO₂ loading. The open porosity as measured by a porosimeter varied between 14.2 and 24.9%. The 14.2% open porosity (19% total porosity) represented a sample pressed from 6μ Mo and 66μ UO₂ powders and

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loaded to 60 v/o UO_2 ; ~ 15% total porosity, most of it open, is desired. The data given above were for 1700°C sinter, but subsequent sintering at 2200°C in Ar did not significantly change the results.

Based on these results, 1/2-in. diam cylinders representing 20 different mixtures were prepared as shown in Table 1. The powders were pressed hydrostatically at 30,000 psi and presintered at 1000°C for 12 h in H_2 . The weight loss encountered during the 1000°C sinter was 0.25 to 0.60%, indicating a normal amount of excess O and H_2O in the powders. The densities after the 1000°C sinter varied between 57.4 and 71.1% of theoretical.

Sintering for 3 h in H_2 at 1700°C resulted in a weight loss of less than 0.1% in most instances. A weight loss of ~ 0.30% was recorded for samples fabricated from the $3.45\mu \text{UO}_2, \text{Y}_2\text{O}_3$ powder. The densities ranged from 67.9 to 88.8% of theoretical (Table 1) with the higher densities representing the samples prepared with the soft (low-fired) $\text{UO}_2, \text{Y}_2\text{O}_3$ agglomerates.

The specimens were given a final sinter for 1 h in Ar at 2200°C. This was required to yield relatively stable material for extended periods of time for an emitter operating temperature of ~ 1800°C. There was essentially no additional weight loss at 2200°C and the densities ranged from 72.8 to 93.6% theoretical. The higher values were associated with the 40 v/o loading and particularly with those samples prepared from the soft $\text{UO}_2, \text{Y}_2\text{O}_3$ agglomerates. The open porosity ranged from 0.7 to 19.9%; a porosity of 15% was desired.

Evaluation of the metallography and the results presented in Table 1 indicated the four compositions (underlined) warranted further study. Fuel pins representative of these conditions are being fabricated from 10% enriched UO_2 and will be evaluated in the MTR reactor after the surfaces are coated with 10 mils of vapor-deposited W.

The reason for the low open porosity of Sample 13-10 is not known; the open porosity of this specimen after the 1700°C sinter was comparable to related samples.

Metallographic evaluations were completed on four Mo- UO_2 pins coated last quarter by H_2 reduction and pyrolysis of WCl_6 . Photomicrographs showed that a rapid reaction occurs between the UO_2 and WCl_6 when WCl_6 makes contact with the Mo- UO_2 surface at 1500°C. The reaction probably occurs between Cl_2 and UO_2 with the products of reaction UCl_x and UO_xCl_y being volatile at that temperature. This occurrence was eliminated by an undercoat of W being deposited by the H_2 reduction of WCl_6 at 800-1000°C followed by W coating by pyrolysis at 1500°C. It was also observed that the W grains were considerably larger when deposited by pyrolysis at 1500°C than when deposited by H_2 reduction at 800-1000°C.

Fabrication of Thermocouple Assemblies

Four plasma thermocouple assemblies have been completed. These four-pin assemblies were composed of compartmentalized Ni collector bodies with two fuel pins and two collectors per compartment. The assemblies were fabricated by welding the Mo-Re alloy tack to the Ni collector; the Ni separators were then welded in place. The final weld joining the Ni collectors was made by the electron beam process.

Insulator Development

Insulators of Y_2O_3 and Al_2O_3 are being fabricated and metallized with W and W- Y_2O_3 , respectively. Problems were encountered with leaks being created in the ceramic during the grinding operation. For the Al_2O_3 , this was attributed to the inherent porosity in the thin (0.040-in.) wall insulator. The pressed and fired Y_2O_3 insulators were unsatisfactory because of laminations, pits, and excessive grain size. Subsequent grinding trials on slip cast Y_2O_3 (Michigan Chemical raw

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Table 1
Porosity Data After 1700 and 2200°C Sintering on 20 Mo-UO₂ Cermet with Four Types of Fuel

Cermet No.	Type UO ₂	UO ₂ Average Particle Size (μ)	UG ₂ Loading v/o	Mo Average Particle Size (μ)	Porosity (%)			
					After 1700°C		After 2200°C	
					Open	Closed	Open	Closed
13-1	Soft UO ₂ , Y ₂ O ₃	127	40	4	5.20	8.3	0.8	5.7
13-2	" " "	"	"	6	11.67	5.0	6.4	5.5
13-3	" " "	78	"	4	6.00	5.2	1.6	6.5
13-4	" " "	"	"	6	12.00	4.5	6.3	5.5
13-5	" " "	"	"	7.6	11.70	5.1	6.4	3.0
13-6	" " "	127	60	4	8.47	3.6	4.0	6.3
13-7	" " "	"	"	6	12.64	5.3	9.3	5.9
13-8	" " "	78	"	4	8.08	5.9	1.7	9.0
13-9	" " "	"	"	6	14.14	3.8	10.4	3.2
13-10	Dense UO ₂ , Y ₂ O ₃	3.45	40	4	17.39	3.1	0.7	9.5
13-11	" " "	"	"	6	22.04	3.5	13.6	2.6
13-12	" " "	"	"	7.6	21.18	3.7	12.3	3.2
13-13	" " "	"	60	4	24.70	1.3	15.0	3.6
13-14	" " "	"	"	6	24.98	2.5	19.9	2.6
13-15	Dense UO ₂ , Y ₂ O ₃ added to Mo	3.60	40	4	19.34	2.8	10.9	3.2
13-16	" " "	"	"	6	22.80	3.3	14.6	3.5
13-17	" " "	"	60	4	24.10	2.2	14.8	3.5
13-18	" " "	"	"	6	25.68	5.3	19.9	3.7
13-19	Dense spheres, no Y ₂ O ₃		40	7.6	18.59	4.0	15.2	5.6
13-20	" "	"	60	7.6	27.33	4.8	10.4	16.8

material) indicated the material can be ground using a resin-bonded diamond wheel without the ceramic sleeve cracking. Preliminary tests showed the material to be dense and fine grained, and thus suitable for the thin sleeves.

PHYSICS

Variable Spacing Cell

The variable spacing cell described in the preceding report has been operative. It has been used to obtain data on the effect of Xe gas fill on both IV characteristic curves and the plasma

parameters of electron density and temperature. Preliminary results were presented at the 27th Annual MIT Physical Electronics Conference, March 1967. The investigation will be continued for the family of inert gases with special attention devoted to Kr and Xe.

A Li absorption cell utilizing the heat pipe concept has been designed and is under construction at this time. This will be used to determine Li oscillator strengths under carefully controlled temperature and pressure conditions resulting from use of the heat pipe.

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Fig. 1. Schematic diagram of experiment for measuring Cs adsorption.

The high-temperature isothermal oven has been modified to permit the addition of inert gases into the systems. Some earlier problems in reproduction of results will be investigated as well as the perturbing effects of inert gas on isothermal Cs plasmas.

Surface Adsorption Experiment

An experiment has been designed to measure the fractional coverage of various surfaces by Cs by the use of a radioactive Cs tracer. Surface temperatures will approximate those found in typical thermionic converters. Cesium used in this experiment will be irradiated in a reactor to such a level of activity that, in a properly calibrated counting geometry, the amount of Cs adsorbed on the hot surfaces may be determined. A schematic diagram of the experiment is shown in Fig. 1.

The cell consists of two thick disks of Ta which form the sides of a vacuum tight "pill box," and a Cs reservoir is attached to it by a tube. The temperature of the reservoir is controllable; hence, the vapor pressure and density of Cs in the cell are known. In the blown-up view, the volume defined by the collimator is shown. Not only are active particles present in the gap, but they are also adsorbed on the two opposing surfaces. The total activity, I , recorded by the phototube consists of two parts. One part, I_v , is due to the presence of particles in the gap, whereas the second, $2I_s$, is due to particles adsorbed on the surface and is not known. From $I = I_v + 2I_s$, I_s can be determined since I is measurable and I_v is known. Since the activity is related to the total number of Cs atoms, the fraction of surface coverage related to I_s may be determined.

The cell is heated by radiant energy from a radiation-shielded resistance heater (Fig. 1) which is contained in a vacuum envelope. One side of the oven is indented to permit the collimator to be as close to the cell as possible.

To date the furnace, cell, and high-current supply are in the last stages of completion. Surfaces of stable, oriented, vapor-deposited W have been attained. Several problems remain, e.g., the handling and measuring of milligram amounts of activated Cs in such a way as to maintain purity through irradiation and subsequent introduction into the experimental cell.

PUBLICATION

"Decalibration of a W/W-25 Re Thermocouple in a Neutron Flux," LA-3662.

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