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MASTER

ISOTOPE KILOWATT PROGRAM QUARTERLY PROGRESS REPORT FOR PERIOD ENDING SEPTEMBER 30, 1970

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REACTOR DIVISION

ISOTOPE KILOWATT PROGRAM QUARTERLY PROGRESS REPORT
for Period Ending September 30, 1970

A. P. Fraas, Program Director

DECEMBER 1970

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee
Operated by
UNION CARBIDE CORPORATION
U. S. ATOMIC ENERGY COMMISSION

FOREWORD

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In 1968 the Oak Ridge National Laboratory started work on a program to evaluate various types of radioisotope energy conversion systems for the production of 1 to 10 kw of electric power for terrestrial and undersea applications. This program is being carried out for the U. S. Atomic Energy Commission Division of Reactor Development and Technology and the Naval Facilities Engineering Command. The first phase of the program was a parametric and engineering analysis comparing the principal isotope fuels and the principal types of energy conversion system that have been proposed for applications of this sort, and the preparation of a set of conceptual designs for the more attractive systems. That work was completed in the summer of 1969 and was reported in Ref. 1. In October of 1969 ORNL was asked to proceed with a detailed engineering study of the three most promising systems selected from those covered in Phase I of the program. These three systems now under study are a 2-kw(e) thermoelectric system, a 3-kw(e) steam Rankine cycle system, and a 5-kw(e) organic Rankine cycle system.

The first step in the effort was to evolve a program plan for a three-year effort to be carried out in calendar years 1970, 1971 and 1972. The conceptual designs presented in Task I were reexamined and possible improvements were considered with particular attention to the difficult development problems. A variety of engineering tests was considered as a means of evaluating the technology, solving the principal technical problems, and investigating engineering uncertainties that should be resolved before settling on the design of a prototype power plant. In view of the limited funds and the desirability of narrowing the field to a single Rankine cycle system, particular attention was given to the relative merits of the steam and organic Rankine cycle systems.

The first quarter of 1970 was devoted to firming up reference designs for the three types of system, selecting the most crucial experiments required to evaluate the technology, and settling on a program plan for the three-year effort. With this first quarter's work as a foundation, the second quarter was then devoted to firming up the details of the reference designs, firming up details of the experiments to be conducted, and

preparation of topical reports covering the three reference designs with their associated experiments. Subsequent quarters will be devoted to a series of tests designed to investigate vital questions in the technology. As the results of these tests become available, the reference designs will be revised accordingly. The objective is to evolve by December 1972 a set of designs for two prototype power plants with a clear delineation of the development program required in each case including firm estimates of the cost and time for the various programmatic steps.

This is the third in a series of quarterly progress reports. Topical reports are being prepared to present the work carried out in particular areas when key tasks are completed.

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1.0 SUMMARY

The design and fabrication of the shield block for a series of organic fluid capsule tests to evaluate the combined effects of temperature and radiation was completed. The radiation source has been prepared except for the closure weld for which a hot cell is scheduled October 13. The materials for preparation of the fluid (a pure form of Dowtherm A) have been procured and several sample glass capsules have been fabricated.

The detail design of the components for the organic fluid test loop has been initiated. A stainless steel Chempump of the proper capacity has been made available from another program that has been discontinued.

The first tests of the aluminum screen thermal insulation - thermal fuse concept have been completed. Examination of the results indicate that the screen has sufficiently good insulating properties and yet will melt if the shield surface temperature rises to 1370°F, and thus it will provide the necessary safety provisions in the event of an accident that interrupts heat removal via the power conversion system.

A new aluminum screen insulation test unit has been designed and is being built for further tests. This will be ready for test when new heater rods (which are on order) arrive, and the heater and wire screen test specimen are assembled in a vacuum-tight vessel. The latter will permit operating the thermal insulation under reduced pressure to determine the effect on the heat loss rate of eliminating thermal convection.

The last series of tests on the reentry tube steam boiler has been completed and a report is being prepared.

Three short lengths of wick for the heat pipe of the thermoelectric module have been fabricated and the first full-scale length has been drawn and sintered. Fabrication of the balance of the parts for the heat pipe test rig is largely completed and assembly has been initiated.

A fixed price contract with 3M for the design and fabrication of a complete full-scale thermoelectric module making use of lead telluride junctions has been negotiated. This contract also calls for 3M to provide a similar design for a thermoelectric module that will employ an advanced thermoelectric material to yield a higher efficiency.

Analyses of the relative performance characteristics of iron and nickel heat block-shield assemblies have been completed and a rough draft report has been prepared. The study shows that nickel will be required if advanced thermoelectric materials become available and are to be operated with a hot junction temperature of 1350°F. Nickel is generally superior to steel, but steel is adequate for the other applications. The cost and delivery time are, of course much greater for nickel, and the differences are being evaluated.

The 4.10 in. diameter fuel capsule for the SrTiO_3 source has been evaluated and a detailed report of the capsule design and safety analysis is in preparation.

2.0 ORGANIC RANKINE CYCLE SYSTEM DESIGN

The effort on the organic Rankine cycle system has proceeded on the basis of the reference design presented in the previous quarterly report.² However, it has become clear that Navy programmatic considerations make it crucially important to obtain firm experimental data on the combined effects of thermal and radiation damage to a pure form of Dowtherm A in a hermetically sealed system. As a consequence, a major effort has been made this quarter to design and build a test facility in which about 30 capsules of fluid can be tested currently. In addition, developments of improved thermoelectric junction materials suitable for operation at higher temperatures have led to a detailed comparison of nickel and iron for use in a heat block-shield assembly suited to any of the applications that appear likely to be of interest.

Heat Block-Shield Design

A range of heat block-shield geometries was investigated using both iron and nickel to delineate the relative advantages of each material, and a report covering this investigation has been prepared.³ Data for some typical units are summarized in Table 1.

If the final requirements for the heat block-shield are such that one unit must serve all systems including the advanced thermoelectric system

Table 1. Comparison of Nickel and Iron Heat Block-Shields
for Thermoelectric Power Units

Material	Fe	Ni	Ni	Ni
Electric output, kw	2	2	2.5	3.0
Hot junction temperature, °F	1050	1050	1350	1350
Peak heat block temperature, °F	1350	1310	1550	1550
Peak fuel capsule temperature, °F	1480	1410	1640	1640
Thermal power, kw	34	34	29	34
Fuel slug diam, in.	3.4	3.4	3.4	3.4
Fueled length, in.	38.4	38.4	38.4	44.8
Shield diam, in.	35.5	32.4	32.4	32.4
Shield length, in.	59.2	57.5	57.5	63.9
Weight, lb	17,200	14,700	14,700	16,300
Cost, \$	10,000	45,000	45,000	50,000

with a 1350°F hot junction, nickel must be used. The thermal conductivity of iron or steel is not high enough to avoid excessive heat block and fuel capsule temperatures for this application. Steel can be used for any of the other systems without a serious penalty.

The physical properties of nickel are much superior to those of iron or steel for use as the heat block-shield material. It has a 50% higher thermal conductivity, somewhat better shielding properties (higher density), does not undergo the crystalline transformation change characteristic of iron or steel, and will give a smaller and lighter system. Its main disadvantage is that the heat block-shield unit will cost about \$35,000 more than for steel. However, this cost will be partially offset by a reduction in the size and cost of the system pressure vessel. The pressure vessel savings will depend on the type of system and the operating depth and will vary from negligible to as much as \$20,000 to \$25,000 for depths approaching 20,000 ft. With present fuel costs, the incremental \$35,000 for the nickel would amount to only 3% of the total system cost.

Organic Fluid Evaluation Tests

Capsule Tests

A test facility for irradiating small capsules containing a very poor form of Dowtherm A has been designed and built. The unit consists of a steel shield block having a diameter of 20 in. and a length of 38 in. Strontium titanate encapsulated in two, 10.5-in. long, 3/16-in. OD, slender tubes will be inserted one above the other in a central hole and a filler plug welded in the top to prevent streaming of radiation out the end of the hole. A set of axial holes at various radial distances will provide sites for irradiating capsules at various dose rates ranging from 10 mr/hr to 100 r/hr. Figures 1 and 2 respectively show a drawing and a photo of this block. The block will be surrounded by electric heaters and thermal insulation so that its temperature can be held at 600°F.

Two capsules will be placed in each of 12 holes and three will be placed in the two outer holes. The locations of the holes and the type of capsule at each location are given in Table 2. Eight of the capsules will be glass containing only Dowtherm A, 17 will be glass containing Dowtherm A and small pieces of stainless steel wire, and 5 will be stainless steel containing only Dowtherm A. Two of the stainless steel capsules will be located in the upper end of the shield and extend into the insulation at the top of the steel block. This will provide a heat loss from the top of the capsule and thus induce condensation and a small amount of reflux within the capsule.

The results of the tests from the 30 capsules will provide a comprehensive picture of the effects of various radiation doses and dose rates as well as a comparison of stainless steel and glass and of static as compared to boiling, condensing and refluxing. The basic information on decomposition and products of decomposition is expected to come from the 25 glass capsules. The stainless steel capsules are included to obtain information on the permeation of hydrogen out of the Dowtherm A and through stainless steel at 600°F.

The steel heat block-shield unit for the organic capsule decomposition test has been fabricated and shipped to the hot cells for installation

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SHIELD BLOCK DETAILS

Fig. 1. Organic Capsule Shield Block.

PHOTO-101253

Fig. 2. Organic Capsule Shield Block.

Table 2. Capsule Location and Dose Rate

Hole Location Radius (in.)	Dose (r/hr)	Capsule ^a	
		Top	Bottom
1 1/4	125	G	G + SS (wire)
1 1/4	125	G + SS (wire)	G + SS (wire)
1 3/4	45	G + SS (wire)	G
1 3/4	45	G + SS (wire)	G + SS (wire)
2 1/2	10	G	G + SS (wire)
2 1/2	10	G + SS (wire)	G
4	1	G	G + SS (wire)
4	1	G + SS (wire)	G
6	0.07	G	G + SS (wire)
6	0.07	G + SS (wire)	SS
8	0.006	G + SS (wire)	G
8	0.006	SS (reflux) + SS	G + SS (wire)
8	0.006	SS (reflux) + SS	G + SS (wire)
8	0.006	G + SS (wire)	G + SS (wire)

^aG = glass capsules, G + SS (wire) = glass capsules containing stainless steel wires, SS = stainless steel capsule, SS (reflux) = stainless steel capsule with refluxing Dowtherm.

of the radiation source. The strontium titanate powder for the radiation source has been installed in the long slender tubes forming the capsules to contain it, and the end plug closures will be welded in about October 13. This work has been delayed for several weeks as a consequence of some unfortunate difficulties that have upset the schedule of work in the hot cells.

Following the recommendations of W. J. Pummer at NBS, arrangements have been made to prepare the fluid at ORNL from pure biphenyl and biphenyl ether so that close control can be maintained over the processes involved in preparing the material. The resulting very pure form of Dowtherm A will then be triple-distilled prior to installation in the glass capsules. The first sample glass and stainless steel capsules have been fabricated (see Fig. 3) and have been found to be satisfactory.

PHOTO 78161

Fig. 3. Glass and Stainless Steel Capsules.

Circulating Loop Test

The detail design of the circulating organic Rankine cycle loop system has been initiated. This loop will be that for which a layout was presented in the Quarterly Report² for June 1970. Fortunately, a small Chempump with the proper capacity for this system has been located and will be inspected to make sure that it is in good condition. It was operated in a water system for only about 1000 hr under a program that has since been discontinued. The designs for the steel heat block-shield assembly, the boiler, the condenser, and the surrogate turbine are being sized for a thermal power input of approximately 8 kw.

3.0 STEAM SYSTEM

The last series of tests on the reentry tube boiler test rig has been completed. The results show the performance of Model 6, which has an insulating sleeve length of 16 in., to be essentially the same as that of Model 2, which had a 12 in. sleeve. Performance curves for Models 1, 2, 5 and 6 are compared in Fig. 4 which shows the exit steam temperature as a function of insulating sleeve length for a flow rate of 5.2 lb/hr and a pressure of 200 psia. The curve through the data points exhibits a broad maximum region with very little difference in exit temperature over the range in length from 10 to 18 in.

The report covering the tests results of the reentry tube boiler and one presenting the reference design steam Rankine cycle system are being prepared.

Fig. 4. Superheater Exit Steam Temperature vs Insulating Sleeve Length at 5.2 lb/hr Flow and 200 psia.

4.0 THERMOELECTRIC SYSTEM

Thermoelectric Heat Transfer Test

Fabrication of the wick structure for the heat pipes has been initiated in the ORNL Metallurgy Division following closely the procedures recommended by Los Alamos. To check out the fabrication techniques two short sections 1-ft long and 1 section 2-ft long have been fabricated. The first section turned out very nicely, but the second had some wrinkles which were found to stem from the wrapping procedure. By improving the procedure this difficulty was avoided in the third section 2-ft long. Fabrication of a full-scale wick was then initiated and a 6-ft long unit was rolled, drawn, and sintered in a large furnace at K-25.

The 0.880 in. OD wicks were fabricated of 400 mesh Type 304 stainless steel wire having a diam of 0.001 in. The maximum pore size after fabrication was found to be 23 microns. Figure 5 shows an enlarged view of the wick after fabrication.

A detailed view of the region at the end of the heat pipe is shown in Fig. 6. The centering plugs will be pushed into the ends of the sintered wick and the assembly will be subjected to a second furnacing to sinter the wick to these plugs. The wick and centering plug assembly will then be installed in the tube serving as the outer wall of the heat pipe, and circumferential indentations will be rolled in the tube about 1 in. from either end to center the plugs. The end closure welds will then be made.

The other parts of both the heat pipe and the test rig have been designed and most of them have been fabricated. Assembly has been initiated and should be completed in another month. The prime objective of the test will be to determine the heat transport capacity of the unit not only in its normal horizontal position but also when vertical with either the condenser or evaporator section at the top. The tests will be run with electric heaters to simulate the heat block, and the heat will be removed through a water jacket of the same length as the thermoelectric junction region. The heat load will be adjusted by changing the composition of a helium-argon mixture in the gas gap between the heat pipe and the water jacket.

Fig. 5. Heat Pipe Wick.

ORNL-DWG 70-13642

PARTS LIST			
ITEM	DWG. NO	QTY	NAME
1			SUB-ASSEMBLY
2		1	$\frac{3}{8}$ X 0.035 WALL X $10\frac{1}{4}$
3	C-115B-6	1	END CAP (FILL END)
4			1 X 0.049 WALL TUBE
5			SCREEN WRAP
6	C-115B-6	1	TAPERED PLUG
7			POROUS TUBE
8	C-115B-6	1	END PLUG
9			$\frac{1}{8}$ X 0.035 WALL X $5\frac{1}{8}$
10	C-115B-6	1	END CAP (TC END)
11		6	CENTERING PINS

- NOTES
 1 ALL MATERIAL 304 SST
 2 ALL MATERIAL TO BE FURNISHED

Fig. 6. Heat Pipe End Detail.

Thermoelectric Module Test

The details of a fixed price contract with 3M for the detail design and fabrication of a complete thermoelectric module with lead telluride junctions have been completed. This module was described in the previous quarterly report. The contract also calls for 3M to prepare a design of a similar module based on their advanced junction material. The latter work is to be completed early in December and the complete module is to be fabricated and performance tested at 3M by early April. The unit will then be shipped to ORNL for evaluation and endurance tests. ORNL will supply the heat pipe on which the thermoelectric module will be assembled and the electric heaters for conducting the performance tests at 3M. The complete unit will be hermetically sealed with an inert gas atmosphere to protect the thermoelectric junction materials from attack by oxygen or moisture and to inhibit sublimation of the junction materials.

5.0 THERMAL FUSE AND INSULATION

The preliminary tests on the aluminum screen insulation have been completed. The test section assembly was modified from the original⁴ in that the cartridge heater was replaced with one that had a heated section extending the full length of the insulation test specimen and the outer surface of the insulation was covered with aluminum foil to prevent convection losses from air flowing through the screen and along the heater.

Thermal conductivity measurements were made at screen inner surface temperatures of 600 to 1100°F. The results of these tests indicate that wire screen insulation with a thickness of 4 in. should be sufficiently effective as thermal insulation to limit the heat losses from the heat block to less than 10% at atmospheric pressure and will be even less at reduced pressure for normal operation. After completion of the heat transfer tests, the heater surface temperature was increased until melting of the aluminum screen occurred at a heater surface temperature of 1370°F. Unfortunately, the heater failed internally at a point where it was covered with ceramic insulation before equilibrium was reached, but the results indicate that

melting of the aluminum screen would prevent the fuel capsule temperature from exceeding 2000°F upon loss of cooling of the heat block via the power conversion system. Figures 7, 8, and 9 show the effects of melting the screen. Note that relatively large globules of aluminum were formed, thus indicating that the oxide layer on the surface of the aluminum wire did not interfere seriously with melting down of the screen.

Two additional series of tests are planned. The first of these will entail further preliminary tests of a cartridge heater in a small diameter roll of screen operated in an enclosed vessel at pressures ranging from atmospheric down to 0.1 psia. The latter should greatly reduce heat transmission thru the screen by thermal convection of atmosphere pressure air. It is believed that a marked improvement can be obtained in this way without reducing the heat transfer effectiveness of the gas gaps in the heat block-shield assembly. The second series will consist of tests of a 1/4 scale heat block with the full-scale insulation thickness. This will also be operated in an enclosed vessel at pressures down to 0.1 psia.

The design of the test assembly for the next series of experiments has been completed. The wire screen test specimen will be 48 in. long, which is the full-scale length, and will be used for all subsequent tests. The vessel is cylindrical with an ID of 6.357 in. and an overall length of 57 in. New electric cartridge heaters have been ordered, which have a heated length of 48 in. and a diameter of 3/4 in. Two new wire screen insulation test specimens have been prepared, and the vessel has been fabricated.

Fig. 7. Aluminum Screen Insulation Test Assembly After Meltdown Test with Heater Partially Withdrawn.

PHOTO 78034

Fig. 8. Closeup View of the Debris from Meltdown Test of Aluminum Screen Insulation with Heater Partially Withdrawn.

Fig. 9. Closeup View of Total Debris from Meltdown Test of Aluminum Screen Insulation.

6.0 FUEL CAPSULE

The capsule for the $^{90}\text{SrTiO}_3$ source to be used in the heat block being designed for this program has been evaluated and a design report is in progress.

In the interest of economy from the standpoints of design effort, fabrication, and loading, a single capsule concept has been evolved which is proposed for use in all of the systems under consideration.

The capsule is basically one which will withstand the total environment to which a power production unit might conceivably be exposed. It will withstand this environment as a singular unit without regard to the protection offered it by the rest of the system. The criteria used in the design of the capsule are an external pressure of 10,000 psi (equivalent to 22,550 feet deep in sea water having a density of 64 lb/ft³) corrosion by sea water for 300 years, oxidation at either a normal operating temperature of 1800°F or at loss-of-coolant design temperature of 2000°F, transient conditions that might conceivably result from accidents or fire during shipping or storage, and normal conditions of transport and operation.

The capsule is a right circular cylinder 4.100-in. in diameter with a total overall length of 40.40 in. It has a wall thickness of 0.325 in. The bottom cap of the capsule is 0.780 in. thick and shall be electron beam (EB) welded with a minimum penetration 0.120 in. The top cap is 1.060 in. thick and is a threaded design for ease and economy of assembly and inspection in a hot cell. The cap will have four (4) threads 3.75 in. in diameter and will be gas-tungsten-arc (GTA) seal welded with a minimum penetration of 0.055 in.

The bottom cap rests on a ledge 0.045 in. wide to reduce the shear stress on the weld when under external pressure. Similarly, the top cap rests on a ledge 0.073 in. wide to reduce the shear stress on the threads. The support provided by these ledges was ignored as a safety factor in the stress calculations. Also ignored in the stress calculations was the support against collapse provided the capsule by the fuel material. The four (4) threads of the top cap represent twice the number of threads required for the expected stresses. A detailed report of the capsule design and safety analysis is in preparation.

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REFERENCES

1. R. A. Robinson, Isotopes Kilowatt Program Task 1 - Conceptual Design and Evaluation, USAEC Report ORNL TM-2366, Oak Ridge National Laboratory, January 1970.
2. A. P. Fraas, Program Director, Isotope Kilowatt Program Quarterly Progress Report for Period Ending June 30, 1970, USAEC Report ORNL TM-3099, Oak Ridge National Laboratory, September 1970.
3. G. Samuels, Comparison of Nickel and Iron Heat Block-Shields, USAEC Report ORNL TM-3213, Oak Ridge National Laboratory, (to be published).
4. A. P. Fraas, Program Director, Isotope Kilowatt Program Quarterly Progress Report for Period Ending March 31, 1970, USAEC Report ORNL TM-3011, July 1970.

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