198
3-7
C

OK

2065
ARCO-3057-8

RADIOISOTOPE-POWERED CARDIAC PACEMAKER

REPORT TO:
UNITED STATES ATOMIC ENERGY COMMISSION

THIS DOCUMENT CONFIRMED AS
UNCLASSIFIED
DIVISION OF CLASSIFICATION
BY GH Kahan/pmb
DATE 3/13/72

ARCO Nuclear Company
ENERGY CONVERSION
TECHNICAL CENTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED
R3463

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

Quarterly Progress Report
for
Phase II
Radioisotope Powered
Cardiac Pacemaker Program

November 1, 1971 to January 31, 1972

Prepared for

UNITED STATES ATOMIC ENERGY COMMISSION
Under Contract AT(11-1)-3057

Mr. Harold Miller, Director
Contracts Division
Chicago Operations Office
United States Atomic Energy Commission
9800 South Cass Avenue
Argonne, Illinois 60439

Commander J. M. Prosser
Instrumentation Branch
Division of Reactor Development
and Technology
United States Atomic Energy Commission
Washington, D. C. 20545

by

ARCO Nuclear Company
P. O. Box 546
Leechburg, Pennsylvania 15656

Approved by:

S. A. Kolenik

S. A. Kolenik
Acting Program Manager
Cardiac Pacemaker Program

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors or their employees, makes any warranty, expressed or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

* * * * *

Availability:

Printed in the United States of America

Available from

National Technical Information Services

Springfield, Virginia 22151

Price: Printed Copy \$3.00; Microfische \$0.65

NOTE

This program is being conducted at the Energy Conversion Technical Center of ARCO Nuclear Company, which is a subsidiary of Atlantic Richfield Company. Prior to November 1, 1971, the Energy Conversion Technical Center was a division of NUMEC.

TABLE OF CONTENTS

	<u>Page</u>
INTRODUCTION	1
TASK 1.0 - PROGRAM MANAGEMENT, CONTROL, AND PLANNING	2
TASK 2.0 - RELIABILITY AND QUALITY ASSURANCE	3
TASK 3.0 - SYSTEM FABRICATION AND PRODUCTION DEVELOPMENT	16
TASK 4.0 - SYSTEM TESTING	21
TASK 5.0 - SAFETY	22

LIST OF TABLES

	<u>Page</u>
Table 1 - Production Model Life Test Data	4
Table 2 - Experimental Model Life Test Data	5
Table 3 - Prototype Model Life Test Data	6
Table 4 - Battery Performance of Pacer No. 7	8
Table 5 - Brazed Tape Results	10
Table 6 - Effect of Temperature on Hot Shoe Isolation Resistance	12
Table 7 - Pacer Data	20

LIST OF FIGURES

Figure 5 - Recommended Cremation Temperature Profile and Comparison with Maximum Temperatures Measured During Eleven Cremation Tests	26
--	----

INTRODUCTION

This is the eighth Quarterly Progress Report of the Radioisotope Powered Cardiac Pacemaker Program Phase II. It describes the results of the development work performed in the period from November 1, 1971 to January 31, 1972.

Task 1.0 - PROGRAM MANAGEMENT, CONTROL, AND PLANNING

The various development preparations for pilot production of Radioisotope Powered Cardiac Pacemakers have continued during this report period. The details of these preparations are discussed under the various task headings in this report. Some problem areas arose requiring preproduction development in order to maintain a high production yield.

During this report period, a fire caused extensive damage to one of the chemistry labs causing a three week delay in tape plating. Appendix A contains a report of this fire.

During this report period, all of the electronic circuit modules were delivered and placed on life test. Also, all qualification testing for those circuit modules was successfully completed. In addition, the recommended minimum cremation environmental conditions that a Radioisotope Powered Cardiac Pacemaker heat source contained within an RPCP system must withstand were submitted.

During this report period, a heat source specification for oxide fuel was established and 12 heat sources were delivered.

Pilot production began during this report period and two of the pilot production systems were implanted in dogs at the National Heart and Lung Institute. In addition, 15 pilot production nuclear batteries were completed with excellent performance. The mean value of electrical power available for cardiac pacing was about 270 microwatts with some units producing almost 300 microwatts of electrical power.

Task 2.0 - RELIABILITY AND QUALITY ASSURANCE

Reliability Data

At the end of January, the various Phase I nuclear batteries have accumulated a total of 43.06 unit years of operation with a total of four thermocouple tape failures, one in each of four nuclear batteries implanted in dogs at NHLI.

At the end of January, the Phase II production nuclear batteries have accumulated a total of 1.14 unit years of operation with no failures.

The first two Phase II production RPCP systems were implanted in dogs at NHLI during the latter part of January.

At the end of January, the Phase I electronic circuits have accumulated a total of 72.22 unit years of operation with a total of 16 circuit failures.

At the end of January, the Phase II electronic circuits have accumulated a total of 34.99 unit years of operation with no failures.

The following three tables summarize the status of the Production Systems, Experimental Models, and Prototype Models.

TABLE 1

Production Model Life Test Data

(1-31-72)

<u>Unit</u>	<u>Hours</u>	<u>B. O. L. Data</u>	
		<u>Pulses/Minute</u>	<u>Output*</u>
NU4-2	1812	76.0	6.8 ma
NU4-3	1812		268.9 μ w
NU4-4	1812	75.5	7.2 ma
NU4-5	1812	75.0	6.8 ma
NU4-6	564	76.5	7.9 ma
NU4-7	350		283.0 μ w
NU4-8 (1)	398	74.0	6.8 ma
NU4-9 (1)	398	73.5	6.0 ma
NU4-10	252	74.5	7.3 ma
NU4-11	252	75.5	7.0 ma
NU4-12	252	74.5	7.2 ma
NU4-13	252	74.0	7.4 ma
TOTAL	9966		

(1) Dog Implants

- * Peak power is given in microwatts if unit has no electronics.
For units with electronics, values are pulse height in milliamperes.

TABLE 2

Experimental Model Life Test Data

(1-31-72)

<u>Unit</u>	<u>Hours</u>	<u>Present Data</u>		<u>B. O. L. Data</u>	
		<u>Output*</u>	<u>Pulses/Minute</u>	<u>Pulses/Minute</u>	<u>Output*</u>
E-3 (1) (2)	35,025	72.0 μ w			84.8 μ w
E-4	34,573	2.6 ma	77.5	78.6	2.9 ma
E-5 (8)	32,846	70.7 μ w			79.6 μ w
E-9 (2)	26,265	84.2 μ w			82.3 μ w
E-10 (5)	24,925	70.8 μ w			77.5 μ w
E-12 (4) (3)	25,694	246.1 μ w			230.0 μ w
E-13BB	19,958	7.6 ma	130.5	123.0	8.0 ma
E-14 (4) (6)	11,701				
E-16 (10)	22,425	204.7 μ w			202.4 μ w
E-17 (4)	21,301	224.2 μ w			
E-18 (9)	22,617	250.6 μ w			247.8 ma
E-20 (7)	<u>18,924</u>	262.2 μ w			260.5 μ w
TOTAL	286,254				

- (1) Battery Unit.
- (2) Stopped pulsing 4-9-70 and could not be restarted. Electronics removed and load line obtained.
- (3) Had stopped in dog test. Electronics failed - removed 6-30-70.
- (4) Implanted in dog.
- (5) Not pulsing 7-14-70. Disconnected and removed electronics 7-16-70.
- (6) Returned 7-23-70. Not pulsing. Hours shown to 7-23-70. Module and electronics failed.
- (7) Disconnected and removed electronics 7-10-70.
- (8) Disconnected and removed electronics 7-29-71.
- (9) Disconnected and removed electronics 7-27-71.
- (10) Electronics failed 8-31-71.

* Peak power is given in microwatts if unit had no electronics on 4-31-71. For units with electronics, values are pulse height in milliamperes.

TABLE 3

Prototype Model Life Test Data

(1-31-72)

Unit	Hours	Present Data		B. O. L. Data	
		Output	Pulse/Minute	Pulse/Minute	Output
P-1 (2) (1)	19,308	6.05 ma	126.5	125.3	5.5 ma
P-2	18,445	6.2 ma	129.0	126.9	5.7 ma
P-3 (2) (5)	19,261	6.0 ma	126.0	126.5	5.7 ma
P-4 (2) (6)	6,742				
P-5 (2) (10)	11,437				
P-6 (2) (3)	<u>2,938</u>				
TOTAL	78,231				
XP-10 (4) (7)	1,344				
XP-14 (8)	560				
XP-15 (9)	540				
PD-1 (11)	207.5				261.96 μ W

- (1) Returned from dog implant and has restarted, electronics was opened to get load line.
- (2) Dog implants.
- (3) 5-15-70 unit not running - observed at NHI. Returned 5-26-70 to NUMEC. Hours shown to 5-15-70.
- (4) Sealed 7-22-70 @ 1255.
- (5) Returned from NHI not pulsing 10-15-70. Restarted this date with external battery. Opened electronics case to get load line. Reconnected to electronics.
- (6) Unit returned 8-27-70 not pulsing. Case punctured and opened 8-28-70. Hours shown to 8-28-70.
- (7) Unit failed 9-15-70, while being tested to destruction during drop testing.
- (8) Sealed 10-13-70. Unit shock tested to destruction. Opened 11-5-70.
- (9) Sealed 10-28-70. Opened 11-20-70.
- (10) P-5 failed 3-15-71.
- (11) B. O. L. 9-21-71, 0935 hrs. Unit failed 0100 hours, September 30, 1971 during vibration testing.

Environmental Testing of Production Pacer No. 7

A production pacer (number 7) was selected and subjected to a series of tests which simulated a possible worse case analysis of a human environment. The electronics were not included in order to monitor the battery performance under test. This battery was the first to be tested with both oxidized tape and oxidized ceramic tabs and represents all of the design changes incorporated in the production modules. The following tests were conducted in sequence:

- (1) pressure test: pressurize pacer to 4 atm. and hold 5 min.
- (2) vibration: 4 g's in each axis while scanning over 20-500-20HZ for 10 min.
- (3) thermal cycling: -40°F to +140°F for 2 cycles and hold at temperature for 2 hours. Rise time was approximately 15 min. and the cool down time was approximately 45 min.
- (4) 5' free fall: 1 drop to concrete.
- (5) low level shock test: 3000 cycles at 50 g (1000 cycles in each axis).
- (6) high level shock test: 12 cycles at 855 g (4 cycles in each axis).

Table 4 is a summary of the battery performance data during testing. The open circuit voltage change was because of the thermal transients induced by handling conditions, however, the battery resistance virtually remained unchanged. This indicates that none of the tapes were affected by the testing. The pacer will now be put on life test.

TABLE 4

Battery Performance of Pacer No. 7

	<u>Open Circuit Voltage (volts)</u>	<u>Voltage at Peak Power</u>	<u>Total Battery Resistance (ohms)</u>
before test	2.49	1.25	5464
after pressure test	2.50	1.25	5442
after vibration	2.54	1.27	5424
after thermal cycling	2.44	1.22	5424
after 5' free fall	2.44	1.22	5424
after 3000-50 g shocks	2.53	1.27	5424
after 12-855 g shocks	2.27	1.14	5424

Thermocouple Tapes

The last Quarterly Report explained in general the results of the testing associated with the low isolation resistance problem, which would reduce tape production yield. Those results, although very valuable, did not offer a solution to the problem and the report concluded that additional testing and evaluation would be performed. Efforts during this report period were directed towards both the preventive and corrective actions. Preventive type actions included the brazing operation and the ceramic tab preparation. The following evaluations during brazing were performed:

1. position of the shoe in the braze chamber during brazing.
2. shoes brazed on newly-cleaned fixtures.

The results of these tests did not indicate any significant difference. It was suggested that brazing in a partial argon atmosphere might improve production yield. One such test was performed and although its isolation resistance was acceptable, the titanium hot shoe visually had discolored. Therefore, the test was discontinued.

Since the investigation of the brazing operation did not uncover a solution to the problem, the hypothesis was substantiated that a conductive material remained on the ceramic after the final step in the ceramic preparation. The sequence in the standard tab preparation after coating was grinding, hand lapping, and grit blasting. After investigating several potential problem areas, it was concluded that the isolation resistance problem was probably caused by residual deposits of Ti and/or Cu and Ag on the isolated surfaces of the ceramic tab prior to brazing. Three probable factors tend to explain the presence of metal on these isolated surfaces:

1. impregnation of titanium into the ceramic surface porosity which is not totally removed by the first grinding operation.
2. presence of residual titanium allows copper and silver to be electroplated on these surfaces.
3. inability to remove metals during final grinding from these surfaces.

Although the isolation resistance of the ceramic tab is acceptable between groove to ground and groove to groove before brazing, the residual metal on the isolated surfaces of the ceramic tabs is activated in such a

manner as to yield tapes with low isolation resistance. To circumvent this problem, a series of experiments were conducted in which the ceramic tabs were prepared by the following treatments:

1. oxidation at 300°C for 1 hour.
2. etching with 10% HF for 4 minutes.

Tabs of each process were brazed and the oxidation process appeared to be the most successful. The results are listed in Table 5. (Note the large number of infinite isolation resistances for the oxidation process.)

TABLE 5

Brazed Tape Results

<u>Tab Treatment</u>	<u>Number Tabs</u>	<u>Yield</u>	<u>Acceptable</u>	<u>Number of Tabs With ∞ Isolation Resistance on x 100 meg. VTVM Scale</u>
HF	10	60%	6	2
Oxidation	15	87%	13	12

It appears that tab oxidation results in acceptable isolation resistance and significantly increases production yield. It is significant to mention that no change in isolation resistance was measured after outgassing the tapes at 500°C indicating stability of the oxidation treatment.

In addition it was found that the quality of the brazed joints using oxidized tabs was found to be unchanged from previous experience. This is to be expected since oxidizing the tabs results in a thin oxide film on the surface.

In the area of corrective action there were two possibilities, namely, grit blasting or oxidizing the brazed tapes. Grit blasting was eliminated because of the possible damage to the wires. Tests were performed on the isolation resistance of oxidized thermocouple tapes (300°C in air for one hour) and compared to non-oxidized tapes. These results are shown in Table 6. All three tapes that were selected for oxidation (157, 169, 174) were rejects due to isolation resistance below 1.0×10^6 meg. before oxidizing. After oxidizing all three tapes were over 1.0×10^6 meg. and also were above 1.0×10^6 meg. at 250°C. However, of the four acceptable tapes tested without oxidation (282, 211, 270, 231), three had isolation resistance below 1.0×10^6 meg. at 250°C. The lowest value was 0.15×10^6 meg. for two of the non-oxidized tapes which would represent approximately 3.5% power loss as given in the last Quarterly Report.

TABLE 6

Effect of Temperature
On Hot Shoe Isolation Resistance
(Oxidized and Non-Oxidized Tapes) (11/18/71)

<u>Tape No.</u> <u>Phase II</u>	<u>Resistance</u> <u>Before Oxidation*</u>	<u>Resistance</u> <u>After Oxidation*</u>	<u>Resistance</u> <u>At 250°C</u>
157	0.5 x 1	50 x 100	60 x 1
169	0.3 x 1	3 x 10	1.6 x 1
174	0.2 x 1	∞ x 100	25 x 1
282	11 x 1		0.15 x 1
211	1 x 1		0.15 x 1
270	∞ x 1		90 x 1
231	6 x 1		0.4 x 1
<u>Phase I</u>			
229	∞ x 100		2.0 x 100

* Reading in meg-ohms of meter scale used in measurement.

Tests were also performed on the three oxidized tapes holding them at 250°C for 142 hours to see if the leakage resistance might degrade with time. Included in these tests was the normal 500°C degassing cycle.

The test results indicated that the leakage resistance did not change with time within the accuracy of the instrumentation.

It should be noted that both Tophel Special and Cupron Special thermocouple materials were developed specifically for operation in an oxidizing atmosphere with a continuous temperature operating range up to and including 1500°F (815°C). Therefore, a one hour air firing at 300°C should have no deleterious effects. Metallographic cross sections have tended to support this conclusion since the only surface effect detected was an oxide layer of about 3 microns thick.

Based on the above tests, all of the tapes are now being oxidized and the isolation problem has apparently been eliminated.

Black deposits on some of the cupron and tophel tapes were observed during the visual inspection of the brazed thermocouple tapes. The deposits randomly occurred on the wire and on the fiberglass. It was hypothesized that small airborne particles such as lint were deposited or embedded in the fibers of the tape and the final degassing caused the particles to turn black. The deposits on the wire when viewed under the microscope did not appear to attack the wire. Past experience indicated that the spots visually disappeared when the tapes were oxidized (1 hr. @ 300°C). November's Progress Report revealed that oxidized tapes showed a significant improvement in both the total and isolation resistance. Additional testing was done to verify that oxidation did not change the physical properties of the tape. A series of tensile tests were performed. The following three groups of tapes were tested and statistically compared: (1) non-oxidized tapes without black spots, (2) oxidized tapes with black spots, and (3) oxidized tapes without black spots. The results of these tests were reported in the December report. There is no significant difference between either the non-oxidized versus the oxidized with black spots or non-oxidized versus the oxidized without black spots. Three pairs of brazed thermocouple tapes are on life test at 250°C in order to evaluate

and to compare the performance of oxidized tapes, non-oxidized tapes, and non-oxidized tapes with black spots. They have accumulated 935.5 hrs., 796.5 hrs., and 1229 hrs. respectively and have not indicated any degradation of performance or significant difference. It was suspected that any degradation would appear rapidly during life testing.

Ceramic Tab Preparation

After air firing the ceramic tabs, approximately 10 to 15% of the tabs turned gray in certain areas. These areas of discoloration were not restricted to one particular location. Our air firing procedure requires heating the ceramics in air to 500°C and holding 1/2 hr. This procedure has not been altered, but the ceramics are from a new lot. Cleansing in trichlor and ultrasonic cleaning did not affect the discoloration. A ceramic engineer from the ceramic vendor was consulted and the following comments were made:

1. The discoloration is not a result of impurity in the ceramics.
2. Discoloration of ceramics during air firing is the result of either the furnace environment or improper cleaning or rinsing at the vendor's facilities.
3. The vendor's cleaning operation has not changed for five years.

The vendor's cleaning procedure is as follows:

1. Ceramics are cleaned with a detergent called alkonox.
2. Rinsed with H₂O.
3. Ultrasonic cleaned.

If the ceramics were not rinsed thoroughly or improperly stacked during ultrasonic cleaning, it is very possible that the alkonox was not completely removed leaving a carbonaceous microfilm behind.

The vendor also stated that the ceramics are sintered at 1700°C and recommended air firing at 1100°C. Air firing at this temperature would not change the structure, dimensions or stability of the ceramics.

Some of the discolored ceramics were then air fired at 1100°C and the discoloration disappeared and all dimensions remained stable.

It was, therefore, necessary to increase the ceramic air firing temperature to 1100°C in order to insure that a thin, carbonaceous residue does not remain on any of the ceramics thus resulting in a uniform product.

Incoming Inspection of Thermocouple Tape

Three hundred and fifty (350) feet of both tophel and cupron thermocouple tape was reordered from Prodesco. A QC engineer visited Prodesco to observe the weaving process, review the tape specification, and inspect completed tape. The total amount of tophel tape was completed and inspected by QC. The general quality of this tape was found to be excellent and it was released for production. The cupron tape was not completed, but should be delivered during the early portion of February.

Task 3.0 - SYSTEM FABRICATION AND PRODUCTION DEVELOPMENT

Electronics

All of the 200 production electronic circuit modules have been completed and the production sample lot has successfully passed all of the vibration, thermal cycling, shock testing, and life testing portions of the specifications and requirements of RDT standard C19-1T. Shipment of the 200 production circuit modules was completed during this report period and all modules were placed on life test.

In addition the computerized mathematical circuit analysis has been completed and a report has been prepared. The basic conclusions of the report are that:

- A. The circuit can be adjusted to operate within specifications under all specified conditions.
- B. Calculated component values agree extremely well with specified values.

In addition comparison between calculated values for selected components and the actual values used in module construction was made and the correlation was found to be excellent in that the two sets of data were within 4%.

Also during this report period a total of 3000 shocks of 855 G's were accumulated on the circuit module reserved for destructive testing. This unit continued to operate within specification with no changes in performance. Higher G level shocks and long-term vibration tests are planned for this unit during the next report period.

Fuel Capsule Components

Last September ARCO Nuclear agreed to replace 80 middle capsules and 80 middle plugs at Mound Laboratory. This was due to the Hastelloy "C-276" that was used having an aluminum content high enough to retard successful welding of the middle capsules. Mound also requested 12 additional middle sets for weld verification. During December this order was completed.

Also during December ARCO Nuclear agreed to send Mound the following additional capsules for fueling: 2 outer capsules, 5 outer plugs,

26 middle capsules, 21 middle plugs, 24 ultrasonically inspected inner capsules, and 26 ultrasonically inspected inner plugs. These components were sent to Mound during January.

Fuel Sources

During this report period, discussions were held at Mound and agreements were reached on the heat source specification and delivery schedule. Basically, it was agreed that 12 metal plus 1 oxide fuels would be delivered the first week of January, 14 oxide fuels the first week of February, 14 oxide fuels the third week of February, 14 oxide fuels the first week of March, and on a tentative basis, 14 oxide fuels by the end of June. With this schedule of heat source deliveries, the dog implant program can proceed as planned.

It was also agreed that 9 additional safety capsules with molybdenum-tungsten fuel simulant will be supplied by Mound sometime after all of the heat sources are delivered.

During this report period, 11 metal plus 1 oxide fuel sources were received from Mound. Two additional metal sources were retained at Mound for radiation testing and will be delivered early during the next report period.

Battery Lid Feedthrough

During copper-silver feedthrough production initiated during this report period, it was observed during production qualification testing that microcracks were forming in the copper wire (within the ceramic only) during brazing. These cracks were not observed previously, but only since a new batch of ceramics was started in process. The internal diameter of the new ceramics is 2 mils smaller than the previous ceramics requiring an additional 2 mils reduction of the copper wire being used. It was concluded after several tests that the drawing and pickling operations required to attain this smaller diameter were causing the problem. It is believed that the main problem is due to hydrogen diffusion into the wire during pickling.

New copper wire, 99.99%, OFHC purity with a .0285" diameter was obtained. This wire is 3/4 to 1 mil larger than the internal diameter of the ceramics now in process. Following the production procedure, this wire was used to produce 18 production feedthroughs without any apparent problem.

As a control, every sixth braze is a test piece for sectioning. The micro-cracks were most likely caused by excessive pickling of the copper wire since a .030 inch diameter wire from which the .0285 inch diameter wire was drawn by the vendor showed severe microcracks after feedthroughs were made from it using the pickling technique to reduce the diameter.

Chemical Processing Fire

The December fire in the thermocouple and insulation tape processing area caused a three week delay in the processing of these components. Since going back into production, tighter controls have been instituted in the startup and shutdown procedures to minimize any future delays. The quality of the products from this area has been good during the past month. Appendix A contains the report concerning this fire.

Tape Brazing

During this report period, $\approx$ 300 thermocouple tapes were brazed. The rejection rate for fabrication defects was somewhat high due to having broken in three new tape assemblers. However, by the end of the report period, they were producing tapes at a fairly high rate without many assembly errors. The brazing and pacer assembly force are at the level needed for production.

A good deal of effort of tape assemblers went into the cleanup of the chem lab fire. The room has been repaired and is into full production with appropriate safety protection. About two to three weeks of tape assembly delay occurred.

Battery Assembly

During this report period, 15 pacer batteries were assembled and sealed. The thermal performance was excellent with both the median and mean values of output power being 269 μ watts or about 30 percent higher than predicted in Reference 1. The data on these units is given in Table 7. This improvement is probably due to the wider border on the thermoelectric tapes which may lower radial conduction. Also, the better control of tape length may also help to lower radial conduction. The consistency of the performance is also good, being less than $\pm$ 10 percent for all but one unit, NU-4-9. This unit's performance was still higher than predicted for nominal fuel. It was found from X-rays of unit NU-4-9 that the wrapping was not as uniform as for other units probably causing a higher radial conduction.

Reference 1-NUPEC 4189-4, Quarterly Progress Report for Phase II, Radioisotope Powered Cardiac Pacemaker Program, page 7, November 1, 1970 to January 31, 1971.

Because of some results on preproduction units indicating the final leak check on the battery units caused internal gas, a battery unit was completed using rejected (but not rejects that would affect thermal performance) tapes with a single tape output to check thermal performance to test a new leak test procedure. This unit was leak checked after TIG welding of the lid, electronics case, and case assembly using the new leak check procedures. The performance was excellent, indicating that any possible previous problems producing residual gases from leak checking has probably been eliminated. A sampling method for leak checking will be used for production, with records of units leak checked. Thus far, units NU-4-7 and 15 have been leak checked with no evidence of internal gas. On unit NU-4-7, the inside wire of the electronics case feedthrough was bent and then broken during leak checking. The fixture has been reworked to eliminate this problem in the future.

Final Assembly

Generally the final assembly steps of adding electronics, welding the electronics case lid and potting have proceeded very well. Eleven units were completed as given in Table 7. Only one unit has been damaged during this procedure. On unit NU-4-12, the outside feedthrough lead was broken during assembly into the potting fixture. This unit had leads spotted onto the wire in the ceramic and will be used for life test data.

On units 10 and 13, the RTV bubbled during the pump down going into the TIG welding chamber. The lids were removed, replaced, and successfully welded. Since this pump down has no technical effect on the unit, but can produce production time losses, it was eliminated by transferring units into the TIG welding chamber in a sealed pressure container.

To meet the production schedule, a second epoxy molding fixture was fabricated. An RTV molded holder for batteries and completed pacers on life test has been developed and 25 units have been fabricated. These holders prevent marking the cases, hold them firmly to a table, and provide plug jacks for taking data.

All production procedures were finalized during this report period, however, to assure that there are no differences between writeup and operations, a task force has been formed to check the procedure in the laboratories.

TABLE 7

Pacer Data

<u>Unit</u>	<u>Date Sealed</u>	<u>Date Completed</u>	<u>O.C.V. Volts</u>	<u>Output μ Watts</u>	<u>Res. Ω</u>	<u>Fuel Watts</u>	<u>Calorimetry Date</u>	<u>Fuel #</u>
NU-4-1	9-17-71		2.36	262	5315	.2253	7-1-70	PF-1-17
NU-4-2	11-17-71	12-21-71	2.40	272	5296	.2243	7-2-70	PF-1-14
NU-4-3	11-17-71	*	2.39	269	5256	.2284	6-30-70	PF-1-16
NU-4-4	11-17-71	12-22-71	2.45	282	5276	.2253	7-1-70	PF-1-17
NU-4-5	11-17-71	12-23-71	2.43	277	5282	.2247	7-1-70	PF-1-18
NU-4-6	1-8-72	1-21-72	2.48	293	5310	.2321	12-1-70	A-1
NU-4-7	1-15-72		2.46	283	5410	.2318	6-30-70	PF-1-13
NU-4-8	1-15-72	1-24-72	2.30	248	5390	.2244	6-30-70	PF-1-15
NU-4-9	1-15-72	1-22-72	2.11	209	5340	.2253	7-2-70	PF-1-20
NU-4-10	1-21-72	1-26-72	2.37	263	5360	.2253	12-1-70	A-2
NU-4-11	1-21-72	1-25-72	2.41	273	5279	.2270	7-3-70	PF-1-29
NU-4-12	1-21-72	1-28-72	2.33	256	5251	.2244	11-25-70	A-3
NU-4-13	1-21-72	1-27-72	2.45	281	5304	.2279	11-25-70	A-4
NU-4-14	1-28-72		2.38	267	5301	.2260	11-30-70	A-5
NU-4-15	1-28-72		2.38	269	5260	.2229	11-30-70	A-7
NU-4-17	1-28-72		2.50	294	5321	.2287	11-30-70	A-8

Note: Thermal load decreases 3/4 of 1% per year.

*Electronics rate high and removed for tests.

Task 4.0 - SYSTEM TESTING

All units continue to operate successfully. Two life test stations have been completed for the electronic circuit modules. A production RPCP unit has successfully passed all environmental testing as discussed in Task 2.0. Life test data was reported in Task 2.0 also.

Task 5.0 - SAFETY

Cremation

The 30 tempil holders for maximum crematory temperatures survey were approximately 80 percent completed. Completion was delayed by late delivery of cutters needed for the finishing fabrication steps. The holders should be finished early in the next report period and the survey initiated. The first units will be sent to the crematories that cooperated in the temperature measuring tests to develop correlations of measured thermocouple data and tempil data and to determine crematory maximum temperature variations.

During this report period, the recommended minimum cremation environmental conditions that a Radioisotope Powered Cardiac Pacemaker System must withstand were submitted. The recommendations were supported by data obtained from actual cremation and related testing. The recommended cremation temperature profile consists of a linear ramp from room temperature to 2100°F in ten minutes, followed by a steady-state hold at 2100°F for two hours followed by air cooling to room temperature. It was also recommended that further statistical and/or other testing as may be appropriate be conducted.

During this report period, a preliminary theoretical analysis of the cremation environment as seen by a Radioisotope Powered Cardiac Pacemaker System was initiated. The results, although considered preliminary at this time, tend to confirm the test data and previous recommendations.

During this report period, it was agreed that Mound will conduct cremation safety tests on completed fueled systems in accordance with a mutually agreed upon test procedure. A draft of this test procedure has been prepared by ARCO Nuclear and reflects the approved minimum cremation environmental conditions that a Radioisotope Powered Cardiac Pacemaker heat source contained within the Radioisotope Powered Cardiac Pacemaker system must withstand. The following is the test procedure as transmitted to Mound for review:

The primary purpose of the procedure is to assure that the recommended cremation temperature profile (Reference 1) is obtained in the simulated

Reference 1 - Letter to Mr. Harold N. Miller, AEC, Chicago Operations Office.

cremation test of the fueled pacemaker system. Also, during this test, the environment should be replenished with air to assure that an oxygen rich atmosphere is maintained throughout the test. This is to simulate the oxygen rich cremation atmosphere which exists during cremation since excess air is used for combustion.

The cremation temperature profile consists of a linear ramp from room temperature to 2100°F in ten minutes, a steady-state hold at 2100°F for the remainder of two hours, followed by air cooling to room temperature. A copy of Figure 5 from Reference 1 showing this profile is included.

General Procedures

The general procedure will be to place the test units into a preheated muffle furnace (at $\approx 1800^\circ\text{F}$), with air being added, wait until the combustion of the epoxy is completed, increase the furnace temperature to 2100°F, hold for the rest of a two hour period, remove the units and air cool. The muffle furnaces will be in the Mound standard high temperature capsule testing hood which has a 100 percent filter to prevent isotope escape if the capsule would fail.

The tests will be run in three parts:

Part 1 - Preliminary tests with air and combustion of ≈ 22 grams of epoxy to set initial furnace temperatures.

Part 2 - Tests with air, combustion of ≈ 22 grams of epoxy and the instrumented tempil pellet holder for setting final test parameters.

Part 3 - Tests on the fueled pacemakers.

Part 1

Preliminary tests are needed with epoxy and air to determine the initial furnace temperatures and establish the general operational procedures. If the initial temperature of the furnace is set at 2100°F, the exothermic reaction of the epoxy may increase the temperature to as high as 2400°F. ARCO Nuclear will supply Mound Laboratory with ≈ 22 gram blocks of the epoxy used on the pacers for these tests. Also, these tests may be necessary to determine the effect of adding air on holding the 2100°F temperature in the furnace. The flow rate should be set high enough to assure complete

replacement of air in the furnace in about five minutes. It is expected that an initial furnace temperature of $\approx 1800^{\circ}\text{F}$ may be satisfactory. Also, it will be important to determine the exact method of obtaining the desired temperature-time cycle.

Part 2

These tests will be similar to the final tests except pacemakers will not be used. The ≈ 22 gram epoxy pieces along with the instrumented tempil holder will be used. At least two platinum-platinum-rhodium thermocouples should be used. Because of the relatively large mass of the tempil holder, temperature excursions of a thermocouple inside the unit will be severely damped. Also, from experiences in the crematories, large differences can exist between bare and shielded couples. Thus, it is recommended that at least one of the couples be shielded in the tempil holder and one couple be a bare couple directly exposed to the gases. Care will have to be made to diffuse the inlet air to minimize temperature gradients inside the furnace. The tempil holders will be used with tempil pellets as a final check on the maximum temperature. These tests will also help correlate the tempil results from the crematory survey with these simulated pacemaker cremation tests. ARCO Nuclear should be able to furnish the thermocouples if they are not readily available at Mound. As part of the test setup, it is recommended that the bare thermocouple can be on a chart recorder output and the internal shielded couple be monitored on a hand balance potentiometer with readings approximately every two minutes during the first twenty minutes and every five minutes thereafter. The thermocouples discussed above are in addition to the thermocouples already in the furnace for heat input control.

Part 3

The test procedures for this part will be essentially identical to those of Part 2 except that the actual fueled pacemaker will be used. The unit will be placed in the muffle furnace after the tempil holder and the thermocouple readings indicate the proper initial temperature. The location in the furnace must be close to the tempil holder but not against it. After the two hours have elapsed, the pacemaker will be removed from the furnace and air cooled. All details as to the geometric location of the pacer in

the furnace, temperature-time recorder records, and pictures of the pacemaker and test system are to be taken. After the pacemaker is removed from the furnace and cooled, wipe tests and radiation measurements must be made. If the unit has no release, as is expected, radiographs of the unit will be taken.

After these radiographs, the unit will be taken to a proper area for removal of outer case parts from the fuel capsule. This setup should be designed so that no danger would exist from a capsule break during the operation. After the capsule has been cleaned of the pacemaker debris, radiographs and leak checks will be made. If the outer capsules have detectable cracks or leaks, they should be removed, again using proper safety precautions, and new radiographs and leak checks made.

RECOMMENDED CREMATION TEMPERATURE PROFILE AND COMPARISON WITH MAXIMUM TEMPERATURES MEASURED DURING ELEVEN CREMATION TESTS (ADJUSTED DATA)

26

APPENDIX A

RPCP THERMOELECTRIC TAPE PLATING EQUIPMENT FIRE ROOM CP-2 REPORT

by: G. Maurer
F. Shipko

January 11, 1972

Discovery and Initial Actions

At approximately 11:30 P.M. on December 15, 1971, Norman Gerheim, the janitor, went by the room where the fire occurred with no indication of smoke or smell of a fire. However, as he was being let out of the building by the guard at the end of his shift, a strong odor of smoke was detected in the laboratory area. Both immediately proceeded to check the various laboratories for the source of the smoke. The fire was discovered in the Chemical Processing-2 room. Gerheim immediately obtained a fire extinguisher, and the guard went to call the various technical people on the callout list. At this point, Gerheim observed considerable arcing of electrical wiring in the fire area so he turned off all the power in that area (Panel LVLP-C, circuit breakers 14 through 26). This immediately reduced the extent of the visible fire. He then turned on the ABC extinguisher directing it into the room from the door and extinguished the fire. The actual time of the fire was probably between 11:30 P.M. and 11:50 P.M., the time of clock stoppage. At 12:30 A.M., December 16, 1971, V. Sheaffer arrived on the scene and in 10 minute, increments V. Speicher and G. Maurer arrived. Sheaffer and Speicher immediately checked out the room to be sure that all electrical circuits were turned off. The circuits that were not related to the room with the fire were then turned back on. At approximately 1:00 A.M., D. Purdy and Dr. Blair arrived. Dr. Blair was interested in the possibility of any nuclear release. F. Shipko and D. Stevens came in later with F. Shipko

especially brought in to determine if the cyanide solutions in the tanks where the fire occurred had created a danger to people entering the room after the fire. He assured those at the scene that there should be no danger to personnel. At approximately 3:00 A.M. when all the circuits were again checked and it was absolutely assured the fire was completely out, the guard was told to check the room approximately every 15 minutes and the Energy Conversion personnel on the scene returned to their homes.

Damage and Repair Costs

The fire damage was primarily confined to the thermocouple tape plating hood, tanks, and related equipment. Other pacer type processing equipment in the room, such as the grit blaster, the vapor degreaser, tape plating fixture, and the rinsing tank were not damaged. The room itself had heavy smoke damage requiring a new ceiling and complete painting and electrical wiring. The list of the lost equipment is attached. There will be additional cost for cleanup of the room and installation of a new ceiling and wiring.

Probable Cause

The fire apparently started in one of the polypropylene tanks for plating the thermoelectric tapes for the pacemaker manufacture. Although both tanks were destroyed by the fire, it was believed that it was started in the side for plating copper by the immersion heater having been left on. After eight hours, most of the plating solution (usually maintained at 55°C) would have evaporated from the tank exposing the immersion heater to air and causing it to become red hot. The tank, being in close proximity to the heater, melted and came in contact with the heater causing the polypropylene to ignite. The primary reason for this conclusion was the fact that the powerstat to the heater was

still on after the fire. It was also observed that the exhaust fan to the hood was off during the fire. Since this fan is normally left running, it was felt that the operator (who was new on the job) had apparently been thinking that he had turned off the heater but instead turned off the fan controls, which was located near the powerstat for the immersion heater. The operator had also left the magnetic stirrers, the grit blaster, and a hot plate in the "on" condition, although these were not related to the fire.

Technically, the suggested mode of ignition could easily have happened because this particular heater with approximately 1000 watts input (which is normally supplied to it) could attain a surface temperature above 1500°F. Polypropylene, having an ignition temperature of approximately 700° to 1000°F, would easily have ignited. At the time of ignition, the polypropylene in close proximity to the heater would have been molten since it distorts at approximately 220°F and is heat resistant to only 300°F.*

Although polypropylene is considered a slow burner, most of the smoke was apparently exhausted into the room and collected on the walls and was drawn into the air conditioning unit rather than having been exhausted by the hood fan. Dr. Foti** was consulted and he stated that polypropylene burns much like benzene giving off a very dense smoke and although it might break down into other gases, such as acetylene and ethylene, he doubts that the polypropylene would have produced a secondary fire from these gases. Some of the low temperature melting plastics in the room did show some distortion in areas up to as much as 12 feet from the fire. However, many of these will distort at temperatures as low as 200°F.

* Mr. Robert Reger, Allied Resins Inc., Coneaut, Ohio, Tel. No. 216-593-1178.

** Dr. Foti, Novamont Co., Wilmington, Delaware, Tel. No. 212-838-6474.

In summary, the fire was probably due to an operator error in not turning off the plating tank heater coupled with the fact that this heater did not have a high temperature safety switch.

Preventive Action

To eliminate any possible reoccurrence of this type of accident, the following precautions and safety devices will be installed on the equipment:

1. Over temperature cut off will be installed on the immersion heater.
2. A red light with a single master switch to the normally off plating equipment (when not plating tapes) will be installed.
3. A green light for the hood fan (which is normally on) switch will be used.
4. The hood, which in the past rested on top of the plating tanks, will be separately supported by a metal frame so that no movement would occur if the tanks were distorted by heat.
5. A strong program of improving operator and supervisory safety programs will be utilized.

LOST EQUIPMENT

2	H-P Power Supplies
2	Gralab Timers
1	Gralab Immersion Heater
1	Gralab Rubber Mat
14	1-1/2" Long Teflon Coated Stirring Bars
2	Polypropylene Tanks
3	1 amp. D. C. ohmmeter
1	2 x 65" copper anode
1	2 x 24" silver anode
1	Bottom part of hood and duct cleanup
1	Plating Table Tray

PACER COMPONENTS LOST

20 yards	Insulation Tape
33 yards	Cupron Thermocouple Tape
28 yards	Tophel Thermocouple Tape

Also, cleanup efforts and installation of new equipment required.

DISTRIBUTION

Cdr. J. M. Prosser, RDT, USAEC, Washington, D. C.	2
Mr. M. A. Rosen, RDT, USAEC, Washington, D. C.	1
Mr. R. E. Cunningham, Division of Materials Licensing, Washington, D. C.	1
Dr. J. D. Goldstein, Dpartment of Biology & Medicine, USAEC Washington, D. C.	1
Col. Seymour Schwiller, Staff Consultant to the Joint Committee for Atomic Energy, Congress of the U.S., Washington D. C.	1
Mr. H. Miller, Director, Contracts Division, AEC, Chicago	2
Mr. H. Potter, Patent Attorney, Patent Group, Brookhaven Office, USAEC Upton, Long Island, New York	1
Dr. A. G. Morrow, Chief, Clinic of Surgery, NHLI, Bethesda, Maryland	1
Dr. P. Frommer, Chief, Myocardial Infarction Branch, NHLI, Bethesda, Maryland	1
Dr. V. Parsonnet, Director of Surgery, Newark Beth Israel Hospital, Newark, New Jersey 07112	2
Mr. E. A. Walker, Dayton Area Office, USAEC, Monsanto Research Corporation, Miamisburg, Ohio 45342	1
Mr. D. L. Prosser, Program Manager, Cardiac Pacemaker Program, Mound Laboratory, Monsanto Research Corporation, Miamisburg, Ohio	1
Dr. E. W. Johnson, Mound Laboratory, Monsanto Research Corporation, Miamisburg, Ohio	1
Mr. T. Iltis, Senior Site Representative, RDT Site Office, USAEC/WARD Madison, Pa.	1
Mr. J. N. Maddox, Division of Applied Technology, Washington, D. C.	1
Cdr. W. Holloman, RDT, USAEC, Washington, D. C.	1
USAEC Division of Technical Information Extension, Oak Ridge, Tennessee (Category UC-33 Distribution)	198

**ENERGY CONVERSION
TECHNICAL CENTER**

ARCO Nuclear Company

LEECHBURG, PENNA. 15656

A Subsidiary of Atlantic-Richfield

198
3-9-72