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RADIOISOTOPE-POWERED CARDIAC PACEMAKER

REPORT TO:
UNITED STATES ATOMIC ENERGY COMMISSION
NEW YORK OPERATIONS OFFICE.

NUMEC-3657-1

NUMEC
ENERGY CONVERSION DIVISION

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Quarterly Progress Report
for
Phase II
Radioisotope Powered
Cardiac Pacemaker Program

August 1, 1971 to October 31, 1971

Prepared for
UNITED STATES ATOMIC ENERGY COMMISSION
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INTRODUCTION

This is the seventh 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 August 1, 1971 to October 31, 1971.

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 two more Phase I electronic circuits failed. In one circuit the output transistor developed an open emitter and in the other the multivibrator stopped operating. This re-confirms previous conclusions made concerning the Phase I circuits. The first 50 Phase II electronic circuits have been completed and passed all of the extremely high standards imposed upon them. These circuits are now on long-term life test.

A total of six nuclear batteries have been assembled using essentially the materials and procedures presently intended for pilot production pacers. The performance of these units is significantly better than predicted.

During this report period an extensive amount of cremation testing has been conducted. The data has been reduced, analyzed and incorporated into a final recommendation that is being prepared and will be submitted during the next report period.

Task 2.0 - RELIABILITY AND QUALITY ASSURANCE

Reliability Data

At the end of October, the various Phase I nuclear batteries have accumulated a total of 39.52 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 October, the Phase I electronic circuits have accumulated a total of 68.95 unit years of operation with a total of 16 circuit failures.

At the end of October, the Phase II electronic circuits have accumulated a total of 4.69 unit years of operation with no circuit failures.

Failure Analysis

During this report period, two additional Phase I electronic circuits (Serial Numbers 135A-39 and 135A-11) failed. Circuit 135A-11 was delivered and placed on life test on 6/6/67. Approximately 2-1/4 years later on 9/16/69, this circuit was incorporated into experimental model E-16 and placed on life test. Approximately 2 years later on 8/31/71 the circuit failed and was removed from the system. It was found that the output transistor Q_3 had failed and that the failure mode was an open emitter of Q_3 .

Circuit 135A-39 was delivered and placed on life test on 12-3-69. Approximately 50 days later on 1-22-70, this circuit was incorporated into prototype model P-6 which 77 days later was implanted in a dog at NHLI on 4-9-70. P-6 was removed from the dog 46 days later on 5-25-70 due to a battery failure and returned on 5-26-70. Circuit 135A-39 was removed from P-6 and placed on life test using a laboratory simulated nuclear battery for its power supply. Approximately 16 months later on 10-8-71 this circuit failed and the failure mode was such that the multivibrator portion of the circuit stopped oscillating. Several attempts were made to restart the circuit all of which were unsuccessful. On the following day, however, the circuit was successfully restarted and it has been operating properly ever since.

These last two failures bring the total to 16 failures out of a total of 29 Phase I circuits.

Long Term Vibration

During September, three nuclear batteries without electronics or epoxy were vibrated to destruction at a greatly accelerated level in order to determine their fatigue characteristics. The last monthly report explained that battery XPD-1 had accumulated 28 million cycles, experienced two tape failures in each sub-group, and still had sufficient power output to operate the electronics within specifications. After 30 million cycles XPD-1 failed completely and the failure analysis revealed that tapes #2, 3, 4, 5 and 6 had multiple breaks at only the hot shoe. All of the jumpers were intact. The attached table illustrates the data obtained during the testing of all three batteries. Testing was done in all three axes. The vibration of the thermopile in the X and Y axes can be viewed as one axis of vibration through the fuel capsule. The summation of the X and Y axes are, therefore, indicated in the table.

The other two batteries (XPD-4, PD-1) were tested in the same manner as XPD-1 except that the g-level was reduced to 2 g's. XPD-4 had the narrow border prototype tape while PD-1 had the wide border production tape. XPD-4 and PD-1 accumulated 23.9 and 17.3 million cycles respectively before the units completely failed. Both ends of the exterior case were removed from XPD-4 in order to view the thermopile intact in the case. At this point a wire was spot-welded to both getter assemblies at the ends of the fuel capsule. Weights corresponding to a 2, 4, and 8 g vibration were suspended from the wire to simulate deflection of the fuel capsule assembly. There is only a slight difference in the amount of deflection in the fuel capsule assembly when loaded to either the 2, 4, or 8 g level. Visually the thermopile appeared tighter at the outside wraps. The unit was then vibrated at the 2 g and 4 g levels. A strobe light was used to compare the vibration of the thermopile and the fuel capsule assembly. It was observed that the fuel capsule vibrates at a higher g level than the thermopile by approximately a factor of 4. A failure analysis has not yet been performed on PD-1. It was calculated that the g level associated with a normal breathing rate would be approximately .01 g's and a maximum of .1 g's with a breathing rate approximately 8 million cycles per year. It is recognized that it is difficult to make a comparison between normal breathing and the greatly accelerated vibration fatigue testing of the three units, but the data does imply that the three

Table 1

FATIGUE VIBRATION TESTING

Unit No.	Test G's	Cond. Hz	Thermopile Tape	Acc. Cycles Before Failure	Total Cycles Per Axis (Million)				Sequence of Failures				Failure Mode
					X	Y	X + Y	Z					
XPD-1	4	30	Narrow Border	30,259,000	12.3	.648	12.9	17.3	2,673,000	3,321,000	7,614,000	18,981,000	Tapes 2, 3, 4, 5, 6 exhibited multiple breaks on the hot side. No break on cold side or jumpers.
XPD-4	2	30	Narrow Border	23,868,000	6.1	2.5	8.6	15.3	6,048,000			6,372,000	
PD-1	2	30	Wide Border	17,280,000	5.8	3.5	9.3	8.1	2,268,000	8,100,000			

units could be subjected to normal vibration for 11 years without any fatigue problems.

Tape Leakage Resistance

In order to increase T/C tape production yield it was suggested in the last Quarterly Report that the minimum allowable leakage resistance be reduced from 10 meg Ω to 1 meg Ω since some of the tapes in production have leakage resistance as low as 1 meg but should not significantly degrade thermopile performance because the production thermopile resistance is 10 times lower than the production thermopile resistance upon which the 10 meg Ω value was based. This was verified by the fact that a battery assembled with tapes having leakage resistances below 10 meg Ω but no lower than 1 meg Ω resulted in excellent performance. In addition the effects of T/C tape leakage resistance on RPCP peak power for both nominal and worst case conditions were calculated.

It was assumed that the leakage resistance appeared directly across the total thermopile and for a given value of leakage the maximum available output power was computed. The nominal case corresponds to all six tapes operating properly and the worst case corresponds to two tapes in each of the two subsets having failed in the open mode.

The calculations as summarized below indicate that for a leakage of 1 meg the power loss is about 1/2% for nominal conditions and about 1-1/2% for worst case. In order to suffer a 5% power loss the leakage resistance would need to be as low as 100K for nominal conditions and 260K for worst case conditions.

<u>Leakage Resistance (ohms)</u>	<u>% Power Loss for Nominal (Battery Resistance of 5.3 K)</u>	<u>% Power Loss for Worst Case (Battery Resistance of 16 K)</u>
∞	0.000	0.000
10 meg	0.053	0.160
5 meg	0.106	0.319
1 meg	0.527	1.575
800 K	0.658	1.961
600 K	0.876	2.597
500 K	1.049	3.101
400 K	1.308	3.846
200 K	2.582	7.407
100 K	5.033	13.793

It was mentioned in the May 1971 progress report that an isolation problem had developed in maintaining the minimum 10 meg Ω resistance between the tape and either the hot or cold shoe. Two approaches were outlined to investigate the problem. The first approach was to determine the cause of the decreasing isolation resistance. Previously, during Phase I, this resistance was always essentially infinite. Secondly, an analysis was performed to establish a minimum acceptable isolation resistance based on the new Phase II series parallel connections of the thermocouple tapes. The analysis as discussed above revealed that the minimum resistance value could be lowered from 10 meg Ω to 1 meg Ω without significantly reducing the performance of the thermopile.

Most of the isolation resistance values were acceptable resulting in satisfactory tape production yield when the problem first began. However, as production continued, a chronological plot of isolation resistance indicated that some of the values are now falling below the new 1 meg limit and a general decrease in isolation resistance could be observed as a function of time. The front and back faces of the ceramics after brazing visually exhibited a streaked deposit. The following tests were conducted to determine if this deposit could be the cause of the problem:

- (1) Compare sections of recently brazed ceramics and ceramics brazed in 1969.
- (2) Check the groove to ground resistance of recently coated ceramics.
- (3) Grit blast the sides of the ceramics after brazing to remove any deposit.

The comparison of metallographic sections from recently brazed ceramics and 1969 brazed ceramics indicates that there is no difference between the two ceramics. The degree of porosity was found to be relatively the same.

Several coated ceramics after final grinding were selected at random and the resistance was checked groove to ground. All of these readings were on the 100 meg scale indicating no leakage. It should also be noted that Q.C. checks each ceramic groove to groove for resistance before assembly.

Grit blasting tests were being conducted simultaneously to the above-mentioned testing. The sides of ceramics on brazed low isolation resistance tapes were grit blasted to remove any deposit formed during brazing or which was left behind after final grinding. The results of the grit blasting tests

were contradictory. The first groups of tapes grit blasted did not significantly improve the isolation resistance. Contrary to this all of the last group of tapes to be grit blasted at the ceramics increased the isolation resistance significantly. Next the ceramics on two tapes rejected for low isolation were hand lapped. After repeated lapping and a final light grit blasting, the resistance improved significantly. Based on these tests the following conclusions were made:

- (1) The isolation problem is not a result of the braze material in the grooves permeating through the ceramic to the metal shoe.
- (2) The deposits of conduction material on the face of the ceramics are the cause of the low resistance, since repeated lapping and/or grit blasting after brazing will improve the resistance significantly.

We are now attempting to resolve the question of how the conductive material is deposited on the ceramic. The methods of coating and grinding the ceramics were investigated first. Ceramics were carefully hand lapped and grit blasted before assembly for brazing. After brazing the tapes were checked and overall there were no significant improvements. Visually the ceramics appeared to have fewer streaks. The lapping-grit blasting operation did however, on many of the ceramics, improve the groove to ground resistance before assembly from the 10 meg Ω level to infinity.

The brazing operation is also being investigated. The brazing is done under vacuum and therefore any condensation of vaporized braze material would occur radially or on a line of sight from the braze heater. Shields were made to protect the front of the ceramics (side facing the tape) from this type of vapor deposit. Although only a few tapes were processed, it did not solve the low leakage resistance problem. However, the tapes were generally cleaner in appearance. The decrease in resistance appeared to correlate with the increase of production and an increase in the number of times a brazing chamber is used in one day. Several single brazes were made in a virtually cold chamber but the problem remained.

In addition, the possibility of smearing the ceramic when the wires are cut after brazing was investigated but did not offer a solution. The possibility of the braze heater giving off a vaporized metal is now being investigated.

It is conceivable that the resistance problem is a result of a number of possible combinations of events such as (1) braze material left behind during grinding of the ceramics, (2) vaporized metal or braze material deposits, and (3) the absence of proper shielding of the ceramics.

Although at this stage of the investigation the optimum solution has not been obtained to significantly reduce production tape rejection rates due to low isolation resistance, the evaluation has uncovered several steps which would aid in producing a better quality thermocouple tape. The investigation will continue in both the areas of ceramic grinding, tape brazing and oxidation procedures for a solution to the isolation resistance problem. A fixture could for example be designed to grit blast the ceramics on low isolation resistance tapes which would assure no degradation of tape reliability yet increase tape production yield. In addition, a procedure could be initiated to oxidize the conductive leakage path which would significantly reduce tape rejection rates.

Drawings

The following drawings for fixtures have been completed during the months of August, September, and October, 1971.

15-A-4189-111	Silastic Plug
15-B-4189-107	Thermocouple Tape - Sand Blasting - Collar Assembly
15-B-4189-112	Exterior Case Lid to Feed Thru & Closure Plug Leak Testing Fixture - Lid Mockup Detail
15-D-4189-231	Life Test Station for Phase II Electronic Circuit Modules - 320 Unit Capacity - 80 Unit Circuit Module Holder Assy & Dets.
15-D-4189-232	Life Test Station for Phase II Electronic Circuit Modules - 320 Unit Capacity Assy & Details
15-D-4189-233	Tempil Pellet Holder Det's.
15-D-4189-234	Mold for Life Test Station Pacer Holders

Middle Fuel Capsules

Some of the Phase II middle capsules and plugs that were sent to Mound Laboratory need to be replaced. This is due to the Hastelloy "C-276" that was used having an aluminum content high enough to retard successful

welding of the capsules. These replacement capsules and plugs will be machined from a Hastelloy "C" rod with a lower aluminum content. Capsules and plugs from this rod have been successfully trial welded by Mound.

The number of Phase II components needing replacement are 80 middle plugs and 80 middle capsules. Mound has also requested 12 additional sets for weld verification.

The order to make these components has been placed with the vendor who made the original 150 sets.

To date, 35 middle plugs, 12 middle capsules for weld verification, and 27 middle capsules for fueling have been sent to Mound. An additional 39 middle capsules have been inspected and will be sent to Mound in the near future. We will send Mound 57 more plugs and 14 more capsules as soon as they are machined.

Thermocouple Tapes

Since the start of development for pilot production, 19 of 98 thermocouple tapes produced have not met the minimum total tape resistance specification of 7700 ohms. Since it is desirable to reduce this 20% rejection rate, an investigation was initiated to determine the cause of the problem.

Resistance checks on ceramic tabs removed from some of the reject tapes showed good resistance values between grooves of the tabs indicating that the problem was in the tape itself. Since measurements of intact low resistance tapes could not isolate the problem, the wires were carefully cut at the ceramic tabs. Then local ceramic tab resistances as well as isolated thermocouple and individual wire resistances were measured. It was found that with the thermocouples disconnected, the resistance between ceramic grooves was essentially infinite indicating that the ceramic tabs were not causing the low tape resistance problem. It was next found that all isolated thermocouples had low resistances and that their individual sum equaled the low total tape resistance previously measured for the intact tape. Finally, measurements of individual isolated wires showed that the Cupron Special wires were well below their proper resistance values and that the Tophel Special wire resistances were normal.

Examination of the tapes revealed a thin silver deposit on the Cupron, but not the Tophel tapes. This was concluded to be an immersion coating of silver formed on copper or copper alloys which come in contact with silver cyanide plating solution and are not an electroplated deposit. This coating was visually observed on about 70% of the completed thermocouple tapes as

spotty or complete coverage coatings and was concluded to be a contributing factor to low total tape resistance.

This silver coating is obviously formed during electroplating of silver on the thermocouple wires. The plating solution either seeped through the fixture to the body of the tape or small quantities splashed into this area during plating or subsequent rinsing of the tape and fixture with water.

In order to prevent plating solution from coming into contact with the body of the tapes, plexiglas blocks were fabricated for the plating fixture which are clamped over the center section of the tapes. Subsequent filling of these sections with water forms an effective seal around the tape. As an added precaution, strips of copper are placed in these sections to indicate the presence of silver which necessitates more careful rinsing.

Since incorporation of these measures, the rejection of tapes by silver coating has been eliminated.

Thermocouple Tape Plating

Aside from the silver coating problem, difficulty was encountered in electroplating copper and silver braze coating to the new wide border thermocouple tapes. During plating, one or two out of the seven plating areas refused to accept a deposit or the entire coating had varying degrees of grainy, non-uniform or non-adherent deposit. These results were shown to be caused by either marginal electrical contact to the cathode lead or an oxide film on the wires.

The electrical contact problem did not exist with previous design tapes, but occurred only since wide border tapes have come into being. These tapes are 1 mil thicker along the border making it difficult to make electrical contact. This problem was eliminated by placing one inch wide aluminum foil strips on the top and bottom at both ends of each unit tape under the plexiglas barrier block previously discussed. All the foils make contact to a common cathode. As an added precaution, a good contact is made firmly to the wires at both ends of the tape.

The oxide film problem originates during desizing and cleaning of tapes. A brown film is clearly evident on the cupron and tophel wires in reflected light. This film is readily removed by a 5 minute soak in 5% NH_4OH . This soak has been incorporated into the desizing procedure as a final step just

before plating.

The grainy or non-adherent deposit is mainly an electrical contact problem, but has also been observed to be related to current density in the silver plating step. Decreasing the current density in this bath by 1/3 has shown considerable improvement in the uniformity of the deposit.

Battery Lid Feedthrough

After experiencing a four out of eight leak test failure rate after degassing of pilot production feedthroughs, a series of experiments were initiated to pin point and resolve the problem.

Cross sections of the failed feedthroughs revealed cracks in the body of the ceramic near the bottom and a poor bond between the copper feedthrough wire and the ceramic with erosion of the wire very evident.

The wire erosion indicated excessive heating which would cause dissolution of the wire in the 72 wt % silver - 28 wt % copper braze alloy. A check of the brazing furnace revealed a hot zone which could have had a deleterious effect on temperature control. The heating elements in the furnace were changed and the brazing zone carefully recalibrated. In addition, the brazing temperature was lowered from 845°C to 830°C, the minimum at which good braze flow has been observed with this braze alloy in this system.

Brazes were made at 830°C using the standard braze (BT) and at 820°C with a 0.2% lithium - 71.8% silver - 28% copper braze (LBT). In one series, a copper feedthrough wire was employed, in another titanium feedthrough wires were used. It became evident in these tests that LBT offered no advantage over BT and its use was discontinued. (The better filleting ability of LBT prompted its trial). Brazes with BT at the lower temperature produced good seals between the wire and ceramic with both titanium and copper with erosion of either wire not evident. Cross sectional examination of these feedthroughs, however, showed cracks persisting in the body of the ceramic and severe cracking in the ceramic adjacent and parallel to the titanium wire. The cracking parallel to the titanium wire persisted in several trials and eliminated titanium as a possible replacement feedthrough wire. The lower brazing temperature produced good results with the copper wire. Degassing at 300°C as required in pacer assembly had no effect on the copper wire to ceramic seal.

The cracks in the body of the ceramic are undoubtedly produced by stresses introduced during cooling after brazing by differential contraction of the titanium flange and aluminum oxide ceramic. The next series of experiments were performed to determine a flange design which would not produce stress cracks in the ceramic. Several different designs with a .025 inch flange wall thickness, the size previously used in feedthroughs, were fabricated. Flange to ceramic joints from .025 inch to .150 inch (the entire length of the ceramic) all resulted in cracks in the ceramic. In another group of tests, the wall thickness of the flange was reduced to .012 inch. No cracking in the ceramic was evident in these tests. The height of the .012 inch flange wall was varied, but no cracks in the ceramic were ever observed. It was concluded that stress cracks in the ceramic were eliminated with the .012 inch wall thickness titanium flange. The final design arrived at is shown in the attached drawing.

NOTES.

1. FOR LOCATION AND BRAZING TEMPERATURE OF GROUP #4 & 5 SEE DWG 15-D-4189-7
2. ALL PIECES TO BE CLEANED AND MACHINED AS PER SPECIFICATION NPS-15A.
3. IN GROUP #3 ITEM #17 IS TO BE LOCATED & SPOT WELDED TO ITEM #4
4. IN GROUP #4 ITEM #9 IS TO BE LOCATED & SPOT WELDED TO ITEM #1
5. ITEM #20 TO BE COATED WITH ITEM #21 PRIOR TO BRAZING

FOR ASSEMBLY SEE DWG 15-D-4189-1
FOR SUB ASSY SEE DWG 15-D-4189-7

[illegible]

Task 3.0 - SYSTEM FABRICATION AND PRODUCTION DEVELOPMENT

All of the 11 preproduction and 39 pilot production electronic circuit modules have been completed, passed all specifications and requirements of RDT Standard Cl9-1T, and passed our incoming Quality Assurance inspections. In addition, one circuit module is being subjected to a "test-to-destruction" sequence (Module #032). Thusfar, it has been subjected to the following with no change in its performance:

- (1) Ten thermal cycles between -10°C and 70°C with a 30 minute dwell at each temperature and a transient time of less than one minute.
- (2) Vibration scan of 4G amplitude for 15 Hz-500 Hz-15 Hz with a 30 minute dwell at each resonant frequency.
- (3) Three thousand shocks of 50G amplitude (one thousand in each axis).
- (4) Five hundred shocks of 855G amplitude.

These destructive tests will continue during the next report period with increasing severity in order to determine the shock capability of the module which has already far exceeded the minimum shock specification requirements.

Process Flow Cards

To assure proper processing and quality control, process flow cards were developed and made up for key items. The cards are color-coded for easy recognition and are shown in Figures 1, 2 and 3. A similar card is being developed for the electronic circuit.

Tape Brazing

The tape brazing has been initiated with production T/C tapes and has generally been very successful. Essentially all tapes have had good brazes with the single braze cycle (second cycle not allowed) and no addition of BT braze material. The assembly in the new fixtures is good with one man being able to assemble up to approximately five complete tapes per day. No significant problems seem to be present in the assembly and brazing of tapes. Temperature limiting controllers are being installed to prevent heating above 850°C during brazing. The general appearance of tape brazes and tabs has been excellent. However, during this report period tape rejection rates have sharply increased due to low isolation resistance. This may be caused during the brazing cycle as discussed in Task 2 and is being evaluated.

INSULATION TAPE NO.

PACER NO.

ASSEMBLY ROUTE CARD

PURCHASE ORDER NO _____
 SPOOL NO _____
 BATCH NO _____

Operation	Desizing	Al ₂ O ₃ Coating	Q.C.	Degas	Q.C.	Cutto Size	Q.C.
DATE OF OPERATION							
OPERATOR							
SPECIFICATION NO	105 001	105 001	205 002	405 001	205 005	115 001	215 001

043-402B

RADIOISOTOPE POWERED CARDIAC PACEMAKER

CONTRACT AT(30-1)-4189

THERMOCOUPLE TAPES

PACER NO.

ASSEMBLY ROUTE CARD

PLATED TAPE STRIP NO - TOPHEL _____ HOT TAB NO _____ HOT SHOE LOT NO _____
 PLATED TAPE STRIP NO - CUPRON _____ COLD TAB NO _____ COLD SHOE LOT NO _____

ASSEMBLY AND BRAZING SPECIFICATION NO. 114 001

Tape End	Assembly Station	Braze Station	Assembly By	Assembly Date	Brazed By	Brazed Date
Hot						
Cold						

Q.C. INSPECTION

SPECIFICATION NO. 214.001

Check	Reading	Operator	Date	Acc./Rej.	Date Degassed
Total Tape					
Hot Shoe					
Cold Shoe					

POLARITY _____ VISUAL ACCEPT _____ LENGTH ACCEPT _____
 Q.C. NO _____ VISUAL REJECT _____ LENGTH REJECT _____
 COMMENTS _____

047-402B

RADIOISOTOPE POWERED CARDIAC PACEMAKER

CONTRACT AT(30-1)-4189

Figure 1

BATTERY LID FEEDTHROUGH ASSEMBLY NO.

PACER NO.

ASSEMBLY ROUTE CARD

042-402B

FEEDTHROUGH FLANGE NO _____

PURCHASE ORDER NO - CLOSURE PLUG _____

PURCHASE ORDER NO - CERAMIC _____

PURCHASE ORDER NO - CU SHIM _____

PURCHASE ORDER NO - TI SHIM _____

Operation	Braze	Isolation	Q.C.	Leak Check	Degrease	Degas
DATE OF OPERATION						
OPERATOR						
SPECIFICATION NO	102 012	102 013	202 007	502 001	302 009	403 001

RADIOISOTOPE POWERED CARDIAC PACEMAKER

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ELECTRONICS CASE ASSEMBLY NO.

PACER NO.

ASSEMBLY ROUTE CARD

044-402B

FEEDTHROUGH FLANGE NO _____

PURCHASE ORDER NO - CERAMIC _____

PURCHASE ORDER NO - NI SHIM _____

PURCHASE ORDER NO - TI SHIM _____

Operation	Braze	Electro-plating	Isolation	Q.C.	Leak Check	Degrease	Degas
DATE OF OPERATION							
OPERATOR							
SPECIFICATION NO	106 010	106 011	106 012	306 007	506 001	306 009	403 001

RADIOISOTOPE POWERED CARDIAC PACEMAKER

CONTRACT AT(30-1)-4189

Figure 2

R.P.C.P. ASSEMBLY NO.

PACER NO.

ASSEMBLY ROUTE CARD

045-4028

SUBASSEMBLIES		OPERATIONS			
Name	Number	Operation	Date	Operator	Spec No
Thermopile	_____	Battery Assembly	_____	_____	117 004
Exterior Case	_____	Battery Tig Weld	_____	_____	118 001
Electronics Case	_____	Low Power Load Line	_____	_____	818 001
Exterior Case Lid	_____	Leak Check	_____	_____	518 001
Electronics Circuit	_____	Degas & E B Weld	_____	_____	119 001
Terminal Block	_____	Leak Check	_____	_____	519 001
Heart Lead	_____	24 hr Steady State Load Line	_____	_____	519 002
		Electronics Placement	_____	_____	120 001
		Electrical Performance	_____	_____	820 001
		RTV Around Electronics	_____	_____	120 002
		Insert Kapton	_____	_____	121 001
		Tig Weld Electronics Lid	_____	_____	721 001
		Tig Weld Terminal Block	_____	_____	721 002
		Grit Blast Top Surfaces	_____	_____	721 002
		Attach Temp Indicator	_____	_____	121 003
		Check Electrical Performance	_____	_____	121 003
		Pour Epoxy	_____	_____	121 003
		Machine Pour Spout	_____	_____	121 004
		Polish & Buff	_____	_____	121 004
		O C & Test	_____	_____	221 001
RADIOISOTOPE POWERED CARDIAC PACEMAKER		CONTRACT AT(30-1)-4189			

RADIOISOTOPE POWERED CARDIAC PACEMAKER

PACER NO

ASSEMBLY ROUTE CARD

046-4028

RADIOISOTOPE POWERED CARDIAC PACEMAKER

CONTRACT AT(30-1)-4189

Figure 3

Thermopile Fabrication

As reported in the last Quarterly Report three batteries had been assembled using production techniques with prototype T/C tapes. The performance was excellent except that XPD-2 had a leak and XPD-3 was low after sealing apparently due to internal gas. Subsequent puncturing and pumpdown showed that the XPD-3 unit degradation had to be caused by internal gases. Also, subsequent assembly of units XPD-2 and XPD-3 have been low indicating internal gases. These units had been leak checked with the new production leak check fixture (after TIG welding of cases) and it is felt that some oil vapors may have entered the thermopiles from this procedure. Developments are now underway to preclude this problem. LPD-1 has been closed after leak checking with a thermal performance better than any previous units.

A fourth unit, XPD-4 with the same fabrication processes, without leak checks on the final TIG welded cases was fabricated. The performance after sealing was excellent as shown in the following table:

<u>XPD-4 Performance After Sealing</u>	
Power	248 μ watts
Open Circuit Voltage	2.29 volts
Resistance	5260 ohms
Fuel Load	0.225 watts

The performance of the four XPD thermopiles averaged 246 μ watts. This is more than 15 percent higher than originally predicted.

The first sealed production unit was called PD-1 and had the following excellent operating characteristics:

<u>PD-1 Performance</u>	
Power	262 μ watts
Open Circuit Voltage	2.36 volts
Resistance	5315 ohms
Fuel Load	0.225 watts

Also, four thermopiles were wrapped for cremation tests to be performed at both our laboratories (unfueled) and at Mound (fueled). These units used tapes that had been rejected except for one tape in each unit used for a voltage output to assure proper vacuum and assembly.

In addition, seven thermopiles were wrapped and are ready for final assembly into cases.

Process Control

In addition to the process flow cards for key items previously discussed, check-off sheets for key processes have been developed. These sheets shall be filled out during assembly and kept on file. These sheets should guarantee that the proper procedures have been followed. The most extensive check-off sheet is the one for thermopile assembly and is included for an example. Other sheets are used for TIG welding, degassing and EB closure, electronic circuit installation, final epoxy molding, and epoxy pour spout removal and polish.

R.P.C.P. THERMOELECTRIC BATTERY ASSEMBLY RECORD

Pacemaker # _____

Start Date _____

Technician _____

Specification # 115.001 - Record as Tapes are Spotted on Hot Shoe

Tape Assembly Order	Tape #	Is Resistance Essentially Same as on Card (Write Yes or No*)	Visual Check (Write Ok or No*)	Polarity + or -	Tech. Initials _____ Time _____ Date _____
6					Remarks*
5					
4					
3					
2					
1					

Specification # 615.001 - Spot Weld Hot Shoes to Hot Strap

Spot Weld Settings			Tech. Initials _____ Time _____ Date _____
Tape Assembly Order	#2 Cu Alloy Tips with .030" Flat on Top, Hand Held Electrodes (Write Yes or No*)	15 Watt Sec, Pulse Position #1 (Write Yes or No*)	Remarks*
6			
5			
4			
3			
2			
1			

Was Visual check made on Polarity order Yes _____ No _____

Was Visual check made during wrapping Yes _____ No _____

R.P.C.P. THERMOELECTRIC BATTERY ASSEMBLY RECORD

Specification # 115.001 - Resistance Checks on Wrapped Thermopile

		Resistance in rounded Megohms Over 50 Megohms, Call ∞			Tech. Initials _____ Time _____ Date _____
Tape Assembly Order	Tape Resistance	Tape to Hot Shoe	Tape to Cold Tab	To Tape Assembly #	Remarks
1				2	
2				3	
3				4	
4				5	
5				6	
6				1	

Specification # 615.002 - Spot Weld Jumper Wires to bus wires

Spot Weld Settings				Tech. Initials _____ Time _____ Date _____
Tape Lead Wire to Bus Wire	#2 Cu Alloy Tip with .030 Flat 2# Pressure Setting (Write Yes or No*)	3 to 4 Watts Sec, Pulse Position #1 (Write Yes or No*)	Visual Check of Weld under Microscope (Write Yes or No*)	
-1 to Bus				Remarks*
-2 to Bus				
-3 to Bus				
+4 to Bus				
+5 to Bus				
+6 to Bus				
Bus to Bus	See Top of Next Page			
+1 to Bus				
+2 to Bus				
+3 to Bus				
-4 to Bus				
-5 to Bus				
-6 to Bus				

R.P.C.P. THERMOELECTRIC BATTERY ASSEMBLY RECORD

Was Bus to Bus Spot Weld made with settings on Page 2
only 5 watt sec. Used Yes _____ No _____

Were any splices needed in bus wire Yes* _____ No _____

*If Yes, how many _____

Specification #817.001 Low Power Load Line Check in Air with Fuel

Fuel # _____ Tech. Initials _____

Open Circuit Voltage _____ Time _____

Resistance which drops voltage in half _____ Date _____

Specification # 415.001 Thermopile Degassing Record

Was Cycle as described in Spec. #415.001 followed Yes _____ No _____

Maximum Temperature _____

Specification #117.001 Thermoelectric Battery Assembly Record

Battery Case # _____ Electronic Case # _____

Battery Case Lid # _____

Fuel # _____

Time and Date of start of Assembly _____

Resistance of Thermopile _____ Tech. Initials _____

R.P.C.P. THERMOELECTRIC BATTERY ASSEMBLY RECORD

Specification # 616.002 - Spot Weld Retainer to Getter Basket

Spot Weld Settings				
Retainer to Getter Basket #	#2 Cu Alloy Tip with .030" Flat 2# Pressure Setting (Write Yes or No*)	15 Watt Sec, Pulse Position #1 (Write Yes or No)	12 Spots 3 between Each Notch (Write Yes or No)	Tech. Initials _____ Time _____ Date _____
1				Remarks*
2				

Getter Lot # _____

Visual Check of Getter Basket Assembly Yes _____ No _____

Specification # 617.001 - Spot Weld Getter Assembly to Hot Strap

Spot Weld Settings				
Getter Assembly # To Hot Strap	#2 Cu Alloy Tip with .030" Flat Hand Held Electrodes (Write Yes or No*)	55 Watt Sec, Pulse Position #1 (Write Yes or No*)	3 Spots on Each of 4 Tabs (Write Yes or No*)	Tech. Initials _____ Time _____ Date _____
1				Remarks*
2				

Specification # 117.001 - Battery Assembly Record Continued

Is isolation resistance of feedthrough infinite

Battery Lid Yes _____ No _____

Electronic Case Yes _____ No _____

Visual Check of Heat Shield Assemblies Yes _____ No _____

R.P.C.P. THERMOELECTRIC BATTERY ASSEMBLY RECORD

Specification # 617.002 - Spot Weld Thermopile Retainer
Strap to Support Bracket

Spot Weld Settings				
Retainer Strap to Support Bracket	#2 Cu Alloy Tip with .030" Flat Hand Held Electrodes (Write Yes or No*)	15 Watt Sec, Pulse Position #1 (Write Yes or No*)	4 Spots on Retainer strap (Write Yes or No*)	Tech. Initials _____ Time _____ Date _____
1				Remarks*

Specification # 817.001 - Low Power Load Line Check after
Retainer Strap Spot Welded

Fuel # _____ Tech. Initials _____
Open Circuit Voltage _____ Time _____
Resistance which drops voltage in half _____ Date _____

Specification # 617.004 - Spot Weld Battery Ground to Case Lid

Spot Weld Settings				
Battery Ground to Case Lid	#2 Cu Alloy Tip with .050" Flat 2# Pressure Setting (Write Yes or No*)	15 Watt Sec, Pulse Position #1 (Write Yes or No*)	3 or 4 Spots, .020" to .030" Separation (Write Yes or No*)	Tech. Initials _____ Time _____ Date _____
One End				Remarks*
Other End				

Specification # 617.003 - Spot Weld Output Wire to Feedthrough
Transition Wire

Spot Weld Settings				
Output Wire to Transition Wire	#2 Cu Alloy Tip with .030" Flat 2# Pressure Setting (Write Yes or No*)	15 Watt Sec, Pulse Position #1 (Write Yes or No*)	One Spot (Write Yes or No)	Tech. Initials _____ Time _____ Date _____
One End				Remarks*
Other End				

R.P.C.P. THERMOELECTRIC BATTERY ASSEMBLY RECORD

Specification # 817.001 - Low Power Load Line check after output wire hook-up

Open Circuit Voltage _____ Tech. Initials _____

Resistance which drops voltage in half _____ Time _____

Was clamping bar Needed to Insert Thermopile into Case Yes _____ No _____

Date _____

Specification # 817.001 - Low Power Load Line check after inserting Thermopile in Battery Case

Open Circuit Voltage _____ Tech. Initials _____

Resistance which drops voltage in half _____ Time _____

Date _____

Specification # 617.005 - Spot Weld Exterior Case

Spot Weld Settings				Tech. Initials _____ Time _____ Date _____
Spot Weld Exterior Case	Spot Weld Tips Dwg. 15-D-4189-228, 6# Pressure (Write Yes or No*)	200 Watt Sec, Pulse Position #1 (Write Yes or No*)	At Least 14 Spots made (Write Yes or No*)	
1				Remarks*

Specification # 817.001 - Low Power Load Line check after spot welding Exterior Case

Open Circuit Voltage _____ Tech. Initials _____

Resistance which drops voltage in half _____ Time _____

Date _____

Specification # 817.001 - Low Power Load Line check after TIG Welding Exterior Case

Open Circuit Voltage _____ Tech. Initials _____

Resistance which drops voltage in half _____ Time _____

Date _____

Signature of Reviewer _____

Task 4 - SYSTEM TESTING

Tables (2) and (3) give the life test data for the experimental model and prototype units respectively. All batteries have continued to operate successfully. The electronics failed in E-16 and has been discussed previously in this report.

Table 2

Experimental Model Life Test Data

(10-31-71)

<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)	32,817	73.2 μ w			84.8 μ w
E-4	32,365	2.45 ma	78.0	78.6	2.9 ma
E-5 (8)	30,638	71.9 μ w			79.6 μ w
E-9 (2)	24,057	82.2 μ w			82.3 μ w
E-10 (5)	22,717	73.1 μ w			77.5 μ w
E-12 (4) (3)	23,486	255.3 μ w			230.0 μ w
E-13BB	17,750	7.4 ma	130.0	123.0	8.0 ma
E-14 (4) (6)	11,701				
E-16 (10)	20,217	201.6 μ w			202.4 μ w
E-17 (4)	19,093	228.9 μ w			
E-18 (9)	20,409	252.8 μ w			247.8 ma
E-20 (7)	<u>16,716</u>	260.6 μ w			260.5 μ w
TOTAL	271,966				

- (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

(10-31-71)

Unit	Hours	Present Data		B.O.L. Data	
		Output	Pulse/minute	Pulse/minute	Output
P-1 (2) (1)	17,100	5.9 ma	125.5	125.3	5.5 ma
P-2	16,237	6.1 ma	128.5	126.9	5.7 ma
P-3 (2) (5)	17,053	5.5 ma	124.0	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	71,507				
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. Re-started 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.

Task 5.0 - SAFETY

Cremation Testing

Both quoted and measured maximum temperatures were determined from eighteen crematories and five cremation furnace manufacturers. Tests were initiated (using the test procedure presented in the following section) at various crematories to measure peak temperatures and the temperature-time profile for a pacemaker in a body and to evaluate the effects of different types of caskets and a body in a casket. Eleven tests were completed on cremation furnaces made by the five major manufacturers. Thermocouple measurements and Tempil pellet measurements were made with a test stand and simulated pacers in various caskets and with bodies in caskets. Figure 4 presents a preliminary summary of measured temperatures from these eleven tests. Further tests are planned during the next report period to evaluate the differences between the peak T/C measurements and the Tempil measurements in order to determine what effective temperatures the actual RPCP unit will be exposed to during cremation. During the next report period a final recommendation on the minimum cremation environment will be submitted.

Cremation Test Procedure

The attached test procedure was prepared during this report period and utilized to conduct the cremation tests.

Recommended Safety Test Requirements

Extensive analyses and testing have been performed in order to define adequate safety test requirements for fuel capsules to be used for Radioisotope Powered Cardiac Pacemakers. By considering the potential for damage that isotopes of the type contemplated for medical devices possess, it is essential to require that the best available technology be applied in a safe and conservative fashion to insure the containment of these potentially hazardous fuels. In certain areas, significant design conservatism was delineated as part of these recommended safety test requirements for cardiac pacemakers.

Thus, minimum safety test requirements (Figures 5 and 6) were prepared and recommended for fuel capsules which are to receive a wide-spread medical device application.

PRELIMINARY SUMMARY OF CREMATION TESTING

	MANUFACTURERS				
TEMPERATURE (°F)	A	B	C	D	E
30 PEAK THERMOCOUPLE	2360	2430	1950	2430	2300
TEMPIL PELLET	2100	2100	X	X	2100

Figure 4

FUEL CAPSULES FOR MEDICAL DEVICES – RECOMMENDED SAFETY TEST REQUIREMENTS

TYPE OF TEST	CONDITIONS	BARE CAPSULE	COMPLETE SYSTEM	TEST PIECE
INDUSTRIAL FIRE	1900°F ENVIRONMENT - 2.63 HRS.	✓	✓	
CREMATION	TEMP. TO BE RECOMMENDED	✓	✓	
INTERNAL PRESSURE (1.5 X DESIGN PRESS.)	CREMATION TEMP. & 200 YR.* LIFE. [MAX. (SYSTEM LIFE + 2 HALF LIVES OF FUEL, OR 200 YRS.)]			✓
INTERNAL PRESSURE (1.0 X DESIGN PRESS.)	CREMATION TEMP. & 2000 YR.* LIFE.			✓
IMPACT	BASED ON 1.5 TIMES TUMBLING TERMINAL VELOCITY OF CAPSULE ONTO GRANITE AT 3 ANGLES.	✓		

(CONTINUED)

(CONTINUED)

FUEL CAPSULES FOR MEDICAL DEVICES – RECOMMENDED SAFETY TEST REQUIREMENTS

<i>TYPE OF TEST</i>	<i>CONDITIONS</i>	<i>BARE CAPSULE</i>	<i>COMPLETE SYSTEM</i>	<i>TEST PIECE</i>
CRUSH	10,000 LB. LOAD	✓ (OR)	✓	
BULLET IMPACT	44 MAGNUM PISTOL	✓ (OR)	✓	
BULLET IMPACT	12 GA. SHOTGUN - RIFLED SLUG	✓ (OR)	✓	
BULLET IMPACT	.22 LONG RIFLE	✓ (OR)	✓	
EXTERNAL PRESSURE – DROWNING	16,000 P.S.I.	✓		
CORROSION	SEA WATER, CHEMICAL	✓		
POWER TOOL	DRILL, SAW, & DISC GRINDER		✓	

Figure 6

TITLE: Cremation Furnace Temperature Measurements

PURPOSE: To monitor the entire temperature versus time curve for typical cremation cycles involving (1) a hardwood casket, (2) a hardwood casket and cadaver, and (3) nothing but the test stand.

EQUIPMENT: 1 Four Channel Texas Instrument Chart Recorder Model FLO-4W with 10" chart and 20 millivolts full scale, 1 model 9B Pyrotest Portable Potentiometer Pyrometer with the 0-53.5 millivolt scale and the Platinum-13% Rh. Platinum scale, 6-20 mil. diameter Platinum-13% Rh. Platinum thermocouples encased in double hole ceramics, a suitable test stand to hold the thermocouples (see test stand drawing), 1 Fairchild Model 7050 Digital Multimeter (calibration traceable to the National Bureau of Standards).

PROCEDURE:

1. Standardize the Pyrotest Potentiometer
 - a. Install the 0-53.5 millivolt scale.
 - b. With "Function" knob in "Off" position check galvanometer zero and adjust if needed.
 - c. With "Function" knob in "Measure" position, depress "Standardize" button, bring galvanometer to zero by turning "Standardize" knob, then release "Standardize" button.
2. Zero the chart recorder by shorting the leads.
3. Connect chart recorder leads to input terminals on potentiometer.
4. Set potentiometer's "Range Selector Knob" to appropriate range as designated by the scale and the "Function Selector Knob" to the "EMF" position.
5. Set potentiometer on 5, 10, 15, and 20 millivolt positions and check the corresponding deflections on the chart recorder. This shall be done for each of the four channels.
6. Determine the polarity of each thermocouple by testing with a match or reasonable facsimile.
7. Affix thermocouples in appropriate positions (see sections on Thermocouple Fabrication and Thermocouple Location).
8. Check each thermocouple for continuity
 - a. Set the Fairchild model 7050 Digital Multimeter on the 1.5K scale and connect the leads to the lead ends of each thermocouple.
 - b. A resistance of ~ 3 ohms designates continuity.

9. Attach the four major thermocouples to the appropriate inputs on the chart recorder. Attach the redundant thermocouple (2b) to the input terminals on the Pyrotest Potentiometer. Redundant thermocouples 2b and 3b shall be alternated after the first 30 minutes of operation (see data sheet).
10. Change scale on Pyrotest Potentiometer to the Platinum-13% Rh. Platinum scale.
11. Correct for ambient temperature
 - a. Turn scale counterclockwise until it stops.
 - b. Read ambient temperature on panel thermometer; then set index line to this temperature on scale.
 - c. Lock index plate with locking thumbscrew.
12. Operate cremation furnace for a typical cycle.
13. Make visual observations if possible and record on data sheet.
14. After cooling disassemble all equipment.
15. Complete data sheet.

Additional Test Procedure (Optional)

Option 1 - Tempil Pellets

A method for determining the maximum temperature achieved during the test cycle by temperature indicating pellets may be used independently or in conjunction with thermocouple instrumentation. Pellets indicating temperature over an appropriate range, for example, 1500-3000°F in 100°F increments, are placed in a suitable holder (drawing 15-D-4189-233) which is placed in the location near where an implanted pacer would be. At any convenient time after completion of the cycle the pellets are examined and the highest temperature pellet which is melted and the lowest temperature pellet which is unmelted are noted. The maximum temperature seen by the holder in the test cycle is in the range determined by the two noted values.

Option 2 - Simulated Pacer

In order to obtain a closer approximation of the temperature the pacer is actually going to see during cremation, a simulated pacer may be used. This simulated pacer is made out of stainless steel bar 1" diameter and 1" long and weighs 90-100 grams (approximating the weight of the actual pacer). Three holes are drilled parallel to the axis equally spaced along a diameter in order to facilitate attachment of the thermocouples. The simulated pacer may then be used in all three

tests. In the first test, that with a hardwood casket, the simulated pacer would be placed on the simulated body insert (~25 lbs of pine which has the same heat or BTU content as an average 150 lb cadaver). In the second test, the one with the hardwood casket and cadaver, the simulated pacer would be placed on the breast plate bone and/or in the left armpit area. In both of these cases the simulated pacer is allowed to travel downward with the deterioration of the insert or body during the cremation. In the third test, with only a test stand, the simulated pacer would rest on the base of the stand and have the primary function of verifying the lower thermocouple on the test stand.

Thermocouple Fabrication

1. Cut 6 6-foot lengths each of 20 mil diameter platinum wire and platinum-13% Rhodium wire.
2. Thread one of each type of wire through double hole ceramic tubing in arbitrary lengths to facilitate handling.
3. Twist the two wires together at one end and snip off any excess.
4. Torch weld the twisted end into a bead.
5. Repeat steps 2, 3, and 4 until a total of six thermocouples are produced.

Thermocouple Location

Possible Burner Location

1. If possible attach the flame temperature thermocouple in position 1a or 1b. This shall depend largely on the particular furnace being tested.
2. Five additional thermocouples are mounted on the test stand at points 2, 3, and 4. Numbers 2b and 3b are redundant ones which may be connected to the pyrotest potentiometer as a means of checking the chart recorder (see test stand drawing).
3. When a casket and cadaver are used, the test stand, (if used) should be placed in the right armpit area. The reason for using the right area versus the left (where the pacer will actually be) are that the majority of caskets are hinged on the left and the base of the stand must go under the body. When a body is not used, the test stand is placed in the area of the actual pacer and the thermocouple leads are fed through a hole in the bottom of the casket.
4. If the simulated pacer is used it shall be placed on the breast plate bone and/or in the left armpit area. (In areas 2a, b and 3a, b respectively). Preferably two are used and one is placed in each area. A minimum of two thermocouples shall be used in each simulated pacer.

Simulated Caskets and Body Inserts

The simulated body inserts are made from 1-1/8" pine approximately 9" high, 18" wide, and 3' long and weigh ~25 pounds. One hole is drilled in the insert to accept the test stand.

The simulated caskets are made from 1-1/8" oak or pine 12" high 25-1/2" wide, and 6'6" long. The oak simulated casket weighs ~164 lbs, and the pine ~124 lbs. Two holes are drilled in each simulated casket, one is for the top of the test stand (14 inches high) and the other is for the thermocouple leads.

CREMATORY FURNACE DATA SHEET

Location:

Date:

Address:

Contacts:

Furnace Manufacturer:

Model No.:

Date of Installation:

Serial No.:

Automatic

Manual

Burner Manufacturer:

Burner Rating (BTU/Hr)

1. Preheater -

2. Main -

3. After Burner -

Location: Top _____
Head End _____
Other _____

Model No.:

Serial No.:

Casket:

1. Manufacturer

2. Model

3. Type

4. Weight

Body Weight: _____

Standardization of Equipment:

1. Pyrotest potentiometer (MV Scale)

2. Chart Recorder

T/C Circle One

a. Channel 1 (red)

1a or 1b

b. " 2 (blue)

2a

c. " 3 (green)

3a

d. " 4 (black)

4

5 MV	10 MV	15 MV	20 MV

3. Thermocouple Continuity

T/C 1a or b

2a

2b

3a

3b

4

4. Pyrotest Potentiometer (PT-13% Rh PT)

PYROTEST TEMPERATURE MEASUREMENTS:

Reference Time After Ignition	Actual Time	T/C 2b	T/C 3b	Furnace Operation Log
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				
28				
29				
30				
35				
40				
45				
50				
55				
60				
70				
80				
90				
100				
110				

Reference Time After Ignition	Actual Time	T/C 2b	T/C 3b	Furnace Operation Log
120				
130				
140				
150				
(Arbitrary After 150 minutes)				

Photographs Taken

Yes _____

No _____

Visual Observations:

Operation Irregularities:

Summary - (discussion of cycle, temperature curves, furnace construction, and any other relative information)

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