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NEW MECHANICALLY RECHARGEABLE ZINC/AIR BATTERY DESIGN

Roland F. Chireau, et al

Yardney Electric Corporation
Pawcatuck, Connecticut

August 1972

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NEW MECHANICALLY RECHARGEABLE ZINC/AIR BATTERY DESIGN

THIRD INTERIM TECHNICAL REPORT

AUGUST 1972

By

R. F. CHIREAU and R. G. GUNTHER

ECOM

UNITED STATES ARMY ELECTRONICS COMMAND - FORT MONMOUTH, N. J.
CONTRACT DAAB-07-71-C-0333

YARDNEY ELECTRIC DIVISION
YARDNEY ELECTRIC CORPORATION
PAWCATUCK, CONNECTICUT 02891

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13. ABSTRACT

The blower-cover assembly described in the Second Quarterly Report was proof tested on the BA-525 (20 Ah) battery at an intermittent high rate regime. The details of the design are presented and performance data are discussed.

A heater system was incorporated in a BA-525 Zinc/Air battery (20 cells, 20 Ah) prototype in order to improve cold temperature performance. The battery was evaluated on a high rate pulse regime using the blower-cover assembly.

We have initiated the finalization of a design concept which will lead to a second generation BA-525( )/U (20 amp hr) standard line zinc air battery with a capability of more reliable operation at higher current densities over a wide range of environmental conditions.

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NEW MECHANICALLY RECHARGEABLE ZINC AIR BATTERY DESIGN

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U. S. ARMY ELECTRONICS COMMAND - FORT MONMOUTH, NEW JERSEY 07703

3.0 ABSTRACT

This report covers the work done during the third quarter on Contract DAAB-07-71-C-0333 for the U. S. Army Electronics Command.

a) The blower-cover assembly described in the Second Quarterly Report was proof tested on the BA-525 (20 AH) battery at an intermittent high rate regime. The details of the design are presented and performance data are discussed.

b) A heater system was incorporated in a BA-525 Zinc/Air battery (20 cells, 20 AH) prototype in order to improve cold temperature performance. The battery was evaluated on a high rate pulse regime using the blower-cover assembly.

c) Endurance tests on air cathodes have continued. Platinum catalyzed electrodes and silver amalgam electrodes are being continuously polarized at 400 ma per square inch as part of the operating life test.

d) Platinum catalyzed cathodes were fabricated with noble metal (Palladium/Gold alloy and Gold) plated nickel current collectors. Based upon the promising results obtained on continuous polarization tests, a BA-525 battery prototype was constructed and evaluated on a high pulse regime. The battery has undergone forty test cycles, to date, with 40 percent degradation in performance. Performance data, on this test series, are presented and analyzed.

e) The search for new, low cost air cathode construction materials has led to the development of a silver amalgam electrode which exhibits very high rate capability and good electrochemical stability and performance. The silver amalgam cathode was evaluated in multicell stack arrangements to determine the effects of the use of air blowers at low and high drain rates and a 1:9 duty cycle regime in order to determine battery operating performance parameters.

f) A study was made of the zinc anode-electrolyte composite in order to improve performance at low temperature. Various ratios of zinc to electrolyte (potassium hydroxide), anode structures and electrolyte composition were investigated.

g) The performance characteristics of a BA-525 battery using the new air cathode structure and the new zinc anode-electrolyte composite formulation were determined on simulated PRC-70 pulse regime consisting of one (1) minute of discharge at 7.0 amps and nine (9) minutes of discharge at 0.125 amps.

h) We have initiated the finalization of a design concept which will lead to a second generation BA-525( )/U (20 amp hr) standard line zinc air battery with a capability of more reliable operation at higher current densities over a wide range of environmental conditions.

4.0

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5.0 PURPOSE

The purpose of this program is to provide the technology for the design and development of new high performance mechanically rechargeable zinc/air batteries for field communication systems.

6.0 BODY OF THE REPORT

6.1 Introduction

This document represents the third quarterly report as defined in Contract DAAB-07-71-C-0333.

It is the purpose of this contract to conduct a program of study, design and development leading to the fabrication of new high performance mechanically rechargeable Zinc/Air batteries capable of meeting the requirements listed in the U. S. Army Electronics Command Technical Guidelines for New Mechanically Rechargeable Zinc/Air Battery Design, dated 25 August, 1970.

The program has been divided into seven (7) Tasks, described in the Technical Plan submitted by Yardney for this project and appended to the first quarterly report (1 July 1971 to 1 November 1971) for this contract. This report presents the work performed during the period 1 February 1972 to 1 May 1972.

6.2 Task III AIR CATHODE DEVELOPMENT

6.2.1 Performance of Platinum Black Catalyzed Cathodes

Having postulated that the deterioration in cathode performance, which was observed during cycling of zinc air batteries, resulted from the formation of an insulating NiO layer on the electrode current collector, a series of experiments were designed to test the validity of this postulate.

The experiments consisted of (1) Replacing the nickel current collectors, (2) Using lithiated NiO surface coatings on the nickel current collectors, (3) poisoning the hydrogen reduction reaction on the platinum surface so that the nickel reduction arrests became more evident during chrono-potential sweeps, (4) gold plating our nickel current collectors.

Experimental 20 AH zinc air cells were fabricated, which incorporated the variations listed above. The cells were then tested by repeatedly discharging them on a transceiver duty cycle regime consisting of one (1) minute at 6.25 amperes and nine (9) minutes at 0.125 amperes. The cells were discharged for twenty (20) hours following which, the expended anodes were removed from the bicells and fresh anodes inserted.

6.2.1 Continued

At the end of ten (10) cycles, all of the cells, with the exception of those fabricated with the gold plated nickel grids exhibited a drop-off in voltage during the high rate discharge (400 ma per sq. in.) compared to the voltage obtained on the first cycle. Cells made with the gold plated grid showed excellent voltage maintenance over the ten (10) cycles. Based on the results obtained from the improved cathode grid structure, it was decided to fabricate a battery incorporating this and other system improvements and to subject the unit to a life cycle test. The details of cell and battery fabrication as well as the test results will be found in this report under paragraph 6.4, Task VI - Design Verification and Testing.

6.2.2 <u>Endurance Tests on Air Cathodes</u>

As reported in our previous Quarterly reports, air cathodes had been placed on continuous polarization to determine their operating life capability in normal air and at ambient room temperature. The purpose of this test was to establish whether life was limited by electrode corrosion and/or carbonation and to determine how many hours of operation could be anticipated as a maximum under the test conditions. The electrodes are tested in a polarization cell, using 31 weight percent KOH and an inert nickel counter electrode wrapped in a layer of Pellon 2505K interseparator. The electrodes are continuously polarized at 400 ma. per square inch. Table I gives data (continued from the last work period) on the polarization voltage of the various electrodes. As can be seen, the life test has brought out some differences in polarization voltage between cathodes made with normal loadings (9mg/cm^2) of platinum black and low loadings. No differences were detected between cathodes having high air permeability and cathodes with low air permeability. The standard YED platinum catalyzed electrode (Type II) operated satisfactorily for over 3000 hours.

Following the continuous polarization tests, the various cathodes were removed from the test fixture, washed with tap water, dried, then reassembled into the test fixture. The electrodes were then individually polarized at current densities ranging from 43 to 517 ma per square inch and their polarization voltages measured against a cadmium wire reference electrode. The data are shown in Table II.

6.2.3 <u>New Cathode Development Work</u>

During the last quarter, work was initiated on silver-amalgam cathodes for use in zinc air batteries for high pulse rate applications.

It is known that pure silver cathodes will not give good performance on extended test cycling because of re-crystallization of fine particles to larger agglomerates.

TABLE I

Endurance Tests on YED Air Cathodes

(a) All potentials are given against Cadmium reference electrodes.

(b) Polarization current density: 400 mA/in^2

Electrode Type	Catalyst Loading (Pt mg/cm^2)	Voltage Initial (millivolts)	Operating Time (Hours)	Voltage Present (millivolts)
1. Type II Vacuum dried Low loading	5.4	830	3854	764
2. Type II Vacuum dried Low loading	6.0	807	4144	791
3. Type II TFE Coagulation time				
0.2 min.	9.0	853	2967	834
1.67 min.	9.0	842	2967	834
4.4 min.	9.0	822	2967	816
4. Type II Low loading	5.6	846	3090	827
5. Type II 20 AH, STD	10.5	856	3086	825
6. Type II High permeability (56 $ml/min/in^2$)	9.0	725	2945	833
7. Type II Low permeability (2 $ml/min/in^2$)	9.0	808	2945	816
8. Type II Low loading Backing not precured	6.2	836	30[illegible]	828
9. Type II Very high permeability (125 $ml/min/in^2$)	9.0	826	2945	830

6.2.1 Continued

At the end of ten (10) cycles, all of the cells, with the exception of those fabricated with the gold plated nickel grids exhibited a drop-off in voltage during the high rate discharge (400 ma per sq. in.) compared to the voltage obtained on the first cycle. Cells made with the gold plated grid showed excellent voltage maintenance over the ten (10) cycles. Based on the results obtained from the improved cathode grid structure, it was decided to fabricate a battery incorporating this and other system improvements and to subject the unit to a life cycle test. The details of cell and battery fabrication as well as the test results will be found in this report under paragraph 6.4, Task VI - Design Verification and Testing.

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6.2.3 New Cathode Development Work

During the last quarter, work was initiated on silver-amalgam cathodes for use in zinc air batteries for high pulse rate applications.

It is known that pure silver cathodes will not give good performance on extended test cycling because of re-crystallization of fine particles to larger agglomerates.

TABLE II

Polarization Data on Cathodes

(Previously Polarized on Endurance Test @400 ma/in^2)

CELL NO.		#3	#5	#8	#9	#4	#1	#7
Cathode Type		0.2 min. coag. time	1.67 min. coag. time	4.4 min. coag. time	backing precured		TFE backing not precured	AZ-32 perm. 125 ml/min
Catalyst Loading		9 mg/cm^2	9 mg/cm^2	9 mg/cm^2	5.6 mg/cm^2	10.5 mg/cm^2	6.2 mg/cm^2	9 mg/cm^2
OCV		1012	1044	1002	1000	1004	1004	1018
ma/in^2	I(ma)	E(mv)	E(mv)	E(mv)	E(mv)	E(mv)	E(mv)	E(mv)
43	50	896	903	894	902	903	900	899
86	100	884	887	879	888	887	887	884
129	150	876	878	867	879	876	876	874
172	200	869	870	858	870	868	868	865
215	250	863	862	848	862	859	859	857
258	300	856	855	839	854	849	851	849
300	350	852	850	832	848	843	845	843
345	400	847	843	824	839	834	838	836
388	450	843	838	816	832	827	831	830
430	500	838	831	807	820	816	823	823
474	550	834	826	798	808	807	816	816
517	600	829	819	789	788	795	808	808

6.2.3 Continued

It was therefore decided to investigate the addition of mercury to prevent the nucleation of silver, much in the same way that indium prevents re-crystallization of cadmium. In addition, work previously done at Yardney has shown the addition of mercuric oxide to finely divided catalytic silver gives a cathode material which exhibits good chemisorption of oxygen with low electrode polarization.

In practice, the silver amalgam electrode is prepared as follows: 67 parts of fine silver are blended with 33 parts of mercuric oxide in a ball mill for two (2) hours. The powder mixture was blended with 20% by weight solids TFE from a #30 Dupont TFE emulsion with an additional 30 parts water for uniform mixing. The resulting paste was dried in an air oven at 100°C for four (4) hours. Propylene glycol was added to the Teflonated mass with constant stirring until a globular rubbery dough was obtained. The Ag/HgO/TFE dough was then passed through rollers until a final film thickness of 25 mils was obtained. The catalyst loading at this thickness was 20 g/ft^2. The finished strip was then heated to 300°C for 5 minutes to "cure" the TFE resin and evaporate the propylene glycol. The cured film was then pressed onto a 70 mesh Teflonated Ni screen at a temperature and pressure to sufficiently bond the catalyst layer to the screen, e.g., 27°C and 800 psi respectively. The final step in the electrode fabrication was to affix an air permeable Teflon hydrophobic film to the "Air" side of the electrode. This was carried out at 270°C and 100 psi.

Finished electrodes were tested in our cathode polarization apparatus with a view towards characterizing the performance of the Yardney Type II air cathode for high rate pulse battery application.

Typical polarization curves for the silver-amalgam cathode are presented in Figures 1 and 2. It is seen that the electrode shows good voltage response at the required discharge current densities (400 ma per square inch) and could be suitable for use in either a primary or mechanically refuelable zinc air system where high rate capability is desired.

Twenty ampere hour cells were fabricated using silver amalgam cathodes in order to evaluate the cathode material at the high pulse rates of discharge (1:9 duty cycle, 6.25 amps/0.125 amp).

Three cell test units were built and tested at room temperature. Four of the six units tested at the above rate delivered more than twenty-four (24) hours of service to 0.91 volt per cell. The remaining two (2) units gave twenty-two (22) hours service. The failures were caused by poor cathode to frame seals.

Typical discharge data for a 20 AH cell with Ag/Hg cathodes, at high pulse rates (room temperature) are shown in Table III.

Typical discharge data for a 20 AH cell with Ag/Hg cathodes, at high pulse rates (0°F) are shown in Table IV.

TABLE III

DISCHARGE DATA

Ag/Hg Cathodes

Constant Current
Test: 1 min @ 6.25 A
9 min @ 0.125 A
Room Temperature

3 Cell Unit

Battery Tested With Blower Assembly

OCV	4.40V	CURRENT (AMPS)
TIME (HRS)		
0	4.06	.125
	3.32	6.25
1	4.03	
	3.23	
2	4.04	
	3.22	
3	4.04	
	3.24	
4	4.04	
	3.25	
5	4.04	
	3.26	
6	4.04	
	3.27	
7	4.04	
	3.25	
8	4.04	
	3.25	
9	4.04	
	3.22	
10	4.04	
	3.20	
11	4.04	
	3.20	
12	4.04	
	3.19	
13	4.04	
	3.15	
14	4.04	
	3.15	
15	4.04	
	3.15	
16	4.04	
	3.15	
17	4.04	
	3.13	
18	4.03	
	3.11	
19	4.02	
	3.10	
20	4.02	
	3.09	

TABLE 1V

DISCHARGE DATA

Ag/Hg Cathodes

Test: 1 min @ 7.0 A
9 min @ 0.125 A
Temperature - 0°F

3 Cell Unit

Battery Tested With Blower Assembly & Parasitic Load

OCV	4.31V	CURRENT (AMPS)
TIME (HRS)		
0	3.95	1.0 A
	3.36	7.0 A
1/2	3.88	
	3.22	
1		
1 1/2	3.85	
	3.10	
2	3.85	
	3.04	
2 1/2	3.83	
	3.03	
3	3.83	
	3.03	
3 1/2	3.82	
	3.04	
4	3.83	
	3.06	
4 1/2		
5	3.82	
	3.03	
5 1/2	3.83	
	3.02	
6	3.83	
	3.02	
6 1/2	3.82	
	3.01	
7	3.81	
	3.00	
7 1/2	3.81	
	2.99	
8	3.80	
	2.98	
8 1/2	3.79	
	2.98	
9	3.80	
	2.95	
9 1/2	3.79	
	2.96	
10	3.79	
	2.95	
10 1/2	3.78	
	2.94	

6.3 TASK IV - ANODE COMPOSITE DEVELOPMENT

Work was continued during the last quarter towards optimizing the 20 ampere hour zinc anode composite.

6.3.1 Our standard anode (designation AZ 20-1) is fabricated by a pressed powder technique and consists of mold pressing a mixture of 71% zinc powder (New Jersey Zinc Co. Grade #1222), 1.4% mercuric oxide, 23.2% potassium hydroxide and 4.3% potassium titanate filler onto an expanded copper mesh (Pattern 5 Cu 30-1/0). The anode contains 58 grams of zinc powder and measures about 0.16 inches in thickness after pressing. The electrode is wrapped with a separator system comprising one layer of fibrous sausage casing and one layer of nylon non-woven fabric. The AZ 20-1 anode anode is depicted in Figures 3 and 4.

6.3.2 Discharge tests conducted on AZ 20-1 anodes have shown that, at the high rate of discharge (6.25 amps, equivalent to 400 ma per square inch), anode discharge efficiency was about 45 percent.

Table V summarizes test data on AZ 20-1 anodes at the 6.25 ampere rate.

Examination of the data show that the AZ 20-1 anode is marginal with respect to capacity and voltage.

6.3.3 In order to improve the performance of the 20 ampere hour anode, we initiated a program of redesign of the anode.

1) Active material was added to the anode. The result is an anode with a total weight of 80 grams.

2) The main separator was changed from fibrous sausage casing to PUDO-193 unplasticized cellophane. The lower electrical resistance of the latter material in KOH gives a better voltage response at the high rate of discharge.

3) The AZ 20-1 anode contained one grid located in the center of the anode. In order to improve electrode conductivity at low temperature, we added a second grid. The AZ 20-2 anode is now constructed with one grid on each side of the plate.

4) The bond between the grid and tab was strengthened by an additional spot-weld.

6.3.4 AZ 20-2 anodes were fabricated, and tested at the high discharge rate (equivalent to 400 ma per square inch).

Test data and results will be found in Table VI; As can be seen, the AZ 20-2 anode shows a distinct improvement over the previously tested AZ 20-1 anode.

6.3.5 One thousand (1000) AZ 20-2 anodes were constructed and used for component and design verification testing.

The test data and a discussion of the results are presented in Section 6.4 of this report.

TABLE V

TEST DISCHARGES

AZ 20 Anode (AZ 20-1)
Activation 25 cc H_2O - **Deionized**
Load: 6.25 Amps I_d to 1.00 V_f Cell, 0.2 V_f Ref.

CODE NO. 0792

BATCH NO. T 204

	CELL	REF	CELL	REF	CELL	REF	CELL	REF	CELL	REF
OCV	1.467		1.488	.48	1.48	.49	1.48	.48	1.47	.48
1'	1.286		1.217	.39	1.23	.40	.122	.39	1.23	.38
15'										
30'			1.135	.32	1.15	.32	1.16	.33	1.17	.33
1.0 Hr	1.088		1.113	.29	1.14	.29	1.15	.31	1.16	.31
1.5 Hr	1.107		1.107	.27	1.13	.28	1.15	.30	1.15	.30
2.0 Hr	1.068		1.065	.23	1.089	.25	1.10	.27	1.12	.27
2.5 Hr	1.045		0.931	.20	1.019	.15	1.0[illegible]	.193	1.07	.21
3.0 Hr	1.010		0.950	.06	.983	.07	.84	.023	.97	.094
3.5 Hr	0.987									
4.0 Hr	0.947									
4.5 Hr										

Time to 1.0 V

TABLE VI

TEST DISCHARGES

AZ 20 Anode (AZ 20-2)

Activation: 25 cc water (deionized)

Load: 6.25 Amps to 1.0 Volt per Cell and 0.2 V Ref. vs. Zinc

CODE NO. 0822

BATCH NO. Experimental

	(1)		(2)		(3)		(4)		(5)	
	Cell	Ref.	Cell	Ref.	Cell	Ref.	Cell	Ref.	Cell	Ref.
OCV	1.51	.50	1.51	.50	1.52	.52	1.51	.51	1.48	-
1'	1.25	.440	1.24	.44	1.22	.42	1.21	.42	1.28	-
1.0 hr	1.16	.38	1.15	.36	1.16	.31	1.12	.35	1.14	
1.5	1.14	.36	1.13	.33	1.15	.30	1.10	.32	1.09	
2.0	1.11	.35	1.10	.31	1.12	.27	1.07	.30	1.07	
2.5	1.09	.33	1.08	.28			1.06	.29	1.05	
3.0	1.07	.31	1.05	.25	1.07	.21	1.03	.26	1.01	
3.5	1.03	.29	1.02	.24	1.03	.19	1.01	.25	.99	
4.0	.994	.20	.876	.16	.97	.19	.98	.20	.92	
4.5										
5.0										
Time to 1.0 volt	3 Hrs. 38'		3 Hrs. 35'		3 Hrs. 45'		3 Hrs. 35'		3 Hrs. 28'	

6.4 TASK VI - DESIGN VERIFICATION AND TESTING

6.4.1 Life Cycle Testing of BA-525 Battery on 150 Watt Regime

A BA-525 Battery (20 ampere-hour, 24 volts) engineering prototype was fabricated using cells containing gold-plated nickel grids in order to evaluate the life cycle capability of the system when tested on the high pulse rate test regime.

6.4.1.1 Battery Fabrication

a) Air Electrodes

The air electrodes, designated as Type III cathodes are comprised of a three (3) layer laminate consisting of an expanded nickel mesh (gold plated) current collector, an electrochemically active Platinum Black-TFE layer and a hydrophobic barrier of microporous Teflon. The platinum catalyst loading is 9 mg/cm^2. Optimum grid corrosion protection is obtained by giving the cathode grid a flash of 80% Gold/20% Palladium Alloy, followed by a plating (100 μ) of pure gold.

b) Zinc Anodes

The anode composite was made by mold pressing a mixture consisting of 71% zinc powder (New Jersey Zinc Grade #1222), 1.4% mercuric oxide, 23.2% potassium hydroxide and 4.3% potassium titanate filler. Each anode consists of 60 grams of powder mix and has a thickness of 0.20 inches with a final porosity of 60-65%.

c) Battery Fabrication

Two cathodes are epoxy bonded to a plastic frame to form a cell as shown in Figure 5.

The battery assembly BA-525( )/U consists of twenty (20) cells as shown in Figure 6. The general configuration and dimensions of the battery assembly are shown in Dwg. P-6140 "Battery BA-525, Mechanically Rechargeable Outline", Figure 7.

When operating the BA-525 battery on the high pulse rate regime, it has been found necessary to incorporate a blower/voltage control unit into the battery system in order to obtain satisfactory performance.

The blower-cover assembly shown in Figure 8 was used in testing the battery prototype.

6.4.1.2 Test Results

Discharge data on the test battery are presented in Table VII. The battery underwent 40 charge-discharge cycles before its capacity dropped below 60 percent of the initial capacity. Failure was due to a short induced by the introduction of a faulty anode in one of the battery bicells. The short caused extensive cathode damage.

TABLE VII

DISCHARGE DATA: BA-525 BATTERY ON LIFE CYCLE TEST REGIMEN

ROOM TEMPERATURE DISCHARGES

BATTERY TYPE	NO CELLS	REC/TRANS. DUTY CYCLE (MINUTES)	DISCHARGE CURRENT (AMPS)	CYCLE NO	OUTPUT HRS TO 20 V	OUTPUT HRS TO 18 V
Engineer-ing Sample S/N 004	20	9:1	0.125/6.25 A	1	25.5	33
				2	24.5	
				3	23	
				4	26.5	
				5	24.25	
				6	23	
				7	23	
				8	25.5	
				9	26.5	
				10	23.5	
				11	22.75	
				12	20.5	
		18:2	0.3/3.0	13	48 +	
				14	23.5	
				15	22.0	
				16	19.5	
				17	24.5	
				18	22.5	
				19	18.5	
				20	22.0	
				21	21.5	
				22	21.0	
				23	21.0	
				24	(2) (No Test)	
				25	18	
				26	18	
				27	17	
				28	17.5	
				29	18	
				30	17.5	
				31	16	
				32	17	
				33	15.5	
				34	15.5	
				35	16	
				36	16	
				37	16	
				38	16	
				39	16	
				40	15.5	

6.4.2 Operation of the BA-525 Battery with Heater System and Blower Assembly.

6.4.2.1 A final design was established for the BA-525 battery heater-blower system following the decision to incorporate this ancillary equipment in the battery for operation at the 150 watt rate and at low temperature.

6.4.2.2 The heater system operates from battery power and is rated at approximately 23 watts. The heater will be in operation only when the battery temperature falls below 65°F.

6.4.2.3 A voltage sensing device will trigger a relay whenever the battery voltage is above 24 volts. The relay activates a heater which is wired in parallel with the radio across the battery. The heating circuit will draw 0.875 A at 25.5 volts.

6.4.2.4 When the operator goes to the transmit mode (high rate) and the battery voltage falls below the 24.5 volt limit, the heater subsides and the blower starts. At no time will the heater and blower operate together. The blower requires .150 A and will operate during the transmit cycle at any temperature.

6.4.2.5 The Heater-Blower circuitry is shown in Figure 9.

6.4.2.6 The Battery blower-cover assembly and the blower cover outline are shown in Figures 8 and 10.

6.4.2.7 One twenty cell battery (BA-525) was discharged at cold temperature (0°F) at the 7.0 amp/0.125 amp rate (1:9 duty cycle). The battery yielded 6½ hours to 20 volts. The data have been plotted in Figure 11.

6.4.2.8 For reference purposes, the same battery was discharged at room temperature 75°F at the 7.0 amp/0.125 amp rate (1:9 duty cycle). The battery yielded 21 hours to 20 volts.
The results are presented in Figure 12.

7.0 Conclusions

1. A BA-525 (20 AH) zinc/air battery was proof-tested at the PRC-70 radio high rate regime. The battery was tested using a blower-cover assembly mounted on the unit. The battery system gave satisfactory performance on the high rate pulse regime.

2. It was found necessary to incorporate a heater system in the BA-525 zinc/air battery in order to improve its cold temperature performance.

3. The search for new, low cost air cathodes, has led to the development of a silver amalgam electrode which exhibits very high rate capability and good electrochemical stability and performance.

4. Noble metal plated nickel current collectors appear to improve the capacity maintenance of platinum catalyzed cathodes on high rate pulse discharge regimes.

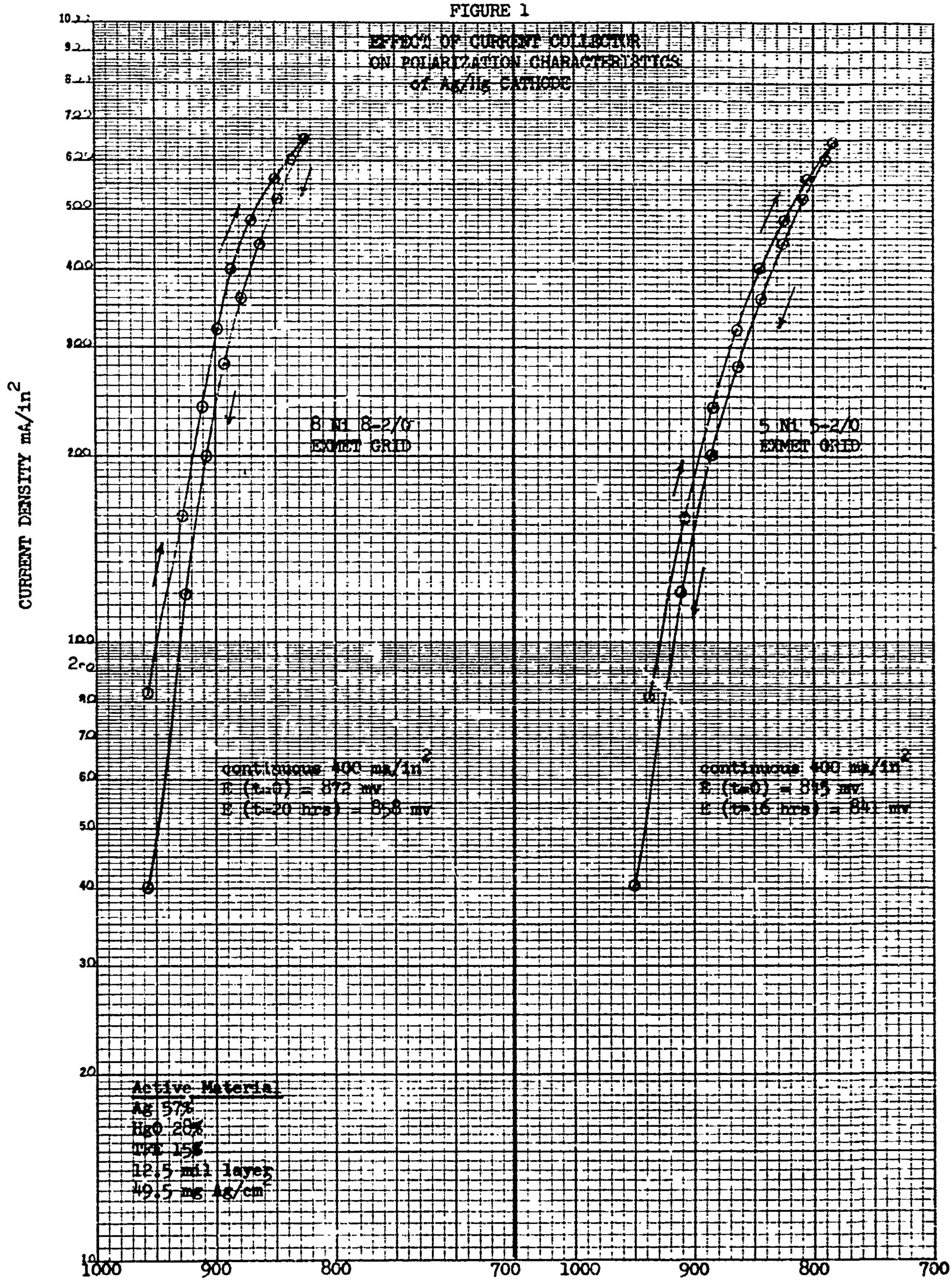
5. Three cell stacks employing a silver-amalgam cathode were tested to determine the effect of air blowers at low and high drain rates and on a 1:9 duty cycle regime. The multicell stacks showed good initial performance. The silver amalgam cathodes substantially reduce the cost of the zinc/air system.

6. A study of the zinc anode-electrolyte composite has shown that the standard 20 AH anode used in the BA-525 battery delivers only 20% of its room temperature capacity when tested at 0°F. Various ratios of zinc to KOH, changes in anode grid structures and electtolyte composition were shown to give improved performance at low temperature.

7. Based upon the performance characteristics of a BA-525 battery, obtained on a simulated PRC-70 regime, using a new air cathode structure and a new zinc anode formulation, we have initiated the finalization of a design concept which will lead to a second generation BA-525( )/U (20 amp-hr) standard line zinc/air battery with a capability of more reliable operation at higher current densities over a wide range of environmental conditions.

APPENDIX

FIGURE 1


EFFECT OF CURRENT COLLECTOR
ON POLARIZATION CHARACTERISTICS
of Ag/Hg CATHODE
CURRENT DENSITY mA/in^2
8 Ni 8-2/0
EXMET GRID
5 Ni 5-2/0
EXMET GRID
continuous 400 ma/in^2
E (t=0) = 872 mv
E (t=20 hrs) = 858 mv
continuous 400 ma/in^2
E (t=0) = 875 mv
E (t=16 hrs) = 841 mv
Active Material
Ag 57%
HgO 28%
TFE 15%
12.5 mil layer
49.5 mg Ag/cm^2
1000
900
800
700
1000
900
800
700
VOLTAGE VERSUS Cd Ref. (MILLIVOLTS)

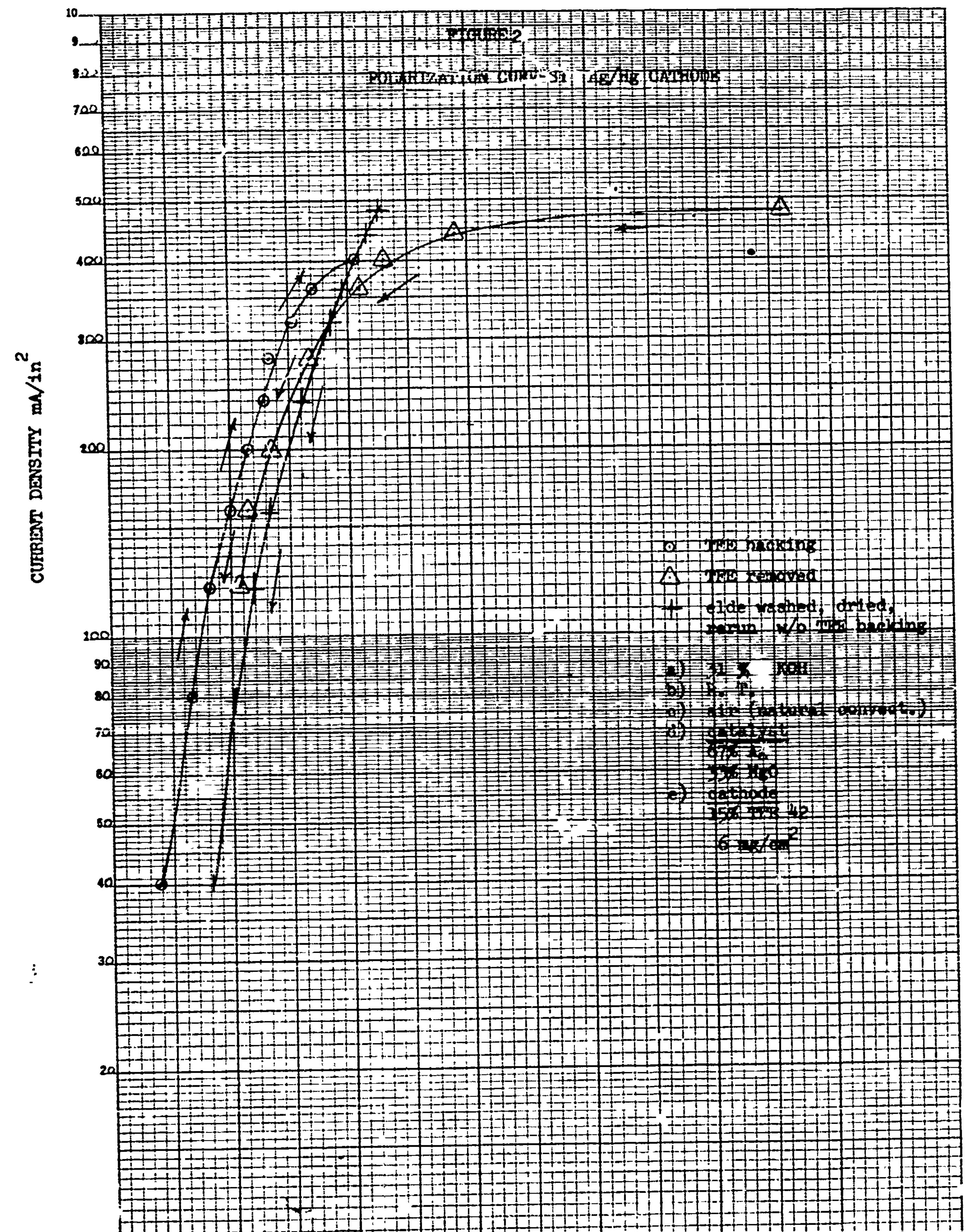


FIGURE 2
Ag/Hg CATHODE
CURRENT DENSITY mA/in²
TFE backing
TFE removed
elde washed, dried,
rerun w/o TFE backing
a) KOH
b) R. T.
c) air (natural convect.)
d) catalyst
e) cathode
6 mg/cm²
1000
900
800
700
600
500
400
Voltage Versus Cd Ref
(MILLIVOLTS)

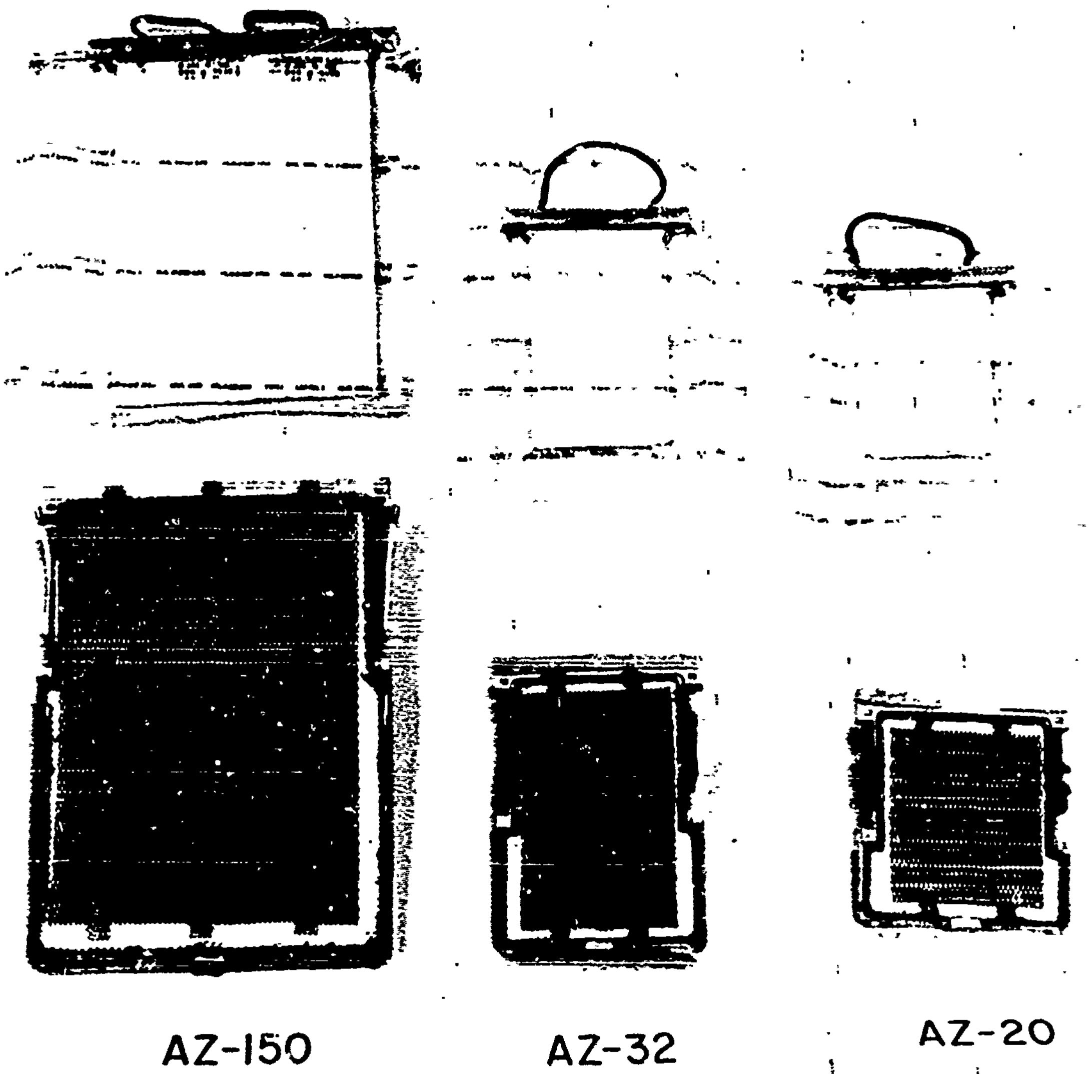


FIGURE 3

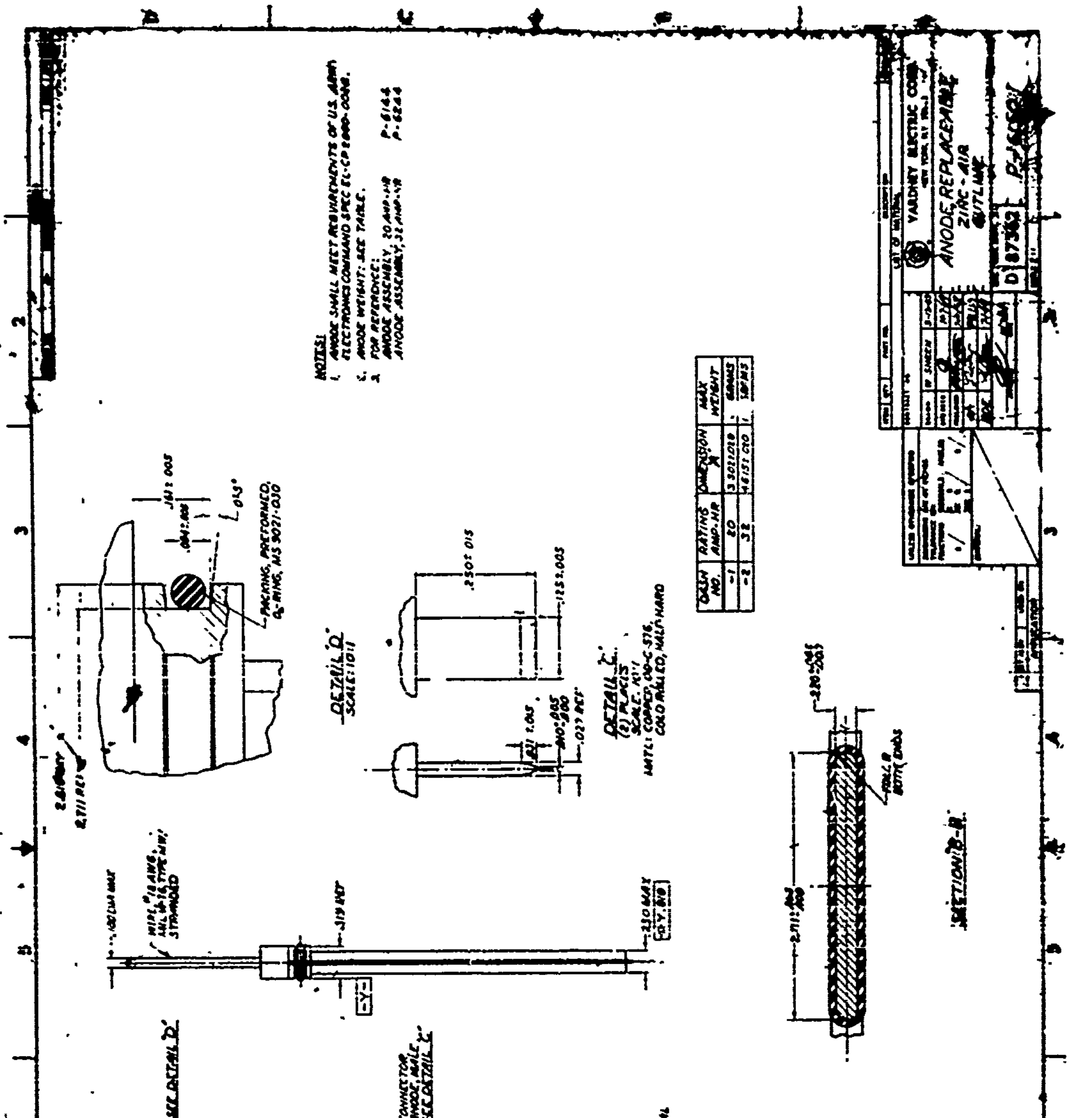
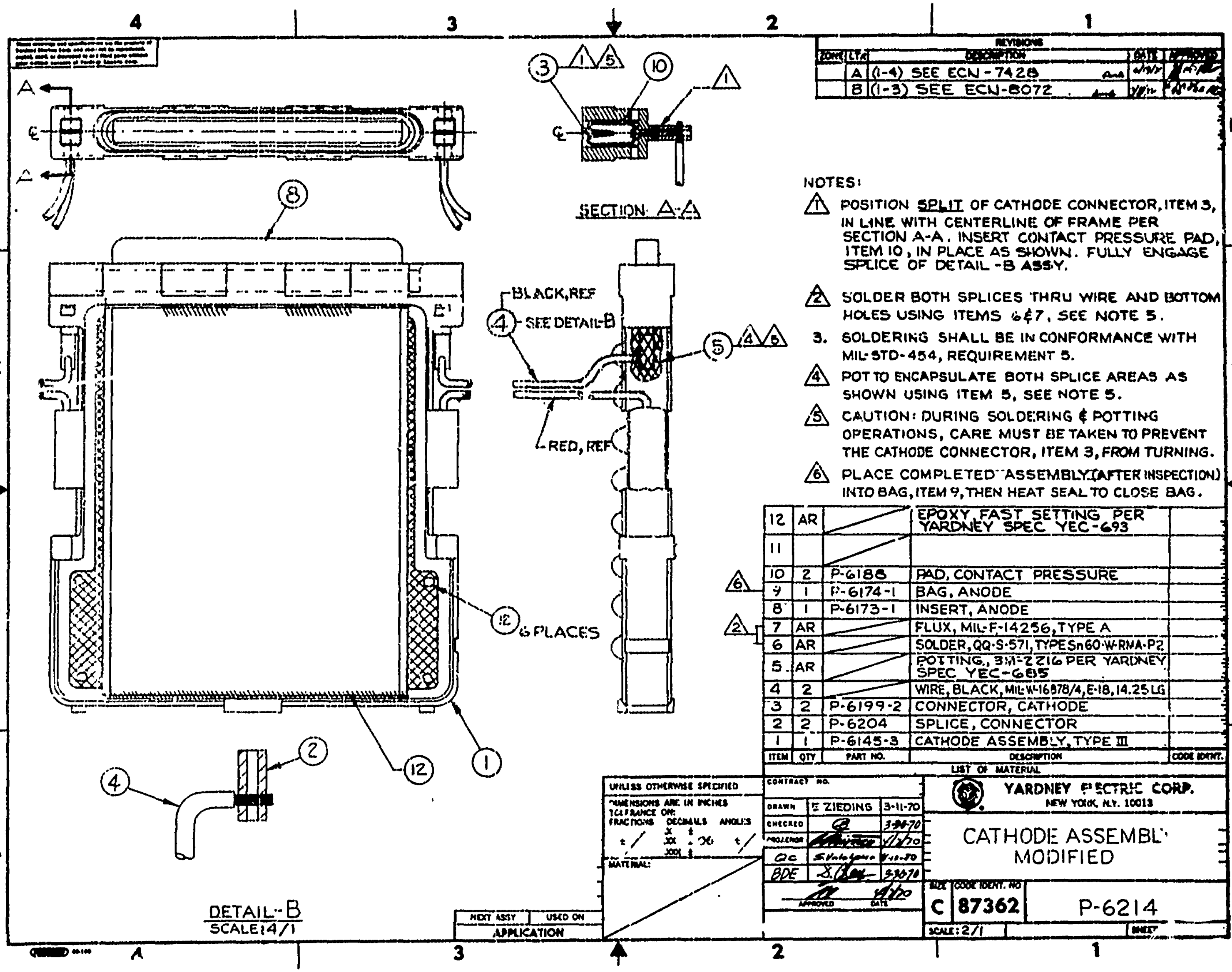

VARDNEY ELECTRIC CORP.
ANODE, REPLACEABLE
ZINC-AIR
OUTLINE
DETAIL 'D'
DETAIL 'C'
SECTION B-B
NOTES:

FIGURE 4



REVISIONS
ZONE | LTR | DESCRIPTION | DATE | APPROVED
A (1-4) SEE ECN-7428
B (1-3) SEE ECN-8072
SECTION A-A
NOTES:
1. POSITION SPLIT OF CATHODE CONNECTOR, ITEM 3, IN LINE WITH CENTERLINE OF FRAME PER SECTION A-A. INSERT CONTACT PRESSURE PAD, ITEM 10, IN PLACE AS SHOWN. FULLY ENGAGE SPLICE OF DETAIL-B ASSY.
2. SOLDER BOTH SPLICES THRU WIRE AND BOTTOM HOLES USING ITEMS 6 & 7, SEE NOTE 5.
3. SOLDERING SHALL BE IN CONFORMANCE WITH MIL-STD-454, REQUIREMENT 5.
4. POT TO ENCAPSULATE BOTH SPLICE AREAS AS SHOWN USING ITEM 5, SEE NOTE 5.
5. CAUTION: DURING SOLDERING & POTTING OPERATIONS, CARE MUST BE TAKEN TO PREVENT THE CATHODE CONNECTOR, ITEM 3, FROM TURNING.
6. PLACE COMPLETED ASSEMBLY (AFTER INSPECTION) INTO BAG, ITEM 9, THEN HEAT SEAL TO CLOSE BAG.
BLACK, REF
SEE DETAIL-B
RED, REF
6 PLACES
DETAIL-B
SCALE: 4/1
12 AR EPOXY FAST SETTING PER YARDNEY SPEC YEC-693
11
10 2 P-6188 PAD, CONTACT PRESSURE
9 1 P-6174-1 BAG, ANODE
8 1 P-6173-1 INSERT, ANODE
7 AR FLUX, MIL-F-14256, TYPE A
6 AR SOLDER, QQ-S-571, TYPE Sn60-W-RMA-P2
5 AR POTTING, 3M-2216 PER YARDNEY SPEC YEC-685
4 2 WIRE, BLACK, MIL-W-16878/4, E-18, 14.25 LG
3 2 P-6199-2 CONNECTOR, CATHODE
2 2 P-6204 SPLICE, CONNECTOR
1 1 P-6145-3 CATHODE ASSEMBLY, TYPE III
ITEM | QTY | PART NO. | DESCRIPTION | CODE IDENT.
LIST OF MATERIAL
UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCE ON: FRACTIONS DECIMALS ANGLES
MATERIAL:
NEXT ASSY | USED ON
APPLICATION
CONTRACT NO.
DRAWN E ZIEDINS 3-11-70
CHECKED
APPROVED DATE
YARDNEY ELECTRIC CORP.
NEW YORK, N.Y. 10013
CATHODE ASSEMBLY
MODIFIED
SIZE C CODE IDENT. NO 87362 P-6214
SCALE: 2/1 SHEET

FIGURE 5

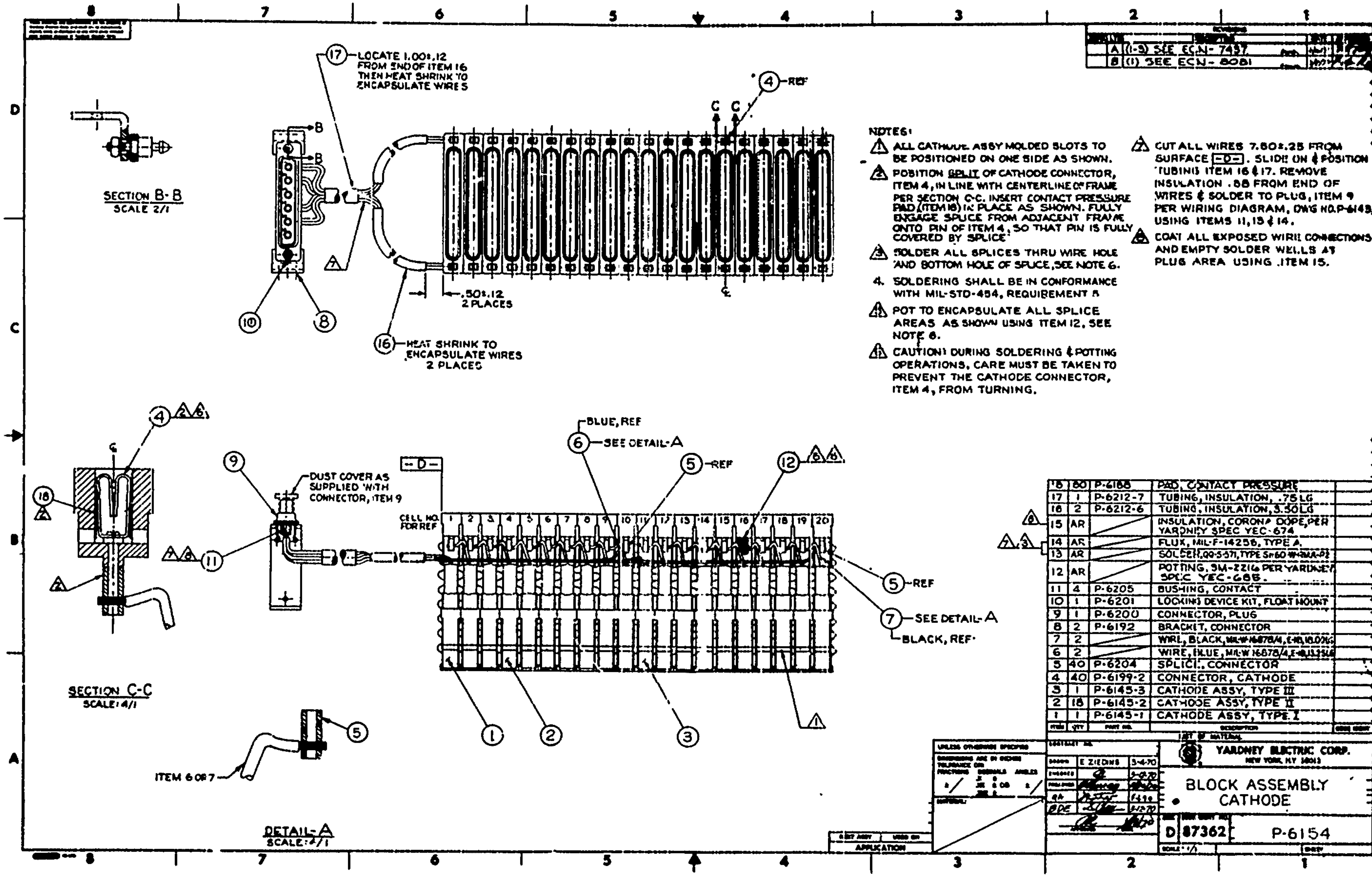

A (1-3) SEE ECN-7457
B (1) SEE ECN-8081
LOCATE 1.00±.12 FROM END OF ITEM 16 THEN HEAT SHRINK TO ENCAPSULATE WIRES
REF
SECTION B-B
SCALE 2/1
.50±.12
2 PLACES
HEAT SHRINK TO ENCAPSULATE WIRES
2 PLACES
NOTES:
1. ALL CATHODE ASSY MOLDED SLOTS TO BE POSITIONED ON ONE SIDE AS SHOWN.
2. POSITION SPLIT OF CATHODE CONNECTOR, ITEM 4, IN LINE WITH CENTERLINE OF FRAME PER SECTION C-C. INSERT CONTACT PRESSURE PAD (ITEM 18) IN PLACE AS SHOWN. FULLY ENGAGE SPLICE FROM ADJACENT FRAME ONTO PIN OF ITEM 4, SO THAT PIN IS FULLY COVERED BY SPLICE.
3. SOLDER ALL SPLICES THRU WIRE HOLE AND BOTTOM HOLE OF SPLICE, SEE NOTE 6.
4. SOLDERING SHALL BE IN CONFORMANCE WITH MIL-STD-454, REQUIREMENT 5
5. POT TO ENCAPSULATE ALL SPLICE AREAS AS SHOWN USING ITEM 12, SEE NOTE 6.
6. CAUTION: DURING SOLDERING & POTTING OPERATIONS, CARE MUST BE TAKEN TO PREVENT THE CATHODE CONNECTOR, ITEM 4, FROM TURNING.
7. CUT ALL WIRES 7.80±.25 FROM SURFACE -D-. SLIDE ON & POSITION TUBING ITEM 16 & 17. REMOVE INSULATION .88 FROM END OF WIRES & SOLDER TO PLUG, ITEM 9 PER WIRING DIAGRAM, DWG NO. P-6143, USING ITEMS 11, 15 & 14.
8. COAT ALL EXPOSED WIRE CONNECTIONS AND EMPTY SOLDER WELLS AT PLUG AREA USING ITEM 15.
BLUE, REF
SEE DETAIL-A
DUST COVER AS SUPPLIED WITH CONNECTOR, ITEM 9
-D-
CELL NO. FOR REF
SEE DETAIL-A
BLACK, REF
SECTION C-C
SCALE 4/1
ITEM 6 OR 7
DETAIL-A
SCALE 4/1
18 | 80 | P-6188 | PAD, CONTACT PRESSURE
17 | 1 | P-6212-7 | TUBING, INSULATION, .75 LG
16 | 2 | P-6212-6 | TUBING, INSULATION, 3.50 LG
15 | AR | | INSULATION, CORONA DOPE, PER YARDNEY SPEC YEC-674
14 | AR | | FLUX, MIL-F-14256, TYPE A
13 | AR | | SOLDER, QQ-S-571, TYPE Sn60 [illegible]
12 | AR | | POTTING, 3M-2216 PER YARDNEY SPEC YEC-688
11 | 4 | P-6205 | BUSHING, CONTACT
10 | 1 | P-6201 | LOCKING DEVICE KIT, FLOAT MOUNT
9 | 1 | P-6200 | CONNECTOR, PLUG
8 | 2 | P-6192 | BRACKET, CONNECTOR
7 | 2 | | WIRE, BLACK, MIL-W-16878/4, [illegible]
6 | 2 | | WIRE, BLUE, MIL-W-16878/4, [illegible]
5 | 40 | P-6204 | SPLICE, CONNECTOR
4 | 40 | P-6199-2 | CONNECTOR, CATHODE
3 | 1 | P-6145-3 | CATHODE ASSY, TYPE III
2 | 18 | P-6145-2 | CATHODE ASSY, TYPE II
1 | 1 | P-6145-1 | CATHODE ASSY, TYPE I
LIST OF MATERIAL
YARDNEY ELECTRIC CORP.
NEW YORK, NY 10013
E ZIEDINS 3-4-70
BLOCK ASSEMBLY CATHODE
D 87362 P-6154
APPLICATION

FIGURE 6

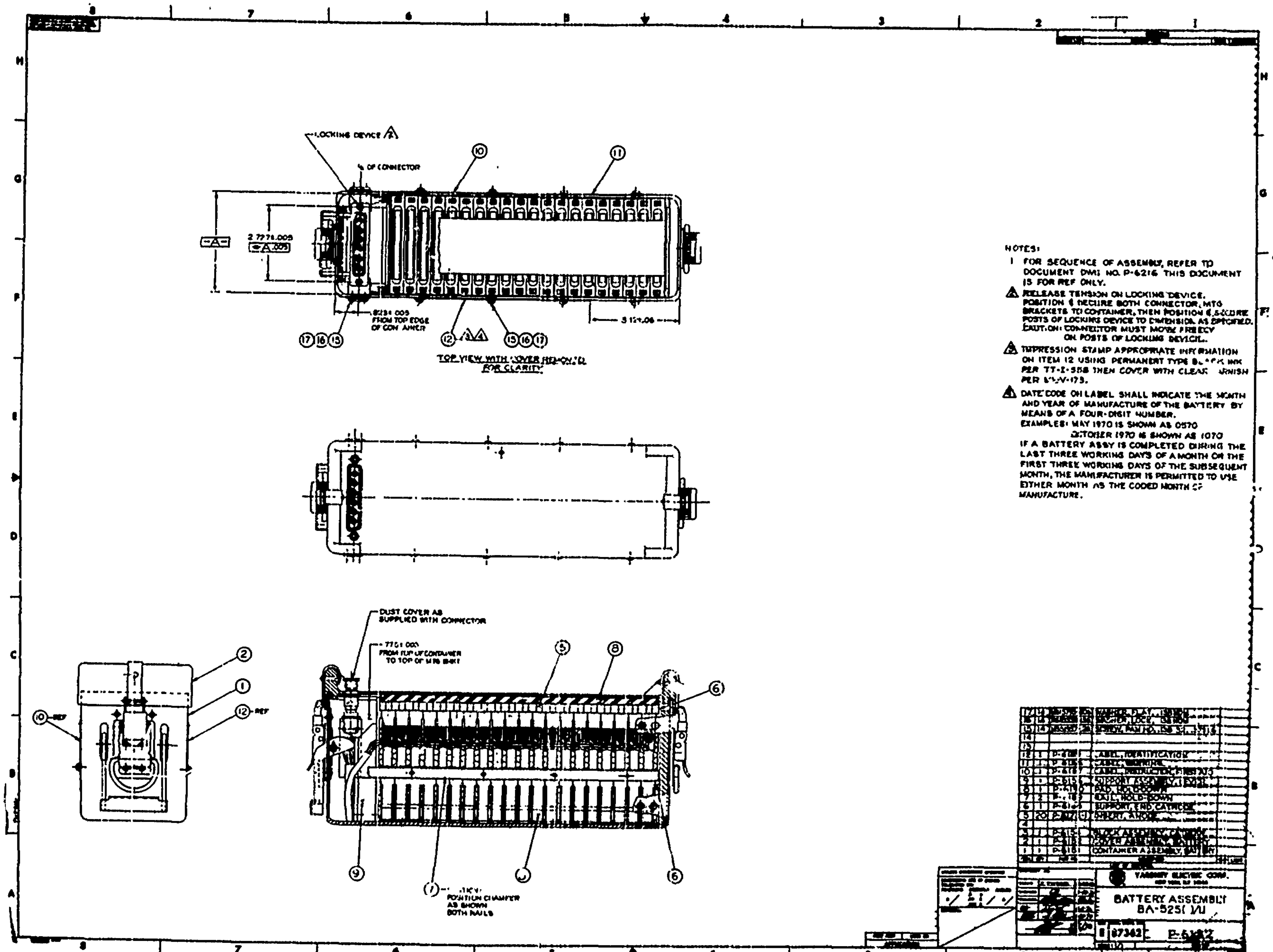

LOCKING DEVICE
℄ OF CONNECTOR
2.727±.005
A
TOP VIEW WITH COVER REMOVED FOR CLARITY
DUST COVER AS SUPPLIED WITH CONNECTOR
POSITION CHAMFER AS SHOWN BOTH RAILS
NOTES:
1 FOR SEQUENCE OF ASSEMBLY, REFER TO DOCUMENT DWG NO. P-6216 THIS DOCUMENT IS FOR REF ONLY.
RELEASE TENSION ON LOCKING DEVICE. POSITION & SECURE BOTH CONNECTOR, MTG BRACKETS TO CONTAINER, THEN POSITION & SECURE POSTS OF LOCKING DEVICE TO DIMENSION AS SPECIFIED. CAUTION: CONNECTOR MUST MOVE FREELY ON POSTS OF LOCKING DEVICE.
IMPRESSION STAMP APPROPRIATE INFORMATION ON ITEM 12 USING PERMANENT TYPE BLACK INK PER TT-I-558 THEN COVER WITH CLEAR VARNISH
DATE CODE ON LABEL SHALL INDICATE THE MONTH AND YEAR OF MANUFACTURE OF THE BATTERY BY MEANS OF A FOUR-DIGIT NUMBER.
EXAMPLES: MAY 1970 IS SHOWN AS 0570
OCTOBER 1970 IS SHOWN AS 1070
IF A BATTERY ASSY IS COMPLETED DURING THE LAST THREE WORKING DAYS OF A MONTH OR THE FIRST THREE WORKING DAYS OF THE SUBSEQUENT MONTH, THE MANUFACTURER IS PERMITTED TO USE EITHER MONTH AS THE CODED MONTH OF MANUFACTURE.
BATTERY ASSEMBLY BA-525( )/U
87342

FIGURE 7

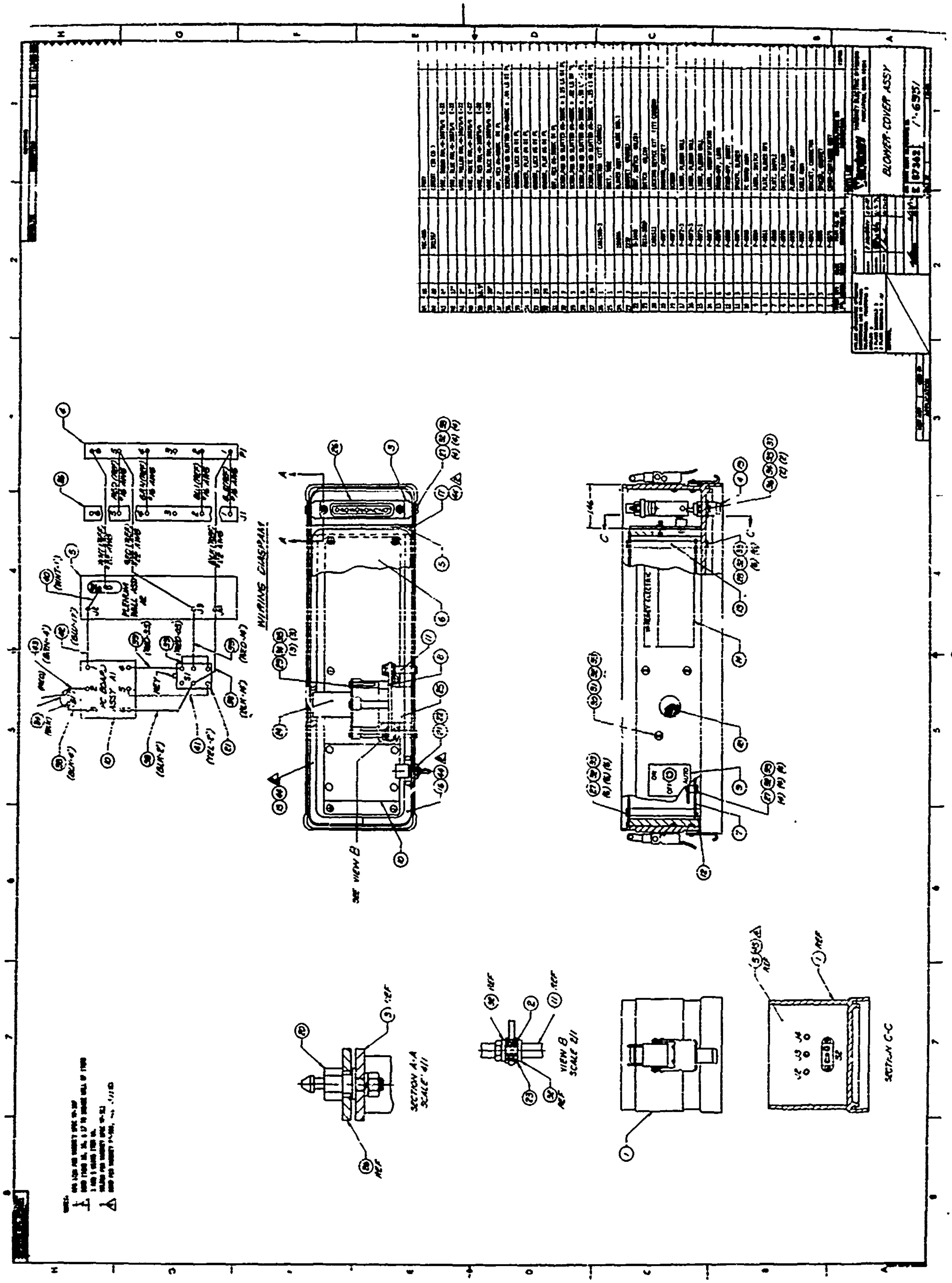

BLOWER-COVER ASSY
WIRING DIAGRAM
SECTION A-A
SCALE 4/1
VIEW B
SCALE 2/1
SECTION C-C

FIGURE 8

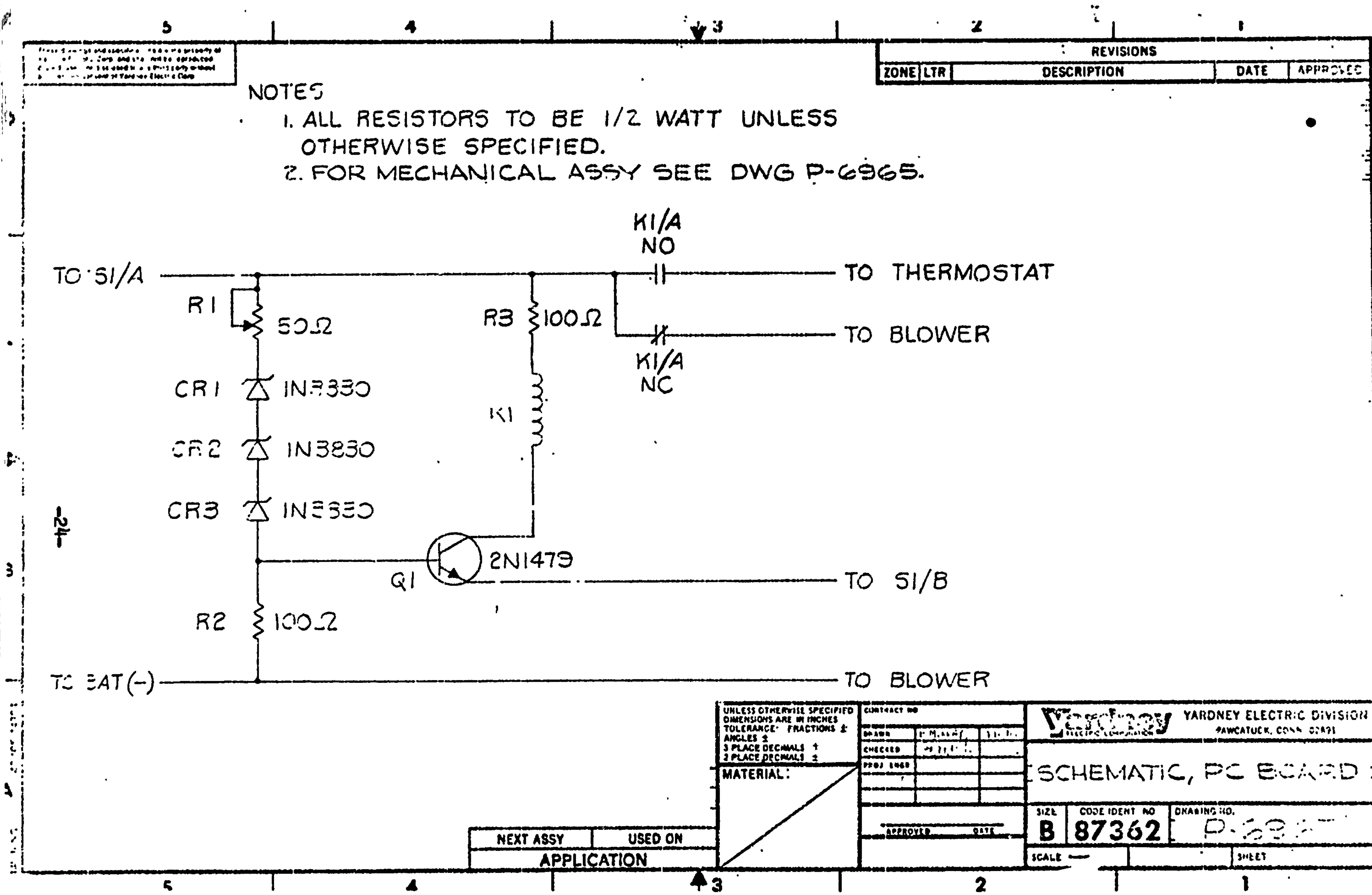

REVISIONS
ZONE
LTR
DESCRIPTION
DATE
NOTES
1. ALL RESISTORS TO BE 1/2 WATT UNLESS OTHERWISE SPECIFIED.
2. FOR MECHANICAL ASSY SEE DWG P-6965.
K1/A NO
K1/A NC
TO S1/A
TO THERMOSTAT
TO BLOWER
R1 50Ω
R3 100Ω
K1
CR1
CR2 IN3830
CR3
Q1 2N1479
TO S1/B
R2 100Ω
TO BLOWER
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCE: FRACTIONS ±
ANGLES ±
3 PLACE DECIMALS ±
2 PLACE DECIMALS ±
MATERIAL:
CONTRACT NO
DRAWN
CHECKED
PROJ ENGR
APPROVED
DATE
YARDNEY ELECTRIC DIVISION
PAWCATUCK, CONN.
SCHEMATIC, PC BOARD
SIZE B
CODE IDENT NO 87362
DRAWING NO.
SCALE
SHEET
NEXT ASSY
USED ON
APPLICATION

FIGURE 9

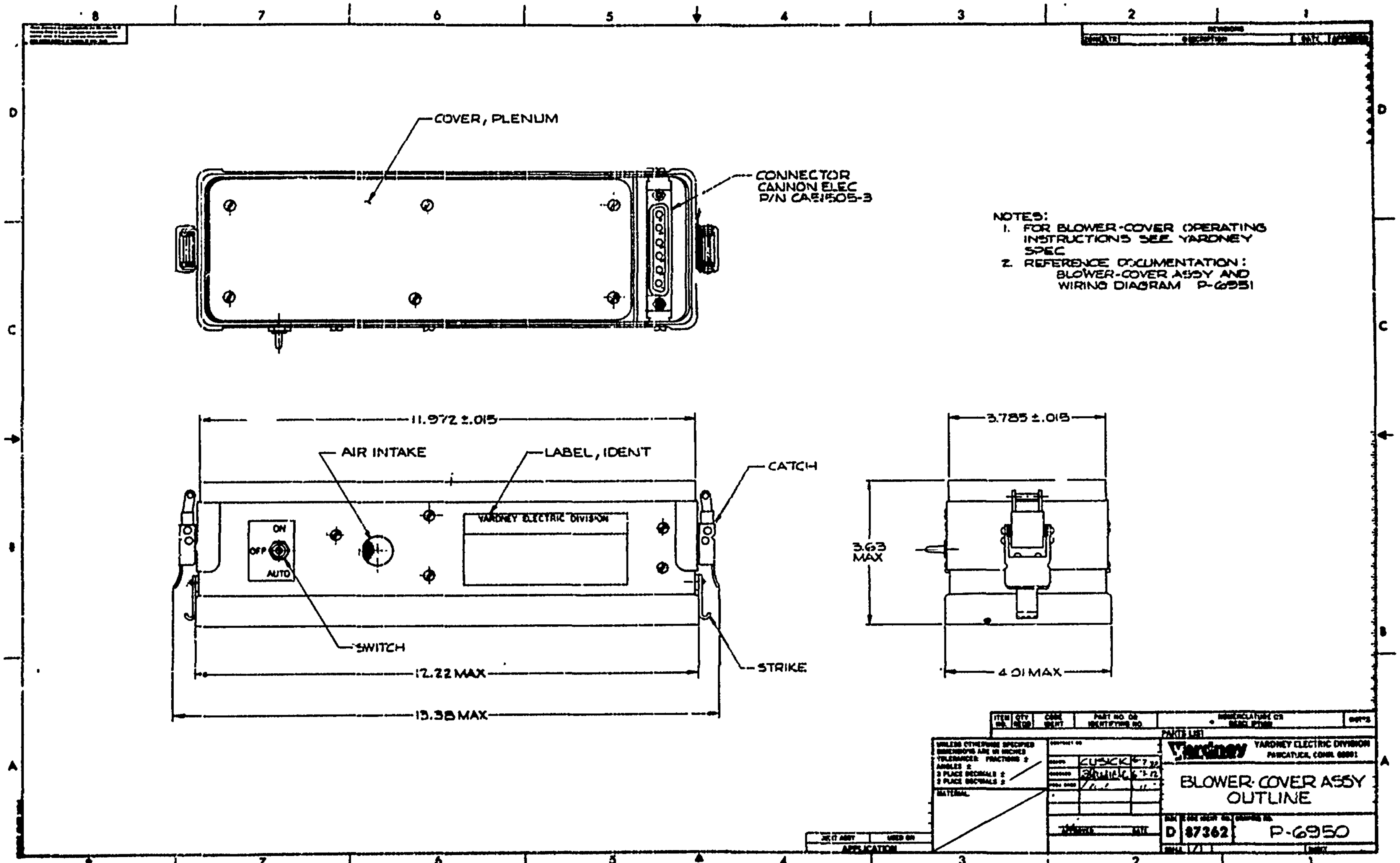
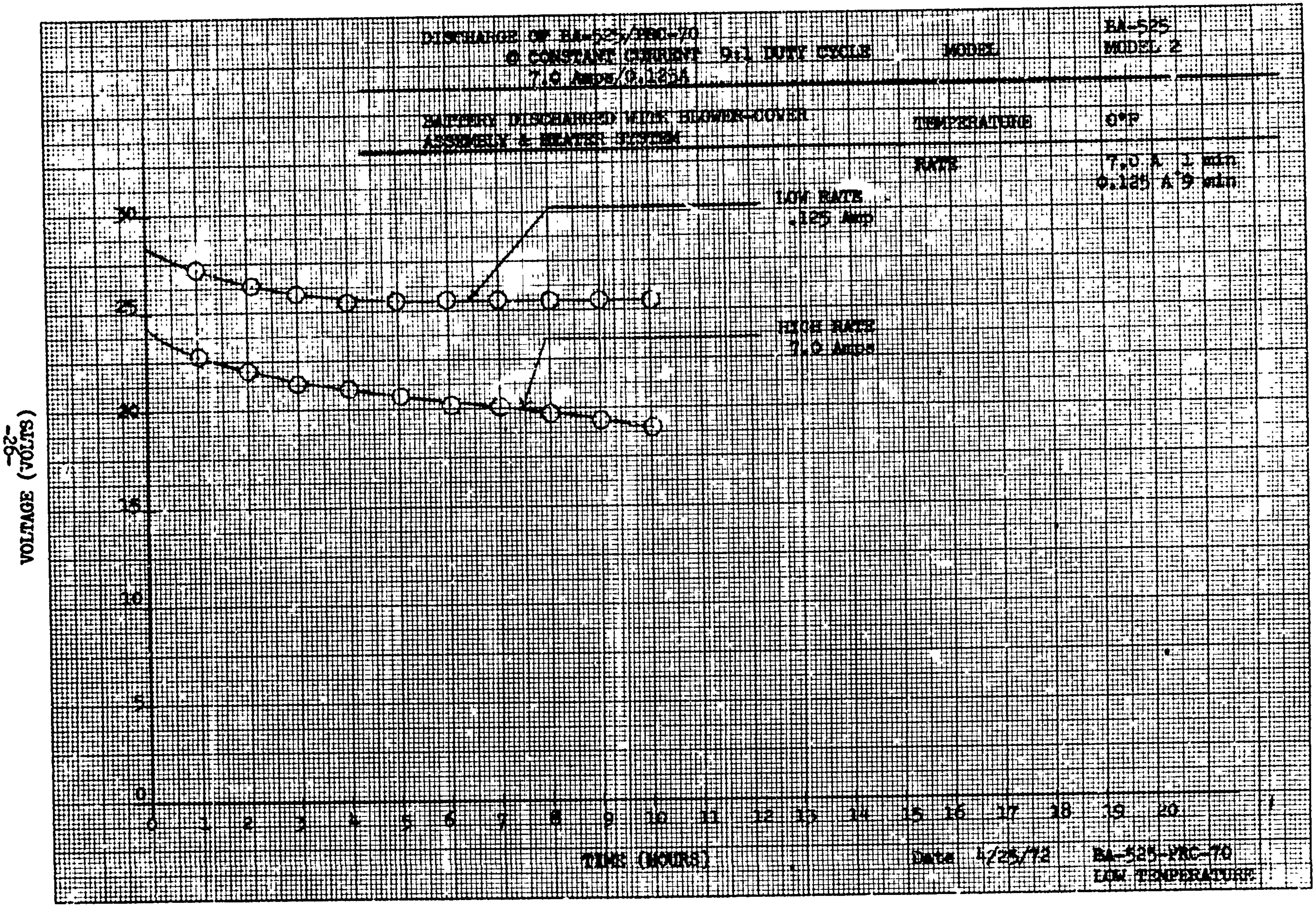

COVER, PLENUM
CONNECTOR
CANNON ELEC
P/N CA3I505-3
NOTES:
1. FOR BLOWER-COVER OPERATING INSTRUCTIONS SEE YARDNEY SPEC
2. REFERENCE DOCUMENTATION: BLOWER-COVER ASSY AND WIRING DIAGRAM P-6951
11.972 ±.015
AIR INTAKE
LABEL, IDENT
YARDNEY ELECTRIC DIVISION
CATCH
ON
OFF
AUTO
SWITCH
12.22 MAX
13.38 MAX
STRIKE
3.785 ±.015
3.63 MAX
4.01 MAX
YARDNEY ELECTRIC DIVISION
BLOWER-COVER ASSY OUTLINE
D 87362 P-6950
APPLICATION

FIGURE 10



DISCHARGE OF BA-525/PRC-70
@ CONSTANT CURRENT 9:1 DUTY CYCLE
7.0 Amps/0.125A
MODEL
BA-525
MODEL 2
BATTERY DISCHARGED WITH BLOWER-COVER
ASSEMBLY & HEATER SYSTEM
TEMPERATURE
0°F
RATE
7.0 A 1 min
0.125 A 9 min
LOW RATE
.125 Amp
HIGH RATE
7.0 Amps
VOLTAGE (VOLTS)
30
25
20
15
10
5
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
TIME (HOURS)
Date 1/25/72
BA-525-PRC-70
LOW TEMPERATURE

FIGURE 11

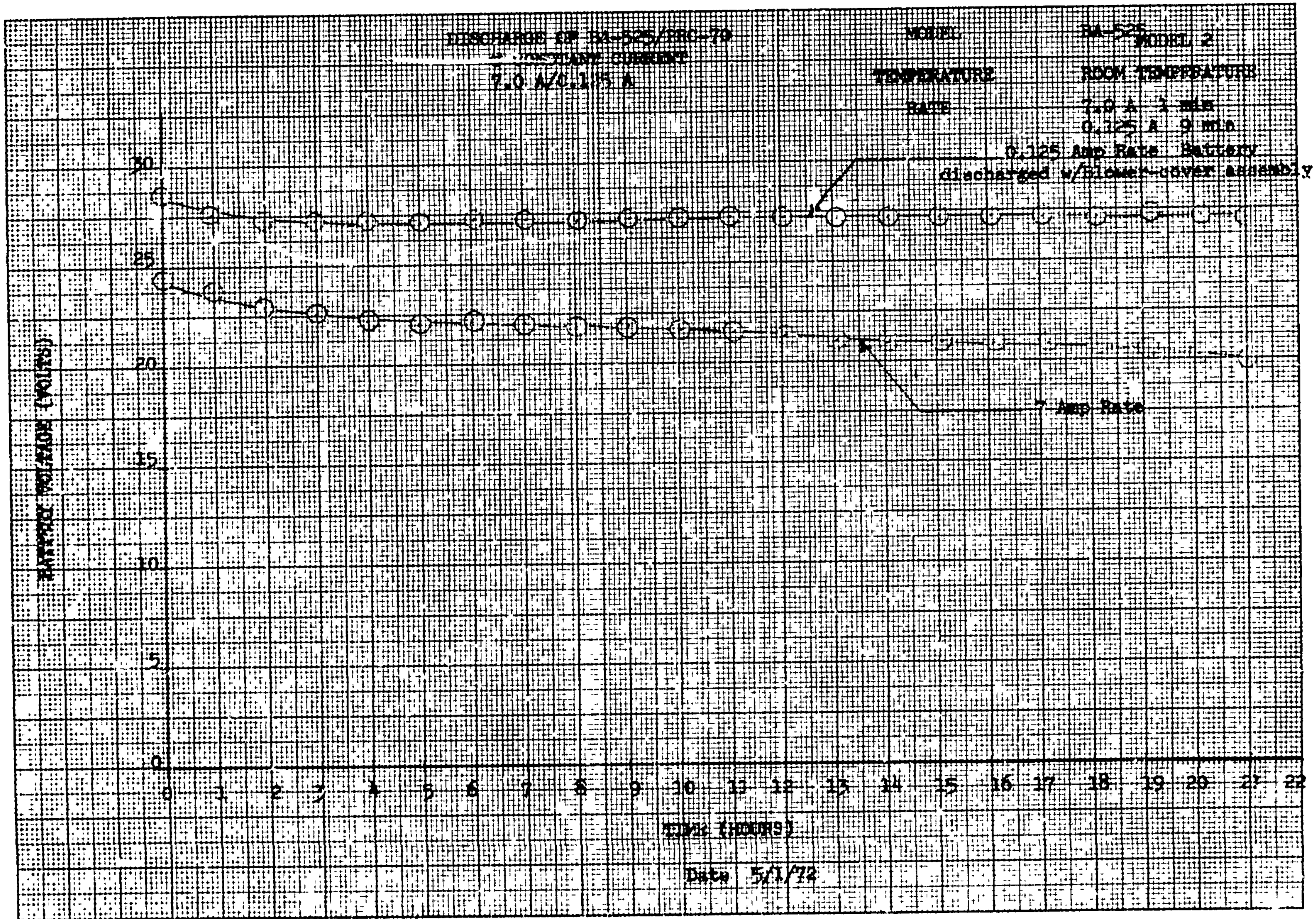


FIGURE 12 Type III Cathode, Blower Assembly