

General Disclaimer

One or more of the Following Statements may affect this Document

- This document has been reproduced from the best copy furnished by the organizational source. It is being released in the interest of making available as much information as possible.
- This document may contain data, which exceeds the sheet parameters. It was furnished in this condition by the organizational source and is the best copy available.
- This document may contain tone-on-tone or color graphs, charts and/or pictures, which have been reproduced in black and white.
- This document is paginated as submitted by the original source.
- Portions of this document are not fully legible due to the historical nature of some of the material. However, it is the best reproduction available from the original submission.

HEAT-STERILIZABLE, REMOTELY ACTIVATED
BATTERY DEVELOPMENT PROGRAM
PHASE I
Second Quarterly Report

Period: October 1 to December 31, 1968

Contract No. 952214
NAS7-100

January 25, 1969

JET PROPULSION LABORATORY
California Institute of Technology
4800 Oak Grove Drive
Pasadena, California 91103

FACILITY FORM 602

N 69-19563

(ACCESSION NUMBER)

39

(PAGES)

CR-100211

(NASA CR OR TMX OR AD NUMBER)

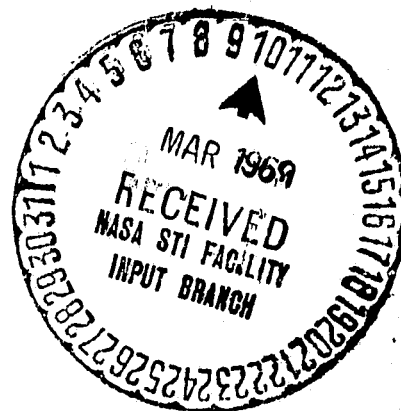
(THRU)

1

(CODE)

03

(CATEGORY)



ELECTRONICS DIVISION
Eagle-Picher Industries, Inc.
Couples Department
Joplin, Missouri

HEAT-STERILIZABLE, REMOTELY ACTIVATED
BATTERY DEVELOPMENT PROGRAM
PHASE I

Second Quarterly Report

Period: October 1 to December 31, 1968

Contract No. 952214
NAS7-100

January 25, 1969

"This work was performed for the Jet Propulsion Laboratory, California Institute of Technology, as sponsored by the National Aeronautics and Space Administration under Contract NAS 7-100."

ELECTRONICS DIVISION
Eagle-Picher Industries, Inc.
Couples Department
Joplin, Missouri

"This report contains information prepared by Eagle-Picher Industries, Inc. under JPL Sub-Contract. Its content is not necessarily endorsed by The Jet Propulsion Laboratory, California Institute of Technology, or The National Aeronautics and Space Administration."

ABSTRACT

This report delineates the progress during the second quarter of the development of a heat-sterilizable, sealed, remotely activated battery per Contract No. 952214 between the Jet Propulsion Laboratory and Eagle-Picher Industries, Inc. The work effort is proceeding in Phase I defined by contract as an investigation of basic cell and battery components and materials to characterize individual capabilities to withstand the heat sterilization routine and retain desirable properties.

Testing of the silver oxide electrodes revealed that due to sterilization, a loss in capacity of approximately 30% - 40% may be expected. In order to minimize the loss in capacity, the plate density and thickness must be optimized.

Studies regarding the absorbent separators continued during the quarter. The cotton, asbestos, and Hemp separators were found to have the best absorption and wicking properties. The polypropylene materials failed during the sterilization cycle.

The electrolyte reservoirs commonly used in Eagle-Picher remote activated batteries were determined to be unaffected by sterilization.

Two (2) propellants have been tested which show promise as being capable of heat sterilization. These propellants are manufactured by Talley Industries (X30-50A-2) and Aerojet General (AN583 AF). The X30-50A-2 propellant is basically an ammonium perchlorate composition while the AN583 AF is an ammonium perchlorate with a polyester styrene binder.

TABLE OF CONTENTS

<u>SECTION</u>		<u>PAGE</u>
ABSTRACT		iii
List of Tables		v
List of Figures		vi
1.0	INTRODUCTION	1
2.0	TECHNICAL DISCUSSION	1
	2.1 Silver Oxide Electrode	1
	2.2 Zinc Electrode	12
	2.3 Separation	13
	2.4 Cell Case and Sealing	17
	2.5 Electrolyte Solution Reservoir and Pyrotechnics	20
	2.6 Cell Test	28
3.0	CONCLUSIONS	32
4.0	RECOMMENDATIONS	32
5.0	NEW TECHNOLOGY	32

LIST OF TABLES

<u>TABLE</u>		<u>PAGE</u>
Table I	Growth Study of Sterilized Positive Plates	2
Table II	Variables Used in the Study of Electroformed Positive Plates	5
Table III	Model for Regression Analysis of Capacity	7
Table IV	Model for Regression Analysis of Plate Growth in Width	10
Table V	Physical Changes in Electroformed Positive Electrodes due to Sterilization	14
Table VI	Absorption Characteristics of Separating Material	16
Table VII	Wicking Characteristics of Separation Material - Sterilized	18
Table VIII	Wicking Characteristics of Separation Material - Unsterilized	19
Table IX	Sterilization Study of Electrolyte Reservoirs	22
Table X	Performance of Sterilized and Unsterilized Propellants in a Water Displacement Fixture	27
Table XI	Performance of Sterilized and Unsterilized Propellants in Water Displacement Fixture	29

LIST OF FIGURES

<u>FIGURE</u>		<u>PAGE</u>
Figure I	Discharge Curves for Sterilized and Unsterilized Cells	31

1.0 INTRODUCTION

This report presents the results of investigating efforts during the second quarter ending 31 December 1968. The presentation includes a description of studies performed during the quarter with the results tabulated and discussed.

The studies were designed to determine parameters affecting the performance of the individual components of the battery system.

The effort has been directed towards those components necessary to a remote activated battery.

2.0 TECHNICAL DISCUSSION

2.1 Silver Oxide Electrode

Preliminary tests were performed on fifteen (15) positive plates to determine the amount of growth expected due to sterilization. The plates represented an electroformed configuration. The plates were measured and placed in a sealed container. They were then subjected to the heat sterilization routine. After the sterilization cycle had concluded, the container with the plates enclosed was removed from the test chamber. The container had seen an internal pressure capable of deforming it past yield. Evidently, this pressure was a result of the expansion of gases within the container, combined with gases evolved from the plates due to decomposition of the silver oxide during the sterilization cycle. When the container was opened, no audible escape of gas was discernible. The plates were removed and dimensioned again. The dimensional results are tabulated in Table I.

The dimensional analysis revealed that the plates had grown in every direction. The average increase in thickness was approximately 11% while the increases in height and width were 0.42% and 3.00%, respectively. The growth was attributed to an increase in grain size.

TABLE I
GROWTH STUDY OF STERILIZED POSITIVE PLATES

Plate Number	Thickness (In.)		% Change	Width (In.)		% Change	Height (In.)		% Change
	Before	After		Before	After		Before	After	
1	.011	.012	+9.1	1.625	1.676	+3.13	1.751	1.762	+0.63
2	.011	.012	+9.1	1.623	1.673	+3.08	1.751	1.761	+0.57
3	.011	.0115	+4.5	1.625	1.679	+3.32	1.750	1.761	+0.63
4	.010	.011	+10.0	1.624	1.671	+2.89	1.750	1.755	+0.29
5	.011	.0115	+4.5	1.625	1.670	+2.77	1.751	1.758	+0.40
6	.011	.012	+9.1	1.624	1.669	+2.77	1.750	1.757	+0.40
7	.011	.012	+9.1	1.625	1.675	+3.07	1.751	1.757	+0.34
8	.011	.012	+9.1	1.625	1.674	+3.01	1.750	1.756	+0.34
9	.011	.012	+9.1	1.625	1.672	+2.89	1.750	1.758	+0.46
10	.010	.0115	+15.0	1.625	1.672	+2.89	1.750	1.758	+0.46
11	.010	.012	+20.0	1.625	1.680	+3.38	1.750	1.759	+0.51
12	.010	.0115	+15.0	1.625	1.680	+3.38	1.750	1.760	+0.57
13	.010	.0115	+15.0	1.625	1.674	+3.01	1.751	1.755	+0.23
14	.010	.0115	+15.0	1.625	1.668	+2.64	1.750	1.751	+0.06
15	.011	.012	+9.1	1.625	1.669	+2.77	1.750	1.758	+0.46

2.1 Silver Oxide Electrode (Continued)

In an effort to verify the above results as well as determine other parameters of the electroformed positive plates, three (3) groups were manufactured. Each group represented a weight per unit surface area. The groups were pressed to four (4) thicknesses. By fabricating the plates in this manner, a wide range of plate weights and densities was available for testing.

Plates were selected representing the extremes and intermediate points of the plate weight. A range of densities was selected at each location. These plates were measured and then placed in a sealed container and subjected to sterilization. At the end of the sterilization cycle, the container was removed and placed at room ambient. The container had deformed as before. The seal at the cover leaked, eliminating the possibility of determining the quantity of gassing due to sterilization. Tests shall be repeated later to determine the amount of gassing.

The plates were fabricated into cells comprised of two (2) negative and one (1) positive plates separated with 2409 cotton separation. Each cell was discharged under a constant 4 amp rate to an end voltage of 1.00 volts.

Data from the above tests was tabulated and examined. A casual observation of a random sampling of the data indicated that there was a relationship existing between the open circuit voltage, plateau voltage, and capacity. The higher density plates appeared to lose less capacity during sterilization. After analyzing the data, it was decided that a regression of the data would provide a better picture of the influence one variable has on another.

2.1 Silver Oxide Electrode (Continued)

The data was tabulated with the following variables:

- 1 - Plate weight before sterilization.
- 2 - Plate thickness before sterilization.
- 3 - Grams of active material per square inch before sterilization.
- 4 - Plate weight after sterilization.
- 5 - Plate density before sterilization.
- 6 - % increase in thickness due to sterilization.
- 7 - increase in height due to sterilization.
- 8 - % increase in width due to sterilization.
- 9 - Plateau voltage.
- 10 - Open circuit voltage.
- 11 - Actual plate capacity.

By recording the original and final plate weights, the per cent weight loss was accounted for as well as the original capacity of the plate. The tabulation may be seen in Table II.

In regressing the data, variable 11 (actual plate capacity) was used as the dependent variable with variables 1 through 8 used as independent variables. The initial model indicated that the plot may be a function of exponentials or cross-products of certain variables. A trial was made using exponentials of the two (2) most significant variables. These were the plate weight prior to sterilization and the percent increase in plate width.

The results of the regression analysis indicated that the most significant variable as far as capacity was the growth of the plate. The original plate weight, as would be expected, was also significant. Other variables indicating a significant effect were the final plate weight, the density and the cube of the original plate weight. This model accounted for 90.7% of the capacity with a standard error of estimate equal to 5.76. The model is shown in Table III.

TABLE II
VARIABLES USED IN THE STUDY OF ELECTROFORMED POSITIVE PLATES

Plate No.	Original Plate Wt (gm)	Original Thickness (In.)	Gm/In ²	Final Plate Wt. (gm)	Original Plate Density (Gm/In ³)	% Growth			Plateau Voltage	Open Circuit Voltage	Actual Capacity (Amp-Min)
						Thick	Height	Width			
55	8.04	.024	2.15	7.69	89.58	8.33	3.40	4.61	1.36	1.73	89.6
65	8.02	.024	2.14	7.63	89.17	4.16	3.25	5.23	1.34	1.72	90.0
75	8.22	.025	2.20	7.84	88.0	4.00	3.15	4.92	1.34	1.80	86.8
128	8.77	.025	2.37	8.35	94.8	8.00	3.65	5.35	1.34	1.81	90.8
126	8.30	.026	2.23	7.90	85.77	3.84	3.25	5.53	1.27	1.81	88.0
51	8.70	.026	2.35	8.29	90.38	3.84	3.50	4.92	1.33	1.82	94.0
113	8.30	.027	2.23	7.88	82.59	7.40	3.25	5.53	1.33	1.70	98.0
140	8.61	.027	2.32	8.15	85.93	7.40	3.50	5.29	1.34	1.72	100.8
271	8.25	.028	2.21	7.89	78.93	21.42	3.00	5.16	1.37	1.67	90.0
97	8.63	.028	2.33	8.16	83.21	28.57	3.35	5.53	1.34	1.68	103.2
275	8.31	.029	2.23	7.89	76.90	3.44	3.00	5.53	1.27	1.79	85.6
102	8.85	.029	2.39	8.39	82.41	6.89	3.50	4.92	1.26	1.80	102.0
304	8.17	.030	2.19	7.68	73.00	16.66	2.90	5.23	1.36	1.66	89.2
172	9.04	.031	2.45	8.61	79.03	16.12	3.50	6.15	1.28	1.68	109.6
2	8.75	.032	2.36	8.28	73.75	6.25	3.40	6.64	1.33	1.64	110.0
170	8.79	.032	2.38	8.34	74.38	6.25	3.50	5.53	1.28	1.67	116.0
194	9.23	.033	2.51	8.75	76.06	6.06	3.50	5.53	1.28	1.80	108.0
204	9.90	.035	2.72	9.37	77.71	11.42	3.35	5.84	1.28	1.80	112.0
61	7.91	.025	2.11	7.51	84.40	20.00	4.50	10.46	1.26	1.70	82.0
68	8.15	.025	2.18	7.79	87.20	12.00	5.75	10.64	1.25	1.79	82.0
39	7.78	.026	2.07	7.42	79.62	19.23	4.25	11.07	1.18	1.78	70.0
293	8.01	.026	2.14	7.67	82.31	19.23	5.00	11.56	1.23	1.76	68.0
151	8.98	.026	2.44	8.53	93.85	15.38	5.75	10.15	1.23	1.70	90.0
228	9.27	.026	2.52	8.87	96.92	15.38	6.25	10.15	1.24	1.70	38.0
279	7.78	.027	2.07	7.50	76.67	14.81	4.60	12.92	1.26	1.77	66.0
286	8.13	.027	2.17	7.87	80.37	22.22	5.00	12.30	1.24	1.80	65.0
149	9.00	.027	2.44	8.55	90.37	14.81	5.85	10.76	1.22	1.73	90.0
242	9.17	.027	2.49	8.72	92.22	18.51	6.25	10.76	1.28	1.73	94.0
27	7.80	.028	2.07	7.46	73.93	14.28	3.25	11.07	1.20	1.63	74.0
36	8.16	.028	2.18	7.84	77.86	10.71	4.15	9.84	1.24	1.78	86.0
264	9.06	.028	2.46	8.64	87.86	17.85	6.50	11.20	1.20	1.76	84.0
231	9.39	.028	2.56	8.91	91.43	14.28	6.75	10.76	1.26	1.78	96.0
305	7.85	.029	2.09	7.50	72.07	13.79	3.80	12.92	1.28	1.67	64.0
105	8.25	.029	2.21	7.84	76.21	20.68	4.10	13.53	1.20	1.78	74.0

NOTE: All plates are sterilized

TABLE II (Continued)

VARIABLES USED IN THE STUDY OF ELECTROFORMED POSITIVE PLATES

Plate No.	Original Plate Wt. (gm)	Original Thickness (In.)	Gm/In ²	Final Plate Wt. (gm)	Original Plate Density (Gm/In ³)	% Growth			Plateau Voltage	Open Circuit Voltage	Actual Capacity (Amp-Min)
						Thick	Height	Width			
266	9.18	.029	2.50	8.81	86.21	20.68	7.00	11.69	1.21	1.74	92.0
245	9.74	.029	2.67	9.25	92.07	24.13	7.00	11.26	1.18	1.76	88.0
311	8.16	.031	2.18	7.81	70.32	9.67	4.25	13.23	1.26	1.66	64.0
299	8.26	.031	2.21	7.97	71.29	12.90	4.25	10.46	1.23	1.77	84.0
12	9.09	.031	2.47	8.65	79.68	16.12	6.10	13.04	1.21	1.66	94.0
253	9.40	.030	2.56	8.94	85.33	10.00	6.50	10.76	1.28	1.74	101.0
183	9.14	.032	2.48	8.69	77.50	18.75	5.65	12.67	1.18	1.78	80.0
165	9.18	.032	2.50	8.83	78.13	15.62	4.65	9.53	1.20	1.80	90.0
211	9.28	.034	2.53	8.86	74.41	11.76	6.00	10.46	1.21	1.79	84.0
193	9.09	.033	2.47	8.64	74.85	21.21	6.25	13.41	1.20	1.78	73.0
210	9.45	.033	2.58	8.99	78.18	15.15	6.15	11.26	1.23	1.77	94.0
174	10.01	.034	2.75	9.54	80.88	14.70	6.60	13.23	1.20	1.77	88.0

NOTE: All Plates are sterilized

TABLE III
MODEL FOR REGRESSION
ANALYSIS OF CAPACITY

Standard Error of Estimate	=	5.75818
Multiple Correlation Coefficient	=	0.907
Goodness of Fit, F (5.40)	=	37.3496
Constant Term	=	84.0745

Variable	Coefficient	Std. Dev. Coeff.	T Value	Beta Coeff.
Original Plate Wt.	92.5423	33.0716	2.7982	3.8716
Final Plate Wt.	-42.8097	23.0581	-1.8566	-1.7573
Original Density	- 3.0575	1.7468	-1.7503	-0.1245
Cubed Original Plate Wt.	-37.4691	25.2799	-1.4821	-1.5202
% Increase Width Cubed	-12.6339	1.5365	-8.2224	-0.6491

2.1 Silver Oxide Electrode (Continued)

The equation for this model would be:

$$\begin{aligned} \text{Capacity} = & 84.0745 + 92.54 A - 42.81B - 3.06(C) - 37.47 A^3 \\ & - 12.63 \left(\frac{D_2 - D_1}{D_1} \right) (100) \end{aligned}$$

Where: A = Original plate weight (gms)

B = Final plate weight (gms)

C = Original plate density (gms/in³)

D₂ = Final plate width (in.)

D₁ = Original plate width (in.)

The goodness of fit for this model was 37.35 with 5/40 degrees of freedom. This indicates that the equation has a fit with a confidence in excess of 99% that the predictions are correct.

A regression analysis was then performed using the open circuit voltage as the dependent variable with the independent variables being 1 through 9. As before, the initial models indicated that exponentials on cross products were involved. Revising the variables and regressing the data resulted in a model with a multiple correlation coefficient of 0.793 and a goodness of fit (15, 30) equal to 3.4109. The variables having the most significance were the original plate weight, the plate growth, and plate density. No further attempt to improve this model was made.

An analysis similar to that of the open circuit voltage was made using the plateau voltage as the dependent variable. With a multiple correlation coefficient of 0.826 and standard error of estimate of 0.03283, the goodness of fit, F (4,41), was 22.08. In this model variable 8 (% increase in plate width) exhibited the greatest significance. The equation predicting the plateau voltage with a 99.9% confidence is:

2.1 Silver Oxide Electrode (Continued)

$$\text{Plateau Voltage} = 1.2690 + 0.119T - 0.118W + 0.107D - 0.054G$$

Where: T = Original plate thickness
W = Final plate weight
D = Original plate density
G = % increase in plate width

Since plate growth was a significant factor in all three (3) of the above analyses, it was decided to attempt to ascertain what variables contributed to the growth. Therefore, a regression was performed using the change in plate width as the dependent variable. The data representing growth in the remaining two (2) directions were left in the analysis and treated as independent variables.

The result of the analysis pointed to the plate density and thickness as being the most significant controllable variables. As can be seen from Table IV, with a multiple correlation coefficient of 0.921 and a standard error of estimate of 1.27535, the variance was due to functions of plate density, original plate thickness, and growth in height and thickness. Since the coefficients of the density and thickness are both negative, an increase in either will result in a decrease in growth. Therefore, an optimum point may be found between the two (2) to minimize the growth. The equation for this model would be:

$$\% \text{ increase in width} = 9.02 - 3.13T - 5.07D + 0.63A + 5.03B$$

Where: T = Original plate thickness
D = Original plate density
A = % increase in thickness
B = % increase in height

The goodness of fit, F (4,41), is 58.0915.

The data used in the above regressions pertaining to plate growth and weight loss during sterilization were tabulated and analyzed.

TABLE IV
MODEL FOR REGRESSION ANALYSIS
of
PLATE GROWTH IN WIDTH

Standard Error of Estimate	=	1.27535
Multiple Correlation Coefficient	=	0.921
Goodness of Fit, F (4.41)	=	58.0915
Constant Term	=	9.0163

Variable	Coefficient	Std. Dev. Coeff.	T Value	Beta Coeff
Original Thickness	-3.1281	0.5674	-5.5129	-0.5277
Original Density	-5.0665	0.6076	-8.3375	-0.8486
% Increase in Thickness	0.6269	0.4594	1.3644	0.0978
% Increase in Height	5.0266	0.4265	11.7840	1.0453

2.1 Silver Oxide Electrode (Continued)

It was determined that the percent weight loss ranged from 3.2% to 6.0%. The mean for this range was 4.715% while the median value was 4.8%. The average increase in thickness was 13.56% for a range from 3.44% to 28.57%. The median value was 14.28%. The change in height ranged from 2.90% to 7.00% for an average of 4.61% compared to a median of 4.25%.

In comparing the values for the increase in width, it was determined that the average increase was 9.098% compared to a median of 10.46%. The range was from a low of 4.61% to a high of 13.53%.

Data for weight loss and plate growth may be found in Table V.

The data in Table V substantiates the regression analysis, in that smaller weight losses result in greater increase in growth while the plates with large weight losses have less growth. A cross reference between tables shows that small weight losses are associated with higher densities and large weight losses accompany low density plates.

It is suspected that the weight loss is negligible towards the end of the sterilization cycle. In order to verify this hypothesis, plates shall be sterilized, the growth and weight loss determined, sterilized again, and a final growth and weight loss determined. If suspicions are proven valid, the potential growth and gassing problems may be avoided by sterilizing the plates prior to cell assembly.

A variation in types of positive plates was made by pasting a divalent silver plate using a polyethylene binder. The plates were dried for 30 minutes at 250°F after pasting. However, when attempts were made to sterilize the plates, the polyethylene reduced the divalent silver. The reaction is exothermic so that at the 275°F temperature, it accelerated completely sintering the plate.

To prove the hypothesis that the polyethylene was the failure mode, another strip was pasted and placed in the sterilization

2.1 Silver Oxide Electrode (Continued)

chamber. Containers were also placed in the chamber containing the binder by itself and the mixture used in pasting. Thermocouples were placed in the three test specimens as well as the chamber. The chamber had been stabilized at 135°C prior to insertion of the test articles. Twenty-five (25) minutes after the components were placed in the chamber the thermocouples read 277°F. The readings were recorded. At 27 minutes, the thermocouple reading deflected off scale. The chamber door was opened. The plates had sintered into lumps of silver on the grid wire. The container filled with the binder had been scorched and that of the mixed powder was warm to the touch. No further effort was directed towards this method of making positive plates.

2.2 Zinc Electrode

Zinc plates were electroformed to an average batch weight of 1.0 grams per square inch and pressed to a thickness of approximately .032 inch. The plates were grouped according to plate weight and density. Samples were selected from the group for testing. These were subjected to the sterilization routine. The test articles were weighed and measured before and after sterilization.

There was no apparent physical change after sterilization. As a result of some oxidation taking place, the plate weight increased slightly during sterilization.

These plates shall be discharged during the next reporting period.

Two (2) types of zinc dust were used to paste negative plates. The binder used was polyethylene.

The first group of plates were pasted using #122 zinc dust with the second group pasted with #444 zinc dust. These plates were made to be approximately 1.0 gram per square inch and pressed to an approximate thickness of 0.032 inch. Plates were selected and treated as were the electroformed plates. After sterilization

2.2 Zinc Electrode (Continued)

it was noted that the thickness had decreased slightly. This was considered to be due to a dispersion of the binder within the plate. The individual plate weights increased approximately 1% as a result of the zinc partially oxidizing during the sterilization cycle.

The sterilized plates were fabricated into cells and activated. The open circuit voltages appeared normal with a range of 1.84 volts to 1.87 volts. When the 4.0 amp rate was imposed on the cells, erratic discharges were noticed. The cells reversed and when left in the circuit responded with a satisfactory voltage. The cells continued with intermittent discharges until removal from load.

It was reasoned that the polyethylene binder had sealed off the zinc, limiting the amount of zinc free for reaction. When the free zinc discharged and reversed, the amount of heat created by the high current density discharge and the gassing of the plate broke more zinc free, permitting the cell voltage to return.

2.3 Separation

Testing has been accomplished on several types of separators regarding absorbency and electrolyte retention. The tests were conducted simply to provide a means of comparison of the separators.

The cotton separator (Items 43 through 46 of Table VI) absorbed more electrolyte than any other separators tested. There was a very slight decrease in the amount absorbed by the samples sterilized compared to those unsterilized.

In comparing the asbestos samples, those with the greater amount of electrolyte absorbed were the .030 asbestos. (Items 3 and 4). The 2505 ML Nylon/B separators, (Items 29 and 30) exhibited a marked increase of 300% in absorbency after sterilization.

TABLE V
PHYSICAL CHANGES
in
ELECTROFORMED POSITIVE ELECTRODES
due to
STERILIZATION

Plate No.	Plate Weight		% Wt. Loss	Thickness			Height			Width		
	Before	After		Before	After	% Change	Before	After	% Change	Before	After	% Change
2	8.75	8.28	5.4	.032	.034	6.25	2.00	2.068	3.40	1.625	1.733	6.64
170	8.79	8.34	5.1	.032	.034	6.25	"	2.070	3.50	"	1.715	5.53
172	9.04	8.61	4.8	.031	.036	16.12	"	2.070	3.50	"	1.725	6.15
304	8.17	7.68	6.0	.030	.035	16.66	"	2.058	2.90	"	1.710	5.23
97	8.63	8.16	5.4	.028	.036	28.57	"	2.067	3.35	"	1.715	5.53
271	8.25	7.89	4.4	.028	.034	21.42	"	2.060	3.00	"	1.709	5.16
55	8.04	7.69	4.4	.024	.026	8.33	"	2.068	3.40	"	1.700	4.61
65	8.02	7.63	4.9	.024	.025	4.16	"	2.065	3.25	"	1.710	5.23
113	8.30	7.88	5.1	.027	.029	7.40	"	2.065	3.25	"	1.715	5.53
140	8.61	8.15	5.3	.027	.029	7.40	"	2.070	3.50	"	1.711	5.29
275	8.31	7.89	5.1	.029	.030	3.44	"	2.060	3.00	"	1.715	5.53
102	8.85	8.39	5.2	.029	.031	6.89	"	2.070	3.50	"	1.705	4.92
194	9.23	8.75	5.2	.033	.035	6.06	"	2.070	3.50	"	1.715	5.53
204	9.90	9.37	5.4	.035	.039	11.42	"	2.067	3.35	"	1.720	5.84
75	8.22	7.84	4.6	.025	.026	4.00	"	2.063	3.15	"	1.705	4.92
128	8.77	8.35	4.8	.025	.027	8.00	"	2.073	3.65	"	1.712	5.35
126	8.30	7.90	4.8	.026	.027	3.84	"	2.065	3.25	"	1.715	5.53
51	8.70	8.29	4.7	.026	.027	3.84	"	2.070	3.50	"	1.705	4.92
61	7.91	7.51	5.1	.025	.030	20.00	"	2.090	4.50	"	1.795	10.46
68	8.15	7.79	4.4	.025	.028	12.00	"	2.115	5.75	"	1.798	10.64
39	7.78	7.42	4.6	.026	.031	19.23	"	2.085	4.25	"	1.805	11.07
293	8.01	7.67	4.2	.026	.031	19.23	"	2.100	5.00	"	1.813	11.56
151	8.98	8.53	5.0	.026	.030	15.38	"	2.115	5.75	"	1.790	10.15
228	9.27	8.87	4.3	.026	.030	15.38	"	2.125	6.25	"	1.790	10.15
279	7.78	7.50	3.6	.027	.031	14.81	"	2.092	4.60	"	1.835	12.92
286	8.13	7.87	3.2	.027	.033	22.22	"	2.100	5.00	"	1.825	12.30
149	9.00	8.55	5.0	.027	.031	14.81	"	2.117	5.85	"	1.800	10.76
242	9.17	8.72	4.9	.027	.032	18.51	"	2.125	6.25	"	1.800	10.76
27	7.80	7.46	4.4	.028	.032	14.28	"	2.065	3.25	"	1.805	11.07
36	8.16	7.84	3.9	.028	.031	10.71	"	2.083	4.15	"	1.785	9.84
264	9.06	8.64	4.6	.028	.033	17.85	"	2.130	6.50	"	1.807	11.20

TABLE V (Continued)
PHYSICAL CHANGES
in
ELECTROFORMED POSITIVE ELECTRODES
due to
STERILIZATION

Plate No.	Plate Weight		% Wt. Loss	Thickness			Height			Width		
	Before	After		Before	After	% Change	Before	After	% Change	Before	After	% Change
231	9.39	8.91	5.1	.028	.032	14.28	2.00	2.135	6.75	1.625	1.800	10.76
305	7.85	7.50	4.5	.029	.033	13.79	"	2.076	3.80	"	1.835	12.92
105	8.25	7.84	5.0	.029	.035	20.68	"	2.082	4.10	"	1.845	13.53
266	9.18	8.81	4.0	.029	.035	20.68	"	2.140	7.00	"	1.815	11.69
245	9.74	9.25	5.2	.029	.036	24.13	"	2.140	7.00	"	1.808	11.26
311	8.16	7.81	4.3	.031	.034	9.67	"	2.085	4.25	"	1.840	13.23
299	8.26	7.97	3.5	.031	.035	12.90	"	2.085	4.25	"	1.795	10.46
12	9.09	8.65	4.8	.031	.036	16.12	"	2.122	6.10	"	1.837	13.04
253	9.40	8.94	4.9	.030	.033	10.00	"	2.130	6.50	"	1.800	10.76
183	9.14	8.69	4.9	.032	.038	18.75	"	2.113	5.65	"	1.831	12.67
165	9.18	8.83	3.8	.032	.037	15.62	"	2.093	4.65	"	1.780	9.53
211	9.28	8.86	4.5	.034	.038	11.76	"	2.120	6.00	"	1.795	10.46
193	9.09	8.64	5.0	.033	.040	21.21	"	2.125	6.25	"	1.843	13.41
210	9.45	8.99	4.9	.033	.038	15.15	"	2.123	6.15	"	1.808	11.26
174	10.01	9.54	4.7	.034	.039	14.70	"	2.132	6.60	"	1.840	13.23
N = 46			216.9			623.9			212.1			418.53
		Min.	3.2		Min.	3.44		Min.	2.90		Min.	4.61
		Max.	6.00		Max.	28.57		Max.	7.00		Max.	13.53
		Ave.	4.75		Ave.	13.563		Ave.	4.611		Ave.	9.098
		Med.	4.8		Med	14.28		Med	4.25		Med.	10.46

TABLE VI

ABSORPTION CHARACTERISTICS OF SEPARATING MATERIAL

Item No.	Material Type	Description	Supplier	Dry Wt. (gms)	Wet Wt. (gms)	Absorption by Wt.	of KOH (cc)	Sterilized	Remarks
1	Asbestos	.010 As Rec'd	Johns-Manville	1.20	3.55	1.96	1.81	Yes	
2				1.20	3.97	3.31	2.13	No	
3	Asbestos	.020 As Rec'd	Johns-Manville	2.75	10.20	3.71	5.72	Yes	
4				2.67	9.82	3.68	5.50	No	
5	Asbestos	7410 40% Glass	Raybestos	.55	3.77	5.85	2.48	Yes	
6				.60	3.66	5.10	2.35	No	
7	Asbestos	7410/5 40% Glass	Raybestos	.40	2.85	6.13	1.88	Yes	
8				.41	2.76	5.73	1.80	No	
9	Asbestos	7401 5% Binder	Raybestos	.25	2.00	7.00	1.34	Yes	
10				.25	2.46	8.82	1.70	No	
11	Asbestos	7401/5 5% Binder	Raybestos	.36	3.25	8.02	2.22	Yes	
12				.39	3.60	8.23	2.47	No	
13	Asbestos	7301 Sintered	Raybestos	.30	1.87	5.23	1.21	Yes	
14				.27	1.57	4.81	1.00	No	
15	Asbestos	7301/5 Sintered	Raybestos	.32	1.50	3.69	0.91	Yes	
16				.29	1.30	3.48	0.78	No	
17	Nylon(100%)	Non-Woven KS-900	Kimberly-Stevens	.40	2.66	5.64	1.74	Yes	
18				.48	2.10	3.38	1.24	No	
19	Nylon(100%)	Woven 9031	Stern & Stern	.30	.94	2.13	0.49	Yes	
20				.31	.93	2.00	0.48	No	
21	Nylon/Dynel	75/25 M1406	Kendall Mills	.19	1.70	7.95	1.16	Yes	
22				.23	1.19	4.18	0.74	No	
23	Nylon/B	2504K	Pellon Corp.	.20	1.40	6.00	0.92	Yes	
24				.23	.98	3.26	0.58	No	
25	Nylon/B	2505	Pellon Corp.	.40	3.23	7.08	2.18	Yes	
26				.40	2.50	5.25	1.62	No	
27	Nylon/B	2505K	Pellon Corp.					Yes	See Note 1
28				.39	1.54	2.95	0.89	No	
29	Nylon/B	2505ML	Pellon Corp.	.38	12.52	31.90	9.32	Yes	
30				.47	4.54	8.67	3.13	No	
31	Nylon/B	2506K	Pellon Corp.	.36	1.36	2.77	0.77	Yes	
32				.37	1.03	1.78	0.51	No	
33	Nylon/B	2506ML	Pellon Corp.	.31	2.87	6.75	1.92	Yes	
34				.37	2.87	6.75	1.92	No	
35	Nylon/PP	SM124.3	Kendall Mills	.37	1.00	1.70	0.48	Yes	
36				.43	1.85	3.30	1.09	No	
37	Polypropylene	EM476	Kendall Mills					Yes	See Note 1
38				.12	.28	1.33	0.12	No	
39	Polypropylene	2530	Pellon Corp.					Yes	See Note 1
40				.77	2.73	2.55	1.51	No	
41	Rayon	R75D	Chicopee Mills	.38	3.50	8.20	2.40	Yes	
42				.41	3.87	8.45	2.66	No	
43	Cotton	2409	Kendall Mills	.80	14.00	16.50	10.15	Yes	
44				.92	15.03	16.40	10.83	No	
45	Cotton	2409	Kendall Mills	.79	13.99	16.70	10.15	Yes	
46				.95	15.06	14.80	10.83	No	
47	Hemp	Filpaco 4366T	Dexter	.17	1.59	8.35	1.09	Yes	
48				.17	1.79	9.54	1.24	No	
49	Hemp	Filpaco 4366T	Dexter	.19	1.42	6.47	0.94	Yes	
50				.19	1.69	7.90	1.15	No	

Note 1: Sample destroyed during the Heat Sterilization Cycle

2.3 Separation (Continued)

A relatively high "absorption by weight" was shown by the Hemp samples (Items 47 through 50). However, the amount of electrolyte retained was below average. By comparing the data for sterilized and unsterilized samples of Hemp, it may be seen that the sterilized samples have less absorbency.

Samples of the separator material tested above were cut into 2" x 5" sizes with graduations drawn along the 5" dimension in 1/2" intervals. The material was placed vertically into electrolyte (Sp. Gr. 1.35) with the liquid level at the first graduation. Measurements were taken of the time interval required for the electrolyte to wick to the graduations. The samples used were both sterilized and unsterilized. Results are shown in Tables VII and VIII.

Most of the Nylon and Polypropylene samples sterilized failed to absorb electrolyte above the liquid level. The Nylon/Dynel samples absorbed electrolyte only beneath the liquid level before sterilization. After sterilization the materials would not absorb electrolyte.

The asbestos samples exhibited little change in the material's ability to wick electrolyte. Sterilization apparently had little effect on the absorption properties of the separator. This material apparently has a reasonable capability to absorb and wick electrolyte.

The cotton separators absorbed electrolyte to a height of 1.5 inches in a reasonable time. This separator exhibited the best characteristics as far as absorption and wicking.

2.4 Cell Case and Sealing

Samples of three (3) types of plastics to be analyzed for possible use as a cell case material have been procured. These include polysulfone (3500 Grade, transparent), polycarbonate, and polyphenylene oxide.

WICKING CHARACTERISTICS OF SEPARATION MATERIAL
STERILIZED

Item No.	Material Type	Description	Supplier	Wicking Time (Sec.)				Remarks
				1/2"	1"	1-1/2"	2"	
1	Asbestos	.010 As Rec'd.	Johns-Manville					After 5 Min., 1/8" Rise
2	Asbestos	.020 As Rec'd	Johns-Manville					After 5 Min, 7/16" Rise
3	Asbestos	7410 40% Glass	Raybestos	120	300			Held @ 1-1/4"
4	Asbestos	7410/5 40% Glass	Raybestos	298				
5	Asbestos	7401 5% Binder	Raybestos	300				Held @ 3/4"
6	Asbestos	7401/5 5% Binder	Raybestos	105				
7	Asbestos	7301 Binder	Raybestos	34				
8	Asbestos	7301/5 Sintered	Raybestos					Held @ 7/16"
9	Nylon(100%)	Non-Woven KS-900	Kimberly-Stevens					No wicking
10	Nylon(100%)	Woven 9031	Stern & Stern					No wicking
11	Nylon/Dynel	75/25 M1406	Kendall Mills					No absorption
12	Nylon/B	2504K	Pellon Corp.					No wicking
13	Nylon/B	2505	Pellon Corp.					No wicking
14	Nylon/B	2505K	Pellon Corp.	300				Held @ 7/16"
15	Nylon/B	2505ML	Pellon Corp.					No wicking
16	Nylon/B	2506K	Pellon Corp.					Held @ 1/8"
17	Nylon/B	2506ML	Pellon Corp.					No wicking
18	Nylon/PP	SM124.3	Kendall Mills					No absorption
19	Polypropylene	EM476	Kendall Mills					Failed Sterilization
20	Polypropylene	2530	Pellon Corp.					Failed Sterilization
21	Rayon	R75D	Chicopee Mills	19	70			
22	Cotton	2409	Kendall Mills	33	54	165		
23	Cotton	2409	Kendall Mills	23	45	170		
24	Cotton	2409	Kendall Mills	19	32	70		
25	Hemp	Filpaco 4366T	Dexter					No wicking

TABLE VIII

WICKING CHARACTERISTICS OF SEPARATION MATERIAL
UNSTERILIZED

Item No	Material Type	Description	Supplier	Wicking Time (Sec.)				Remarks
				1/2"	1"	1-1/2"	2"	
1	Asbestos	.010 As Rec'd	Johns-Manville					Held @ 1/4"
2	Asbestos	.020 As Rec'd	Johns-Manville	300				
3	Asbestos	7410 40% Glass	Raybestos	83				
4	Asbestos	7410/5 40% Glass	Raybestos	255				
5	Asbestos	7410/5 40% Binder	Raybestos					Held @ 7/16"
6	Asbestos	7401/5 5% Binder	Raybestos	83				
7	Asbestos	7301 Sintered	Raybestos	55				
8	Asbestos	7301/5 Sintered	Raybestos					Held @ 7/16"
9	Nylon(100%)	Non-Woven KS-900	Kimberly-Stevens	240				
10	Nylon(100%)	Woven 9031	Stern & Stern					No Absorption
11	Nylon/Dynel	75/25 M1406	Kendall Mills					No wicking
12	Nylon/B	2504K	Pellon Corp.	70				
13	Nylon/B	2505	Pellon Corp.					No wicking
14	Nylon/B	2505K	Pellon Corp.	138				
15	Nylon/B	2505ML	Pellon Corp.	45	168			
16	Nylon/B	2506K	Pellon Corp.	42				
17	Nylon/B	2506ML	Pellon Corp.	223				
18	Nylon/PP	SM124.3	Kendall Mills					No wicking
19	Polypropylene	EM476	Kendall Mills					No wicking
20	Polypropylene	2530	Pellon Corp.					No wicking
21	Rayon	R75D	Chicopee Mills	7	23	47	85	

2.4 Cell Case and Sealing (Continued)

The polysulfone was procured as sheet in thicknesses of 1/16 inch, 1/8 inch, and 3/4 inch. Attempts shall be made to devise methods of joining the material by using a solvent seal. Initial tests shall be concerned with a direct soak in methylene chloride. If a quality seal cannot be obtained in this manner, a glue made of polysulfone resin dissolved in methylene chloride shall be used.

Sample joints shall be made for tension tests. Data from these tests should relate the strength of the material with any degradation due to sterilization.

Cell cases shall be fabricated and tested for burst strength before and after sterilization.

Polycarbonate was procured in the same thicknesses as the polysulfone. Work with this material shall parallel that of the polysulfone. Methylene chloride shall be the initial solvent used for joining the test specimen.

Polyphenylene oxide was procured in thicknesses of 1/4 inch and 3/4 inch. The material is Alhalux-400. The same tests shall be performed with this material as the polysulfone with the exception that the material shall be joined with an epoxy.

2.5 Electrolyte Solution Reservoir and Pyrotechnics

Two (2) electrolyte reservoirs were fabricated and filled with a 1.3 specific gravity electrolyte solution. These reservoirs represented two individual designs. The first reservoir was a standard Eagle-Picher Battery BA 472/U electrolyte reservoir. This is a tubular, wraparound, copper coil filled to approximately 93% of capacity with electrolyte. The remaining void is comprised of air. At each end of the reservoir two (2) .004 inch frangible copper diaphragms are employed to retain the electrolyte. A void of approximately 1.5 cc separates the diaphragms at each end. At one end of the reservoir is brazed an adapter

2.5 Electrolyte Solution Reservoir and Pyrotechnics (Continued)

to connect the reservoir to the battery manifold and at the remaining end a holder for the gas generator is brazed. Several points were located on the reservoirs for measurements. These measurements were made along the tubes, across the tubes for the height, along the tube ending with the manifold adapter, and along the tube ending with the gas generator holder.

The reservoir was subjected to sterilization in the 135°C ambient after measurement. Subsequent to sterilization the coil was placed at room ambient and while warm, measurements were taken at the same locations as before. The results are tabulated in Table IX.

The second electrolyte reservoir was a 180° reverse bend tubular reservoir used in the Eagle-Picher GAP 4230 Battery. After being filled to approximately 93% of capacity, the reservoir was measured similar to the first and subjected to sterilization. After sterilization the reservoir was placed at room ambient and measured again while warm. The results are tabulated in Table IX.

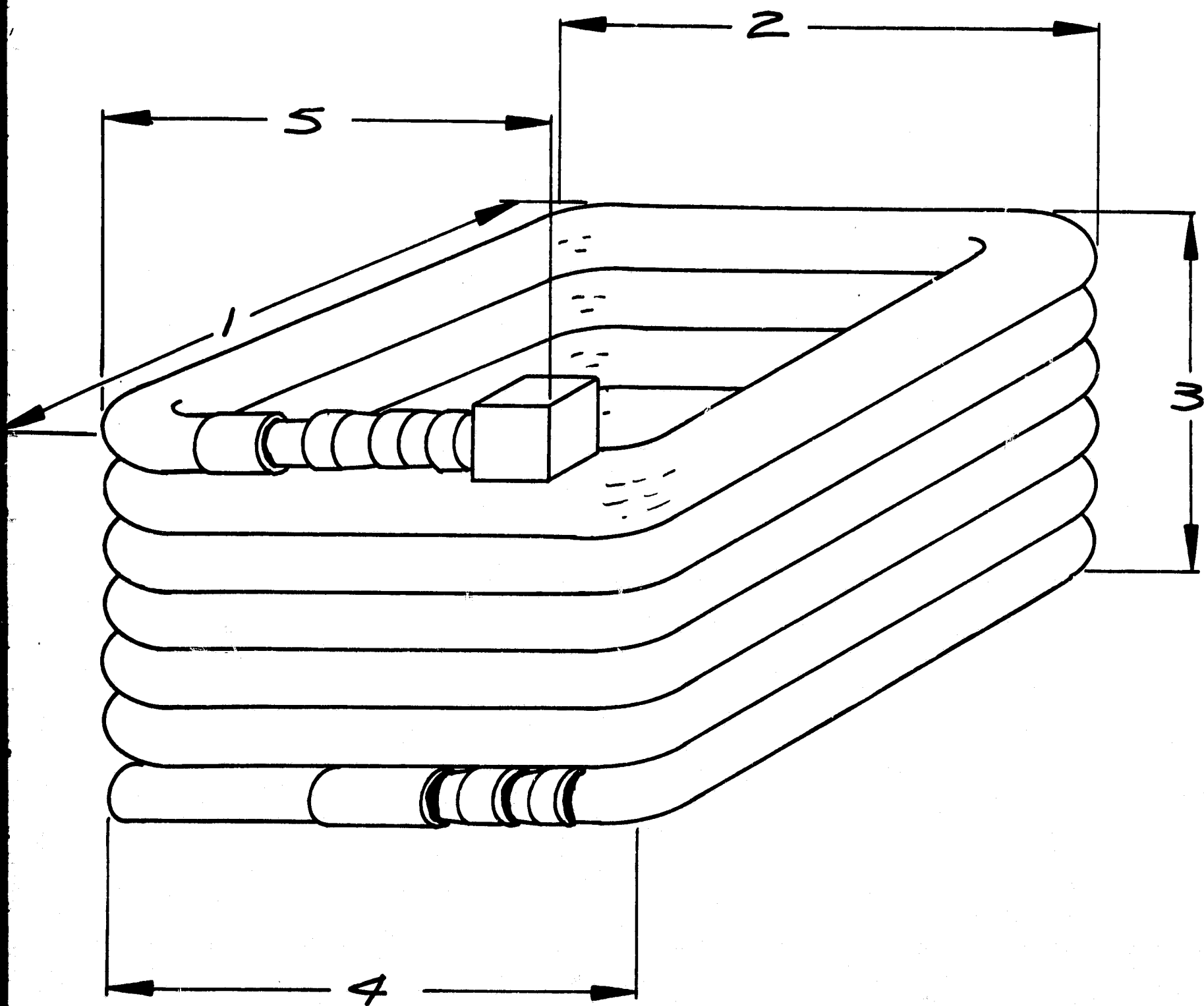
A visual examination of both reservoirs was made before and after sterilization. No deterioration of the copper reservoir was found. The diaphragms restrained without failure the pressure increase due to the elevated temperature. No external leakage was discernible.

Weights were taken prior to and subsequent to sterilization. There was a minor weight loss on both reservoirs. However, the weight loss was attributed to error between scales and counter weights used in measurement.

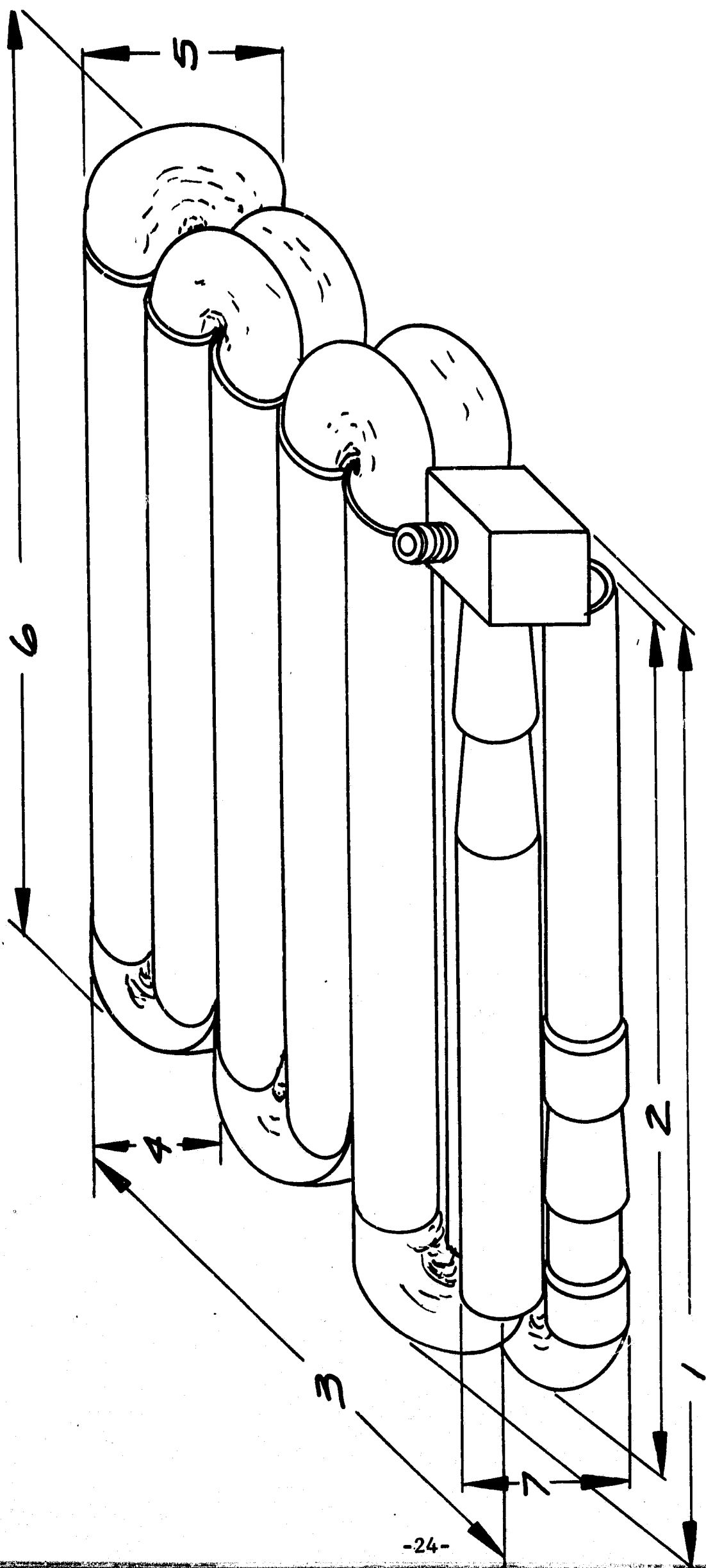
Tests were conducted using several different types of propellants. These included an ammonium perchlorate (X30-50A-2) from Talley Industries, two (2) RTV zirconium potassium perchlorate formulations (LB-PL394-P29 and LB-429D-19) from Atlantic Research, and

TABLE IX
STERILIZATION STUDY OF ELECTROLYTE RESERVOIRS

Reservoir	Dimension	Before Sterilization	After Sterilization (Warm)	% Change	Weight (gms)		% Change
					Before	After	
BA472/U	1	5.691	5.712	+0.37	967	961	-0.62
	2	5.705	5.724	+0.33			
	3	3.090	3.090	0.0			
	4	5.347	5.340	-0.13			
	5	5.050	5.060	+0.20			
GAP 4230	1	5.595	5.600	+0.09	907	896	-1.21
	2	5.390	5.392	+0.04			
	3	3.888	3.920	+0.82			
	4	1.325	1.355	+2.26			
	5	1.263	1.262	0.00			
	6	5.845	5.845	0.00			
	7	1.293	1.310	+1.21			



BA 472 / U



GAP 4230

2.5 Electrolyte Solution Reservoir and Pyrotechnics (Continued)

a polyester styrene ammonium perchlorate (AN583 AF) made by Aerojet General.

The initial tests involved propellants from Talley Industries and Atlantic Research along with N-5 propellant.

Two (2) gas generators were fabricated with each propellant. For redundancy, two (2) Atlas IGN 17 ignitors were used as the initiators. These generators were made of propellants weighing 1.850 grams. Two (2) generators were made using N-5 propellant with the same ignitors. Using the N-5 as a control standard, one each of the generators was tested in a water displacement fixture to ascertain the volumetric output and to determine the pressure and burning rate potential of the propellant.

Essentially, the water displacement fixture is a cylindrical container with a smaller cylinder on the top. The two cylinders are joined by a hole between them. A tube is brought from the bottom to a position slightly above or level with the top of the larger cylinder. The generator is placed in the small cylinder which is then sealed with a cover. Electrical connections are made through the cover with sealed terminals isolated from the cover by an insulator. The larger cylinder is filled with water. Once the cover is in place over the small cylinder (fire tower), the only release to the atmosphere is through the tubing.

The N-5 and Talley X30-50A-2 propellant displaced 1210 cc and 1300 cc of water, respectively. The displacement time was virtually the same for the two generators. A visual examination of the fire tower in the fixture demonstrated that the amount of residue was not excessive. Inspection of the expended gas generators suggested no abnormalities. The propellants had been completely consumed and the internal structure of the generators remained in place.

2.5 Electrolyte Solution Reservoir and Pyrotechnics (Continued)

The generators containing the Atlantic Research propellant displaced 250 cc (LB-PL394-P29) and 230 cc (LB-429D-19). Examination of the test units revealed that the propellant had been expelled from the generator and had extinguished in the water. This would indicate that the burning rates of the propellant were much higher than that of the N-5 and ammonium perchlorate propellants. However, the data was not sufficient to rule either propellant unsatisfactory at this time.

One each of the propellants exclusive of the N-5 was sterilized according to the prescribed requirements. The propellants were weighed prior to and subsequent to sterilization in order to determine the percent weight loss. The propellants were then machined to size and weight for installation into generators. The weight used was based on a proportional weight loss from the 1.850 gram weight previously used compared to that empirically determined.

Each propellant was examined for any physical change subsequent to sterilization. The LB-PL394-P29 propellant had a powder film over the surface. The LB-429D-19 propellant turned from a white color to a pale yellow cast. The X30-50A-2 ammonium perchlorate changed from a burnt orange color to a dark brown.

Generators were constructed with the sterilized propellants. These were tested along with the four (4) remaining sterilized units. The test fixture was the same open water displacement fixture used in the first tests with the addition of a pressure transducer under the water level.

Results of the tests indicate that the Atlantic Research propellants have a higher pressure time relationship than N-5. A comparison of samples numbers 4 and 5 of Table X indicates that the burning rate of the LB-PL394-P29 propellant was increased due to sterilization.

TABLE X
PERFORMANCE OF STERILIZED AND UNSTERILIZED PROPELLANTS
In A
WATER DISPLACEMENT FIXTURE

Sample Number	Propellant	Treatment	Volume (cc)	Displacement Time (Sec.)	Peak Pressure (Psig)	Time to Peak (MS)	Manufacturer
1	N-5	None	1210	3			Naval Ordnance Lab
2	N-5	None	1280	5	6	45	" " "
3	LB-PL394-P29	None	250 ¹	1.5			Atlantic Research
4	LB-PL394-P29	None	1170	4	17	615	" "
5	LB-PL394-P29	Sterilized ²	1000	4	21	35	" "
6	LB-429D-19	None	230 ¹	1.5			" "
7	LB-429D-19	None	1100	4	30	760	" "
8	LB-429D-19	Sterilized ^{2,3}	260 ¹	1	17	775	" "
9	X30-50A-2	None	1300	1.5			Talley Industries
10	X30-50A-2	None	1320	4	15	1760	" "
11	X30-50A-2	Sterilized ⁴	1440	5	12	960	" "

1 - Propellant Expelled into Water

2 - Powder Film on Surface after Sterilization

3 - White color changed to a yellow cast

4 - Burnt Orange Color Changed to Dark Brown

2.5 Electrolyte Solution Reservoir and Pyrotechnics (Continued)

Samples of the three propellants were machined to size along with samples of the Aerojet General propellant. The Talley Industries, Atlantic Research, and two (2) samples of the Aerojet General propellants were subjected to the sterilization cycle. The two (2) Aerojet General cycles were sterilized as fabricated gas generators, while the remaining samples were in propellant form. After sterilization, the samples were fabricated into gas generators and tested in the water displacement fixture. Results of the test can be seen in Table XI.

The Talley Industries propellant (X30-50A-2) depicted a uniform water displacement with peak pressures between 12 and 22 psig occurring in a range of 230 ms to 94 ms. The Atlantic Research propellant (LB-PL394-P29) displaced 950 cc and 960 cc at pressures of 8.5 and 11 psig at times of 1370 and 122 ms, respectively. The LB-429D-19 propellant displaced 850 cc's with a peak pressure of 33 psig occurring at 160 ms.

The Aerojet General propellant indicated relatively little change due to sterilization. The two (2) units which were sterilized displaced water at approximately 1440 cc and 1600 cc with pressures of 19.5 and 37.5 psig, respectively. The times to peak pressures were 370 ms and 1820 ms. The unsterilized units had water displacements of 1430 cc and 1460 cc. The times to peak pressures for these two units were 2240 ms and 2600 ms, with pressure of 13 and 15.5 psig, respectively. Further tests shall be conducted with this propellant to better define the effect of sterilization.

2.6 Cell Test

Two (2) cells were constructed using electroformed positive and negative electrodes separated by 2409 cotton separator as manufactured by Kendall Mills. The cell was designed to have a capacity of 4 ampere-hours. Molded polysulfone cell cases were used to contain the cells. One of the cells was sterilized at

TABLE XI
PERFORMANCE
of
STERILIZED AND UNSTERILIZED PROPELLANTS
in
WATER DISPLACEMENT FIXTURE

ITEM NO.	PROPELLANT	PRESSURE						DISPLACED VOLUME	REMARKS	
		1st Peak		2nd Peak		3rd Peak				
		Time (MS)	Pressure PSIG	Time (MS)	Pressure PSIG	Time (MS)	Pressure PSIG			
1	LB-PL394-P29	40	12	580	5.8	1370	8.5	960	Sterilized Propellant Only	
2	LB-PL394-P29	60	7.5	122	11			950	" "	
3	LB-429D-19	160	33					850	" "	
4	X30-50A-2	180	10	940	22			1330	" "	
5	X30-50A-2	50	8	230	12	2770	12.4	1390	" "	
6	AN583 AF	70	11	2600	15.5			1430	Unsterilized	
7	AN583 AF	120	5.5	1820	19.5			1440	Sterilized as Assembled Generator	
8	AN583 AF	50	7	2240	13			1460	Unsterilized	
9	AN583 AF	170	36	370	37.5			1600	Sterilized as Assembled Generator	
		Note 1:	Items 1, 2, 3, and 4 Propellant Weights were 1.85 grams							
		2:	Item 5 Propellant Weight was 1.800 grams							
		3:	Items 6, 7, 8, and 9 Propellant Weights were 2.00 grams							

2.6 Cell Test (Continued)

135°C. After sterilization the cells were activated with a 1.30 specific gravity electrolyte solution and discharged at a constant 8 amp rate. Neither cell was sealed. Discharge curves are depicted in Figure 1.

The unsterilized cell reached an end voltage of 1.00 volt in approximately 32 minutes, while the sterilized cell dropped below 1.00 volt in approximately 22 minutes. The difference in capacities of the two (2) cells indicated a loss of 31% due to sterilization. Plateau voltages for the unsterilized and sterilized cells were 1.36 volts and 1.33 volts, respectively. The sterilized cells had a lower transient voltage (1.25 volts) than the unsterilized cell (1.35 volts). This would be due to the sterilized cell positive plates being closer to a monovalent level than the unsterilized plates.

The 2409 cotton separator appeared to be in satisfactory condition after sterilization. A slight discoloration was noted, however, indicating some effect from the sterilization cycle.

After discharge the two (2) cells were examined. The negative plates appeared normal for both cells. The positive electrodes of the sterilized cell depicted an even discharge. The plates were a smooth cream color.

The positive plates of the unsterilized cell were not evenly discharged. A small amount of silver oxide was still present on the surface of the plates. However, the available area of discharge was too small to support the rate causing the cell voltage to drop off.

The results of these tests served to illustrate sterilization capabilities. First, the cell materials were shown to be compatible during sterilization. The polysulfone was sterilized dry with no visible effects. No apparent degrading interaction between the separator material and the positive and negative plates had apparently occurred.

FIGURE 1

Discharge Curves for
Sterilized and Unsterilized
Cells

11/27/68 8 Amp Rate

Cell Voltage
(Volts)

Unsterilized

Sterilized

Time
(Minutes)