LABORATORY DISCHARGE STUDIES OF A 6 V ALKALINE LANTERN-TYPE BATTERY EVEREADY ENERGIZER NO. 528, UNDER VARIOUS AMBIENT TEMPERATURES (-15°C AND + 22°C) AND LOADS (30 Ω AND 60 Ω)

S. T. Ahrens
Department of Physics
N. C. A&T State University
Greensboro, North Carolina 27411

(919) 379-7646

ABSTRACT

Using a dual channel chart recorder, the voltages of two Eveready No. 528 batteries--one the test battery, the other the control battery--were simultaneously recorded as they were discharged across 30 Ω loads. The test battery was initially put in a freezer at -15 ± 3°C. After its voltage had fallen to .6 V, it was brought back out into the room at 22 ± 3°C. A second run was made with 60 Ω loads.

Assuming a 3.0 V cut-off, the total energy output of the test battery at -15°C was 26 WHr @ 30 Ω and 35 WHr @ 60 Ω, and the corresponding numbers for the control battery at 22°C were 91 WHr and 100 WHr. When the test battery was subsequently allowed to warm up, the voltage rose above 4 V and the total energy output rose to 80 WHr @ 30 Ω and 82 WHR @ 60 Ω.

INTRODUCTION

During the past three years, while getting our experiments ready, we have spent a considerable amount of time looking for a battery suitable for our payload. Most recently, our attention has been focused on a 6 V alkaline lantern-type battery, the Eveready Energizer No. 528 (.850 kg, 434 cm^3).

Our interest in alkalines was motivated primarily by their generally acknowledged excellent shelf-life, high energy density and minimal hazzard potential. We picked the 6 V lantern-type battery because our power requirements called for the equivalent of many D-size alkaline cells. The 6 V lantern-type with its 4 F-size cells--each F cell being approximately 50% bigger than a D cell--and its rugged construction would thus cut down greatly on the number of electrical connections that would have to be checked out every time these primary batteries had to be replaced. The Eveready brand was chosen because Eveready D-size alkalines had already been successfully used by another GAS user.

In studying the Eveready No. 528, we attempted to answer the following questions:

1. What do the discharge curve and total energy output look like?
2. How are these two characteristics affected by different temperatures and different load levels?

We were able to secure from Eveready a handbook[1] and some data sheets on alkalines. Unfortunately, only very general data was found for the F cells and the 528.

APPARATUS

The setup used is seen in Fig. 1. It consists of a dual channel chart recorder, two decade resistance boxes, two batteries--one the test battery, the other the control battery--and a freezer.

Not shown in the figure is a second chart recorder and two thermocouples used to monitor ambient temperatures of the test and control batteries.

PROCEDURE

Two batteries were chosen at random from an initial collection of a 20 Ω donated by Union Carbide. Both decade resistance boxes were adjusted for 30.0 Ω and checked with a digital multimeter. The control battery was left on the laboratory bench at 22 ± 3°C. The test battery was placed in the freezer at -15 ± 3°C. Both batteries were simultaneously connected to their resistance boxes and their voltages were monitored by digital multimeters and recorded by a calibrated chart recorder set a 1 cm/hr.

When the test battery voltage reached .6 V, it was removed from the freezer and placed alongside the control battery, where the discharge was allowed to proceed uninterrupted. The recording of voltages continued until both were below .6 V.

A second run was then made using the same procedures with two fresh batteries and new load resistances of 60.0 Ω.

RESULTS AND DISCUSSION

The raw data resulting from this study was in the form of curve traces on chart recorder paper. Even at the slowest selectable speed available (1 cm/hr) the output for the 30 Ω discharge was 11 feet long while the output for the 60 Ω discharge was 19 feet long. In order to be able to easily see the major patterns in the discharge curves, the results have been replotted using a highly compressed time scale (Fig. 2). The replotted curves accurately represent the original curves with one exception. Namely, in the original curves below 3.0 V, there were occasional small bumps (up to 2 hrs in duration and .2 V high) and numerous spikes (less than 1 sec in duration and up to .5 V high). The spikes were most abundant in the control battery. Wherever the bumps and spikes were found time averages have been used to simplify the replotting. Above 3.0 V the original curves were all very smooth and thus the replotted curves are very realistic.

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[1] Eveready Battery Engineering Data, Union Carbide, Vol. II, 1982.

The first major feature that can be readily seen in the discharge curves of Fig. 2 is the significantly quicker drop-off rate for the test battery at -15°C. At 30 Ω with a 3.0 V cut-off the control battery lasted for about 6 days, whereas the test battery lasted approximately 2 days. At 60 Ω the same general pattern is seen with the number of days being approximately 13 days and 6 days respectively.

The second, and definitely most surprising, feature seen in the discharge curves of both runs is the rise in the voltage of the test battery from .6 V to over 4.0 V when it was removed from the freezer and put along side the control battery.

Some numerical analysis of the chart recorder data was also done. For each run, a convenient sampling time interval was chosen. For the 30 Ω run quarter days were used; for the 60 Ω run half-days. For each time interval, the average voltage was determined from the chart recorder output. If the discharge was linear over the interval, mid points were used; if the discharge was non-linear, the interval was broken down further into a subset of smaller intervals from which an overall average voltage was calculated. Using the average voltages found, further calculations were done for each interval to give average current, average power and average energy output in amp-hours and watt-hours. In addition, a running total of amp-hours and watt-hours was kept. The results are given in Tables 1, 2, 3 and 4 and summarized in Table 5.

Table 5 shows how temperature affects the 528 Energizer. Again using a 3.0 Ω cut-off, the total energy output of the test battery at -15°C was 26 WHr @ 30 Ω and 35 WHr @ 60 Ω. The corresponding numbers from the control battery at 22°C were 91 WHr and 100 WHr. In addition, when the test battery was subsequently allowed to warm up to 22°C, the total energy output recovered to 80 WHr @ 30 Ω and 82 WHr @ 60 Ω.

CONCLUSION

The performance of the Eveready No. 528:

1. Is severely hurt at the low temperatures used in this study.
2. Improves significantly if the battery is subsequently warmed back up.
3. Is, as expected, greatest with the slowest discharge rate.

ACKNOWLEDGEMENTS

We are grateful to Mr. Wayne Crigler, Visiting Professor of Electrical Engineering from Bell Labs, for helping direct this study. We would also like to thank the students, Mr. Brian Burnette, Mr. Derrick Hood and Ms. Tonya Crawford, who worked so diligently collecting and analyzing this data.

FIGURE 1. BATTERY TESTING LAYOUT

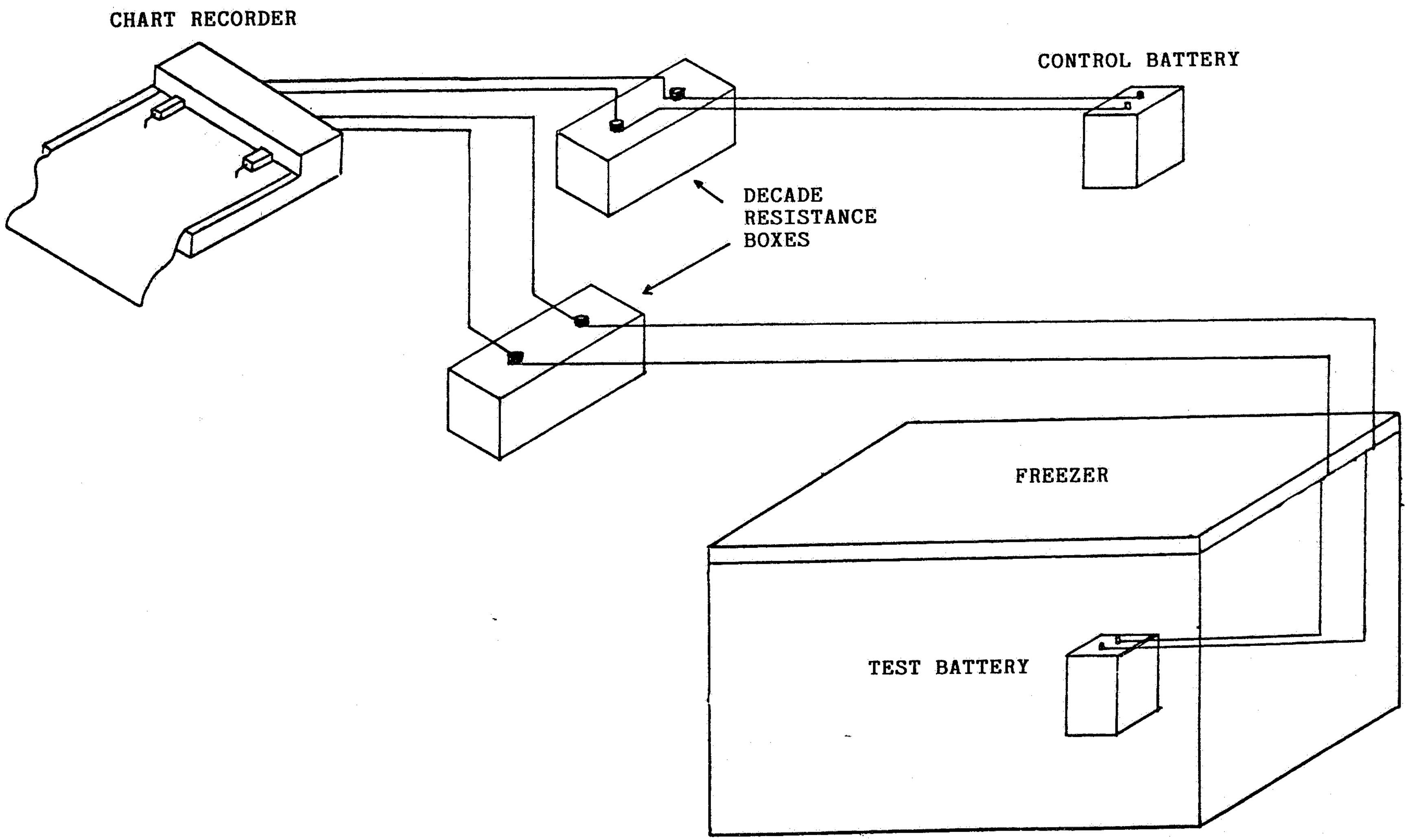

FIGURE 2. REPLOTTED DISCHARGE CURVES: Voltage (Volts) vs Elapsed Time (Days)

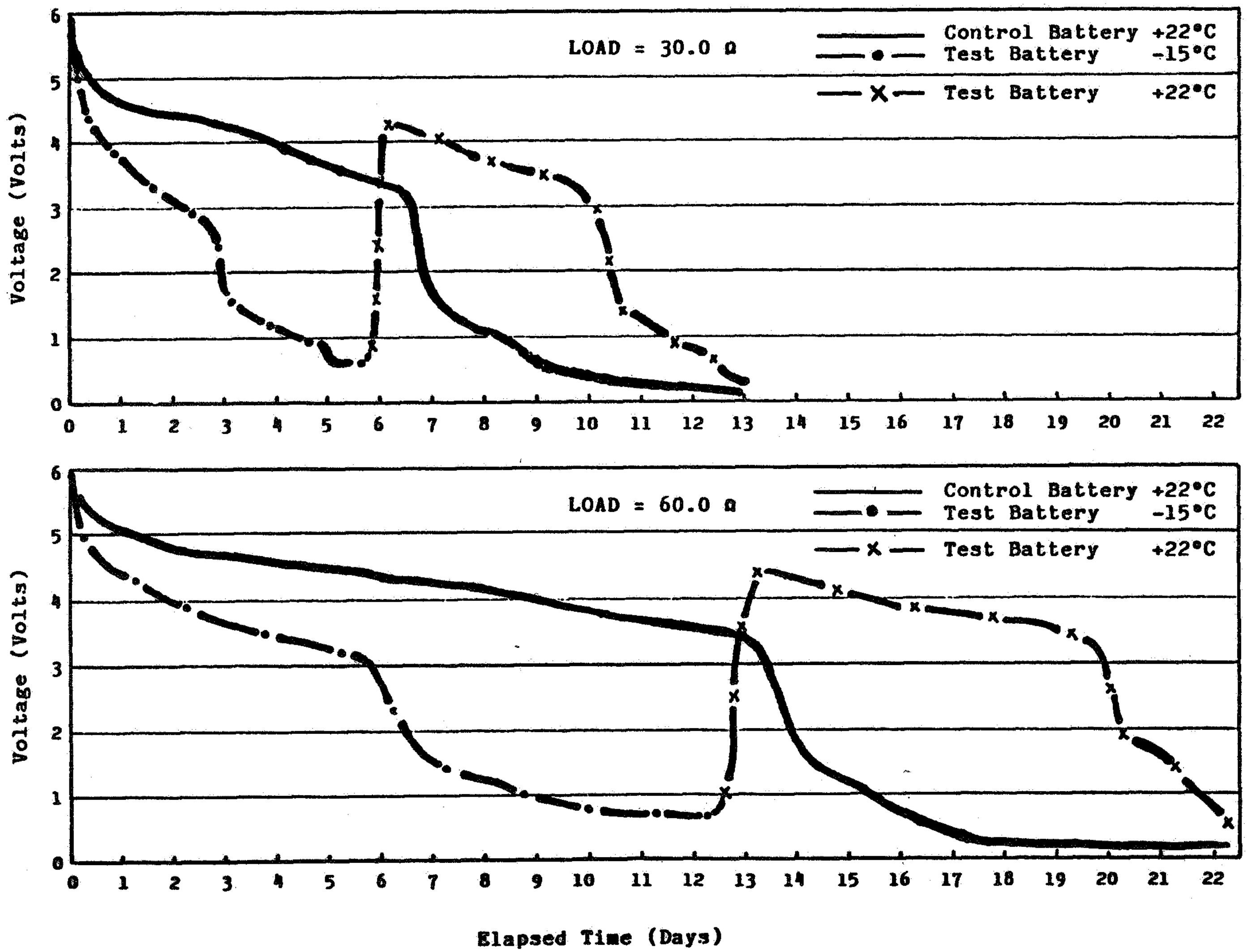

Table 1. Test Battery

Load = 30.0 Ω 1T = 1/4 Day

T	AVG.(V)	AVG.(I)	AVG.(P)	A.H./ T	CUMM.AH	W.H./ T	CUMM.WH
1	4.97V	0.166A	0.823W	0.994AH	0.994	4.940WH	4.940
2	4.38V	0.146A	0.639W	0.876AH	1.870	3.837WH	8.777
3	4.08V	0.136A	0.555W	0.816AH	2.686	3.329WH	12.106
4	3.85V	0.128A	0.494W	0.770AH	3.456	2.965WH	15.071
5	3.63V	0.121A	0.439W	0.726AH	4.182	2.635WH	17.706
6	3.46V	0.115A	0.399W	0.692AH	4.874	2.394WH	20.101
7	3.33V	0.111A	0.370W	0.666AH	5.540	2.218WH	22.318
8	3.20V	0.107A	0.341W	0.640AH	6.180	2.048WH	24.366
9	3.05V	0.102A	0.310W	0.610AH	6.790	1.861WH	26.227
10	2.92V	0.097A	0.284W	0.584AH	7.374	1.705WH	27.932
11	2.78V	0.093A	0.258W	0.556AH	7.930	1.546WH	29.478
12	2.39V	0.080A	0.190W	0.478AH	8.408	1.142WH	30.620
13	1.55V	0.052A	0.080W	0.310AH	8.718	0.481WH	31.101
14	1.45V	0.048A	0.070W	0.290AH	9.008	0.421WH	31.521
15	1.32V	0.044A	0.058W	0.264AH	9.272	0.348WH	31.870
16	1.18V	0.039A	0.046W	0.236AH	9.508	0.278WH	32.148
17	1.06V	0.035A	0.037W	0.212AH	9.720	0.225WH	32.373
18	1.00V	0.033A	0.033W	0.200AH	9.920	0.200WH	32.573
19	0.94V	0.031A	0.029W	0.188AH	10.108	0.177WH	32.750
20	0.91V	0.030A	0.028W	0.182AH	10.290	0.166WH	32.915
21	0.60V	0.020A	0.012W	0.120AH	10.410	0.072WH	32.987
22	0.60V	0.020A	0.012W	0.120AH	10.530	0.072WH	33.059
23	0.60V	0.020A	0.012W	0.120AH	10.650	0.072WH	33.131
24	1.55V	0.052A	0.080W	0.310AH	10.960	0.481WH	33.612
25	4.25V	0.142A	0.602W	0.850AH	11.810	3.613WH	37.224
26	4.25V	0.142A	0.602W	0.850AH	12.660	3.613WH	40.837
27	4.18V	0.139A	0.582W	0.836AH	13.496	3.494WH	44.331
28	4.11V	0.137A	0.563W	0.822AH	14.318	3.378WH	47.710
29	4.03V	0.134A	0.541W	0.806AH	15.124	3.248WH	50.958
30	3.91V	0.130A	0.510W	0.782AH	15.906	3.058WH	54.015
31	3.85V	0.128A	0.494W	0.770AH	16.676	2.965WH	56.980
32	3.77V	0.126A	0.474W	0.754AH	17.430	2.843WH	59.823
33	3.70V	0.123A	0.456W	0.740AH	18.170	2.738WH	62.561
34	3.65V	0.122A	0.444W	0.730AH	18.900	2.665WH	65.225
35	3.60V	0.120A	0.432W	0.720AH	19.620	2.592WH	67.817
36	3.55V	0.118A	0.420W	0.710AH	20.330	2.521WH	70.338
37	3.50V	0.117A	0.408W	0.700AH	21.030	2.450WH	72.788
38	3.45V	0.115A	0.397W	0.690AH	21.720	2.380WH	75.168
39	3.35V	0.112A	0.374W	0.670AH	22.390	2.245WH	77.413
40	3.20V	0.107A	0.341W	0.640AH	23.030	2.048WH	79.461
41	2.95V	0.098A	0.290W	0.590AH	23.620	1.740WH	81.201
42	2.15V	0.072A	0.154W	0.430AH	24.050	0.925WH	82.126
43	1.40V	0.047A	0.065W	0.280AH	24.330	0.392WH	82.518
44	1.38V	0.046A	0.063W	0.276AH	24.606	0.381WH	82.898
45	1.24V	0.041A	0.051W	0.248AH	24.854	0.308WH	83.206
46	1.08V	0.036A	0.039W	0.216AH	25.070	0.233WH	83.439
47	0.91V	0.030A	0.028W	0.182AH	25.252	0.166WH	83.605
48	0.84V	0.028A	0.024W	0.168AH	25.420	0.141WH	83.746
49	0.75V	0.025A	0.019W	0.150AH	25.570	0.112WH	83.858
50	0.65V	0.022A	0.014W	0.130AH	25.700	0.085WH	83.943
51	0.35V	0.012A	0.004W	0.070AH	25.770	0.025WH	83.967
52	0.30V	0.010A	0.003W	0.060AH	25.830	0.018WH	83.985

Table 2. Control Battery

Load = 30.0 Ω 1T = 1/4 Day

T	AVG.(V)	AVG.(I)	AVG.(P)	A.H./ T	CUMM.AH	W.H./ T	CUMM.WH
1	5.35V	0.178A	0.954W	1.070AH	1.070	5.725WH	5.725
2	5.02V	0.167A	0.840W	1.004AH	2.074	5.040WH	10.765
3	4.81V	0.160A	0.771W	0.962AH	3.036	4.627WH	15.392
4	4.70V	0.157A	0.736W	0.940AH	3.976	4.418WH	19.810
5	4.60V	0.153A	0.705W	0.920AH	4.896	4.232WH	24.042
6	4.55V	0.152A	0.690W	0.910AH	5.806	4.141WH	28.182
7	4.50V	0.150A	0.675W	0.900AH	6.706	4.050WH	32.232
8	4.47V	0.149A	0.666W	0.894AH	7.600	3.996WH	36.228
9	4.42V	0.147A	0.651W	0.884AH	8.484	3.907WH	40.136
10	4.38V	0.146A	0.639W	0.876AH	9.360	3.837WH	43.973
11	4.31V	0.144A	0.619W	0.862AH	10.222	3.715WH	47.688
12	4.27V	0.142A	0.608W	0.854AH	11.076	3.647WH	51.334
13	4.25V	0.142A	0.602W	0.850AH	11.926	3.613WH	54.947
14	4.18V	0.139A	0.582W	0.836AH	12.762	3.494WH	58.441
15	4.10V	0.137A	0.560W	0.820AH	13.582	3.362WH	61.803
16	4.05V	0.135A	0.547W	0.810AH	14.392	3.281WH	65.084
17	3.92V	0.131A	0.512W	0.784AH	15.176	3.073WH	68.157
18	3.83V	0.128A	0.489W	0.766AH	15.942	2.934WH	71.091
19	3.75V	0.125A	0.469W	0.750AH	16.692	2.813WH	73.903
20	3.68V	0.123A	0.451W	0.736AH	17.428	2.708WH	76.612
21	3.60V	0.120A	0.432W	0.720AH	18.148	2.592WH	79.204
22	3.54V	0.118A	0.418W	0.708AH	18.856	2.506WH	81.710
23	3.48V	0.116A	0.404W	0.696AH	19.552	2.422WH	84.132
24	3.40V	0.113A	0.385W	0.680AH	20.232	2.312WH	86.444
25	3.32V	0.111A	0.367W	0.664AH	20.896	2.204WH	88.649
26	3.15V	0.105A	0.331W	0.630AH	21.526	1.985WH	90.633
27	2.89V	0.096A	0.278W	0.578AH	22.104	1.670WH	92.304
28	1.81V	0.060A	0.109W	0.362AH	22.466	0.655WH	92.959
29	1.50V	0.050A	0.075W	0.300AH	22.766	0.450WH	93.409
30	1.38V	0.046A	0.063W	0.276AH	23.042	0.381WH	93.790
31	1.25V	0.042A	0.052W	0.250AH	23.292	0.313WH	94.102
32	1.10V	0.037A	0.040W	0.220AH	23.512	0.242WH	94.344
33	1.10V	0.037A	0.040W	0.220AH	23.732	0.242WH	94.586
34	1.00V	0.033A	0.033W	0.200AH	23.932	0.200WH	94.786
35	0.80V	0.027A	0.021W	0.160AH	24.092	0.128WH	94.914
36	0.75V	0.025A	0.019W	0.150AH	24.242	0.112WH	95.027
37	0.53V	0.018A	0.009W	0.106AH	24.348	0.056WH	95.083
38	0.50V	0.017A	0.008W	0.100AH	24.448	0.050WH	95.133
39	0.45V	0.015A	0.007W	0.090AH	24.538	0.041WH	95.174
40	0.45V	0.015A	0.007W	0.090AH	24.628	0.041WH	95.214
41	0.40V	0.013A	0.005W	0.080AH	24.708	0.032WH	95.246
42	0.35V	0.012A	0.004W	0.070AH	24.778	0.025WH	95.271
43	0.33V	0.011A	0.004W	0.066AH	24.844	0.022WH	95.292
44	0.25V	0.008A	0.002W	0.050AH	24.894	0.012WH	95.305
45	0.25V	0.008A	0.002W	0.050AH	24.944	0.012WH	95.317
46	0.30V	0.010A	0.003W	0.060AH	25.004	0.018WH	95.335
47	0.25V	0.008A	0.002W	0.050AH	25.054	0.012WH	95.348
48	0.20V	0.007A	0.001W	0.040AH	25.094	0.008WH	95.356
49	0.20V	0.007A	0.001W	0.040AH	25.134	0.008WH	95.364
50	0.20V	0.007A	0.001W	0.040AH	25.174	0.008WH	95.372
51	0.15V	0.005A	0.001W	0.030AH	25.204	0.004WH	95.376
52	0.10V	0.003A	0.000W	0.020AH	25.224	0.002WH	95.378

Table 3. Test Battery

Load = 60.0 Ω   1T = 1/2 Day

T	AVG.(V)	AVG.(I)	AVG.(P)	A.H./ T	CUMM.AH	W.H./ T	CUMM.WH
1	4.95V	0.082A	0.408W	0.990AH	0.990	4.900WH	4.900
2	4.50V	0.075A	0.338W	0.900AH	1.890	4.050WH	8.951
3	4.30V	0.072A	0.308W	0.860AH	2.750	3.698WH	12.649
4	4.05V	0.067A	0.273W	0.810AH	3.560	3.281WH	15.929
5	3.90V	0.065A	0.254W	0.780AH	4.340	3.042WH	18.971
6	3.70V	0.062A	0.228W	0.740AH	5.080	2.738WH	21.709
7	3.60V	0.060A	0.216W	0.720AH	5.800	2.592WH	24.301
8	3.50V	0.058A	0.204W	0.700AH	6.500	2.450WH	26.751
9	3.40V	0.057A	0.193W	0.680AH	7.180	2.312WH	29.063
10	3.30V	0.055A	0.182W	0.660AH	7.840	2.178WH	31.241
11	3.20V	0.053A	0.171W	0.640AH	8.480	2.048WH	33.289
12	3.05V	0.051A	0.155W	0.610AH	9.090	1.861WH	35.149
13	2.30V	0.038A	0.088W	0.460AH	9.550	1.058WH	36.207
14	1.65V	0.028A	0.045W	0.330AH	9.880	0.545WH	36.752
15	1.40V	0.023A	0.033W	0.280AH	10.160	0.392WH	37.144
16	1.30V	0.022A	0.028W	0.260AH	10.420	0.338WH	37.482
17	1.15V	0.019A	0.022W	0.230AH	10.650	0.265WH	37.747
18	1.00V	0.017A	0.017W	0.200AH	10.850	0.200WH	37.946
19	0.90V	0.015A	0.014W	0.180AH	11.030	0.162WH	38.109
20	0.80V	0.013A	0.011W	0.160AH	11.190	0.128WH	38.236
21	0.78V	0.013A	0.010W	0.156AH	11.346	0.122WH	38.358
22	0.70V	0.012A	0.008W	0.140AH	11.486	0.098WH	38.456
23	0.70V	0.012A	0.008W	0.140AH	11.626	0.098WH	38.554
24	0.68V	0.011A	0.008W	0.136AH	11.762	0.092WH	38.647
25	0.65V	0.011A	0.007W	0.130AH	11.892	0.085WH	38.731
26	2.50V	0.042A	0.104W	0.500AH	12.392	1.250WH	39.981
27	4.40V	0.073A	0.323W	0.880AH	13.272	3.872WH	43.853
28	4.30V	0.072A	0.308W	0.860AH	14.132	3.698WH	47.551
29	4.23V	0.071A	0.298W	0.846AH	14.978	3.579WH	51.130
30	4.10V	0.068A	0.280W	0.820AH	15.798	3.362WH	54.492
31	4.00V	0.067A	0.267W	0.800AH	16.598	3.200WH	57.692
32	3.95V	0.066A	0.260W	0.790AH	17.388	3.120WH	60.812
33	3.85V	0.064A	0.247W	0.770AH	18.158	2.965WH	63.777
34	3.80V	0.063A	0.241W	0.760AH	18.918	2.888WH	66.665
35	3.75V	0.063A	0.234W	0.750AH	19.668	2.813WH	69.477
36	3.70V	0.062A	0.228W	0.740AH	20.408	2.738WH	72.215
37	3.62V	0.060A	0.218W	0.724AH	21.132	2.621WH	74.836
38	3.60V	0.060A	0.216W	0.720AH	21.852	2.592WH	77.428
39	3.45V	0.057A	0.198W	0.690AH	22.542	2.380WH	79.809
40	3.25V	0.054A	0.176W	0.650AH	23.192	2.113WH	81.921
41	1.91V	0.032A	0.061W	0.382AH	23.574	0.730WH	82.651
42	1.79V	0.030A	0.053W	0.358AH	23.932	0.641WH	83.292
43	1.40V	0.023A	0.033W	0.280AH	24.212	0.392WH	83.684
44	0.98V	0.016A	0.016W	0.196AH	24.408	0.192WH	83.876
45	0.55V	0.009A	0.005W	0.110AH	24.518	0.061WH	83.936
46	0.53V	0.009A	0.005W	0.106AH	24.624	0.056WH	83.992

Table 4. Control Battery

Load = 60.0 Ω   1T = 1/2 Day

T	AVG.(V)	AVG.(I)	AVG.(P)	A.H./ T	CUMM.AH	W.H./ T	CUMM.WH
1	5.45V	0.091A	0.495W	1.090AH	1.090	5.941WH	5.941
2	5.15V	0.086A	0.442W	1.030AH	2.120	5.304WH	11.245
3	5.00V	0.083A	0.417W	1.000AH	3.120	5.000WH	16.245
4	4.85V	0.081A	0.392W	0.970AH	4.090	4.705WH	20.950
5	4.75V	0.079A	0.376W	0.950AH	5.040	4.512WH	25.462
6	4.70V	0.078A	0.368W	0.940AH	5.980	4.418WH	29.880
7	4.68V	0.078A	0.365W	0.936AH	6.916	4.380WH	34.260
8	4.60V	0.077A	0.353W	0.920AH	7.836	4.232WH	38.492
9	4.57V	0.076A	0.348W	0.914AH	8.750	4.177WH	42.669
10	4.50V	0.075A	0.338W	0.900AH	9.650	4.050WH	46.719
11	4.46V	0.074A	0.332W	0.892AH	10.542	3.978WH	50.698
12	4.40V	0.073A	0.323W	0.880AH	11.422	3.872WH	54.570
13	4.30V	0.072A	0.308W	0.860AH	12.282	3.698WH	58.268
14	4.30V	0.072A	0.308W	0.860AH	13.142	3.698WH	61.966
15	4.20V	0.070A	0.294W	0.840AH	13.982	3.528WH	65.494
16	4.20V	0.070A	0.294W	0.840AH	14.822	3.528WH	69.022
17	4.10V	0.068A	0.280W	0.820AH	15.642	3.362WH	72.384
18	4.03V	0.067A	0.271W	0.806AH	16.448	3.248WH	75.632
19	3.96V	0.066A	0.261W	0.792AH	17.240	3.136WH	78.768
20	3.85V	0.064A	0.247W	0.770AH	18.010	2.965WH	81.733
21	3.79V	0.063A	0.239W	0.758AH	18.768	2.873WH	84.606
22	3.70V	0.062A	0.228W	0.740AH	19.508	2.738WH	87.344
23	3.65V	0.061A	0.222W	0.730AH	20.238	2.665WH	90.008
24	3.60V	0.060A	0.216W	0.720AH	20.958	2.592WH	92.600
25	3.50V	0.058A	0.204W	0.700AH	21.658	2.450WH	95.050
26	3.45V	0.057A	0.198W	0.690AH	22.348	2.380WH	97.431
27	3.25V	0.054A	0.176W	0.650AH	22.998	2.113WH	99.543
28	2.30V	0.038A	0.088W	0.460AH	23.458	1.058WH	100.601
29	1.45V	0.024A	0.035W	0.290AH	23.748	0.421WH	101.022
30	1.30V	0.022A	0.028W	0.260AH	24.008	0.338WH	101.360
31	1.10V	0.018A	0.020W	0.220AH	24.228	0.242WH	101.602
32	0.80V	0.013A	0.011W	0.160AH	24.388	0.128WH	101.730
33	0.60V	0.010A	0.006W	0.120AH	24.508	0.072WH	101.802
34	0.70V	0.012A	0.008W	0.140AH	24.648	0.098WH	101.900
35	0.30V	0.005A	0.001W	0.060AH	24.708	0.018WH	101.916
36	0.27V	0.004A	0.001W	0.054AH	24.762	0.015WH	101.932
37	0.25V	0.004A	0.001W	0.050AH	24.812	0.012WH	101.945
38	0.22V	0.004A	0.001W	0.044AH	24.856	0.010WH	101.954
39	0.22V	0.004A	0.001W	0.044AH	24.900	0.010WH	101.964
40	0.20V	0.003A	0.001W	0.040AH	24.940	0.008WH	101.972
41	0.20V	0.003A	0.001W	0.040AH	24.980	0.008WH	101.980
42	0.20V	0.003A	0.001W	0.040AH	25.020	0.008WH	101.988
43	0.19V	0.003A	0.001W	0.038AH	25.058	0.007WH	101.995
44	0.19V	0.003A	0.001W	0.038AH	25.096	0.007WH	102.002
45	0.19V	0.003A	0.001W	0.038AH	25.134	0.007WH	102.010
46	0.19V	0.003A	0.001W	0.038AH	25.172	0.007WH	102.017

Table 5. Summary

LOAD RESISTANCE = 30.0 Ω				LOAD RESISTANCE + 60.0 Ω			
TEST BATTERY		CONTROL BATTERY		TEST BATTERY		CONTROL BATTERY	
CONDITIONS	CUMULATIVE WATT-HRS	CONDITIONS	CUMULATIVE WATT-HRS	CONDITIONS	CUMULATIVE WATT-HRS	CONDITIONS	CUMULATIVE WATT-HRS
Freezer (3.0 V cut-off)	26	Room (3.0 V cut-off)	91	Freezer (3.0 V cut-off)	35	Room (3.0 V cut-off)	100
Freezer (.6 V cut-off)	33	Room (.6 V cut-off)	95	Freezer (.6 V cut-off	39	Room (.6 V cut-off	102
Room (3.0 V cut-off)	80			Room (3.0 V cut-off)	82		
Room (.6 V cut-off)	84			Room (.6 V cut-off)	84		