Computer Methods For The Reduction
Correlation And Analysis Of
Space Battery Test Data

By

Dr. J. W. Mauchly

J. H. Waite

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Montgomeryville Industrial Center

Montgomeryville, Pa.

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ABSTRACT

This report describes the computer techniques developed by Mauchly Systems, Inc. on NASA contract NAS-10203, to extract information from large volumes of spacecraft battery test data.

Novel statistical methods (application of cryptanalytic-like processes) have been used to identify failure mechanisms from descriptions of failed cells, and to predict cell life from data patterns hidden in the test data.

Computer programs have been written to reduce the cell test data for a desired interval of time or for any selected measurement parameters, and to produce output documentation easy to understand by the space craft design engineer.

The results of these programs include specific predictions of failure, many thousands of cycles before actual failure, from less than 1000 cycles of data.

INTRODUCTION

1. Background

Secondary batteries used for space power requirements have been investigated in many test programs. Such battery-test programs include acceptance tests, cycling tests (in which batteries are charge-discharge cycled within simulated space-mission requirements), and life-test programs.

Despite the number of these tests, basic engineering information concerning the performance of NiCd Batteries under space-flight operational conditions has been difficult or impossible to obtain. Although large amounts of data have been accumulated, interpretation of such data relative to mission requirements is necessary. Sheer bulk of raw test data without adequate analysis does not help the power engineer, who must make selections and decisions vital to real missions.

Examination of space-battery test programs indicated the need for developing improved methods of (1) selecting cells for space batteries, (2) predicting battery/cell performance within various operational requirements, and (3) determining the magnitude, duration, and dynamics of a new test experiment.

The contract work now being reported is directed toward these objectives. Methods of data reduction and analysis leading to indicators useful for both acceptance and development of improved cells have been devised. Suggestions for better test programs are included.

The data used in this contract come from just one test program--that at Crane N.A.D. Clearly, the methods have broader applicability, but are well illustrated and checked by the data used.

INTRODUCTION (cont'd)

Since about January, 1963, the Secondary Battery Section of the Quality Evaluation Department at N.A.D., Crane, Indiana, has been monitoring and collecting data on sealed nickel-cadmium cells cycled within various environmental parameters.

Cycling consists of charging and discharging cells, repetitively. For purposes of this test, this charge-discharge time period is called an orbit period. These orbit periods and their individual charge-discharge time periods are shown in Table 1.

Every individual orbit period is not recorded. The cycles recorded are determined by the test design as follows:

TABLE 1.

Orbit Period In Hours	Discharge Period In Hours	Charge Period In Hours	Recording Frequency In Cycles
1.5	0.5	1.0	32
3.0	0.5	2.5	16
8.0	1.0	7.0	12
24.0	1.0	23.0	8

The cells are connected in series to form packs of five or ten cells each. The packs are cycled in the ambient temperature and depth of discharge combinations shown in Table 2.

INTRODUCTION (Cont'd)

TABLE 2.

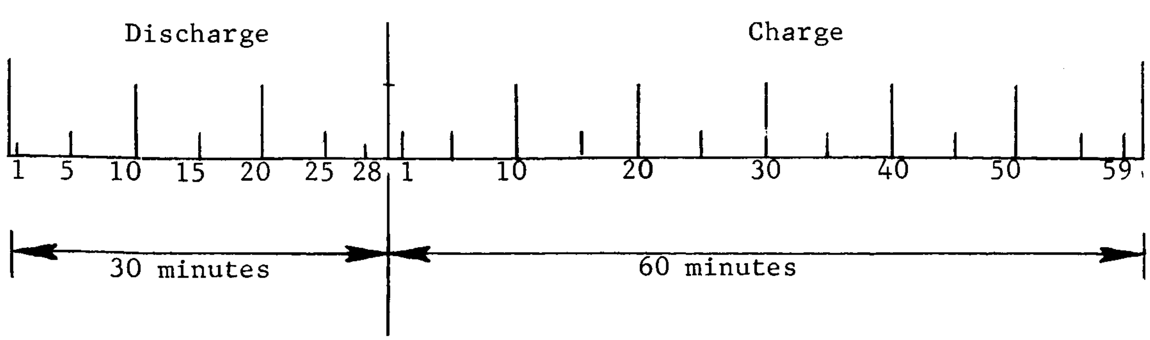
		TEMPERATURE -- DEGREES CENT.			
		-20	0	* 25	40
Depth	15%	X	X		X
of	25%	X	X	X	X
Discharge	40%		X	X	

* 25^{o} ambient was not as well regulated -- just sitting in an air conditioned room.

The packs being cycled are monitored. Individual cell voltage, cell temperature, pack current, pack voltage, the monitoring time after the beginning of the cycle, and pack identification are recorded. A maximum of eighteen battery packs may be monitored simultaneously.

Each of a maximum set of eighteen battery packs is sequentially recorded. The recording of all monitored information for all packs in a set may take one and one half minutes.

Recordings are taken at monitor points during the orbit period. An example of monitor points in a ninety minute orbit period follows:



Time In Minutes

For more detailed explanation of this cycling and recording see N.A.D. Crane Reports.

2. Purpose and Significance

The first purpose of this work is to develop methods, techniques, and computer programs to extract useful and reliable information out of the space battery test data being collected at N.A.D. Crane, Indiana. Several initial assumptions implicit in this approach are:

1. That defects in cells are reflected in their operational behavior long before failure.
2. That the optimum information elements which reflect these defects are not known.
3. That the Crane data do in fact contain information which can be discerned by appropriate reduction and analysis methods.
4. That new methods and techniques are needed, since those used in the past have not been reliable or useful.
5. That the ultimate purpose of this work is to provide the power-engineer with a method to assess the evaluated potentialities of space-battery-cells, permiting cell selection within various space mission operational requirements.
6. That the large volume of Crane data be reduced in order to critically view selected portions of it.
7. That methods be established to facilitate this reduction and yet not distort or eliminate relevant information in the data.
8. That results of this work be reported so as to facilitate the application of new procedures to current battery technology.

Within the framework of analysis, improved methods for collection and handling of the Crane data will be developed.

INTRODUCTION (Cont'd)

Inclusion of a computer in the data acquisition system is recommended. Also, the requirements for an automated test procedure will be analyzed and reported.

This work is significant in that it initializes a new approach to the analysis and evaluation of space battery test data.

3. Problem

A major problem area in this work was the handling of a very large volume of data -- 600,000 punched cards. Some reduction of this volume had to be made to allow critical scanning to detect differences which might be relevant. In making such reductions, a prime aim is to avoid distortion or elimination of relevant features of the data. When data reduction of this sort is possible, there are actually several advantages. Reduction aids in:

1. Simplifying subsequent analysis.
2. Development of statistical methods for cell-failure prediction.
3. Reducing the cost of repeatedly processing the large original files which may contain irrelevant or redundant information, or both.
4. Development of methods suited to an automated data management system, including logging, reduction and analysis.

Reduction, in this case, produced 20,000 punched cards from the original total of 600,000 punched cards.

During the reduction process, certain problem areas were identified and dealt with. These problem areas include:

1. Cards out of order.
2. Missing cards.
3. Duplicate cards.
4. Data errors.

The computer programs used to accomplish data reduction were designed to check for various types of errors, to take action to eliminate those which were easily corrected, and to produce error messages showing what type of error was encountered. With some error types, for example -- "Cards out of order", an option permitted operator intervention (to re-sort the cards), to correct error condition.

4. Method

The approach used in the development of this work was to consider all of the 600,000 data cards, the domain to be analyzed, and to work from this whole body of information downwards into the individual pieces as differences were identified. This orientation, examining the data and working back into it to identify and correlate its separate parts, required the fewest assumptions.

It was determined that cell voltage first-differences included much vital information regarding cell behavior and incipient failure voltage patterns. This determination produced the 5-cycle Delta-Volt-Histogram Program, described in the Appendix of this report. This program used the Crane data as input and produced, as output, 5-cycle Delta, or first difference, Voltage Histograms. These Histograms contain all of the voltage difference information for each identified cell for a set of 5 observed cycles of information. This program extracted pertinant voltage data and effected a data reduction, Crane data to 5-cycle data, of 30 to 1.

Analysis of the 5-cycle Histogram output enabled a cell-failure prediction technique described in Section III of this report.

Another computer program for reduction and analysis of the Crane data is the Superposed Curve-pattern Indicator Program. This program creates overlayed or superposed sets of charge-discharge cycle curves. These are then examined for patterns which might be associated with a history of high occurrance in failed cells. This program is fully described in Section II of this report.

5. Organization

The material in this report is presented in four Sections and five Appendices.

Section I covers data collection and Appendix A contains referenced data-collection charts.

Section II covers data analysis and reduction and Appendix B contains referenced charts.

Section III covers cell failure prediction and Appendix C contains failure prediction charts and other referenced material.

Section IV is conclusions and recommendations.

Appendix D presents a data reduction method; the 5 cycle-Delta-Volt-Histogram Program.

Appendix E contains cell failure histories.

SECTION I

DATA COLLECTION

Data Collection is defined as the acquisition and recording of test measurements from the analog signal to the printed digital record.

Examination of Sample Data Collected in the Crane NICD Battery Life Test. Appendix A contains the data sheets for 40 out of an elapsed time of 1200 cycles of data on ten cells which represent Battery Pack #62. This pack was still on test as of December, 1966, and reached the elapsed cycle count of over 15,000 cycles. It is estimated that the total data for the hundred-plus packs on test will involve some 18,000 pages of data, such as those found in Appendix A. Some of the data sheets contained are repeated here to assist in the discussion of the techniques used to obtain usefull information from this vast store of data. Areas of interest on these data sheets have been marked and annotated for their significance. It is important to note that the type of inspection to be discussed is limited to a "one-measurement-at-a-time" kind of perusal. It is equivalent to looking at curve plots of charge-discharge cycles one at a time; however, the printed data in Appendix A does give some additional information requiring computation plus some additional environmental and identifying information. From the small sample of data presented in Appendix A, eight types of information "flagged" in the data sheets are listed below.

Type of Observation	Place of Occurrence
	Page:
1. High End of Charge Reading	1. 44 thru 48
2. Low End of Discharge Reading	2. 45
3. Data Transcription Errors	3. 46
4. False Cut-In of Charge Limiter	4. 44
5. End-of-Chg Cut-In of Chg. Lim.	5. 45, 46, 47
6. Low Current on Pack	6. 48

It is interesting to note from the flagged data in Appendix A that cells exhibiting these points of interest result in the identification of cells 2, 4, 5, 10 as being suspect. Actually, cells 4, 5, 7, 10 failed on test, but thousands of cycles later.

In order to facilitate reading of Appendix A, a short description of the output is presented here. The first column of figures on page 44 , (shown on the following page) starting at the top left hand side of the page with 1.0, are time measurements and fractions. The data for five cells are recorded on one punch card or one line of the tabulation. When the pack contains ten cells, two punched cards are used with the same time and cycle data given on both cards. The last number of each row is always a '1' or a '2' (for 10 cell packs), indicating the first card which holds data for cells 1 thru 5, or the second card which holds the data for cells 6 thru 10.

Time periods range from 1.0 to 90.0 minutes for the 1½ hour orbits, with thirty minutes for discharge and sixty minutes for charge. Discharge readings are made on the average of every five minutes, and charge readings are made on the average of every ten minutes. There is some variation in the clocking of these readings, so that curve plotting and analysis complications arise. This clocking problem also effects the number of points or readings obtained in some cycles. Interpolation techniques could be used to correct this problem, but they were not considered in this phase of the work for they involve assumptions not justified at this stage.

The clocking time distributions are illustrated on the following page (page 49 of Appendix B) in the top block for 3970 cycles of information. (Elapsed cycle time). From such distributions, it is estimated that 60% of the clocking times are correct for the middle portions of the charge and discharge curves. For the terminal portions of the curves the readings are not as good. For future data acquisition data on cells 1-5

data on cells 6-10

Monitor Time	Elapsed Cycle	Pack #	Pack volt	Pack cur.	Cell Voltages					Cell Temperatures					Ambient temp.
1.0	1.	62	14.29	3.10	139	141	140	140	141	-.9	-1.1	-.8	.0	-.8	-4.51
1.0	1.	62	14.29	3.10	140	140	140	140	140	-1.0	-1.5	-.9	-1.3	-1.3	-4.52
5.6	1.	62	13.73	3.13	133	135	135	134	134	-1.5	-1.3	.4	-1.1	-1.1	-3.31
5.6	1.	62	13.73	3.13	135	135	134	134	135	-.3	-.4	-.5	1.0	-.5	-3.32
10.5	1.	62	13.34	3.04	130	131	132	130	130	-1.7	.2	-.3	-.1	.0	-2.31
10.5	1.	62	13.34	3.04	131	131	130	131	131	1.0	-25.1	.8	1.0	-.3	-2.32
15.6	1.	62	13.09	3.01	128	128	129	128	128	.4	.4	.6	.6	2.0	-1.31
15.6	1.	62	13.09	3.01	129	128	128	129	128	2.0	.8	-.1	.1	.4	-1.32
20.6	1.	62	12.89	3.00	126	126	127	125	126	1.4	.8	1.6	1.4	2.4	-.61
20.6	1.	62	12.89	3.00	126	126	126	126	126	1.0	.6	.6	2.2	-.7	-.62
30.0	1.	62	12.67	2.99	124	124	125	123	124	-.8	-1.1	.1	-.7	1.0	-3.51
30.0	1.	62	12.67	2.99	124	124	124	124	123	-.0	.0	.4	.2	-1.3	-3.52
32.6	1.	62	13.48	1.72	131	132	132	131	132	.1	.3	.6	1.5	2.9	-2.41
32.6	1.	62	13.48	1.72	131	131	132	132	132	.6	.4	.6	1.4	.6	-2.42
41.8	1.	62	14.00	1.73	137	137	137	137	138	.2	1.1	.8	1.2	1.6	-1.31
41.8	1.	62	14.00	1.73	137	137	137	137	137	.6	1.3	.6	.8	.4	-1.32
50.6	1.	62	14.34	1.71	140	141	140	140	141	-.8	-.5	.0	.0	-1.1	-3.71
50.6	1.	62	14.34	1.71	140	140	140	140	141	-.6	.8	-.8	-.3	-.5	-3.72
60.6	1.	62	14.72	1.51	143	144	144	144	145	.8	.0	-2.8	-.1	-1.3	-3.11
60.6	1.	62	14.72	1.51	143	144	144	144	145	.0	-3.9	.0	-1.5	-.4	-3.12
70.6	1.	62	14.99	1.03	146	147	147	147	147	3.1	3.1	1.1	-5.5	1.1	2.91
70.6	1.	62	14.99	1.03	146	146	147	146	148	-6.9	1.1	1.0	-15.9	-11.7	2.92
80.6	1.	62	15.23	.71	148	149	149	149	149	-42.8	41.7	-13.9	77.0	-41.2	-6.91
80.6	1.	62	15.23	.71	148	148	149	148	152	3.3	3.1	77.2	-11.7	-15.9	-6.92
89.6	1.	62	15.89	.87	152	156	153	158	157	37.7	77.1	75.4	-85.2	39.6	-2.81
89.6	1.	62	15.89	.87	154	156	157	152	$\boxed{161}$	-86.8	39.6	4.0	3.2	-86.8	-2.82
1.4	31.	62	14.25	3.04	140	140	140	140	140	-2.5	-3.3	-3.9	-3.0	-3.3	-3.31
1.4	31.	62	14.25	3.04	140	140	140	140	140	-4.7	-3.1	-3.2	-2.1	-2.6	-3.32
5.9	31.	62	13.63	3.04	133	134	134	133	133	-2.1	-3.5	-2.5	-3.9	-1.9	-2.71
5.9	31.	62	13.63	3.04	134	134	133	134	134	-2.3	-3.3	-2.3	-1.9	-3.1	-2.72
10.5	31.	62	13.22	3.03	129	130	130	129	129	-1.6	-1.1	-1.9	-1.9	-1.3	-2.01
10.5	31.	62	13.22	3.03	130	130	129	130	130	-1.7	-1.7	-1.5	-1.3	-.9	-2.02
15.5	31.	62	12.96	3.01	127	127	127	126	126	-.7	-1.1	-.8	-3.1	-1.3	-1.61
15.5	31.	62	12.96	3.01	128	127	127	127	127	-1.1	-1.1	-1.6	.8	-.4	-1.62
20.6	31.	62	12.68	3.00	126	126	126	124	125	-2.7	-3.3	-2.9	-2.7	-2.9	-4.31
20.6	31.	62	12.68	3.00	126	126	125	126	125	-2.8	-3.6	-2.6	-2.1	-2.5	-4.32
25.5	31.	62	12.62	2.99	124	124	124	123	123	-2.2	-3.5	-3.9	-1.6	-1.9	-3.51
25.5	31.	62	12.62	2.99	124	124	123	124	123	1.0	-3.3	-1.5	-.9	-3.3	-3.52
29.7	31.	62	12.43	2.97	123	123	123	121	121	.6	-1.1	-.5	.3	1.4	-1.31
29.7	31.	62	12.43	2.97	123	123	122	123	122	1.2	-.1	.0	.8	-.7	-1.32
35.3	31.	62	13.51	1.74	132	133	132	133	133	.2	-.3	-.3	1.4	.4	-1.51
35.3	31.	62	13.51	1.74	132	132	132	132	133	1.6	.8	.8	.6	.4	-1.52
40.6	31.	62	13.79	1.75	135	136	135	136	136	.2	.0	.2	.4	.8	-1.31
40.6	31.	62	13.79	1.75	135	135	135	135	136	.3	.8	.6	1.2	.2	-1.32

odd numbered rows contain data on cells 1 - 5

even numbered rows contain data on cells 6 - 10

early cut-in of charge limiter

high end of charge-cell #10

EXAMPLE OF CRANE DATA

```
IST.TIME DIFF.  1   2   3   4   5   6   7   8   9  10
 62 3970  93        .                       .     1                    .             01 DT
 62 3970      1     210 7193511 8           .                          .             02 DT
 62 3970  3         1 2   2 51744 5     1 1                            .             03 DT
 62 3970  2         . 1 4   71261 3 5 1 1     1                        .             04 DT
 62 3970            1   1 2 52457 4 2 1 .         1   1                .             05 DT
 62 3970  2 1       1 2 1 2 12260 3 3   1                              .             06 DT
 62 3970          2 1 21116241440 1 7 2 .         1                    .             07 DT
 62 3970  1     110352714 7 1           1                              .             08 DT
 62 3970            .   2     1 2 2 2 7 110361617 2 1                  1             09 DT
 62 3970  1       1 1   1   3       1   1 1   4  2857 1 1 2 .             10 DT
 62 3970  2 1 1     .   1   1       1 1 . 1 1 1  1968 3 1   .             11 DT
 62 3970            1 1     2 2         .     1 12065 3   3 1      1      12 DT
 62 3970            .   1   1   1   2   .   3   22063 4     .             13 DT
 62 3970      3     .         1     1   1 522132910 9       .             14 DT
```

DISTRIBUTION OF TIME DIFFERENCE

work, this is one area where much tighter control will be desired. Also, as a result of work done to date, and conferences with others doing tests, it is clearly evident that more points should be monitored.

The next column of numbers, starting with 1. and ending with 31. represents the actual cycle count from which the data was taken. The test required that approximately every thirtieth cycle (every 2nd day) be monitored, which represents an initial loss of data of over ninety percent. For life-test monitoring, this is not a restriction, but with a computer analysis requirement this is not the place for any reduction to be imposed. One test facility in the country, already monitors every cycle of data collected, and transcribes this to magnetic tape. Even if one does not choose to print out every cycle of data monitored, it may be stored on magnetic tape for permanent reference.

In the next column of figures of the Appendix A data, the number 62 represents the pack number.

The next column of numbers, starting with 14.29, represents pack voltage. The pack voltage is an operating parameter of the charge system. During this phase of the analysis, no work was done with pack voltage information. It is important to use this information in future work.

The next column, starting with 3.10, represents the pack current, in amperes, which was set for an upper limit at a fixed level of about 3.0 for discharge and 1.7 for charge. When the charge limiter cuts in, the current readings are depressed.

The next five columns which read across as: 139, 141, 140, 140, and 141, represent the readings for cells 1 thru 5 multiplied by 100. The voltage readings for cells 6 thru 10 are found in the following row directly under those for cells 1 thru 5. Most of the work in this report concerns these measurements. Packs have either five cells or ten cells.

An analysis of cell position in a pack, compared to failure distribution, did not indicate any particular effect of cell position in the pack upon cell performance.

Voltage measurements on a clocked time increment are the customary procedures in all test facilities but one. This one facility uses specific voltage change increments computed from the total range to initiate readings. This dependence of measurement clocking on precalculated conditions and levels is an interesting aspect of an on-line test-data acquisition system.

The next five columns on the Appendix A data sheet, which read - .9, -1.1, - .8, 10, - .8, are cell temperature readings for cells 1 thru 5. Similar measurements for cells 6 thru 10 appear directly below in the following row. The strange readings which occur at the end of charge appear (marked EOC) to be caused by signal noise from the charge limiter cut-in. Temperatures were analyzed in this work in the hopes that a correlation between voltage behavior and temperature behavior would help in the cell performance prediction. It was observed, however, that voltage symptoms of trouble always preceded any temperature ones, so that most of the temperature work was restricted to an analysis of the accuracy of temperature measurement control.

The last column of data which starts with -4.51 represents the ambient temperature plus a final digit which is a card designation number as described before.

1.3 Computer Programs Prepared For The Data Collection Phase.

The following computer programs were written for the data collection phase of the project:

Program Name and Description	Where Written
1. Voltage Cycle Plot Program (A RCA-301 program which takes edited charge-discharge readings and draws the plot)	1. RCA - 1st phase

Program Name and Description	Where Written
2. Temperature Plot Program (An IBM-1620 program which takes cell and pack temp. measurements and lists the points of plot on a page grid	2. Mauchly Systems 2nd Phase
3. Test Data Edit Programs (These programs are composed of a set of six. Three by RCA to handle data on magnetic tape formated for Fortran, Machine language, and retrieval purposes, resp.) Three are by Mauchly Systems to print out test data with all card handling and data errors removed, a separate listing of all errors and corrections, and a Fortran format data edit program.	3. RCA-1st phase Mauchly Systems (2nd phase)
4. Paper-Tape to Card Transcription Program (This program takes the digitalized test data from paper tape into the IBM-1620 computer, or IBM-360 and produces punched card outputs.	4. Crane-2nd & 1st phase
5. Card to Magnetic Tape Conversion Program (This program converts the Crane cards to RCA-301 and IBM-7090 magnetic tape.)	5. RCA-1st phase U of Pa-2nd phase

1.4 Conclusions and Recommendations for Data Collections

As a result of the work done to date, the following recommendations are made:

1.) Every cycle of data should be monitored and recorded on magnetic tape. There is no reason with data acquisition equipment presently available to eliminate any data at the source.

2.) The number of points per curve which are monitored should be increased to the maximum compatible to the flow rate of the acquisition system. (One organization conducting an on-line test has allocated 20 points for a half hour discharge.)

3.) A computer should be included in the Data Acquisition System. It should feature a programmable clock, two magnetic tape channels, a word size of 16 bits and an input bit rate capable of handling 2500 measurements per minute. (Three decimal digits/measurement.)

4.) Increase the parameters measured on each cell. These should include internal pressure, impedance, and capacitance calculations on line) percent of over-charge, auxiliary electrode voltages, reference electrode voltages, and perhaps some special parameters.

5.) Include a standard cell test-point to automatically check the analog-digital calibration.

6.) Include an automatic shut-off feature for individual cells that exceed selected thresholds, with a manual or automatic switch-in option.

7.) In addition to the measured information on each charge-discharge cycle which is stored for the cells, a Header Block of initial input data should be included which provides background information on the cell, such as, manufacturer's rated characteristics, test conditions under which the cell is being operated, design features, and a performance rating for cell at certain cycle life times. This Header Block will then permit automatic cell selection and automatic report summaries.

SECTION II

DATA ANALYSIS AND REDUCTION

Data analysis and reduction is defined as the identification and extraction of essential elements of information. In this case, reduction produced 20,000 punched cards from a total of 600,000 punched cards.

The formal analysis of the test data is important, since cell design and acceptance has been completed for the cells under test. Failure mechanisms and cell defects can be identified and analyzed. This information can be applied to the design and manufacture of new cells to effect a longer operational life. A major objective of this analysis is the development of statistical methods for prediction of cell and/or pack failure as a function of failure characteristics and operating constraints. In addition, other important objectives which are closely associated with the data analysis are also to be considered. These additional objectives include:

1.) The association of data characteristics to certain failure modes.

2.) The development of methods for presentation of battery data for more informative reporting of results.

3.) "To develop" improved methods for the collection and handling of the Crane data.

4.) "To develop" mathematical models related to battery tests as practicable and useful to the battery user.

5.) The determination of operational test system limitations under various environmental and operational extremes.

6.) The mechanization of an automatic life-test reporting system for periodic management review and evaluation.

These new objectives, however, affect the whole data collection system since not only are more parameters desirable, but also, more measurements are required to permit more precise control.

Other purposes for analyzing and reducing the data are to develop an Automated Data Management System and to reduce the cost of repeatedly processing large volumes of redundant information.

The problem associated with the selection of any procedure to reduce the data is to make certain that essential information is not lost in the data reduction process. This requires that clean distinction between redundant data and new information be made. The important question is: What are the correct elements of information? It also involves several initial assumptions:

1.) That defects in cells are reflected in their operational behavior long before failure.
2.) That the optimum information elements which reflect these defects are not known.
3.) That the Crane Data is sufficient to establish a new perspective in Battery Data Analysis.

It must always be kept in mind that no statistical technique can reveal information not inherent in the data.

The approach used in the development of this work was to consider all of the 600,000 data cards the domain to be analyzed, and to work from this whole body of information downwards into the pieces as differences were identified. This orientation required the fewest assumptions.

Another problem one encounters in trying to implement this approach is that of handling the large volume of data. Some reduction of this volume must be made in order to critically view a portion of it, and yet this reduction must not distort or eliminate any part of the data. The technique selected to accomplish this for cell voltage histories was one of superposing charge-discharge curves upon one another. If, in fact, ten or more charge-discharge curves were all the same, then the resultant superposed curve of all of them would look exactly the same as any one of them. Pages B 49 thru B-50 of Appendix B illustrates 93 superposed curves for ten cells of pack 62. This data corresponds to the data described in Appendix A-45 thru A-48 , except that it represents ten times as much more.

In order to continue with references to actual test data, a short description of Page B-49 (Pages B-49 to B-50 reproduced on the following page) of Appendix B will now be provided. A complete set of the data sheets is provided in Appendix B of this report.

DIST. TIME DIFF., represents the distribution of timing intervals for each of fourteen points monitored on a charge-discharge curve. The first seven rows are associated with the discharge portion of the curve, and the last seven rows are associated with the charge portion of the curve. The numbers, from 1 to 10, on the top row refer to actual minutes between two consecutive points monitored. The 3970 which is repeated for every row is the number of elapsed cycles reached in order to obtain 93 cycles of information. Crane monitors every thirty-second cycle of measurement in general. The numbers found between the cycle number, 3970, and the monitoring point numbers, 1 thru 14, on the right hand side of the page are counts of frequencies of occurrence of time

```
DIST.TIME DIFF.  1    2    3    4    5    6    7    8    9   10
   62 3970   93          .                   .       1            .            01 DT
   62 3970      1        210 7193511 8       .                    .            02 DT
   62 3970   3           1 2   2 51744 5   1 1                    .            03 DT
   62 3970   2           . 1 4   71261 3 5 1 1    1               .            04 DT
   62 3970               1   1 2 52457 4 2 1 .        1    1      .            05 DT
   62 3970   2 1         1 2 1 2 12260 3 3   1                    .            06 DT
   62 3970            2 1 21116241440 1 7 2 .         1           .            07 DT
   62 3970   1     110352714 7 1             1                    .            08 DT
   62 3970               .   2      1 2 2 2 7 110361617 2 1       1            09 DT
   62 3970   1      1 1    1    3        1   1 1   4   2857 1 1 2 .            10 DT
   62 3970   2 1 1   .     1    1        1 1 . 1 1 1   1968 3 1   .            11 DT
   62 3970               1 1      2 2        .     1 12065 3   3 1      1      12 DT
   62 3970               .   1    1    1    2    .  3   22063 4  .            13 DT
   62 3970      3        .          1        1   1 522132910 9    .            14 DT


  VOLTS X 100...   120                  140                  160               TP CLN
   62 3970               .          1   4 1265012             .               01 03
   62 3970               .     1 1 73444 6   .                .               02 03
   62 3970               .   2 84125 5       .                .               03 03
   62 3970   1           . 2254225 3         .                .               04 03
   62 3970               2264425 2           .                .               05 03
   62 3970            1 6223830 2            .                .               06 03
   62 3970         713215124 4 1             .                .               07 03
   62 3970               .    205617 4       .                .               08 03
   62 3970   1           .          82654 9 2 .               .               09 03
   62 3970               .            1  295023 1             .               10 03
   62 3970               .                1 4255617           .               11 03
   62 3970               .                  1 2 1274225 3     .               12 03
   62 3970               .                   . 1 1 3 7 520212711 1 1          13 03
   62 3970               .                   .   1 1    72721 6 6 7 6 3 8 2   14 03

  VOLTS X 100...   120                  140                  160               TP CLN
   62 3970               .          3 9 6174018 1             .               01 04
   62 3970               .      4143434 7    .                .               02 04
   62 3970               . 1134023 4         .                .               03 04
   62 3970   1           5214025 6           .                .               04 04
   62 3970   1     1 6204424 3               .                .               05 04
   62 3970   2 5 9193923 2                   .                .               06 04
   62 3970   2021313610 2    1               .                .               07 04
   62 3970               . 1 83050 5 3       .                .               08 04
   62 3970               .         10275012  1                .               09 04
```

```
62 3970            .              4215027 1 1                  .             10 04
62 3970            .                1 6285512 1                .             11 04
62 3970            .                    710224615 1            .             12 04
62 3970            .                    3 4 6 4 7 7181625 7 .     1          13 04
62 3970            .                    2 4 5 2 1 1 4 110 7 310 71715 5      14 04

 VOLTS X 100...  120                    140                   160            TP CLN
62 3970            .           3 411293214 1                   .             01 09
62 3970    1       .      1 515243512    .                     .             02 09
62 3970            .    3162428 9 1      .                     .             03 09
62 3970    1       .  322252917 1        .                     .             04 09
62 3970            224252918 1           .                     .             05 09
62 3970        1 221233417 1             .                     .             06 09
62 3970      1 519363622 2               .                     .             07 09
62 3970            .    323183022    1   .                     .             08 09
62 3970            .        113252327 9 2                      .             09 09
62 3970            .              516312723 1                  .             10 09
62 3970            .                1 6352628 7                .             11 09
62 3970            .                    411312323 7 1          .             12 09
62 3970            .                    . 2 3 414252125 3 1 .                13 09
62 3970            .                    .   1   5204716 4 1 1                14 09

 VOLTS X 100...  120                    140                   160            TP CLN
62 3970  29        .      2 1 1 3 32624 5                      .             01 10
62 3970  31 1 1    .      3121326 6      .                     .             02 10
62 3970  28        . 2101916 6           .                     .             03 10
62 3970  31       1 8 83018 2            .                     .             04 10
62 3970  34    3 71332 9 1               .                     .             05 10
62 3970  38 3 81921 9 1                  .                     .             06 10
62 3970  72171212 6 2                    .                     .             07 10
62 3970  26        . 1 52726 4 1         . 2 1 1 3             .             08 10
62 3970  24        .      2 93022 4      .      1 3            . 2 2 1       09 10
62 3970  25        .          1112630 3           3            .     3 r 1   10 10
62 3970  26    2   .            1  163415 1       1 2          .     1 2 2   11 10
62 3970  24        .              2   42133 7 2     1    2 .           1 1   12 10
62 3970  24        .            1      1 1 5112612 5 1 2       . 2 2     3   13 10
62 3970  22        .          1        1   1152117 3 2 1 1 2 2 2    3        14 10

 VOLTS X 100...  120                    140                   160            TP CLN
```

intervals for each monitoring point. For example, under 5 on the top row, which refers to the five-minute period between two points monitored, there appear the numbers: 8, 44, 61, 57, 60 and 40, vertically. These numbers represent the number of times five-minute intervals occurred between readings for the 2nd, 3rd, 4th, 5th, 6th, and 7th readings of discharge. If the timing control had been exact, all these numbers should be 93. Likewise, for charge, which should be all ten-minute intervals, the actual distribution is shown in rows 9 thru 13. This particular distribution table is associated with the next data blocks which are numbered on the right most column of each block. These numbers correspond to cell numbers for pack 62.

The remainder of the charts on page B- 51 thru B- 58 are similar in construction, but they cover smaller and smaller segments of test data. The voltage levels of 100 (equals 1.00), 120 (equals 1.20), 140 (equals 1.40) and 160 (equals 1.60) are listed at the top of each cell data, and the numbers taken two at a time which represents a voltage change of 0.02 volts are the frequency distributions of the voltages at the scalar level for the 93 charge discharge curves. In other words, the curves are represented here in a digital form, where each point on a graph is a counter which adds one to itself every time a plot passes through it.

Page B- 59 to B- 62 , represent ten selected superposed curve profiles selected. Cells 2, 4 and 5 extend above 1.60 volts at the end of charge. Cells 1, 3, 6, and 10 have counts above the 1.60 volt level, but the highest count on the ordinate which determines the profile is not found above 1.60 volts. Cells 1, 3, 7, 8 and 9 show a drop at the end of charge. Cells 4, 5 and 10 show a lower end of discharge. Cell 10 shows a complete bottoming-out at 1.00v. This is explained by the fact that cell #10 failed at 2995 cycles, which is within the elapsed cycle range taken for the data.

If the ten cell profiles on pages 49 thru 62 are compared the following points are noticed:

1.) The normal family of superposed curves vary around the high values for each point between counts of 50 and 60. (example, cell #1)

2.) The voltage ranges for cells which do not fail are 1.38v to 1.18v for discharge, and 1.18v to 1.52v for charge. (example, cell #1 - Note that pack 62 is at 0 degrees ambient T)

3.) High counts for voltages above 1.60 at the end of charge are associated with cells which fail. (example, cells 4, 5)

4.) The high counts for suspect cells are lower than for normal cells. (example, cells 4 and 10)

5.) High counts for voltages less than 1.18v are associated at the end of discharge with cells which fail. (example, cell 5, 10)

6.) A variation in the voltage level for the respective high count location appears associated with cells which fail. (example, cells 5, 10- From this characteristic, the first difference method for detecting curve variations was developed. This technique will be described later in this section)

Items 2, 3, and 5, above, have already been observed in the section on Collection and are standard points of interest throughout industry. Items 1, 4 and 6, however, are associated with sets of curves, rather than single measurement observations. They concern curve profile changes in a set, the measurement of these changes along the whole charge-discharge cycle, and the distribution of the changes. In order to detect such things, a computer is essential. The techniques developed, to date, to implement these 'set variation measurements' for curves are unsophisticated and they are intended to lead to a basis for the development of sophisticated probabilistic methods to measure changes in curve-sets. For example, if the superposed counts were changed to probability constants derived from 'n' cycles of data then the next 'k' cycles could be used to produce new probability constants which could be compared against the original ones. In addition, the point-to-point transition probabilities could be calculated and compared against norms to determine the sequential variations somewhat similar to point 6 above.

Pages B-59 through B-62 covers all the available cycles for pack 62 up through 3970 total elapsed cycles. If this material is divided into four sections; the first quarter of life, the midpoint of life, the third quarter of life and the last quarter of life, serves to illustrate how cell symptoms are reflected respectively. Pages B-59 through B-62 of Appendix B represents the same material as 49 through 50 , but is divided into four, approximately 25 cycle sets; B- 57 through B-58 is the last quarter of the data. Cell #10 is dead, as is seen from the fact that all the counts are under 100 volts. From the low end of discharge, cells 4, 5 and 7 look suspect. Pages B- 55 through B-56 represents the third quarter of the life. Cell #1 looks ideal; cell #2 is too scattered, probably from bad data; cells 3, 4 and 5 all have high end of charges, and low end of discharges; cells 6,7, 8, and 9 look alright but not as good as cell #1; and cell #10 is beginning to fail, especially on the discharge portion of the curve. Pages B-53 through B-54 continue to show the same performance, and so does the first quarter of data on pages B-51 through B-52 .

The interesting conclusion to be made from an examination of the superposed curve sets found on pages B-51 through B-58 is fact that the suspect cells which actually did fail looked suspect throughout the whole history of the data. Also that cell #1 looked the best throughout its history.

SECTION II (Cont'd)

In addition to the observations made concerning pack 62 (described on page 9), a summary of all types of suspect features with illustrations for the superposed curve-sets is listed here:

1.) The end of charge must be at least greater than 0.06v more than the start of discharge. (see pack 27, cell 4, page B-70)

2.) The end of charge should be above 1.40v. (same as one, above)

3.) The end of charge should not be above 1.60v (Pk 52, cell 7, B- 65)

4.) Dispersion during charge should not be more than 0.12v. (Pack 27, cell 4, page B- 70) & (pack 52, cell 7, page B-65)

5.) There should be no zeros in charge or discharge. (Pack 26, cell 6, page B- 69, - discharge is coded on the chart as #13)

6.) The charge limiter should not cut-in below 1.45v. This happens because the charge limiter is triggered by the pack voltage, not the individual cell voltage. However, if certain cells can continually be cut-off on charge, they may never have a chance to charge up. For this reason, this point must be watched. (example, Pack 26, cell 10, B-70)

7.) The end of charge voltage should not drop more than 0.06v after the charge limiter cuts-in. (example, Pack 49, cell 1 pp B-65)

8.) The superposed curve-set should not have 'side shoots' in the profile. (example, pack 62, cell 10, pp B- 56)

9.) The start of discharge should not be lower than 1.30v. (example, pack 16, cell 7, page B-66)

10.) The end of discharge should not be lower than 1.15v (example, pack 16, cell 7, pp. B- 66)

11.) Dispersion during charge should not be more than 0.08v. (example, pack 52, cell 2, page B-65)

Table 1

Index Chart for Environmental

Effects on Charge-Discharge Cycle

Pack#/Cell#	Page	Temperatures 40	25	0	Depth of Disch. 15%	25%	40%	Effect
37/5	71	*			*			lowered dispersed
85/4	71	*			*			lowered dispersed
26/8	69	*				*		lowered dispersed
3/1	69		*			*		normal
13/3	69		*			*		normal
49/10	71			*	*			higher
96/1	68		*				*	lower
14/6	68		*				*	lower
2/9	68		*				*	lower

All of the above effects refer to cells which did not fail. In other words, not only failure mechanisms cause changes in the voltage cycle characteristics, but also certain environmental changes. Thresholds must be changed accordingly. Life times are affected. On page B- 70 , cell 4. of pack 27, the superposed curve sets are shown for a cell which did not fail, but was at the point of failure when the pack itself failed. Also attached is the curve set for the same cell 3000 cycles earlier. In orbits where the length of discharge varies from relatively short periods to very long times, it will be very important to obtain results from an analysis of the life test data, since the interplay of failure mechanisms and environmental changes are at a maximum. This study has not analyzed the effect of percent overcharge on the voltage histories.

The second major computer program used to analyze the collection data described in Section I of this report, is the first-difference histogram program.* This program generates a histogram for five charge-discharge cycles at a time. It is a tabulation of all the differences between each set of two consecutive points of voltage data monitored. The ordinate is increments in voltage measurements, shown in steps of 0.1 volts, and the abcissa is a count of the occurrences for each voltage measurement.

Pages 104 through 107 are the histogram tabulations for the same data as is represented by the superposed curves on pages B-49 through B-50 . Taken together, these two programs cover both slope changes and 'curve-to-curve' changes, which, in turn are used for prediction. It is anticipated that these programs will be very useful with carefully controlled input data.

Superposed curve-pattern indicator program:

This program searches juxtaposed, overlayed or superposed sets of charge-discharge cycles for patterns which are associated with a history of high occurance in failed cells. It has some advantages over the first differences techniques. Environmental effects show up better, and so do end of charge and end of discharge problems. It also has the advantage of direct meaning to the battery specialist.

* This program was described in the previous contract.

SUPERPOSITIONED CURVES

1. The twelve superpositioned discharge-charge curves (Appendix B, Page B-68 thru Page B -71) were selected as being typical within individual environmental groups.
2. The environmental conditions are specified to the left of each set. They are depth of discharge, in percent; ambient temperature, in degrees Centigrade; cycle orbit period, in hours.
3. Curve set identifiers:
   - a. The first three digits specify battery pack number.
   - b. The next four digits specify cycle of the last cycle in set number.
   - c. The column headed TP specifies time period.
   - d. The column headed CLN specifies cell number.
   - e. The dotted lines headed 120, 140, 160 specify the levels of 1.20 volts, 1.40 volts, and 1.60 volts respectively.
4. In these sets of superpositioned curves the ordinate is voltage and the abcissa is time.
5. Time periods one through seven are the discharge portion. Time periods eight through fourteen are the charge portion.

SECTION II (Cont'd)

Other types of observations that could be made but are not which are not "flagged" in the data collection of Appendix A are:

Type of Observation

1. LOW VOLTAGE ON START OF DISCHARGE
2. HIGH VOLTAGE ON START OF DISCHARGE
3. HIGH CURRENT ON CHARGE
4. NO CHARGE LIMITER CUT-IN
5. HIGH CURRENT ON DISCHARGE
6. LOW MIDPOINT VOLTAGE ON DISCHARGE
7. HIGH RATIO OF END OF CHARGE TO START OF DISCHARGE FOR CONSECUTIVE CYCLES
8. LOW PACK VOLTAGE

Consideration should be given to the screening of cells selected for the packs, so that matched cells from some short pre-test program following acceptance testing are assigned to the same pack. Cells of a lower capacity should be assigned to another pack, and finally a random mix of cells (all from the same manufacturer) should be assigned to a third pack. In this way, one can determine if pack performance can be improved by pre-test cell selection.

ANALYSIS - SECTION II

Failure Cycle Patterns

Battery and cell failure data is included with other test data in the publication "Monthly Progress Report on National Aeronautics and Space Administration Space Cell Test Program." This publication is produced by the Secondary Battery Section of the Quality Evaluation Department at N.A.D. Crane, Indiana, who is conducting the test program. The basic cell failure information contained in this publication was the basis of the tables in this report Section and in Appendix E.

The cycle number at which failure was observed was tabulated for each failed cell within each pack that had one or more cell failures (to December, 1966). Table A , Pages110 through113, shows the cycle numbers of cell failure in the body of the table. The leftmost column, headed P, is the pack number. The second through sixth columns, headed M, C, D, T, O, contain coded information for each numbered pack. Table A , Page110, lists the coding structure for the table. Table A indicates the incidence of failure and serves as a reference.

Table B , Pages114through116, shows cell failures within 1000 cycle groupings. The row headings indicate pack number and the column headings indicates the 1000 cycle group within which the cell(s) failed. The body of the table contains the actual cell numbers, 1 through 10 for ten-cell packs, of failed cells within each identified pack. A cell number listed in a column headed "Less than 5000 cycles" means that that cell failed somewhere between 4000 and 4999 cycles of operation.

Two patterns appear in Table B . (1.) The bunching of failures under 5000 cycles, and (2.) The grouping within one pack of three or more cell failures before 2000 cycles. Further study of Table B , shows that the position of a cell in a pack is not related to its success or failure.

The bunching of cell failures under 5000 cycles can be examined in more detail by referral to Table T which follows. Failure frequencies are shown for 500 cycle intervals for the first 10,00 cycles of operation, not by pack number but by test condition parameters. Table T is actually three sub-tables with common column headings (cycle interval number). The Tables break down this set of frequencies by (1) depth of discharge in percentage, (2) by orbit period in hours, (3) and by ambient temperature in degrees centigrade. A failed cell is entered into its proper failure cycle interval group three times; once for each of the three test condition parameters. A few packs were cycled in a twenty-four hour orbit period with fifty percent depth of discharge. These were not included in Table T. It can be observed that there is less bunching (1) for 15% discharge than for 25% or 40% discharge, (2) for 1.5 hour orbits than for 3.0 hour orbits, and (3) for $0^{\circ}C$ than for $25^{\circ}C$ or for $40^{\circ}C$.

TABLE T

Number of cells that failed within cycle intervals:

500 cycle intervals -- cycle 0001 --- 10500

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Depth 40%	09	08	04	12	07	04	02	07	06	08	04	00	00	01	00	00	00	00	00	00	00
Of 25%	14	12	10	12	13	18	14	12	18	06	00	00	01	00	00	03	03	03	00	02	03
Disch. 15%	04	02	09	11	05	12	04	01	08	03	04	00	02	00	02	03	02	02	04	02	02
Orbit 3.0	10	16	16	15	09	08	06	12	15	05	02	00	00	00	00	00	00	00	00	00	00
Hours 1.5	17	06	07	20	16	26	14	08	17	12	06	00	03	01	02	06	05	05	04	04	05
Amb. 40	14	11	12	19	11	18	07	09	14	08	03	00	02	00	02	03	00	02	04	01	00
Temp. 25	11	11	07	16	12	11	09	11	13	09	04	00	01	01	00	02	04	01	00	00	03
Cent. 0	02	00	04	00	02	05	04	00	05	00	01	00	00	00	00	01	01	02	00	03	02

As additional reference, Table C , Pages 117 through 121, show coded failure characteristics for each failed cell in every identified pack. This information was extracted from the previously mentioned "Monthly Progress Report", which contains cell post-mortem autopsy data. These data were encoded as twenty-one possible failure characteristic types, represented by the letters A through U. Table C , Page 117, shows the code structure. A maximum of seven failure characteristics per cell is permitted so that the failure history of one entire pack can be represented by one punched card. This maximum was sufficient to record all the failure data that was presented.

The body of Table C shows coded failure characteristic data for each cell identified by the column headings. Row headings contain pack and manufacturer identification.

SECTION III

CELL FAILURE PREDICTION

Prediction in this application is defined as the determination of those cell voltage pattern changes which permit an early differentiation of cells which fail from cells which do not fail.

The purposes of developing prediction capability from life cycle test data are:

1.) To establish a higher level of confidence in an operational battery system.
2.) To establish a basis for better identification of failure modes, by providing an early warning of failure, so that the cell may be removed and inspected.
3.) To provide a basis for estimating the effects of unscheduled operational changes upon the life of the mission.
4.) To evaluate the relative advantages of the available manufacturers products.
5.) To indicate the requirements for new design goals.
6.) To utilize more efficiently the costly but essential life test data.

The basis of the prediction techniques developed in this report follows from the work done in the Data Analysis and Reduction section. Here new elements of information were developed through voltage curve slope studies and through curve set studies. At first, the information elements which were first difference histograms and the superposed curves were classified into types depending upon the different characteristics which appeared in them. Then they were subclassified by the environmental conditions under which the cells were tested. Finally, the failure histories were taken to subclassify again the total information. The mode of failure information obtained by cutting open failed cells was so uncertain that no attempt was made to apply this information to the data. A correlation was then made between the characteristics associated with the cells that failed against the characteristics associated with the cells that did not fail. Those characteristics which showed a high correlation with failed cells were programmed as indicators which were used for prediction.

The prediction programs used the reduced data as input. There are four prediction programs.

1.) Histogram Indicator Program:

This program searches the first-difference histograms for established patterns in the charge or discharge tallies which are known to be associated with failure. A description of the actual indicators is included in Appendix C. When these patterns are identified, a weight is associated with the cell which accumulates for each new pattern identified in the cell history. When these weights reach a certain threshold, the cell is predicted to fail. The thresholds must be changed for different environmental conditions in accordance with the results described in Section II. The lead times to failure are the differences between the actual elapsed cycle time of failure, and the elapsed cycle time when the prediction was made. No attempt has been made to predict the lead time to failure, since the data has not been collected with enough control to permit this. For example, the monitoring point times and the elapsed cycle intervals not recorded are not consistently constant. This means the rate of change of cell performance cannot be related to a well structured reference system to permit lead time predictions, and extrapolation at this point is not advisable. Nevertheless, Pages C-72 through C-92 of Appendix C show an average lead time of 5400 elapsed cycles where predictions are made after 1000 elapsed cycles of data, and a lead time of 1300 elapsed cycles where predictions are made before 1500 elapsed cycles of data. It is also true that those cells where predictions could be made during the first 1500 cycles, usually failed relatively early in life. An example of the output of this program is presented on pages C-94 through C-97 .

2.) Histogram Weight-Gaming Program:

Although the above program involved human decisions to establish the data pattern material to indicate defective cells, the implementation or the automatic application of these rules to the data was of such a nature, that the rules could be changed without requiring any change to the program. This meant that random changes to the rules could be programmed in the form of an arbitrary assignment of weights which would in turn accomplish the same thing as comparing portions of the charge discharge curve against each other to predict failure. The resulting predictions could then be compared to the actual failure data in order to assess the merits of the randomly changed rules. In this way, an interesting check on the human choices could be made. The results, although still incomplete, have turned up some interesting conclusions. In general, all of the manually selected rules do result in better than average success; however, the machine has found one which competes equally with the manual ones. Essentially, this rule compares the upper middle portion of the discharge curve with the lower middle portion of the discharge curve. Appendix C, Page C-93 contain data and the tabular results from this program. One of the advantages of this program is that it permits an automatic setting of the thresholds used for prediction. The desired percent success can be fixed, and the program will only select those indicators which meet or exceed the performance level required of the system. This type of gaming is only possible on the computer since the amount of routine clerical work is too large to merit manual costs. The gaming process to identify indicators of failure can take into consideration different operational environments. In this way the best conditions for testing can be established.

INDICATORS - SECTION III

Delta-Volt Histograms are constructed for each cell for both charge and discharge. These Histograms are the result of summing the Delta Volt levels zero to nine for a specific number of cycles within a cyclic group. All delta volt occurrences above 9 DV are counted as 9 DV. All delta volt occurrences that are negative are counted as DVO. These Histograms are in effect a distribution of a specific number of Histograms.

On a per cell basis, the number of occurrences of delta volts 1 through 9 are multiplied by their individual values. These nine values are then summed to produce the area under the Histogram. This procedure is carried out for both charge and discharge. We now have a numerical value for the area under each entire Histogram.

This area is then subdivided into three individual areas. The summed value of DV 1-2-3, summed value of DV 4-5-6, the summed value of DV 7-8-9. For clarity we will call these three areas DV low, DV mid, DV high, respectively.

Indicator - Discharge

Indicator #1 - If DV high equals 9 - - - count 1 against cell

Indicator #2 - If DV high equals $>$ 9 - - - count 2 against cell

Indicator - Discharge

Indicator #3 - If DV high is more than 1/4 the value of DV low - - - count against cell

Indicator - Discharge

Indicator #4 - If DV low is $\pm$ 15 from DV mid - - - count 1 against cell.

Indicator #5 - If DV low and DV mid differ by more than +15 - - - count 2 against cell.

Indicator #6 - If DV mid is higher in value than DV low - - - count 1 against cell.

Indicator - Charge

Indicator #7 - If DV low is 4 or more times larger or 1/4 less than DV mid - - - count 1 against cell.

Indicator #8 - If DV high is more than 1/2 the value of DV low - - - count 1 against cell.

Indicator - Charge - Discharge

Indicator #9 - If DV mid charge is more than twice or less than 1/2 the value of DV mid (discharge) - - - count 1 against cell.

These counts are then totaled for each cell. Cells that have highest count will fail earliest.

SECTION IV CONCLUSIONS

The initial assumptions, set forth in Section II of this report, have proven to be correct. These assumptions are:

1. That defects in cells are reflected in their operational behavior long before failure.
2. That the optimum information elements which reflect these defects are not known.
3. That the Crana data are sufficient to establish a new perspective in battery data analysis.

Computer programs, developed in this work and described elsewhere in this report, have been used to analyze specific portions of the Crane data and have shown useful predictive ability regarding cell failure. These programs, which detect certain voltage behavior patterns and voltage magnitude ranges, have predicted cell failure, with a high percent of reliability, many thousands of cycles before actual failure.

To produce a time factor, relative to cell failure prediction, will require an increase in the cycling parameters measured and an increase in the accurately timed monitor points per voltage curve.

This work has shown that cycling environmental parameters affect both the cell voltage characteristics and cell life. These prime effects, described in this report, have been applied to various statistical techniques with excellent results; a high percentage of incipient cell failures were detected early in battery pack life. However, further improvement of predictive techniques relative to pack and cell failure may require that the data base be broadened to include additional parameters. Although one cannot say in advance just which such measurements will prove most useful, some of the candidates are internal pressure, cell impedance, percent of overcharge, etc.

Voltage behavior patterns and environmental parameter effects were identified and isolated within the Crane data by working downward from the mass of data into individual sub-sets which displayed cause and effect relationships. After noting suggested relationships, randomly selected pack test histories were examined for the same relationships. Thus, relationships derived from a sub-set of the data were validated on independent data. Voltage behavior patterns, environmental parameter effects, and various inter- and intra-relationships do constitute information elements contained within the structure of the Crane data.

It is stated that this method has established a new perspective in battery data analysis. As one instance, this work suggests that the resultant charge-discharge curve may be determined as a function of operational and environmental parameters. In addition, the present work supports proposed new battery tests wherein only data "flagged" by pre-set thresholds and indicators would be recorded for analysis.

The ultimate purpose of the work done in this contract is to develop methods leading to timely and accurate correlation of various space mission power requirements with well defined potentialities and limitations of all battery cell types for which test information can be secured.

RECOMMENDATIONS

The present Crane Data Acquisition System becomes saturated somewhere about three times its present data flow rate. The addition of pressure measurements, the increase in the number of test points monitored per time unit, and the collection of data during every cycle of testing will increase the data flow rate at least two hundred times. To accomplish this extension of mission, a computer in the data acquisition system appears to be unadvoidable.

With a computer in the data acquisition system, bottle-necks of data storage and access, and data flow-rate capacities disappear; and the data collection system now becomes defined by requirements imposed from the following four areas of consideration:

1. The Simulated Operational Environment

   Considerations of this area determine the design of the test experiment, the number of cells in a pack, the number of packs in the test, the types of cells, the orbit regime, the parameters measured, and the environmental and operational ranges to be tested or controlled.

2. The Data Acquisition Equipment

   Consideration of this area determines the precision limits on measurements, the rate and volume of maximum data flow, the accuracy of timing controls, the channels available for measurement, the minimum interval for data taking, the calibration and control of the analog-to-digital conversion, the channel interrupt or cell removal options, the operational thresholds and controls, the adaptability of the acquisition system to changes in requirements, the sensitivity to noise, and the safeguards against damage to cells on test.

3. The Data Processing Equipment

Consideration of this area determines the speed at which data can be received from the acquisition equipment, added to, (i.e., identifiers, past performance indicators, calculated variables such as pack voltage, Watt hour efficiencies, cell impedance, etc.), stored and/or reduced and edited for output to the printer or various storage mediums. The processing equipment has two major functions. The first is an on-line data management and control function, and the other is an analysis function. It is probable that these two functions are not compatible in the same machine. The analysis function requires a large memory and high speed on an off-line basis for data retrieval and statistical analysis; whereas, the data-management function requires a slower but continuous on-line operation. Although a large machine could handle the data-management function, the necessity to remain on-line and shifting back and forth from data-management to analysis is an inefficient and expensive way to accomplish the job. Even the programming for these two functions require different categories of personnel.

4. The Analysis Methods

Considerations of this area determine the size and the speed of the processing equipment, the amount of high-speed memory, the type of back-up storage for efficient retrieval, the data-indexing system, the reliability of prediction, and the sophistication of the overall test system.

RECOMMENDATIONS (Cont'd)

In the Crane test experiment, the battery pack number was arbitrarily assigned, and therefore has no functional meaning other than an identification tag. It would be helpful if this number were a code which would include the identification of the manufacturer, the cell-rated characteristics, and the cell design features; in order to permit the computer to use this information for extracting classes of cells with specific common characteristics. Also, in the same respect, a code should be included for the cell operating characteristics.

One other consideration for future data collection would be the desirability of obtaining Watt-hour and ampere-hour efficiency calculations to be included information for the analysis work.

APPENDIX A

DATA COLLECTION CHARTS

	Monitor Time	Elapsed Cycle	Pack #	Pack volt	Pack cur.	Cell Voltages					Cell Temperatures					Ambient temp.	
	1.0	1.	62	14.29	3.10	139	141	140	140	141	-.9	-1.1	-.8	.0	-.8	-4.51	
data on cells 1-5	1.0	1.	62	14.29	3.10	140	140	140	140	140	-1.0	-1.5	-.9	-1.3	-1.3	-4.52	data on cells 6-10
	5.6	1.	62	13.73	3.13	133	135	135	134	134	-1.5	-1.3	.4	-1.1	-1.1	-3.31	
	5.6	1.	62	13.73	3.13	135	135	134	134	135	-.3	-.4	-.5	1.0	-.5	-3.32	
	10.5	1.	62	13.34	3.04	130	131	132	130	130	-1.7	.2	-.3	-.1	.0	-2.31	
	10.5	1.	62	13.34	3.04	131	131	130	131	131	1.0	-25.1	.8	1.0	-.3	-2.32	
	15.6	1.	62	13.09	3.01	128	128	129	128	128	.4	.4	.6	.6	2.0	-1.31	- odd numbered rows contain data on cells 1 - 5
	15.6	1.	62	13.09	3.01	129	128	128	129	128	2.0	.8	-.1	.1	.4	-1.32	
	20.6	1.	62	12.89	3.00	126	126	127	125	126	1.4	.8	1.6	1.4	2.4	-.61	
	20.6	1.	62	12.89	3.00	126	126	126	126	126	1.0	.6	.6	2.2	-.7	-.62	
	30.0	1.	62	12.67	2.99	124	124	125	123	124	-.8	-1.1	.1	-.7	1.0	-3.51	
	30.0	1.	62	12.67	2.99	124	124	124	124	123	-.0	.0	.4	.2	-1.3	-3.52	- even numbered rows contain data on cells 6 - 10
	32.6	1.	62	13.48	1.72	131	132	132	131	132	.1	.3	.6	1.5	2.9	-2.41	
	32.6	1.	62	13.48	1.72	131	131	132	132	132	.6	.4	.6	1.4	.6	-2.42	
	41.8	1.	62	14.00	1.73	137	137	137	137	138	.2	1.1	.8	1.2	1.6	-1.31	
	41.8	1.	62	14.00	1.73	137	137	137	137	137	.6	1.3	.6	.8	.4	-1.32	
	50.6	1.	62	14.34	1.71	140	141	140	140	141	-.8	-.5	.0	.0	-1.1	-3.71	
	50.6	1.	62	14.34	1.71	140	140	140	140	141	-.6	.8	-.8	-.3	-.5	-3.72	
early cut-in of charge limiter	60.6	1.	62	14.72	1.51	143	144	144	144	145	.8	.0	-2.8	-.1	-1.3	-3.11	
	60.6	1.	62	14.72	1.51	143	144	144	144	145	.0	-3.9	.0	-1.5	-.4	-3.12	
	70.6	1.	62	14.99	1.03	146	147	147	147	147	3.1	3.1	1.1	-5.5	1.1	2.91	
	70.6	1.	62	14.99	1.03	146	146	147	146	148	-6.9	1.1	1.0	-15.9	-11.7	2.92	
	80.6	1.	62	15.23	.71	148	149	149	149	149	-42.8	41.7	-13.9	77.0	-41.2	-6.91	
	80.6	1.	62	15.23	.71	148	148	149	148	152	3.3	3.1	77.2	-11.7	-15.9	-6.92	
	89.6	1.	62	15.89	.87	152	156	153	158	157	37.7	77.1	75.4	-85.2	39.6	-2.81	
	89.6	1.	62	15.89	.87	154	156	157	152	161	-86.8	39.6	4.0	3.2	-86.8	-2.82	high end of charge-cell #10
	1.4	31.	62	14.25	3.04	140	140	140	140	140	-2.5	-3.3	-3.9	-3.0	-3.3	-3.31	
	1.4	31.	62	14.25	3.04	140	140	140	140	140	-4.7	-3.1	-3.2	-2.1	-2.6	-3.32	
	5.9	31.	62	13.63	3.04	133	134	134	133	133	-2.1	-3.5	-2.5	-3.9	-1.9	-2.71	
	5.9	31.	62	13.63	3.04	134	134	133	134	134	-2.3	-3.3	-2.3	-1.9	-3.1	-2.72	
	10.5	31.	62	13.22	3.03	129	130	130	129	129	-1.6	-1.1	-1.9	-1.9	-1.3	-2.01	
	10.5	31.	62	13.22	3.03	130	130	129	130	130	-1.7	-1.7	-1.5	-1.3	-.9	-2.02	
	15.5	31.	62	12.96	3.01	127	127	127	126	126	-.7	-1.1	-.8	-3.1	-1.3	-1.61	
	15.5	31.	62	12.96	3.01	128	127	127	127	127	-1.1	-1.1	-1.6	.8	-.4	-1.62	
	20.6	31.	62	12.68	3.00	126	126	126	124	125	-2.7	-3.3	-2.9	-2.7	-2.9	-4.31	
	20.6	31.	62	12.68	3.00	126	126	125	126	125	-2.8	-3.6	-2.6	-2.1	-2.5	-4.32	
	25.5	31.	62	12.62	2.99	124	124	124	123	123	-2.2	-3.5	-3.9	-1.6	-1.9	-3.51	
	25.5	31.	62	12.62	2.99	124	124	123	124	123	1.0	-3.3	-1.5	-.9	-3.3	-3.52	
	29.7	31.	62	12.43	2.97	123	123	123	121	121	.6	-1.1	-.5	.3	1.4	-1.31	
	29.7	31.	62	12.43	2.97	123	123	122	123	122	1.2	-.1	.0	.8	-.7	-1.32	
	35.3	31.	62	13.51	1.74	132	133	132	133	133	.2	-.3	-.3	1.4	.4	-1.51	
	35.3	31.	62	13.51	1.74	132	132	132	132	133	1.6	.8	.8	.6	.4	-1.52	
	40.6	31.	62	13.79	1.75	135	136	135	136	136	.2	.0	.2	.4	.8	-1.31	
	40.6	31.	62	13.79	1.75	135	135	135	135	136	.3	.8	.6	1.2	.2	-1.32	

	50.6	31.	62	14.23	1.75	139	140	138	139	140	-1.3	-1.8	-1.9	-1.1	-25.1	-3.71	
	50.6	31.	62	14.23	1.75	139	138	139	139	140	-1.0	-1.3	-.6	-1.3	-1.5	-3.72	
	60.5	31.	62	14.59	1.75	143	143	142	143	144	-1.7	-1.8	-1.7	-1.1	-.4	-1.91	
	60.5	31.	62	14.59	1.75	142	142	142	143	143	-.8	-1.1	-1.3	.0	-.7	-1.92	
	70.5	31.	62	14.80	1.74	145	147	146	147	148	-.5	.8	-1.3	-3.1	.0	-.91	
	70.5	31.	62	14.80	1.74	146	146	146	146	147	-.4	-.7	-.5	-.7	-.4	-.92	high end of
charge	80.6	31.	62	15.66	1.52	151	154	155	157	157	-1.1	4.0	-2.7	37.7	2.4	3.21	charge cells
limiter	80.6	31.	62	15.66	1.52	154	153	152	152	156	3.2	4.0	58.7	-2.7	42.7	3.22	4, 5
cut-in	89.5	31.	62	16.03	.82	151	157	157	166	165	-82.7	77.2	-82.7	58.7	-82.8	-6.81	bad tempera-
	89.5	31.	62	16.03	.82	157	156	153	153	158	77.2	-80.7	58.7	3.2	-85.2	-6.82	ture readings
	7.9	77.	62	13.26	3.32	132	132	132	130	113	-2.2	-2.2	-.9	-1.9	.8	.81	on charge limiter
	7.9	77.	62	13.26	3.32	132	132	134	131	131	-1.7	-1.7	-1.1	-.5	-1.0	.82	
	11.1	77.	62	12.98	3.30	129	130	130	128	111	-1.8	-1.1	-1.7	-.7	-.9	-1.61	
	11.1	77.	62	12.98	3.30	129	130	131	129	129	-.7	-1.3	.0	-1.1	-1.0	-1.62	
	15.5	77.	62	12.74	3.27	127	127	127	126	109	-1.3	-.9	-1.0	-1.1	.2	-1.11	
	15.5	77.	62	12.74	3.27	127	127	129	127	127	.0	1.0	-.2	.1	-1.0	-1.12	
	22.9	77.	62	12.54	3.22	125	124	125	123	107	-.3	.0	.3	.2	.2	-.11	
	22.9	77.	62	12.54	3.22	124	125	126	125	124	.1	.3	1.2	1.2	-1.0	-.12	
	25.4	77.	62	12.42	3.20	124	124	124	122	106	-.3	-1.1	.2	1.2	1.2	-.31	
	25.4	77.	62	12.42	3.20	124	124	126	124	123	.2	.2	.2	1.0	-1.0	-.32	
	32.4	77.	62	12.98	1.68	131	130	130	129	135	-1.5	-1.1	.0	-.7	.6	-2.71	
Low	32.4	77.	62	12.98	1.68	130	130	130	131	130	.0	-99.1	.0	-79.1	-1.0	-2.72	
Discharge	40.6	77.	62	13.46	1.74	135	136	135	136	141	-1.2	-.5	-.5	.4	.4	-1.61	
Cell 5	40.6	77.	62	13.46	1.74	135	135	135	136	136	.8	.4	.4	1.2	-1.0	-1.62	
	50.5	77.	62	13.86	1.75	139	140	138	139	146	-.3	-.5	.0	-.1	.2	-.71	
	50.5	77.	62	13.86	1.75	139	139	139	140	140	-.1	1.2	.2	.2	-1.0	-.72	
	60.5	77.	62	14.20	1.75	142	143	142	143	149	-2.1	-1.1	-1.1	-1.3	-.5	-2.91	
	60.5	77.	62	14.20	1.75	142	142	142	143	143	-.9	-.9	-.5	-.5	-1.0	-2.92	
	70.6	77.	62	14.43	1.75	147	148	147	149	149	-1.0	-1.0	-1.0	-2.9	-.3	-1.51	
	70.6	77.	62	14.43	1.75	147	147	144	147	149	.8	-.7	-.7	-.6	-1.0	-1.52	
	80.5	77.	62	15.19	1.55	152	156	156	158	158	-1.0	-1.0	-1.0	-75.9	-.5	1.01	
	80.5	77.	62	15.19	1.55	155	155	151	153	156	-82.8	-.1	37.7	.0	-1.0	1.02	
	88.9	77.	62	15.59	.90	153	162	159	167	169	-1.0	-1.0	-1.0	-1.0	-82.8	-20.31	high end of
	88.9	77.	62	15.59	.90	158	159	151	155	157	3.2	3.2	37.7	39.5	-1.0	-20.32	charge
	1.9	93.	62	13.67	3.04	137	138	138	137	137	-1.9	-3.1	-1.5	-1.7	-.5	-1.61	cells 2,4,5
	1.9	93.	62	13.67	3.04	138	138	138	138	138	-.7	-.9	-1.5	.0	-.9	-1.62	
	5.5	93.	62	13.24	3.05	133	134	134	132	132	-1.5	-1.6	-2.7	-.8	-.6	-1.11	
	5.5	93.	62	13.24	3.05	133	134	133	133	134	-1.3	-.8	-.7	.0	-1.3	-1.12	
	9.8	93.	62	12.87	3.03	129	130	130	128	128	-3.2	-3.3	-1.8	-3.3	-3.6	-3.71	
	9.8	93.	62	12.87	3.03	130	130	130	129	130	-2.5	-3.1	-3.1	-1.1	-2.9	-3.72	
	15.1	93.	62	12.57	3.03	127	127	127	126	126	-2.9	-2.9	-1.7	-3.1	-1.7	-3.11	
	15.1	93.	62	12.57	3.03	127	127	127	127	127	-1.6	-1.5	-3.1	-1.7	-2.9	-3.12	
	19.8	93.	62	12.42	3.02	125	125	125	124	124	-.7	-3.5	-.7	-.7	-1.5	-1.71	
	19.8	93.	62	12.42	3.02	126	125	125	125	125	-3.2	1.0	-1.1	-1.3	-1.7	-1.72	

25.8	93.	62	12.20	3.02	124	123	124	122	122	.8	-.5	-1.5	-.9	.2	-.91	
25.8	93.	62	12.20	3.02	123	123	123	123	123	-1.1	.2	.8	-.9	.8	-.92	
29.8	93.	62	12.04	3.02	122	122	122	120	120	-.3	-.9	-1.3	-.3	-.9	-1.11	
29.8	93.	62	12.04	3.02	122	122	122	122	121	-.9	.4	-1.1	-.3	-.8	-1.12	
32.0	93.	62	12.94	1.73	130	130	129	130	130	.8	.2	1.0	1.2	.6	-.11	
32.0	93.	62	12.94	1.73	130	130	130	130	130	.6	1.4	.4	.6	.2	-.12	
40.2	93.	62	13.45	1.74	135	136	134	135	135	-1.7	-1.3	-1.3	-.9	-.7	-3.31	
40.2	93.	62	13.45	1.74	135	134	135	135	135	-1.3	-1.3	-1.3	-1.3	-1.6	-3.32	
49.8	93.	62	13.81	1.74	139	139	138	139	139	-.5	-.9	-1.1	.0	-.5	-.91	
49.8	93.	62	13.81	1.74	138	138	139	139	139	-.4	.2	-.9	.0	-1.1	-.92	
59.8	93.	62	14.16	1.73	141	142	141	142	143	-.5	-2.8	-.9	2.8	.0	-.91	
59.8	93.	62	14.16	1.73	142	142	142	142	142	-3.3	.8	2.8	.2	1.2	-.92	
69.5	93.	62	14.51	1.73	145	146	145	146	146	1.6	3.2	1.2	3.4	.9	.01	
69.5	93.	62	14.51	1.73	145	145	145	145	146	-3.3	2.2	1.1	1.2	4.0	.02	
79.9	93.	62	15.28	1.67	151	154	154	155	155	-6.8	18.8	-6.8	40.4	3.2	-19.91	
79.9	93.	62	15.28	1.67	153	153	152	151	152	-42.8	-.7	3.4	3.2	77.2	-19.92	high end of
88.9	93.	62	15.69	.88	151	161	157	167	166	-42.7	4.2	4.2	-85.2	23.5	-42.81	charge cells
88.9	93.	62	15.69	.88	156	156	153	153	154	41.2	-40.8	25.8	3.2	-83.3	-42.82	2, 4, 5
1.4	125.	62	13.86	3.02	139	140	140	140	139	-1.1	-1.6	-.7	-1.3	-1.1	-1.11	
1.4	125.	62	13.86	3.02	140	140	140	139	140	-1.3	-.9	-.4	.8	-.8	-1.12	
5.1	125.	62	13.51	3.03	133	135	134	133	133	-1.7	-.9	-1.3	1.0	-1.7	-.91	data
5.1	125.	62	13.51	3.03	137	137	450	100	132	-.3	-1.3	1.0	-.5	.8	-.92	error
10.1	125.	62	12.84	3.03	129	130	130	128	128	-.9	-1.3	-.3	.2	.4	.81	
10.1	125.	62	12.84	3.03	130	130	129	129	129	.2	1.0	-.9	.2	.8	.82	
15.1	125.	62	12.55	3.03	126	127	127	125	125	.0	-.9	.4	.4	1.0	-.11	
15.1	125.	62	12.55	3.03	127	127	126	126	126	.0	.6	.4	.6	.8	-.12	
20.1	125.	62	12.38	3.03	125	125	125	123	123	-1.1	-.4	-.4	-.8	1.0	-3.11	
20.1	125.	62	12.38	3.03	125	125	125	125	124	-.9	-.1	-.4	-.1	-.7	-3.12	
25.1	125.	62	12.17	3.02	123	123	123	122	121	-1.3	.0	.0	1.3	.6	-1.31	
25.1	125.	62	12.17	3.02	123	123	123	123	122	.6	1.0	.3	.1	-1.5	-1.32	
29.8	125.	62	11.95	3.02	121	121	121	119	119	-1.5	.8	-.1	.8	.4	-.91	
29.8	125.	62	11.95	3.02	121	121	121	121	120	.4	1.0	.3	1.0	.4	-.92	
31.7	125.	62	12.86	1.74	129	130	129	129	129	.6	1.2	.6	1.6	2.0	-1.11	
31.7	125.	62	12.86	1.74	129	129	130	129	130	.8	2.0	.8	1.8	.0	-1.12	
40.1	125.	62	13.40	1.74	134	135	134	135	134	-.4	.0	.2	.6	1.0	-2.51	
40.1	125.	62	13.40	1.74	134	134	135	135	135	.4	1.2	.4	.4	-.3	-2.52	
50.1	125.	62	13.80	1.73	138	139	137	139	139	.0	-1.3	1.0	.2	.9	-11.11	
50.1	125.	62	13.80	1.73	138	138	139	139	139	.4	1.4	.2	1.4	.4	-11.12	
60.2	125.	62	14.14	1.73	141	142	141	143	142	-1.1	-2.8	-.9	-1.5	.0	-3.71	
60.2	125.	62	14.14	1.73	141	141	142	142	142	-2.7	-.4	-.8	-1.3	-1.9	-3.72	
70.1	125.	62	14.57	1.73	145	146	146	147	147	-.7	-.3	-.6	-.8	-1.1	-1.71	
70.1	125.	62	14.57	1.73	146	146	146	146	146	2.8	-1.1	-2.8	.2	-.8	-1.72	
80.1	125.	62	15.36	1.28	150	156	155	157	158	-6.8	-82.8	3.2	-60.7	-6.8	-13.31	
80.1	125.	62	15.36	1.28	154	154	152	151	152	42.7	4.0	75.4	2.9	-85.2	-13.32	

89.2	125.	62	15.63	.79	151	$\boxed{162}$	155	$\boxed{165}$	$\boxed{166}$	3.2	-82.8	-83.1	26.0	-83.2	3.41	high end of charge cells 2,4,5
89.2	125.	62	15.63	.79	155	155	152	152	153	75.4	-42.8	41.6	3.4	-82.8	3.42	
1.4	158.	62	13.87	3.16	139	140	140	139	139	-1.7	.8	-1.5	-.7	-1.3	-.91	
1.4	158.	62	13.87	3.16	140	140	140	139	140	-.4	-1.3	.2	-.5	-1.0	-.92	
4.1	158.	62	13.43	3.16	134	135	135	135	134	-1.1	-1.0	-.8	.0	.8	-.91	
4.1	158.	62	13.43	3.16	135	135	135	135	135	-.3	.2	-.8	.2	-1.0	-.92	
7.7	158.	62	13.02	3.16	131	131	132	130	130	-1.3	-1.3	-.1	.6	.4	-.91	
7.7	158.	62	13.02	3.16	132	132	131	131	131	.8	.4	1.4	.8	-1.0	-.92	
15.7	158.	62	12.50	3.15	126	126	126	125	125	-1.9	-1.4	-1.7	-1.3	-.1	-4.71	
15.7	158.	62	12.50	3.15	126	126	126	126	126	.0	-3.5	.4	1.0	-1.0	-4.72	
18.1	158.	62	12.41	3.15	125	125	125	124	124	-1.9	-1.1	-.9	.0	-.3	-3.51	
18.1	158.	62	12.41	3.15	125	125	125	125	125	.0	.1	.8	.2	-1.0	-3.52	
22.7	158.	62	12.24	3.14	123	124	124	122	122	-.5	-1.1	.1	-.9	.3	-2.91	
22.7	158.	62	12.24	3.14	124	124	124	124	123	1.2	-.1	.6	.2	-1.0	-2.92	
28.7	158.	62	11.98	3.02	121	121	121	119	119	-1.0	-1.0	-1.0	-1.0	-1.0	-1.01	
28.7	158.	62	11.98	3.02	121	121	121	121	120	-1.0	-1.0	-1.0	-1.0	-1.0	-1.02	
32.3	158.	62	12.89	1.74	130	130	129	129	129	-1.0	-1.0	-1.0	-1.0	-1.0	-1.01	
32.3	158.	62	12.89	1.74	129	129	130	130	130	-1.0	-1.0	-1.0	-1.0	-1.0	-1.02	
37.8	158.	62	13.24	1.73	133	134	132	133	133	.2	1.2	.6	1.6	2.0	.01	
37.8	158.	62	13.24	1.73	132	132	133	133	133	1.8	2.1	2.4	2.2	-1.0	.02	
47.7	158.	62	13.69	1.73	137	138	136	137	138	-1.1	.0	-.9	1.0	.6	-2.91	
47.7	158.	62	13.69	1.73	137	137	137	138	138	.4	2.0	1.2	-.1	-1.0	-2.92	
57.7	158.	62	14.03	1.73	140	141	140	141	142	-.5	.0	.1	.8	.3	-1.21	
57.7	158.	62	14.03	1.73	140	140	140	141	141	.4	1.3	.8	1.2	-1.0	-1.22	
67.7	158.	62	14.40	1.73	144	145	144	145	145	-1.0	-1.0	-1.0	-1.0	-1.0	-1.01	
67.7	158.	62	14.40	1.73	144	144	144	144	145	-1.0	-1.0	-1.0	-1.0	-83.1	-1.02	
78.3	158.	62	15.15	$\boxed{1.60}$	150	153	153	154	154	3.2	45.0	1.2	3.4	3.2	-13.31	
78.3	158.	62	15.15	$\boxed{1.60}$	151	151	151	150	151	3.1	-.4	40.0	2.0	-1.0	-13.32	
88.7	158.	62	15.54	$\boxed{.86}$	151	$\boxed{161}$	155	$\boxed{162}$	$\boxed{165}$	-5.5	60.8	3.4	-79.2	60.6	41.91	high end of charge cells 2,4,5
88.7	158.	62	15.54	$\boxed{.86}$	154	153	153	152	152	41.6	41.9	43.9	-40.3	-1.0	41.92	
1.4	190.	62	13.77	3.03	138	139	139	139	138	-3.1	-.9	-1.3	-1.1	.2	-1.01	
1.4	190.	62	13.77	3.03	139	139	139	138	139	.2	-.5	.4	.1	-.3	-1.02	
5.2	190.	62	13.25	3.04	133	133	134	132	132	-.9	-.8	-.9	-.1	.1	-.91	
5.2	190.	62	13.25	3.04	133	134	133	133	133	.1	.0	-.1	1.0	-.7	-.92	
9.9	190.	62	12.80	3.02	128	129	129	128	128	-1.5	-.4	.8	.2	.9	77.21	
9.9	190.	62	12.80	3.02	129	129	129	129	129	.3	.3	.6	-.3	.2	77.22	
14.9	190.	62	12.51	3.02	126	127	126	125	125	.0	-.1	.4	.3	.4	-.31	
14.9	190.	62	12.51	3.02	126	126	126	126	126	1.0	2.8	.8	1.0	.4	-.32	
19.9	190.	62	12.32	3.01	124	124	124	123	123	-.5	-.7	.1	.1	.9	-2.91	
19.9	190.	62	12.32	3.01	125	124	124	124	124	1.4	.9	.6	.6	.8	-2.92	
24.9	190.	62	12.13	3.01	122	122	123	121	121	-.7	-.8	-.4	2.8	1.1	-3.11	
24.9	190.	62	12.13	3.01	123	123	123	122	122	.8	.4	1.3	1.2	.3	-3.12	
28.4	190.	62	11.97	3.01	121	121	121	119	119	.8	-1.3	.8	.4	1.2	-.91	
28.4	190.	62	11.97	3.01	121	121	121	121	120	-1.5	.4	1.6	1.0	1.2	-.92	

	31.7	190.	62	12.81	1.74	129	129	128	128	128	1.4	.4	.7	1.6	2.0	-.71	
	31.7	190.	62	12.81	1.74	129	129	129	129	129	1.4	2.2	2.4	2.2	.8	-.72	
	39.9	190.	62	13.31	1.73	134	134	133	134	134	.8	.4	2.0	2.1	2.0	-.11	
	39.9	190.	62	13.31	1.73	133	133	134	134	134	2.0	2.8	2.6	2.3	1.2	-.12	
	50.3	190.	62	13.74	1.73	138	138	137	138	138	.0	-.5	.0	.3	1.0	-2.41	
	50.3	190.	62	13.74	1.73	137	137	138	138	138	.4	1.2	1.3	1.0	.2	-2.42	
	59.9	190.	62	14.05	1.72	140	141	141	142	142	-.4	-1.1	.2	.6	.2	-.51	
	59.9	190.	62	14.05	1.72	141	140	141	141	141	.8	1.6	.6	1.5	.6	-.52	
	69.9	190.	62	14.47	1.72	144	145	145	146	146	1.0	-.3	1.3	.6	-1.3	.01	
	69.9	190.	62	14.47	1.72	144	144	145	145	145	1.0	1.1	1.3	1.1	.4	.02	
	79.9	190.	62	15.05	1.12	149	152	152	153	153	26.0	71.6	4.0	59.3	4.0	66.01	
	79.9	190.	62	15.05	1.12	151	150	150	149	150	44.9	35.3	71.6	-60.3	-82.7	66.02	high end of
low pack	89.7	190.	62	15.37	.59	150	159	155	161	164	55.0	-81.2	-82.8	39.6	18.8	39.61	charge cells
current	89.7	190.	62	15.37	.59	153	152	151	151	151	62.2	47.3	63.9	25.8	-86.7	39.62	4,5
	1.4	222.	62	13.78	3.02	138	139	139	138	138	-.5	.1	.0	-1.0	-.7	.41	
	1.4	222.	62	13.78	3.02	139	139	139	138	138	.8	.4	.8	1.0	-1.3	.42	
	5.3	222.	62	13.21	3.04	133	133	133	132	132	-1.5	-.6	-1.5	-.8	-.7	-2.61	
	5.3	222.	62	13.21	3.04	133	133	133	132	133	-1.7	-.5	.6	-.9	1.0	-2.62	
	11.6	222.	62	12.67	3.04	127	128	128	126	126	-1.0	-1.1	-1.3	.8	-.1	-1.11	
	11.6	222.	62	12.67	3.04	128	128	127	127	127	-.4	1.2	.2	-25.7	-.3	-1.12	
	15.6	222.	62	12.48	3.04	125	126	126	124	124	-1.0	-1.5	.8	.4	1.2	-1.31	
	15.6	222.	62	12.48	3.04	126	126	126	125	125	1.0	.0	.6	1.1	.8	-1.32	
	20.0	222.	62	12.32	3.04	124	124	124	123	123	-.5	.0	-.1	.2	1.4	.81	
	20.0	222.	62	12.32	3.04	124	124	124	124	124	1.0	3.0	.7	2.0	-.3	.82	
	24.5	222.	62	12.14	3.03	122	122	122	121	121	2.0	1.8	.6	.4	2.2	.61	
	24.5	222.	62	12.14	3.03	122	122	122	122	122	2.1	-39.5	3.0	3.5	3.0	.62	
	25.1	222.	62	12.09	3.03	122	122	122	120	120	2.2	2.0	-7.1	2.6	3.0	.31	
	25.1	222.	62	12.09	3.03	122	122	122	122	121	2.6	3.0	3.5	4.9	2.1	.32	
	29.0	222.	62	11.92	3.03	120	120	121	118	118	3.2	.4	3.4	.6	2.4	-1.51	
	29.0	222.	62	11.92	3.03	120	120	120	120	119	2.6	12.7	3.4	2.9	3.1	-1.52	
	31.9	222.	62	12.81	1.74	128	128	128	128	128	1.3	1.0	2.2	1.6	2.4	-3.31	
	31.9	222.	62	12.81	1.74	128	128	129	129	129	2.2	-7.1	3.5	2.4	2.0	-3.32	
	40.0	222.	62	13.29	1.73	134	134	133	133	133	2.0	1.8	2.2	2.8	2.6	-1.31	
	40.0	222.	62	13.29	1.73	133	133	134	133	133	1.6	2.6	3.4	2.3	2.1	-1.32	
	50.0	222.	62	13.74	1.72	137	138	137	137	138	.6	1.0	2.2	1.5	1.8	-.71	
	50.0	222.	62	13.74	1.72	137	137	137	138	137	.6	1.6	3.1	3.0	1.2	-.72	
	60.0	222.	62	14.02	1.72	141	141	140	141	142	.8	-.1	-1.1	.3	.6	-1.91	
	60.0	222.	62	14.02	1.72	140	140	141	140	141	.8	1.4	1.6	1.4	1.3	-1.92	
	70.1	222.	62	14.43	1.72	144	145	145	146	146	-1.3	.2	-1.3	.8	-2.8	-.51	
	70.1	222.	62	14.43	1.72	144	144	144	144	144	.8	.6	1.3	1.4	.3	-.52	
	80.2	222.	62	15.11	1.25	149	153	153	153	154	44.7	2.0	4.0	69.8	-82.7	75.01	
	80.2	222.	62	15.11	1.25	151	150	150	149	150	-86.8	4.4	41.8	13.9	70.1	75.02	high end of
	88.9	222.	62	15.63	.81	150	165	155	167	168	42.8	40.0	41.2	-81.2	12.9	77.21	charge cells
	88.9	222.	62	15.63	.81	154	153	152	151	151	77.2	42.0	4.0	41.6	-85.2	77.22	2, 4, 5

APPENDIX B

DATA ANALYSIS AND

REDUCTION CHARTS

```
DIST.TIME DIFF.  1   2   3   4   5   6   7   8   9   10
   62 3970  93       .                   .     1             .            01 DT
   62 3970     1     210 7193511 8       .                   .            02 DT
   62 3970   3       1 2   2 51744 5   1 1                   .            03 DT
   62 3970   2       . 1 4   71261 3 5 1 1   1               .            04 DT
   62 3970           1   1 2 52457 4 2 1 .       1   1       .            05 DT
   62 3970   2 1     1 2 1 2 12260 3 3   1                   .            06 DT
   62 3970         2 1 21116241440 1 7 2 .       1           .            07 DT
   62 3970   1   110352714 7 1           1                   .            08 DT
   62 3970           .   2     1 2 2 2 7 110361617 2 1       1            09 DT
   62 3970   1     1 1   1   3       1   1 1   4  2857 1 1 2 .            10 DT
   62 3970   2 1 1   .   1   1       1 1 . 1 1 1  1968 3 1   .            11 DT
   62 3970           1 1     2 2         .     1 12065 3   3 1     1      12 DT
   62 3970           .   1   1   1   2   .   3   22063 4     .            13 DT
   62 3970     3     .         1     1   1 522132910 9       .            14 DT

    VOLTS X 100...  120                 140                 160           TP CLN
   62 3970           .         1   4 1265012                 .            01 03
   62 3970           .     1 1 73444 6   .                   .            02 03
   62 3970           .   2 84125 5       .                   .            03 03
   62 3970   1       . 2254225 3         .                   .            04 03
   62 3970           2264425 2           .                   .            05 03
   62 3970       1 6223830 2             .                   .            06 03
   62 3970     713215124 4 1             .                   .            07 03
   62 3970           .    205617 4       .                   .            08 03
   62 3970   1       .         82654 9 2 .                   .            09 03
   62 3970           .           1  295023 1                 .            10 03
   62 3970           .               1 4255617               .            11 03
   62 3970           .                 1 2 1274225 3         .            12 03
   62 3970           .                   . 1 1 3 7 520212711 1 1          13 03
   62 3970           .                   .   1 1     72721 6 6 7 6 3 8 2  14 03

    VOLTS X 100...  120                 140                 160           TP CLN
   62 3970           .         3 9 6174018 1                 .            01 04
   62 3970           .     4143434 7     .                   .            02 04
   62 3970           . 1134023 4         .                   .            03 04
   62 3970   1       5214025 6           .                   .            04 04
   62 3970   1   1 6204424 3             .                   .            05 04
   62 3970   2 5 9193923 2               .                   .            06 04
   62 3970  2021313610 2   1             .                   .            07 04
   62 3970           . 1 83050 5 3       .                   .            08 04
   62 3970           .        10275012   1                   .            09 04
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DESCRIBED ON PAGES 63-64

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62 3970            .             4215027 1 1                .             10 04
62 3970            .               1 6285512 1              .             11 04
62 3970            .                   710224615 1          .             12 04
62 3970            .                   3 4 6 4 7 7181625 7 .      1       13 04
62 3970            .                   2 4 5 2 1 1 4 110 7 310 71715 5    14 04

 VOLTS X 100...  120                    140                   160           TP CLN
62 3970            .          3 411293214 1                 .             01 09
62 3970    1       .     1 515243512    .                   .             02 09
62 3970            .   3162428 9 1      .                   .             03 09
62 3970    1       . 322252917 1        .                   .             04 09
62 3970          224252918 1            .                   .             05 09
62 3970      1 221233417 1              .                   .             06 09
62 3970    1 519363622 2                .                   .             07 09
62 3970            .   323183022   1    .                   .             08 09
62 3970            .       113252327 9 2                    .             09 09
62 3970            .             516312723 1                .             10 09
62 3970            .               1 6352628 7              .             11 09
62 3970            .                    411312323 7 1       .             12 09
62 3970            .                    . 2 3 414252125 3 1 .             13 09
62 3970            .                    .   1   5204716 4 1 1             14 09

 VOLTS X 100...  120                    140                   160           TP CLN
62 3970  29        .     2 1 1 3 32624 5                    .             01 10
62 3970  31 1 1    .     3121326 6      .                   .             02 10
62 3970  28        . 2101916 6          .                   .             03 10
62 3970  31     1 8 83018 2             .                   .             04 10
62 3970  34   3 71332 9 1               .                   .             05 10
62 3970  38 3 81921 9 1                 .                   .             06 10
62 3970  72171212 6 2                   .                   .             07 10
62 3970  26        . 1 52726 4 1        . 2 1 1 3           .             08 10
62 3970  24        .      2 93022 4     .       1 3         . 2 2 1       09 10
62 3970  25        .          1112630 3           3         .     3 1 1   10 10
62 3970  26   2    .            1  163415 1       1 2       .     1 2 2   11 10
62 3970  24        .              2   42133 7 2    1   2 .         1 1   12 10
62 3970  24        .            1     1 1 5112612 5 1 2     . 2 2     3   13 10
62 3970  22        .          1       1   1152117 3 2 1 1 2 2 2   3       14 10

 VOLTS X 100...  120                    140                   160           TP CLN
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DIST.TIME DIFF.  1   2   3   4   5   6   7   8   9  10
   62 0856  21       .                   .                   .            01 DT
   62 0856           . 5 2 7 3 3 1       .                   .            02 DT
   62 0856   2       . 1   2 3 9 3 2   1 .                   .            03 DT
   62 0856   1       .   2   5 213 1 1   .   1               .            04 DT
   62 0856           1       2 613       .           1       .            05 DT
   62 0856     1     . 1       612 2 1   1                   .            06 DT
   62 0856         1 .   3 5 4 2 5   4   .       1           .            07 DT
   62 0856   1     3 3 9 3 3 1           1                   .            08 DT
   62 0856           .   2     1 1 2 1 4 .  12 1 2           .            09 DT
   62 0856         1 1   1   1           . 1   2   712 1   1 .            10 DT
   62 0856     1     .                 1 .     1   813 1     .            11 DT
   62 0856           1         1         .         616     1 .            12 DT
   62 0856           .       1           .         616 1     .            13 DT
   62 0856           .         1         .   2 3 8 7 2       .            14 DT

    VOLTS X 100...  120                 140                 160           TP CLN
   62 0856           .                 910 2                 .            01 03
   62 0856           .           416 1   .                   .            02 03
   62 0856           .      13 7 3       .                   .            03 03
   62 0856           .   417 4 1         .                   .            04 03
   62 0856           . 317 3             .                   .            05 03
   62 0856           315 6               .                   .            06 03
   62 0856         417 3 1               .                   .            07 03
   62 0856           .     913 1 1       .                   .            08 03
   62 0856           .         613 6 1   .                   .            09 03
   62 0856           .              19 6 3                   .            10 03
   62 0856           .                 118 4 2               .            11 03
   62 0856           .                   1  15 9             .            12 03
   62 0856           .                   .       2 2 6 7 2 3 1 1          13 03
   62 0856           .                   .           413 6 1 .            14 03

    VOLTS X 100...  120                 140                 160           TP CLN
   62 0856           .               411 6                   .            01 04
   62 0856           .         215 4     .                   .            02 04
   62 0856           .    11 9 3         .                   .            03 04
   62 0856           . 215 6 3           .                   .            04 04
   62 0856           116 6               .                   .            05 04
   62 0856         215 7                 .                   .            06 04
   62 0856     3 910 2 1                 .                   .            07 04
   62 0856           .   11110 2         .                   .            08 04
   62 0856           .         414 5 3   .                   .            09 04
```

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62 0856            .             115 9 3                    .           10 04
62 0856            .                  1310 2                .           11 04
62 0856            .                   . 21111 1            .           12 04
62 0856            .                   .       2 3 7 4 6 2  .           13 04
62 0856            .                   .             1 2 1 1 4 2 6 4 3  14 04

 VOLTS X 100...  120                  140                 160           TP CLN
62 0856            .               1 910   1                .           01 09
62 0856   1        .         2 6 7 5   .                    .           02 09
62 0856            .     1 813 1       .                    .           03 09
62 0856            .   5 910 2         .                    .           04 09
62 0856            . 4 711 1           .                    .           05 09
62 0856           4 613 1              .                    .           06 09
62 0856         214 7 2                .                    .           07 09
62 0856            .     4 612 2       .                    .           08 09
62 0856            .         2 712 4 1 .                    .           09 09
62 0856            .               41111 2                  .           10 09
62 0856            .                 4 611 3 1              .           11 09
62 0856            .                   . 4 810 1 1          .           12 09
62 0856            .                   .       6 6 7 4 1    .           13 09
62 0856            .                   .         713 3 1    .           14 09

 VOLTS X 100...  120                  140                 160           TP CLN
62 0856   1        .               7 8 5                    .           01 10
62 0856   1        .         114 5     .                    .           02 10
62 0856   1        .     8 8 6         .                    .           03 10
62 0856   1        .  14 9 2           .                    .           04 10
62 0856   1       113 7 1              .                    .           05 10
62 0856   1     6 8 8 1                .                    .           06 10
62 0856   2 4 4 9 4 2                  .                    .           07 10
62 0856   2        .    11 6 4 1       .                    .           08 10
62 0856            .       1 910 3 3   .                    .           09 10
62 0856   1        .            10 8 6 3                    .           10 10
62 0856       2    .                10 6 6 1                .           11 10
62 0856            .               1  211 6 3 2             .           12 10
62 0856            .             1     .   2 3 5 7 4   2    .           13 10
62 0856            .           1       .     5 3 8 3 1 1 1 1            14 10

 VOLTS X 100...  120                  140                 160           TP CLN
```

```
DIST.TIME DIFF.  1    2    3    4    5    6    7    8    9   10
   62 1935  25        .                        .                        .        01 DT
   62 1935            1 1    411 3 3           .                        .        02 DT
   62 1935            . 1      1 313 1         1                        .        03 DT
   62 1935    1       . 1 1    1 218        1 1                         .        04 DT
   62 1935            .   1    2 715 1         .                        .        05 DT
   62 1935    1       .     1    319 1         .                        .        06 DT
   62 1935            . 1 3 6 5 214     1 1 .                           .        07 DT
   62 1935          4 8 5 7 1                  .                        .        08 DT
   62 1935            .                     1 . 410 2 7    1            .        09 DT
   62 1935    1       .        1               .       1   717          .        10 DT
   62 1935    1   1   .                   1    .           220 1        .        11 DT
   62 1935            .          1             .         1 517 1        .        12 DT
   62 1935            .   1               1    .         1 416 1        .        13 DT
   62 1935      3     .                   1    1    8 2 7    3          .        14 DT

   VOLTS X 100...   120                       140                      160       TP CLN
   62 1935            .          1    1   417 2                         .        01 03
   62 1935            .     1    2 711 2       .                        .        02 03
   62 1935            .   1 1 7 9 2            .                        .        03 03
   62 1935    1       . 1 21012                .                        .        04 03
   62 1935            1 11014                  .                        .        05 03
   62 1935          1 .1311                    .                        .        06 03
   62 1935          41712                      .                        .        07 03
   62 1935            .     316 6              .                        .        08 03
   62 1935    1       .          1 418 1       .                        .        09 03
   62 1935            .            1    119 6                           .        10 03
   62 1935            .                 1   518 2                       .        11 03
   62 1935            .                     1 .   512 7                 .        12 03
   62 1935            .                        . 1    1 1    3 512 2 .           13 03
   62 1935            .                        .  1          311 7      1    2    1   14 03

   VOLTS X 100...   120                       140                      160       TP CLN
   62 1935            .          1 1    416 3                           .        01 04
   62 1935            .        311 7 2         .                        .        02 04
   62 1935            .   3 8 8 1              .                        .        03 04
   62 1935    1       1 4 911                  .                        .        04 04
   62 1935          1 41110                    .                        .        05 04
   62 1935      1   611 7                      .                        .        06 04
   62 1935    2 8 714 2                        .                        .        07 04
   62 1935            .   1 518 1              .                        .        08 04
   62 1935            .          1 321         .                        .        09 04
```

```
62 1935           .             1  18 8                   .            10 04
62 1935           .               1   717 1               .            11 04
62 1935           .                   1 1 517 1           .            12 04
62 1935           .                   . 1 1 1   1 4 7 9 1 .            13 04
62 1935           .                   .   1       4   1 2 1 1 3 3 8 2  14 04

 VOLTS X 100...  120                 140                 160           TP CLN
62 1935           .           1   2 21010                 .            01 09
62 1935           .       1   412 6   .                   .            02 09
62 1935           .   1   210 6 1     .                   .            03 09
62 1935   1       . 1   312 9         .                   .            04 09
62 1935           1   31210           .                   .            05 09
62 1935         1 . 213 9             .                   .            06 09
62 1935         1 41810               .                   .            07 09
62 1935           .        1212   1   .                   .            08 09
62 1935           .           1 118 4 1                   .            09 09
62 1935           .               1  1212 1               .            10 09
62 1935           .                   1 519 1             .            11 09
62 1935           .                   . 1 1 418 1         .            12 09
62 1935           .                   .     1   2 516   1 .            13 09
62 1935           .                   .       1  15 7 2 1 .            14 09

 VOLTS X 100...  120                 140                 160           TP CLN
62 1935           .         1 1 11111 .                   .            01 10
62 1935           .     1 4 8 9 1     .                   .            02 10
62 1935           . 1 4 8 7           .                   .            03 10
62 1935   1       2 611 6             .                   .            04 10
62 1935       1 1 914 1               .                   .            05 10
62 1935   2   5 711                   .                   .            06 10
62 1935  16 7 6 3 1                   .                   .            07 10
62 1935           . 1  1014           .                   .            08 10
62 1935           .       1  1212     .                   .            09 10
62 1935           .           1  1016 .                   .            10 10
62 1935           .             1   515 5                 .            11 10
62 1935           .               1   2 516 1             .            12 10
62 1935           .                   1 1 1 512 3   1     . 1          13 10
62 1935           .                   1   1 613 3   1     .       1    14 10

 VOLTS X 100...  120                 140                 160           TP CLN
```

```
DIST.TIME DIFF.  1    2    3    4    5    6    7    8    9   10
  62 2995  24         .                             .                       .        01 DT
  62 2995      1      . 1  4  6  8  1  4            .                       .        02 DT
  62 2995   1         1           312  2            .                       .        03 DT
  62 2995             .    1     1 613  2  2        .                       .        04 DT
  62 2995             .          1 615  1           .         1             .        05 DT
  62 2995             1  1       1 614      1       .                       .        06 DT
  62 2995          1  .  1  3  3  7 513        1    .                       .        07 DT
  62 2995           15  6  3                        .                       .        08 DT
  62 2995             .               1        1    .  310  4  3  2         1        09 DT
  62 2995             .                             1        1    814       .        10 DT
  62 2995             .    1                        .             419  1  1 .        11 DT
  62 2995             . 1        2                  .        1    318  1   1 .       12 DT
  62 2995             .               1             .     1     1 913       .        13 DT
  62 2995             .                             .     6  310  3  1      .        14 DT

   VOLTS X 100...   120                            140                     160       TP CLN
  62 2995             .                    1  1  712  3                     .        01 03
  62 2995             .                215  7  1    .                       .        02 03
  62 2995             .          312  4             .                       .        03 03
  62 2995             .      9  9  6  1             .                       .        04 03
  62 2995             .  9  9  5  1                 .                       .        05 03
  62 2995           2  9  5  7  1                   .                       .        06 03
  62 2995        4  912  8  1                       .                       .        07 03
  62 2995             .          414  6             .                       .        08 03
  62 2995             .                 618  1      .                       .        09 03
  62 2995             .                       610  9                        .        10 03
  62 2995             .                          1  217  6                  .        11 03
  62 2995             .                             .     5  814            .        12 03
  62 2995             .                             .        1  2  3  3  4  8  4 .   13 03
  62 2995             .                             .                 2  6  3  1  3  2  1  3  2   14 03

   VOLTS X 100...   120                            140                     160       TP CLN
  62 2995             .                       2  710  5                     .        01 04
  62 2995             .              413  7  1      .                       .        02 04
  62 2995             .      410  5                 .                       .        03 04
  62 2995             .  810  6  1                  .                       .        04 04
  62 2995   1       1  8  9  4  1                   .                       .        05 04
  62 2995      1  5  410  4                         .                       .        06 04
  62 2995   8  412  9  1                            .                       .        07 04
  62 2995             .    1  716                   .                       .        08 04
  62 2995             .                 416  5      .                       .        09 04
```

```
62 2995            .               115 9                   .             10 04
62 2995            .                  120 5                .             11 04
62 2995            .                   .  513 9            .             12 04
62 2995            .                   .     1 2 3 5 2 8 3 .     1       13 04
62 2995            .                   .               7 1 . 3 2 8 2     14 04

 VOLTS X 100...   120                 140                 160            TP CLN
62 2995            .             4   7 9 4                 .             01 09
62 2995            .       1 6 413 1   .                   .             02 09
62 2995            .   1 6 6 4 2       .                   .             03 09
62 2995            .   7 7 4 6 1       .                   .             04 09
62 2995            . 8 6 2 7 1         .                   .             05 09
62 2995            6 7 4 6 1           .                   .             06 09
62 2995        2 5 9 8 9 1             .                   .             07 09
62 2995            .     8 5 3 8       .                   .             08 09
62 2995            .         4 7 5 4 4 1                   .             09 09
62 2995            .             1 410 1 9                 .             10 09
62 2995            .                 112 2 6 5             .             11 09
62 2995            .                   1 4 9 3 4 5 1       .             12 09
62 2995            .                   .   1 2 3 8 5 5 1   .             13 09
62 2995            .                   .       3 7 9 4     .             14 09

 VOLTS X 100...   120                 140                 160            TP CLN
62 2995    4       .     2 1   2 2 8 5 .                   .             01 10
62 2995    6 1 1   .     2 8 4 3       .                   .             02 10
62 2995    8       . 1 6 3 1           .                   .             03 10
62 2995    8     1 6 2 5 3             .                   .             04 10
62 2995    7   2 6 3 5 1               .                   .             05 10
62 2995    9 3 3 6 2 1                 .                   .             06 10
62 2995   25 6 2   1                   .                   .             07 10
62 2995            .   5 6 6           . 2 1 1 3           .             08 10
62 2995            .           8 7 1   .       1 3         . 2 2 1       09 10
62 2995            .             1 8 8 .           3       .     3 1 1   10 10
62 2995            .                 113 4         1 2     .     1 2 2   11 10
62 2995            .                   . 511 3       1   2 .       1 1   12 10
62 2995            .                   .   2 3 9 2 1       . 1 2     3   13 10
62 2995            .                   .     4 5 6         1 2 2   2     14 10

 VOLTS X 100...   120                 140                 160            TP CLN
```

```
DIST.TIME DIFF.  1   2   3   4   5   6   7   8   9  10
   62 3970  23       .                   .     1             .            01 DT
   62 3970           1 3 1 213 4         .                   .            02 DT
   62 3970           .       1 216       .                   .            03 DT
   62 3970           .         217   2   .                   .            04 DT
   62 3970           .     2   514 2 2 1 .                   .            05 DT
   62 3970   1       .   1 1   715   1   .                   .            06 DT
   62 3970           1   2 2 8 5 8 1 2   .                   .            07 DT
   62 3970       1 3 9 7 1 3             .                   .            08 DT
   62 3970           .               1 1 1 3 4 9 5           .            09 DT
   62 3970           .       1       1   .         614   1 1 .            10 DT
   62 3970   1       .       1           . 1 1     516       .            11 DT
   62 3970           .                   .         614 1   1 1     1      12 DT
   62 3970           .               1   .   2     118 2     .            13 DT
   62 3970           .                   . 5 6 5 4   3       .            14 DT


    VOLTS X 100...  120                 140                 160           TP CLN
   62 3970           .             2   611 5                 .            01 03
   62 3970           .       1 3 810 2   .                   .            02 03
   62 3970           .   1 4 9 5         .                   .            03 03
   62 3970           . 110 6 3 1         .                   .            04 03
   62 3970           113 8 3 1           .                   .            05 03
   62 3970       1 310 5 6 1             .                   .            06 03
   62 3970     7 9 4 5 1 2 1             .                   .            07 03
   62 3970           .     413 4 3       .                   .            08 03
   62 3970           .         1 312 6 2 .                   .            09 03
   62 3970           .               315 5 1                 .            10 03
   62 3970           .                 2 .17 7               .            11 03
   62 3970           .                   1 1 213 4 3         .            12 03
   62 3970           .                   .   1 1 2   8 5 5 2 .            13 03
   62 3970           .                   .     1       1 2 2 4 4 2 2 4    14 03

    VOLTS X 100...  120                 140                 160           TP CLN
   62 3970           .         2 8 4 2 3 4 1                 .            01 04
   62 3970           .     4 7 8 5       .                   .            02 04
   62 3970           . 1 611 1           .                   .            03 04
   62 3970           4 7 6 2 2           .                   .            04 04
   62 3970       1 4 7 8 4 2             .                   .            05 04
   62 3970   2 3 4 7 3 5 2               .                   .            06 04
   62 3970  10 6 3 3 5 1   1             .                   .            07 04
   62 3970           . 1 5 7 6 2 3       .                   .            08 04
   62 3970           .         5 6 8 4   1                   .            09 04
```

```
62 3970  .      2 5 8 7 1 1         .      10 04
62 3970  .        6 7 8 4 1         .      11 04
62 3970  .          6 7 1 5 4 1     .      12 04
62 3970  .          3 3 5 2 3  2 3 2 1 .   13 04
62 3970  .          2 4 4 2 1 1    3 1 2   1   14 04

 VOLTS X 100...  120       140       160   TP CLN
62 3970  .      2  811 3            .      01 09
62 3970  .   1 3 710 3  .           .      02 09
62 3970  .  1 9 8 1     .           .      03 09
62 3970  . 210 6 3      .           .      04 09
62 3970  112 9 4        .           .      05 09
62 3970 1 111 8 4 1     .           .      06 09
62 3970 1 311 9 3 1 1   .           .      07 09
62 3970  .  311 7 3     .           .      08 09
62 3970  .     1 710 5 1 .          .      09 09
62 3970  .        4 710 3           .      10 09
62 3970  .         1 116 8          .      11 09
62 3970  .          3 213 6         .      12 09
62 3970  .          . 2 2 1 5 9 4  1 .     13 09
62 3970  .          .  1  1 610 2 1  1     14 09

 VOLTS X 100...  120       140       160   TP CLN
62 3970 24  .          .          .        01 10
62 3970 24  .          .          .        02 10
62 3970 19  .          .          .        03 10
62 3970 21  .          .          .        04 10
62 3970 26  .          .          .        05 10
62 3970 26  .          .          .        06 10
62 3970 29  .          .          .        07 10
62 3970 24  .          .          .        08 10
62 3970 24  .          .          .        09 10
62 3970 24  .          .          .        10 10
62 3970 26  .          .          .        11 10
62 3970 24  .          .          .        12 10
62 3970 24  .          .          .        13 10
62 3970 22  .          .          .        14 10

 VOLTS X 100...  120       140       160   TP CLN
```

```
DIST.TIME DIFF.   1   2   3   4   5   6   7   8   9   10
   62 3970  23        .                   .     1             .           01 DT
   62 3970            1 3 1 213 4         .                   .           02 DT
   62 3970            .       1 216       .                   .           03 DT
   62 3970            .         217   2   .                   .           04 DT
   62 3970            .     2   514 2 2 1 .                   .           05 DT
   62 3970    1       .   1 1   715   1   .                   .           06 DT
   62 3970            1   2 2 8 5 8 1 2   .                   .           07 DT
   62 3970        1 3 9 7 1 3             .                   .           08 DT
   62 3970            .               1 1 1 3 4 9 5           .           09 DT
   62 3970            .       1       1   .        614    1 1 .           10 DT
   62 3970    1       .       1           . 1 1    516        .           11 DT
   62 3970            .                   .        614 1    1 1     1     12 DT
   62 3970            .               1   .   2    118 2      .           13 DT
   62 3970            .                   . 5 6 5 4  3        .           14 DT

    VOLTS X 100...  120                 140                 160           TP CLN
   62 3970            .             2 314 5                   .           01 01
   62 3970            .         712 5     .                   .           02 01
   62 3970            .     413 2         .                   .           03 01
   62 3970            .   9 8 4           .                   .           04 01
   62 3970            1 614 5             .                   .           05 01
   62 3970          1 511 9               .                   .           06 01
   62 3970        111 9 5 2 1             .                   .           07 01
   62 3970            .     316 3 2       .                   .           08 01
   62 3970            .         2 8 8 5 1 .                   .           09 01
   62 3970            .               114 8 1                 .           10 01
   62 3970            .                 2 118 5               .           11 01
   62 3970            .                   2 1 312 5 1         .           12 01
   62 3970            .                   . 1 1 1 1 7 7 4 1 1 .           13 01
   62 3970            .                   .   1     1 3 4 9 1 . 2 1     1 14 01

    VOLTS X 100...  120                 140                 160           TP CLN
   62 3970            .       1     2 211 7 1                 .           01 02
   62 3970            . 1     1 7 8 6 1   .                   .           02 02
   62 3970            1   1 6 8 3         .                   .           03 02
   62 3970          1 .   9 8 2 1         .                   .           04 02
   62 3970          1 1 911 3 1           .                   .           05 02
   62 3970    1     3 810 4               .                   .           06 02
   62 3970    1 5 7 8 4 1 2 1             .                   .           07 02
   62 3970            .   2 314 2 3       .                   .           08 02
   62 3970            .         210 8 3 1 .                   .           09 02
   62 3970            .               115 7 1                 .           10 02
   62 3970            .                 2 515 4               .           11 02
```

```
62 3970            •                   2 1 512 4           •            12 02
62 3970            •                   • 1 1 2   6 7 5 2   •            13 02
62 3970            •                   •   1       1 4 3 7 2   1 1 1 2  14 02

 VOLTS X 100...   120                 140                 160           TP CLN
62 3970            •             2   611 5                 •            01 03
62 3970            •       1 3 810 2   •                   •            02 03
62 3970            •   1 4 9 5         •                   •            03 03
62 3970            • 110 6 3 1         •                   •            04 03
62 3970           113 8 3 1            •                   •            05 03
62 3970        1 310 5 6 1             •                   •            06 03
62 3970      7 9 4 5 1 2 1             •                   •            07 03
62 3970            •    413 4 3        •                   •            08 03
62 3970            •         1 312 6 2 •                   •            09 03
62 3970            •               315 5 1                 •            10 03
62 3970            •                 2 •17 7               •            11 03
62 3970            •                   1 1 213 4 3         •            12 03
62 3970            •                   •   1 1 2   8 5 5 2 •            13 03
62 3970            •                   •     1       1 2 2 4 4 2 2 4    14 03

 VOLTS X 100...   120                 140                 160           TP CLN
62 3970            •         2 8 4 2 3 4 1                 •            01 04
62 3970            •     4 7 8 5       •                   •            02 04
62 3970            • 1 611 1           •                   •            03 04
62 3970            4 7 6 2 2           •                   •            04 04
62 3970        1 4 7 8 4 2             •                   •            05 04
62 3970    2 3 4 7 3 5 2               •                   •            06 04
62 3970   10 6 3 3 5 1   1             •                   •            07 04
62 3970            • 1 5 7 6 2 3       •                   •            08 04
62 3970            •         5 6 8 4   1                   •            09 04
62 3970            •             2 5 8 7 1 1               •            10 04
62 3970            •                 6 7 8 4 1             •            11 04
62 3970            •                   6 7 1 5 4 1         •            12 04
62 3970            •                   3 3 5 2 3   2 3 2 1 •            13 04
62 3970            •                   2 4 4 2 1 1       3 1 2     1    14 04

 VOLTS X 100...   120                 140                 160           TP CLN
62 3970            •           2  1010 2                   •            01 05
62 3970            •     2 411 6 1     •                   •            02 05
62 3970            • 1 411 3           •                   •            03 05
62 3970            2 4 9 5 1           •                   •            04 05
62 3970          2 510 7 2             •                   •            05 05
```

```
62 3970     2   7 8 7 2               .                   .           06 05
62 3970   3 6 7 6 5 1   1             .                   .           07 05
62 3970           .   2 414 1 3       .                   .           08 05
62 3970           .         1 711 3 2 .                   .           09 05
62 3970           .               213 6 3                 .           10 05
62 3970           .                 1 117 6 1             .           11 05
62 3970           .                   . 2 410 5 3         .           12 05
62 3970           .                   .   1 1 2 3 6 7 2 2 .           13 05
62 3970           .                   .     1     1 1 4 4 2 2 1 1 2 1 14 05

 VOLTS X 100...  120                 140                 160          TP CLN
62 3970           .           1 1 212 7 1                 .           01 06
62 3970           .       2 610 6     .                   .           02 06
62 3970           .   1 7 8 3         .                   .           03 06
62 3970           . 111 6 2 1         .                   .           04 06
62 3970           112 7 5 1           .                   .           05 06
62 3970       1 112 6 5 1             .                   .           06 06
62 3970   1 5 7 8 4 1 2 1             .                   .           07 06
62 3970           .   3 9 8 1 3       .                   .           08 06
62 3970           .       1 312 6 1 1 .                   .           09 06
62 3970           .             210 9 2 1                 .           10 06
62 3970           .               1 113 8 3               .           11 06
62 3970           .                   2 2 8 8 4           .           12 06
62 3970           .                   . 1 1 2   7 6 5 2   .           13 06
62 3970           .                   .   1     1 1 2 8 3 2   3   1   14 06

 VOLTS X 100...  120                 140                 160          TP CLN
62 3970           .           1 1 211 8 1                 .           01 07
62 3970           .       2 5 8 9     .                   .           02 07
62 3970           .   1 611 1         .                   .           03 07
62 3970           . 1 9 9 1 1         .                   .           04 07
62 3970           11111 2 1           .                   .           05 07
62 3970       1 1 910 5               .                   .           06 07
62 3970     1 910 5 2 1 1             .                   .           07 07
62 3970           .   113 7 3         .                   .           08 07
62 3970           .       1 513 4 1   .                   .           09 07
62 3970           .             316 3 1 1                 .           10 07
62 3970           .               2  16 7 1               .           11 07
62 3970           .                   2 214 4 2           .           12 07
62 3970           .                   . 1 1 2 4 6 7 2 1   .           13 07
62 3970           .                   .   1     2 3 8 5 1 1     1     14 07

 VOLTS X 100...  120                 140                 160          TP CLN
62 3970           .             1 1 813 1                 .           01 08
```

```
62 3970           .       1 4 810 1   .                   .            02 08
62 3970           .   1 211 5         .                   .            03 08
62 3970           .    410 5 2        .                   .            04 08
62 3970           . 413 7 2           .                   .            05 08
62 3970         1 510 6 4             .                   .            06 08
62 3970     1 5 610 3 3   1           .                   .            07 08
62 3970           .     210 8 3 1     .                   .            08 08
62 3970           .         1 412 5 1 1                   .            09 08
62 3970           .               1 613 2 2               .            10 08
62 3970           .                 1 110 9 4             .            11 08
62 3970           .                   . 2 2 610 4         .            12 08
62 3970           .                   .   1 1 2   7 6 5   2            13 08
62 3970           .                   .     1     1 4 410 . 1     1    14 08
 VOLTS X 100...  120                 140                 160           TP CLN
62 3970           .           2   811 3                   .            01 09
62 3970           .     1 3 710 3     .                   .            02 09
62 3970           .   1 9 8 1         .                   .            03 09
62 3970           . 210 6 3           .                   .            04 09
62 3970           112 9 4             .                   .            05 09
62 3970       1 111 8 4 1             .                   .            06 09
62 3970     1 311 9 3 1 1             .                   .            07 09
62 3970           .   311 7 3         .                   .            08 09
62 3970           .       1 710 5 1   .                   .            09 09
62 3970           .             4 710 3                   .            10 09
62 3970           .               1 116 8                 .            11 09
62 3970           .                   3 213 6             .            12 09
62 3970           .                   . 2 2 1 5 9 4   1   .            13 09
62 3970           .                   .   1   1 610 2 1   1            14 09

 VOLTS X 100...  120                 140                 160           TP CLN
62 3970  24       .                   .                   .            01 10
62 3970  24       .                   .                   .            02 10
62 3970  19       .                   .                   .            03 10
62 3970  21       .                   .                   .            04 10
62 3970  26       .                   .                   .            05 10
62 3970  26       .                   .                   .            06 10
62 3970  29       .                   .                   .            07 10
62 3970  24       .                   .                   .            08 10
62 3970  24       .                   .                   .            09 10
62 3970  24       .                   .                   .            10 10
62 3970  26       .                   .                   .            11 10
62 3970  24       .                   .                   .            12 10
62 3970  24       .                   .                   .            13 10
62 3970  22       .                   .                   .            14 10
```

TIME DIFFERENCE/ SUPERPOSITION CURVE SET PROGRAM NAB-P3

This program takes a pre-determined number of cycles of Crane data and plots the voltage/time curve of each cycle one on top of the other.

The ordinate of the graph is voltage from less than 1.20V. to more than 1.60V.

The abcissa of the graph is time, divided into fourteen time points; seven in discharge and seven in charge.

The first plotted curve places a 'one' at its voltage level for each of the time points. Each successive curve in the group repeats this same process on top of the first curve. Where the voltage levels of each curve coincide within each time point, each plotted point is incremented by the number of coincidences, to give the total number of occurrences of that position.

The output of this program is a physical/numerical representation of a set of voltage/time curves showing their voltage levels and time differences within the discharge and charge.

The time difference/superposition curve set program makes possible the examination of many voltage/time curves at one time. The examination and comparison of sets of these curves gives the ability to see the effects of varying cycling parameters and to discriminate against 'noise'.

It is not possible to separate out the individual curves of a set.

DISTRIBUTION OF TIME DIFFERENCES

This is a part of the superpositioned curve set program. It establishes fourteen time periods and plots the number of occurrences of varying times within each.

The output is a graph. The ordinate has fourteen time periods, seven for discharge and seven for charge. The abcissa is time, in minutes, from less than one minute to more than 10 minutes.

This graph is a distribution of time differences. It shows the number and distribution of time occurrences, within fourteen time periods, for the set of superpositioned voltage/time curve sets that follow.

There is no correction of the time intervals of the original input data.

Timing looseness in the original data can cause a great spread in the voltage/time curve sets. This spread can cause difficulty and error in various predictive theories.

In the future tests, time control should be better regulated.

```
VOLTS X 100...   120               140               160          TP CLN
52 4551           .          1 2   2 2 3              .           01 07   4
52 4551           .      3 1 5 1     .                .           02 07   3
52 4551           .  2 4 2           .                .           03 07   8
52 4551           . 1 5 5            .                .           04 07
52 4551           . 5 4              .                .           05 07
52 4551          3 5 2               .                .           06 07
52 4551         3 7 2                .                .           07 07
52 4551           .        2 8       .                .           08 07
52 4551           .             2 7 1                 . #3        09 07
52 4551           .                 3 3 3 2           .   &       10 07
52 4551           .                 .    2 2 4 1 1    . 1   #4    11 07
52 4551           .                 .        2 1 2 1 3 .    1  &  12 07
52 4551           .                 .        1   1   1 . 2 4  1 #8 13 07
52 4551           .                 .            1 1 1 . 1 1 2 2 1 14 07


VOLTS X 100...   120               140               160          TP CLN
04915315          .             5 9 9 1               .           01 01
04915315          .        11013 1   .                .           02 01
04915315          .    11410 1       .                .           03 01
04915315          .  419 1           .                .           04 01
04915315          . 421 2            .                .           05 01
04915315         617 1               .                .           06 01
04915315        217 6                .                .           07 01
04915315          .      917         .                .           08 01
04915315          .           418 3 .                 .           09 01
04915315          .             11014                 .           10 01
04915315          .                 . 1 711 6         .           11 01
04915315          .                 .        1 1 1 6 110 5        12 01
04915315          .                 .           313 7 . 2         13 01
04915315          .                 .           11110   3   #7    14 01
```

```
VOLTS X 100...   120                 140                 160        TP CLN
2 6671            .           1013 1  .                   .          01 03
2 6671            .      317 6        .                   .          02 03
2 6671            .  17 9 1           .                   .          03 03
2 6671            215 8               .                   .          04 03
2 6671        2 811 6                 .                   .          05 03
2 6671    3 9 9 4 . 1                 .                   .          06 03
2 6671   23 2 1 1 .                   .                   .          07 03
2 6671         4 511 3 2 1            .                   .          08 03
2 6671            .          116 8 2  .                   .          09 03
2 6671            .                 1213                  .          10 03
2 6671            .                   422                 .          11 03
2 6671            .                   . 717 2             .          12 03
2 6671            .                   . 1 515 2 3         .          13 03
2 6671            .                   . 1 813 2 1  #7     .          14 03
```

```
                                                                    124
VOLTS X 100...   120                 140                 160        TP CLN
16 2306           .     218 #9        .                   .          01 07  13
16 2306           . 317               .                   .          02 07  10
16 2306          1 312                .                   .          03 07  11
16 2306        1 511                  .                   .          04 07   9
16 2306      1 5  3                   .                   .          05 07
16 2306    114 3  .                   .                   .          06 07
16 2306    20 5 1 .                   .                   .          07 07
16 2306    #10    .   1 116 2         .                   .          08 07
16 2306           .           2 217   .                   .          09 07
16 2306           .                  119                  .          10 07
16 2306           .                   114 5               .          11 07
16 2306           .                   .   117             .          12 07
16 2306           .                   .   1 316           .          13 07
16 2306           .                   .   1 613           .          14 07
```

```
VOLTS X 100...   120                 140                 160               TP CLN
52 1402           .         1     3 1 2 9 3 1             .               01 02
52 1402           .       2 3   5 5 3 2   #12             .               02 02
52 1402           .   3 1 1 4 7 2     .                   .               03 02
52 1402           1 3 1 5 6 4         .                   .               04 02
52 1402         1 3 1 6 9             .                   .               05 02
52 1402     1 1 2 1 7 6 2             .                   .               06 02
52 1402   1   3 2 9 6 1               .                   .               07 02
52 1402                 1 1 2 5 4 5 2 .                   .               08 02
52 1402                         4 7 8                     .               09 02
52 1402                           1 8 5 6                 .               10 02
52 1402   1 #5                        . 3 9 6 1           .               11 02
52 1402                               .   2 2 6 7 2 1     . #4            12 02
52 1402                               .     1 2 2 3 7 5 3 .               13 02
52 1402                               .       1 3 2 2 7 1 2 1             14 02
```

40% D.O.D.
25° AMB.TEMP.
1.5 HR.ORB.

```
  VOLTS X 100...  120                 140                 160           TP CLN
096 1006   1       .       21014 1     .                   .             01 01
096 1006           .     914 6         .                   .             02 01
096 1006           . 1 718 1           .                   .             03 01
096 1006           2 817 3             .                   .             04 01
096 1006           915 3               .                   .             05 01
096 1006       21314 3                 .                   .             06 01
096 1006   81010 4 2                   .                   .             07 01
096 1006           1   617 4 1 1       .                   .             08 01
096 1006           .         41311 2   .                   .             09 01
096 1006           .             51114 .                   .             10 01
096 1006           .               2 819                   .             11 01
096 1006   1       .                 21019                 .             12 01
096 1006           .                   1 41214             .             13 01
096 1006   1       .               1   . 1 11013 1         .             14 01
```

40% D.O.D.
25° AMB.TEMP.
1.5 HR.ORB.

```
  VOLTS X 100...  120                 140                 160           TP CLN
014 0968           .         1211 1    .                   .             01 06
014 0968           .     1211          .                   .             02 06
014 0968           .  1 810            .                   .             03 06
014 0968           . 11215 1           .                   .             04 06
014 0968           11111 3             .                   .             05 06
014 0968       1 11111 1               .                   .             06 06
014 0968   3 5 614 5 2 2               .                   .             07 06
014 0968           2  1011 1 1         .                   .             08 06
014 0968           .      2 813 5      .                   .             09 06
014 0968           .          11012 5  .                   .             10 06
014 0968           .              314 8                    .             11 06
014 0968           .                215 9                  .             12 06
014 0968           .                  11210 3              .             13 06
014 0968           .                   . 41210             .             14 06
```

40% D.O.D.
25° AMB.TEMP.
1.5 HR.ORB.

```
  VOLTS X 100...  120                 140                 160           TP CLN
002 1004           .         2 9 9 3   .                   .             01 09
002 1004           .     1 810 6       .                   .             02 09
002 1004           .   4 714 2         .                   .             03 09
002 1004           . 4 814 1           .                   .             04 09
002 1004           4 714 3             .                   .             05 09
002 1004   1     410 8 2               .                   .             06 09
002 1004   2 2 710 4 2 1               .                   .             07 09
002 1004         1 .   613 4 2 1       .                   .             08 09
002 1004           .      1 810 5 4    .                   .             09 09
002 1004           .            513 2 9 1                  .             10 09
002 1004           .              113 5 5 3                .             11 09
002 1004           .                  412 2 7 1            .             12 09
002 1004           .                   . 4 8 8 5 2         1             13 09
002 1004           .                   .   7 5 9 4 1 1     .             14 09
```

25% D.O.D.

25° AMB.TEMP.

1.5 HR.ORB.

```
  VOLTS X 100...  120                 140                 160           TP CLN
003 1028   1       .             110 610 1                 .            01 01
003 1028           .         2 914 1 1 .                   .            02 01
003 1028           .     3 814 2 1     .                   .            03 01
003 1028           .   2 913 1 1       .                   .            04 01
003 1028           . 2 916 2 1         .                   .            05 01
003 1028           5 713 2 1           .                   .            06 01
003 1028         6 813 1   1           .                   .            07 01
003 1028           . 1     71110       .                   .            08 01
003 1028           .           31015   .                   .            09 01
003 1028           .               61013                   .            10 01
003 1028           .                 3 815 1               .            11 01
003 1028           .                   11211 2 1           .            12 01
003 1028           .                   . 3 7 710           .            13 01
003 1028           .                   .   7 5 8 3         .            14 01
```

25% D.O.D.

25° AMB.TEMP.

1.5 HR.ORB.

```
  VOLTS X 100...  120                 140                 160           TP CLN
013 1041   1       .         1 31012 1 .                   .            01 03
013 1041           .       2 719 2     .                   .            02 03
013 1041           .     2 910 1       .                   .            03 03
013 1041           .   1 812 8         .                   .            04 03
013 1041           1 1 613 7           .                   .            05 03
013 1041           2 814 7             .                   .            06 03
013 1041         21415 7 1             .                   .            07 03
013 1041           . 1 1 817 3         .                   .            08 03
013 1041           .       31213 2     .                   .            09 03
013 1041           .           61211   .                   .            10 03
013 1041           .             41111 3                   .            11 03
013 1041           .             1 2 813 6                 .            12 03
013 1041           .             1   5 21110 2             .            13 03
013 1041           .               1 1 1 3 410 5 3         .            14 03
```

25% D.O.D.

50/40° AMB.TEMP.

1.5 HR.ORB.

```
  VOLTS X 100...  120                 140                 160           TP CLN
026 0999           .       4 411 9     .                   .            01 08
026 0999           .   4 611 5 2       .                   .            02 08
026 0999           . 4 8 7 4           .                   .            03 08
026 0999           21213 3             .                   .            04 08
026 0999       1 21213 2               .                   .            05 08
026 0999   1 3 1 913 2                 .                   .            06 08
026 0999  12 9 8 7 3                   .                   .            07 08
026 0999           1 2 614 4 1         .                   .            08 08
026 0999           .       1   11311 3 .                   .            09 08
026 0999           .               323 5                   .            10 08
026 0999           .                1311 4     1           .            11 08
026 0999           .                 913 6     1           .            12 08
026 0999           .                 913 5     1           .            13 08
026 0999           .               1 912 9                 .            14 08
```

25% D.O.D.

50/40° AMB.TEMP.

1.5 HR.ORB.

```
  VOLTS X 100...  120                 140                 160           TP CLN
026 0999           .       4 213 8 1   .                   .            01 10
026 0999           .   4 610 7 1       .                   .            02 10
026 0999           . 412 4 3           .                   .            03 10
026 0999           314 7 6             .                   .            04 10
026 0999       1 214 8 5               .                   .            05 10
026 0999   1 1 610 9 2                 .                   .            06 10
026 0999  17 3 9 7 3                   .                   .            07 10
026 0999           . 21011 5           .                   .            08 10
026 0999           .       1   417 7 1 .                   .            09 10
026 0999           .              1016 5                   .            10 10
026 0999           .               21214 1                 .            11 10
026 0999           .               11012 6                 .            12 10
026 0999           .               11210 5                 .            13 10
026 0999           .                1013 8                 .            14 10
```

15% D.O.D.

50/40° AMB.TEMP.

1.5 HR.ORB.

```
  VOLTS X 100...  120                 140                 160           TP CLN
027 4485   1       .         2 9 9 3 2 .                   .            01 04
027 4485           .     2 410 9 2     .                   .            02 04
027 4485           . 1 2 6 5 6 1       .                   .            03 04
027 4485         1 . 3 4 9 3 2         .                   .            04 04
027 4485       2 1 3 6 9 4 2           .                   .            05 04
027 4485   2 1   4 4 5 3 2 1           .                   .            06 04
027 4485   7 2 51212 2 1 1             .                   .            07 04
027 4485         1 . 2   4 2 6 6 5 1   .                   .            08 04
027 4485           .           1 6 3 7 4 5   1             .            09 04
027 4485           .               3 312 3 3 2 1           .            10 04
027 4485           .               1 5 9 6 5   1   2       .            11 04
027 4485           .                 2 9 6 5 2 1     1     . 1          12 04
027 4485           .                 2 412 5 1 1     1     . 1          13 04
027 4485           .                 1 6 8 5   2   1       1            14 04
```

15% D.O.D.

50/40° AMB.TEMP.

1.5 HR.ORB.

```
  VOLTS X 100...  120                 140                 160           TP CLN
027 1083   1       .           11215   .                   .            01 04
027 1083           .       1 218 7     .                   .            02 04
027 1083           .       617 4       .                   .            03 04
027 1083           .   1 911 5         .                   .            04 04
027 1083           . 21211 4 1         .                   .            05 04
027 1083           21011 2 3           .                   .            06 04
027 1083         6 611 5 1             .                   .            07 04
027 1083           .   1 512 7 3       .                   .            08 04
027 1083           .           31511   .                   .            09 04
027 1083           .               618 3                   .            10 04
027 1083           .                 817 1                 .            11 04
027 1083           .                 321 3                 .            12 04
027 1083           .                 220 7                 .            13 04
027 1083           .                 312 8                 .            14 04
```

15% D.O.D.

50/40° AMB.TEMP.

1.5 HR.ORB.

```
  VOLTS X 100...  120                 140                 160           TP CLN
037 0990   1        .        2 713 2    .                   .           01 05
037 0990            .      811 8 1      .                   .           02 05
037 0990           1   3 5 4 5 1        .                   .           03 05
037 0990         1 . 4 3 512 1          .                   .           04 05
037 0990       1 1 4 5 8 8              .                   .           05 05
037 0990   1 2 3 3 212 4 1              .                   .           06 05
037 0990  18 2 4 9 4 3                  .                   .           07 05
037 0990           . 2 516 4 1          .                   .           08 05
037 0990            .        418 6      .                   .           09 05
037 0990            .           2 719 1 .                   .           10 05
037 0990            .            2 618 1                    .           11 05
037 0990            .              416 8                    .           12 05
037 0990            .              21015 1                  .           13 05
037 0990            .              2 416 2                  .           14 05
```

15% D.O.D.

50/40° AMB.TEMP.

1.5 HR.ORB.

```
  VOLTS X 100...  120                 140                 160           TP CLN
085 1134   1        .      1 6 7 9 4    .                   .           01 04
085 1134            .    3 6 415        .                   .           02 04
085 1134           1   4 5 2 8 1        .                   .           03 04
085 1134           1 6 4 5 9 5          .                   .           04 04
085 1134   1     1 6 4 710 1            .                   .           05 04
085 1134       1 6 312 9                .                   .           06 04
085 1134   1 2 2 71610                  .                   .           07 04
085 1134           . 1 4 515 4          .                   .           08 04
085 1134            .      3 7 8 9 4    .                   .           09 04
085 1134            .           5 6 9 9 .                   .           10 04
085 1134            .            6 310 9                    .           11 04
085 1134            .            2 5 512 6                  .           12 04
085 1134            .              6 510 8                  .           13 04
085 1134            .              4 510 7                  .           14 04
```

15% D.O.D.

0° AMB.TEMP.

1.5 HR.ORB.

```
  VOLTS X 100...  120                 140                 160           TP CLN
049 5315            .              410 9   1                .           01 10
049 5315            .           813 3 1 .                   .           02 10
049 5315            .      519 1 1      .                   .           03 10
049 5315            .    914   1        .                   .           04 10
049 5315            . 1015 1 1          .                   .           05 10
049 5315            . 716   1           .                   .           06 10
049 5315           617 1 1              .                   .           07 10
049 5315            .    421 1          .                   .           08 10
049 5315            .        11014      .                   .           09 10
049 5315            .             1 915 .                   .           10 10
049 5315            .                1 515 4                .           11 10
049 5315            .                   .  1 2 1 511 5      .           12 10
049 5315            .                   .          612 7    .           13 10
049 5315   1        .                   .            1013 1 .           14 10
```

APPENDIX C

CELL FAILURE PREDICTION CHARTS

PACK #15

1st DIFFERENCE HISTOGRAM

INDICATOR COUNT PREDICTION PROGRAM

CELL #	CYCLE 0001 to 1152	1184 to 2122	FAILURE CYCLE	LEAD TIME	CORRECT PREDICT.	(A) MISS PREDICT.	(B) MISS PREDICT.
1	21	24				1	
2	22	21				1	
3	17	17			1		
4	16	17	10382				1
5	16	17	8714				1
6	24	21				1	
7	18	15	8065				1
8	17	15	8254				1
9	20	16	10382	8260	1		
10	24	20	10123	8001	1		

CUMULATIVE

1	21	45
2	22	43
3	17	34
4	16	33
5	16	33
6	24	45
7	18	33
8	17	32
9	20	36
10	24	44

CELLS SELECTED TO FAIL -- 9-1-10-6-2

CELLS SELECTED NOT TO FAIL -- 3-4-5-7-8

A = CELLS SELECTED TO FAIL THAT DID NOT.

B = CELLS SELECTED NOT TO FAIL THAT DID.

PACK 26

1st DIFFERENCE HISTOGRAM PREDICTION

INDICATOR COUNT FOR 1st 1500 CYCLES

CELL NO.	LOW COUNT (1-2-3)		MEDIUM COUNT (4-5-6)		HIGH COUNT (7-8-9)		TOTAL POINTS (2H+M-2L)	FAILURE CYCLE	LEAD TIME (CYC.)	CORRECT PREDICTION	(A) MISS PREDICT.	(B) MISS PREDICT.
1	1	1	3	1	4	1	9	2487	987	1	0	
2	0	2	6	2	2	2	10				1	
3	0	3	4	3	4	3	12	3344	1844	1	0	
4	1	4	7	4	0	4	5	3625	2125	1	0	
5	3	5	5	5	0	5	-1			1	0	
6	0	6	6	6	2	6	10	2993	1493	1	0	
7	0	7	6	7	2	7	10	2993	1493	1	0	
8	3	8	4	8	1	8	0			1	0	
9	2	9	5	9	1	9	3	2902	1402	1	0	
10	4	10	3	10	1	10	-3			1	0	

CELLS SELECTED TO FAIL 1, 2, 3, 4, 6, 7, 9

CELLS SELECTED NOT TO FAIL 5, 8, 10

A = CELLS PREDICTED TO FAIL THAT DID NOT.

B = CELLS PREDICTED NOT TO FAIL THAT DID.

CELLS ACTUALLY FAILING 1, 3, 4, 6, 7, 9

CELLS NOT FAILING 2, 5, 8, 10

PACK 26

1st DIFFERENCE HISTOGRAM

INDICATOR COUNT PREDICTION PROGRAM

CELL #	CYCLE 0001 to 1194	FAILURE CYCLE	LEAD TIME	CORRECT PREDICT.	(A) MISS PREDICT.	(B) MISS PREDICT.
1	43	2487	1293	1		
2	36				1	
3	43	3344	2150	1		
4	28	3625				1
5	28			1		
6	39	2993	1799	1		
7	37	2993	1799	1		
8	32				1	
9	24	2902				1
10	30			1		

CELLS SELECTED TO FAIL -- 1 - 2 - 3 - 6 - 7 - 8

CELLS SELECTED NOT TO FAIL -- 4 - 5 - 9 - 10

A = CELLS SELECTED TO FAIL THAT DID NOT

B = CELLS SELECTED NOT TO FAIL THAT DID.

PACK 50

1st DIFFERENCE HISTOGRAM

INDICATOR COUNT PREDICTION PROGRAM

CELL #	CYCLE 0001 to 1064	3533 to 4717	FAILURE CYCLE	LEAD TIME	CORRECT PREDICT.	(A) MISS PREDICT.	(B) MISS PREDICT.
1	22	41				1	
2	10	28			1		
3	28	41	13500	8783	1		
4	26	39				1	
5	31	34	12609	7892	1		
6	21	36				1	
7	8	15			1		
8	24	28				1	
9	20	25			1		
10	24	28				1	

CUMULATIVE

1	22	63
2	10	38
3	28	69
4	26	65
5	31	65
6	21	57
7	8	23
8	24	52
9	20	45
10	24	52

CELLS SELECTED TO FAIL -- 3 - 4 - 5 - 1 - 6 - 10 - 8

CELLS SELECTED NOT TO FAIL -- 7 - 2 - 9

A = CELLS SELECTED TO FAIL THAT DID NOT.

B = CELLS SELECTED NOT TO FAIL THAT DID.

PACK 51

1st DIFFERENCE HISTOGRAM

INDICATOR COUNT PREDICTION PROGRAM

CELL #	CYCLES 0001 to 1087	1122 to 2090	2124 to 2946	3006 to 4079	4103 to 5186	FAILURE CYCLE	LEAD TIME	CORRECT PREDICT.	(A) MISS PREDICT.	(B) MISS PREDICT.
1	2	1	1	2	1			1		
2	7	2	3	10	7			1		
3	8	11	2	10	3				1	
4	4	7	6	12	7			1		
5	0	8	8	22	9				1	
6	3	6	1	17	18				1	
7	4	4	1	3	7			1		
8	3	3	2	21	17				1	
9	4	4	4	12	9			1		
10	2	8	6	17	19	14737	9551	1		

CUMULATIVE

CELL #	0001 to 1087	1122 to 2090	2124 to 2946	3006 to 4079	4103 to 5186
1	2	3	4	6	7
2	7	9	12	22	29
3	8	19	21	31	34
4	4	11	17	29	36
5	0	8	16	38	47
6	3	9	10	27	45
7	4	8	9	12	19
8	3	6	8	29	46
9	4	8	12	24	33
10	2	10	16	33	52

CELLS SELECTED TO FAIL -- 3 - 5 - 6 - 8 - 10

CELLS SELECTED NOT TO FAIL -- 1 - 2 - 4 - 7 - 9

PACK 52

1st DIFFERENCE HISTOGRAM

INDICATOR COUNT PREDICTION PROGRAM

CELL #	CYCLE 0001 to 1250	2506 to 3193	FAILURE CYCLE	LEAD TIME	CORRECT PREDICT.	(A) MISS PREDICT.	(B) MISS PREDICT.
1	22	22			1		
2	32	24				1	
3	24	22	10994	7801	1		
4	24	27				1	
5	22	19			1		
6	25	27				1	
7	25	35	9724	6531	1		
8	23	26	7858	4665	1		
9	24	26	9724	6531	1		
10	17	14	8367				1
CUMULATIVE							
1	22	44					
2	32	56					
3	24	46					
4	24	51					
5	22	41					
6	25	52					
7	25	60					
8	23	49					
9	24	50					
10	17	31					

CELLS SELECTED TO FAIL -- 3-7-2-6-4-9-8

CELLS SELECTED NOT TO FAIL -- 10-5-1

A = CELLS SELECTED TO FAIL THAT DID NOT.

B = CELLS SLECTED NOT TO FAIL THAT DID.

PACK 62

1st DIFFERENCE HISTOGRAM

INDICATOR COUNT PREDICTION PROGRAM

CELL #	CYCLE 0001 to 0896	0922 to 1963	2008 to 3194	FAILURE CYCLE	LEAD TIME	CORRECT PREDICT.	(A) MISS PREDICT.	(B) MISS PREDICT.
1	4	21	18			1		
2	7	30	34			1		
3	14	37	32				1	
4	27	29	33	4066	872	1		
5	25	31	34	4441	1247	1		
6	19	30	32				1	
7	14	26	35	8590	5396	1		
8	21	30	30				1	
9	15	28	18			1		
10	18	29	33	2995	0	1		
CUMULATIVE								
1	4	25	43					
2	7	37	71					
3	14	51	83					
4	27	56	89					
5	25	56	90					
6	19	49	81					
7	14	40	75					
8	21	51	81					
9	15	43	61					
10	18	47	80					

CELLS SELECTED TO FAIL -- 5 - 4 - 7 - 3 - 8 - 6 - 10

CELLS SELECTED NOT TO FAIL -- 1 - 9 - 2

A = CELLS SELECTED TO FAIL THAT DID NOT.

B = CELLS SELECTED NOT TO FAIL THAT DID.

PACK 66

1st DIFFERENCE HISTOGRAM PREDICTION

INDICATOR COUNT FOR 1st 1500 CYCLES

CELL NO.	LOW COUNT (1-2-3)		MEDIUM COUNT (4-5-6)		HIGH COUNT (7-8-9)		TOTAL POINTS (2H+M-2L)	FAILURE CYCLE	LEAD TIME (CYC.)	CORRECT PREDICTION	(A) MISS PREDICT.	(B) MISS PREDICT.
1	5	1	3	1	0	1	-7			1		
2	5	2	3	2	0	2	-7			1		
3	3	3	4	3	1	3	0	1417	0			1
4	6	4	1	4	1	4	-13	4414	2914			1
5	0	5	3	5	4	5	+11	1237	0	1		
6	0	6	5	6	2	6	+9	1045	0	1		
7	2	7	3	7	3	7	+5	2122	622	1		
8	4	8	2	8	1	8	-4	1173	0			1
9	0	9	4	9	3	9	+10				1	
10	1	10	6	10	0	10	+4				1	

CELLS SELECTED TO FAIL 5, 6, 7, 9, 10

CELLS SELECTED NOT TO FAIL 1, 2, 4, 8, 3

A = CELLS SELECTED TO FAIL THAT DID NOT

B = CELLS SELECTED NOT TO FAIL THAT DID

CELLS ACTUALLY FAILING 3, 4, 5, 6, 7, 8

CELLS NOT FAILING 1, 2, 9, 10

PACK 66

1st DIFFERENCE HISTOGRAM

INDICATOR COUNT PREDICTION PROGRAM

CELL #	CYCLE 0001 to 1012	FAILURE CYCLE	LEAD TIME	CORRECT PREDICT.	(A) MISS PREDICT.	(B) MISS PREDICT.
1	16			1		
2	18			1		
3	27	1417	405	1		
4	12	4414				1
5	35	1237	225	1		
6	36	1045	33	1		
7	24	2122	1110	1		
8	16	1173				
9	33				1	1
10	24				1	

CELLS SELECTED TO FAIL -- 6 - 5 - 9 - 3 - 7 - 10

CELLS SELECTED NOT TO FAIL -- 1 - 2 - 4 - 8

A = CELLS SELECTED TO FAIL THAT DID NOT

B = CELLS SELECTED NOT TO FAIL THAT DID

PACK 68

1st DIFFERENCE HISTOGRAM PREDICTION

INDICATOR COUNT FOR 1st 1200 CYCLES

CELL NO.	LOW COUNT (1-2-3)		MEDIUM COUNT (4-5-6)		HIGH COUNT (7-8-9)		TOTAL POINTS (2H+M-2L)	FAILURE CYCLE	LEAD TIME (CYC.)	CORRECT PREDICTION	(A) MISS PREDICT.	(B) MISS PREDICT.
1	5	1	2	1	1	1	-1	0	0	1	0	0
2	3	2	5	2	0	2	-1	0	0	1	0	0
3	5	3	3	3	0	3	-7	0	0	1	0	0
4	6	4	2	4	0	4	-10	0	0	1	0	0
5	5	5	2	5	1	5	-1	0	0	1	0	0
6	6	6	1	6	1	6	-9	0	0	1	0	0
7	6	7	2	7	0	7	-10	0	0	1	0	0
8	4	8	2	8	2	8	-2	0	0	1	0	0
9	6	9	2	9	0	9	-10	0	0	1	0	0
10	7	10	1	10	0	10	-13	0	0	1	0	0

CELLS SELECTED TO FAIL - NONE

CELLS SELECTED NOT TO FAIL - ALL TEN

A = CELLS SELECTED TO FAIL THAT DID NOT.

B = CELLS SELECTED NOT TO FAIL THAT DID.

CELLS ACTUALLY FAILING - NONE

CELLS NOT FAILING - ALL TEN

PACK 301

1st DIFFERENCE HISTOGRAM

INDICATOR COUNT PREDICTION PROGRAM

CELL #	CYCLE 0063 to 1528	3290 to 4911	FAILURE CYCLE	LEAD TIME	CORRECT PREDICT.	(A) MISS PREDICT.	(B) MISS PREDICT.
1	28	38				1	
2	26	32			1		
3	27	45				1	
4	25	42	5586	675	1		
5	28	36				1	

CUMULATIVE

1	28	66
2	26	58
3	27	72
4	25	67
5	28	64

CELLS SELECTED TO FAIL -- 1-3-4-5

CELLS SELECTED NOT TO FAIL -- 2

A = CELLS SELECTED TO FAIL THAT DID NOT.

B = CELLS SELECTED NOT TO FAIL THAT DID.

SUPERPOSITIONED DISCHARGE - CHARGE CURVE

PREDICTION INDICATOR COUNT

PACK #16

CELL NO.	CYCLE 0623	1578	FAILURE CYCLE	LEAD TIME	CORRECT PREDICT.
1	4	4-11-12	4741	3163	1
2	4	4-11			1
3		4			1
4	4	4-11-12	5013	3435	1
5	3-4	4-11-12	4917	3339	1
6	4	4-10-11-12	4473	2895	1
7		4-10-11-12	3985	2407	1
8	4-3	4-10			1
9		4			1
10	4	10-11-12	4917	3339	1

CELLS SELECTED TO FAIL -- 1 - 4 - 5 - 6 - 7 - 10

CELLS SELECTED NOT TO FAIL -- 2 - 3 - 8 - 9

SUPERPOSITIONED DISCHARGE - CHARGE CURVE

PREDICTION INDICATOR COUNT

PACK #51 (STILL BEING CYCLED)

CELL NO.	CYCLE 644	1404	2292	3104	FAILURE CYCLE	LEAD TIME	CORRECT PREDICT.
1	5	11-4	0				
2		12-4-11	0				
3		12-4-11	0				
4	4	12-4	0	4			
5	3-4	12-4	0	4			
6	4	12-4	0	4-3			
7	4	12-4-11	0				
8	4	12-4-11	0	4			
9	4	12-4-3	0	12-4			
10	4	12-4-11	0	4	14737	11633	1

CELLS SELECTED TO FAIL -- 4 - 5 - 6 - 8 - 9 - 10

CELLS SELECTED NOT TO FAIL -- 1 - 2 - 3 - 7

SUPERPOSITIONED DISCHARGE - CHARGE CURVE

PREDICTION INDICATOR COUNT

PACK #52

CELL NO.	CYCLE 609	3196	FAILURE CYCLE	LEAD TIME	CORRECT PREDICT.	(A) MISS PREDICT.	(B) MISS PREDICT.
1	3	11			1		
2	3	11			1		
3	3	4-10-11-12	10994	7798	1		
4	4	11			1		
5		11-12			1		
6		11			1		
7		3-4-11-12	9724	6528	1		
8		4-11-12	7858	4662	1		
9	3-4	3-4-11-12	9724	6528	1		
10	4-12	4-11	8367	5171	1		

CELLS SELECTED TO FAIL -- 3 - 7 - 8 - 9 - 10

CELLS SELECTED NOT TO FAIL -- 1 - 2 - 4 - 5 - 6

SUPERPOSITIONED DISCHARGE - CHARGE CURVE

PREDICTION INDICATOR COUNT

PACK #62

CELL NO.	CYCLE 698	CYCLE 2376	FAILURE CYCLE	LEAD TIME	CORRECT PREDICT.	(A) MISS PREDICT.	(B) MISS PREDICT.
1					1		
2	3-4-10-13	3-4			1		
3	4	3-4			1		
4	10-4-3	3-5-10-11-13	4066	1690	1		
5	3-4-12-13	3-4-10-11-13	4441	2065	1		
6					1		
7	13		8590			1	
8					1		
9					1		
10	4-5-10-13	10-11-13	2995	619	1		

CELLS SELECTED TO FAIL -- 4 - 5 - 10

CELLS SELECTED NOT TO FAIL -- 1 - 2 - 3 - 6 - 7 - 8 - 9

A = CELLS SELECTED NOT TO FAIL THAT DID.

B = CELLS SELECTED TO FAIL THAT DID NOT.

SUPERPOSITIONED DISTRIBUTION

(SUM OF SQUARES)

ANALYSIS FOR PACK #62

FOR CYCLES 0001 TO 2376

	CELL 1	CELL 2	CELL 3	CELL 4	CELL 5	CELL 6	CELL 7	CELL 8	CELL 9	CELL 10
<100	19	5	13	16	7	17	15	19	10	6
200	16	11	18	15	14	18	15	18	22	13
300	5	10	3	2	3	3	6	1	7	7
400	1	6	2	4	4	1			1	2
500	1	1			2		1			2
600		1	1	2	4		1	2		1
700	1	1	1		3	2	2			
800		1				1				1
900			1	2	3				1	1
>1000	1	1	2	2	2				1	7

SUPERPOSITIONED DISCHARGE - CHARGE CURVE

PREDICTION INDICATOR COUNT

PACK #73

CELL NO.	CYCLE 0580	1483	FAILURE CYCLE	LEAD TIME	CORRECT PREDICT.
1	4	3-4-11	6120	4637	1
2	12-13				1
3	3-4-10-12-13	3-4-9-10-11-12	1776	1196	1
4	10-4	10-11-13	7763	6280	1
5	4	11-13			1

CELLS SELECTED TO FAIL -- 1 - 3 - 4

CELLS SELECTED NOT TO FAIL -- 2 - 5

SUPERPOSITIONED DISCHARGE - CHARGE CURVE

PREDICTION INDICATOR COUNT

PACK #76

CELL NO.	CYCLE 0875	1583	2224	FAILURE CYCLE	LEAD TIME	CORRECT PREDICT.
1						1
2	3-4-5-12-13	4-10-11-13	9-10-11-13	7697	5473	1
3		10-11-13	2-10-11-13	9348	7124	1
4	12-13	10-11-13	10-11-13	7698	5474	1
5	12	4-10	13			1

CELLS SELECTED TO FAIL -- 2 - 3 - 4

CELLS SELECTED NOT TO FAIL -- 1 - 5

SUPERPOSITIONED DISCHARGE - CHARGE CURVE

PREDICTION INDICATOR COUNT

PACK #82

CELL NO.	CYCLE 0619	1417	2165	FAILURE CYCLE	LEAD TIME	CORRECT PREDICT.	(A) MISS PREDICT.	(B) MISS PREDICT.
1	4	11	10-11	10878	8713	1		
2		11		7527			1	
3			10-13			1		
4		11				1		
5	4-13-5-12	11		10624	8459	1		

CELLS SELECTED TO FAIL -- 1-5

CELLS SELECTED NOT TO FAIL -- 2 - 3 - 4

A = CELLS SELECTED NOT TO FAIL THAT DID.

B = CELLS SELECTED TO FAIL THAT DID NOT.

SUPERPOSITIONED DISCHARGE - CHARGE CURVE

PREDICTION IND IDCATOR COUNT

PACK #98

CELL NO.	0898	1669	2420	FAILURE CYCLE	LEAD TIME	CORRECT PREDICT.
1	3-4-5-12	3-4	3-4-10-11-12	8619	6199	1
2	4-12	4				1
3	3-4-12	4-12	4			1
4	3-4-12	3-4-12	3-4-11-12	10641	8221	1
5	3-4-10-12-13	3-4-10-11-12-13	3-4-10-11-12-13	3556	2658	1

CELLS SELECTED TO FAIL -- 1 - 4 - 5

CELLS SELECTED NOT TO FAIL -- 2 - 3

SUPERPOSITIONED DISCHARGE - CHARGE CURVE

PREDICTION INDICATOR COUNT

PACK #99

CELL NO.	CYCLE 0756	1532	FAILURE CYCLE	LEAD TIME	CORRECT PREDICT.
1	4-5-10-12-13	10-11-13	4853	4097	1
2	4-10-12-13	10-11-13	3841	2309	1
3	4-7-10-12-13	4-5-10-11-12-13	3841	3085	1
4	4-10-12-13	10-13			1
5	4-5-12-13	10-13			1

CELLS SELECTED TO FAIL -- 1 - 2 - 3

CELLS SELECTED NOT TO FAIL -- 4 - 5

TALLY-WEIGHT
PROGRAM

CONTROL CARDS
AND
OUTPUT

```
CT TALLY WT TST 10 10 10 10 10 10 10 10 10 10 10 10 10 10 10 10 10 10 10 10 TEST
AB TALLY WT TST 00 40 40 40-40-40-40 00 00 00 00-40-40-40 40 40 40 00 00 00 TEST
BA TALLY WT TST 00 04 08 12-16-20-24-28 00 00 00 00 08 12 16 20-24-28-32-36 TEST
JW TALLY WT TST 00 10 20 30 40 50 60 70 80 90 00 90 80 70 60 50 40 30 20 10 TEST
WJ TALLY WT TST 00 10 20 30 40 50 60 70 80 90 00 10 20 30 40 50 60 70 80 90 TEST
TB TALLY WT TST 00 10 20 00 00 00 00 0  80 90 00 00 00 30 40 00 00 00 80 90 TEST
BT TALLY WT TST 00 10 00 30 00 50 00 70 00 90 00 10 00 30 00 50 00 70 00 90 TEST
SE TALLY WT TST 00 00 20 00 40 00 60 00 80 00 00 00 20 00 40 00 60 00 80 00 TEST
END


X 052 0096 01 5CT 032 024 014 AB 048-016 199 BA-006 013-266 JW 096 146-020
X 052 0096 01 5WJ 096 084 006 TB 033 040-009 BT 058 042 015 SE 038 042-004
X 052 0096 02 5CT 032 024 014 AB 048-020 242 BA-007 022-192 JW 102 156-020
X 052 0096 02 5WJ 102 084 009 TB 024 047-032 BT 048 050-002 SE 054 034 022
X 052 0096 03 5CT 032 024 014 AB 052-036 549 BA-003 012-172 JW 099 159-023
X 052 0096 03 5WJ 099 081 009 TB 035 036-001 BT 057 037 021 SE 042 044-002
X 052 0096 04 5CT 032 024 014 AB 044-020 266 BA-004 013-195 JW 093 153-024
X 052 0096 04 5WJ 093 087 003 TB 023 041-028 BT 045 037 009 SE 048 050-002
X 052 0096 05 5CT 032 024 014 AB 060-008 130 BA 000 012-099 JW 089 148-024
X 052 0096 05 5WJ 089 092-001 TB 031 057-029 BT 049 044 005 SE 040 048-009
X 052 0096 06 5CT 031 026 008 AB 036-028 799 BA-004 005-299 JW 096 160-024
X 052 0096 06 5WJ 096 100-002 TB 028 053-030 BT 044 052-008 SE 052 048 003
X 052 0096 07 5CT 031 026 008 AB 048-000 099 BA-006 007-699 JW 092 150-023
X 052 0096 07 5WJ 092 100-004 TB 029 057-032 BT 038 042-004 SE 054 058-003
X 052 0096 08 5CT 031 026 008 AB 040-016 233 BA-005 007-619 JW 090 149-024
X 052 0096 08 5WJ 090 101-005 TB 031 052-025 BT 044 061-016 SE 046 040 006
X 052 0096 09 5CT 031 026 008 AB 048-008 139 BA-003 006-277 JW 087 151-026
X 052 0096 09 5WJ 087 099-006 TB 035 042-009 BT 053 049 003 SE 034 050-019
X 052 0096 10 5CT 031 026 008 AB 048-032 499 BA-002 017-131 JW 086 171-033
X 052 0096 10 5WJ 086 089-001 TB 028 054-031 BT 028 029-001 SE 058 060-001
X 052 0294 01 5CT 029 028 001 AB 036 004 079 BA-001 021-111 JW 099 174-027
X 052 0294 01 5WJ 099 106-003 TB 058 055 002 BT 025 056-038 SE 074 050 019
X 052 0294 02 5CT 029 028 001 AB 020 024-009 BA-006 032-145 JW 107 175-024
X 052 0294 02 5WJ 107 105 000 TB 062 065-002 BT 015 041-046 SE 092 064 017
X 052 0294 03 5CT 029 028 001 AB 060-024 233 BA 000 024-099 JW 094 184-032
X 052 0294 03 5WJ 094 096-001 TB 036 040-005 BT 048 044 004 SE 046 052-006
X 052 0294 04 5CT 029 028 001 AB 044 012 057 BA 002 023-084 JW 103 168-023
X 052 0294 04 5WJ 103 112-004 TB 058 064-004 BT 029 060-034 SE 074 052 017
X 052 0294 05 5CT 029 028 001 AB 036 016 038 BA-002 032-118 JW 101 175-026
X 052 0294 05 5WJ 101 105-001 TB 050 074-019 BT 033 045-015 SE 068 060 006
X 052 0294 06 5CT 028 028 000 AB 036 004 079 BA 000 023-096 JW 094 171-029
```

66	1	127	5	2	1	0	0	1	0	0	0	4	1	Z001
66	1	127	5	2	1	0	0	0	0	*		3	2	Z002
66	1	127	5	2	1	0	0	1	0	1	0	5	3	Z003
66	1	127	5	2	1	0	0	0	0	0		3	4	Z004
66	1	127	5	2	1	0	0	0	0	1	1	5	5	Z005
66	1	127	5	2	1	0	0	0	0	1	1	5	6	Z006
66	1	127	5	2	1	0	0	0	0	1	0	4	7	Z007
66	1	127	5	2	1	0	2	0	0	1	1	7	8	Z008
66	1	127	5	2	1	0	0	1	0	1	0	5	9	Z009
66	1	127	5	2	1	0	0	1	0	0	0	4	10	Z010
66	162	364	5	0	0		0	1	0	0	0	1	1	Z011
66	162	364	5	0	0					1	0	1	2	Z012
66	162	364	5	2	1	0	0	1	0	0	0	4	3	Z013
66	162	364	5	1	0	0	0	1	0	0	0	2	4	Z014
66	162	364	5	2	1	2	0	1	0	1	0	7	5	Z015
66	162	364	5	2	1	0	0	1	0	1	0	5	6	Z016
66	162	364	5	0	0	0	0	1	0	1	0	2	7	Z017
66	162	364	5	0	0								8	Z018
66	162	364	5	2	1	0	0	1	0	1	0	5	9	Z019
66	162	364	5	2	1	0	0	0	0	0	0	3	10	Z020
66	398	522	5	0	0								1	Z021
66	398	522	5	0	0					1	0	1	2	Z022
66	398	522	5	2	1	0	0	1	0	0	0	4	3	Z023
66	398	522	5	0	0	0	2	0	0	0	0	2	4	Z024
66	398	522	5	2	1	0	0	0	0	0	1	4	5	Z025
66	398	522	5	2	1	0	0	1	0	1	0	5	6	Z026
66	398	522	5	0	0					1	0	1	7	Z027
66	398	522	5	0	0	0	0	1	0	0	0	1	8	Z028
66	398	522	5	2	1	0	0	1	0	1	0	5	9	Z029
66	398	522	5	2	1	0	0	0	0	1	0	4	10	Z030
66	613	705	5	2	1	0	0	0	0	0	1	4	1	Z031
66	613	705	5	2	1	0	0	0	0	1	1	5	2	Z032
66	613	705	5	2	1	0	0	0	0	0	1	4	3	Z033
66	613	705	5	2	1	0	0	0	0	0	1	4	4	Z034
66	613	705	5	2	1	0	2	0	0	1	1	7	5	Z035
66	613	705	5	2	1	0	0	1	0	1	0	5	6	Z036
66	613	705	5	2	1	0	0	1	0	1	0	5	7	Z037
66	613	705	5	2	1	0	0	0	0	0	1	4	8	Z038
66	613	705	5	2	1	0	2	0	0	1	1	7	9	Z039
66	613	705	5	2	1	0	0	1	0	1	0	5	10	Z040
66	735	853	5	2	1	0	0	0	0	0	0	3	1	Z041
66	735	853	5	2	1	0	0	0	0	1	0	4	2	Z042
66	735	853	5	2	1	0	0	0	0	0	0	3	3	Z043
66	735	853	5	0	0								4	Z044

66	735	853	5	2	1	2	0	1	0	1	0	7	5	Z045
66	735	853	5	2	1	2	0	1	1	1	0	8	6	Z046
66	735	853	5	2	1	0	0	1	0	1	0	5	7	Z047
66	735	853	5	2	1	0	0	0	0	0	0	3	8	Z048
66	735	853	5	2	1	0	0	0	0	1	0	4	9	Z049
66	735	853	5	2	1	0	0	0	0	1	0	4	10	Z050
66	885	1012	5	2	1	0	0	1	0	0	0	4	1	Z051
66	885	1012	5	0	0	2	0	1	0	1	0	4	2	Z052
66	885	1012	5	2	1	2	0	1	0	1	0	7	3	Z053
66	885	1012	5	0	0	0	0	1	0	0	0	1	4	Z054
66	885	1012	5	2	1	0	0	1	0	1	0	5	5	Z055
66	885	1012	5	2	1	2	0	1	1	1	0	8	6	Z056
66	885	1012	5	2	1	2	0	1	0	1	0	7	7	Z057
66	885	1012	5	0	0	0	0	1	0	0	0	1	8	Z058
66	885	1012	5	2	1	0	2	0	0	1	1	7	9	Z059
66	885	1012	5	2	1	0	0	0	0	1	0	4	10	Z060
66	1045	1237	5	2	1	0	0	0	0	0	0	3	1	Z061
66	1045	1237	5	0	0	0	0	1	0	1	0	2	2	Z062
66	1045	1237	5	0	0	0	0	1	0	0	0	1	3	Z063
66	1045	1237	5	2	1	0	0	0	0	0	0	3	4	Z064
66	1045	1237	5	2	1	2	0	1	0	1	0	7	5	Z065
66	1045	1237	5	2	1	0	0	1	0	0	1	5	6	Z066
66	1045	1237	5	2	1	2	0	1	0	1	0	7	7	Z067
66	1045	1237	5	2	1	0	2	0	0	0	0	5	8	Z068
66	1045	1237	5	2	1	2	0	1	0	1	0	7	9	Z069
66	1045	1237	5	2	1	2	0	1	0	0	0	6	10	Z070
66	1268	1416	5	0	0	0	1	0	0	0	1	2	1	Z071
66	1268	1416	5	0	0	0	0	1	0	1	0	2	2	Z072
66	1268	1416	5	2	1	0	0	0	0	0	0	3	3	Z073
66	1268	1416	5	2	1	0	2	0	0	1	1	7	4	Z074
66	1268	1416	5	**********FAILURE CELL NO. 5										Z075
66	1268	1416	5	**********FAILURE CELL NO. 6										Z076
66	1268	1416	5	2	1	2	0	1	0	1	0	7	7	Z077
66	1268	1416	5	**********FAILURE CELL NO. 8										Z078
66	1268	1416	5	0	0								9	Z079
66	1268	1416	5	0	0	0	0	1	0	0	0	1	10	Z080
66	1443	1606	5	2	1	0	2	0	0	0	1	6	1	Z081
66	1443	1606	5	2	1	0	0	0	0	1	0	4	2	Z082
66	1443	1606	5	0	0	0	1	0	1	0	1	3	3	Z083
66	1443	1606	5	2	1	0	0	1	0	0	0	4	4	Z084
66	1443	1606	5	**********FAILURE CELL NO. 5										Z085
66	1443	1606	5	0	0	0	1	0	1	0	1	3	6	Z086
66	1443	1606	5	2	1	2	0	1	0	1	0	7	7	Z087
66	1443	1606	5	0	0		*		1	0	1	2	8	Z088

66	1443	1606	5	2	1	0	0	1	0	0	0	4	9	Z089
66	1443	1606	5	2	1	0	0	0	0	0	1	4	10	Z090
66	1639	1767	5	2	1	0	2	0	0	0	1	6	1	Z091
66	1639	1767	5	2	1	0	0	0	0	1	1	5	2	Z092
66	1639	1767	5	0	0	0	2	0	0	0	1	3	3	Z093
66	1639	1767	5	2	1	0	0	1	0	1	0	5	4	Z094
66	1639	1767	5	0	0						1	1	5	Z095
66	1639	1767	5	0	0								6	Z096
66	1639	1767	5	2	1	2	0	1	0	1	0	7	7	Z097
66	1639	1767	5	0	0	*	*		1	0	0	1	8	Z098
66	1639	1767	5	2	1	0	0	1	0	1	0	5	9	Z099
66	1639	1767	5	2	1	0	0	1	0	1	1	6	10	Z100
66	1798	1940	5	2	1	0	0	0	0	0	1	4	1	Z101
66	1798	1940	5	2	1	0	2	0	0	1	1	7	2	Z102
66	1798	1940	5	0	1	0	0	0	1	0	1	3	3	Z103
66	1798	1940	5	2	1	2	0	1	0	1	0	7	4	Z104
66	1798	1940	5	**********FAILURE CELL NO. 5										Z105
66	1798	1940	5	**********FAILURE CELL NO. 6										Z106
66	1798	1940	5	2	1	2	0	1	0	1	0	7	7	Z107
66	1798	1940	5	**********FAILURE CELL NO. 8										Z108
66	1798	1940	5	0	0	0	0	1	0	1	0	2	9	Z109
66	1798	1940	5	2	1	0	0	0	0	0		3	10	Z110
66	1984	2105	5	2	1	0	1	0	0	1	0	5	1	Z111
66	1984	2105	5	2	1	0	0	0	0	1	0	4	2	Z112
66	1984	2105	5	**********FAILURE CELL NO. 3										Z113
66	1984	2105	5	2	1	0	0	0	0	0		3	4	Z114
66	1984	2105	5	**********FAILURE CELL NO. 5										Z115
66	1984	2105	5	**********FAILURE CELL NO. 6										Z116
66	1984	2105	5	2	1	2	0	1	0	1	0	7	7	Z117
66	1984	2105	5	**********FAILURE CELL NO. 8										Z118
66	1984	2105	5	2	1	0	0	0	0	1	0	4	9	Z119
66	1984	2105	5	2	1	0	0	0	0	0	0	3	10	Z120
66	2122	2253	5	2	1	0	0	0	0	0	1	4	1	Z121
66	2122	2253	5	2	1	0	0	1	0	1	0	5	2	Z122
66	2122	2253	5	**********FAILURE CELL NO. 3										Z123
66	2122	2253	5	2	1	0	2	0	0	0	1	6	4	Z124
66	2122	2253	5	**********FAILURE CELL NO. 5										Z125
66	2122	2253	5	**********FAILURE CELL NO. 6										Z126
66	2122	2253	5	2	1	0	0	1	0	1	0	5	7	Z127
66	2122	2253	5	**********FAILURE CELL NO. 8										Z128
66	2122	2253	5	2	1	0	0	0	0	0	1	4	9	Z129
66	2122	2253	5	2	1	0	0	0	0	0	1	4	10	Z130
66	2283	2427	5	2	1	0	0	0	0	0	1	4	1	Z131
66	2283	2427	5	2	1	0	0	0	0	0	1	4	2	Z132

66	2283	2427	5	**********FAILURE CELL NO. 3										Z133
66	2283	2427	5	2	1	0	0	1	0	0	0	4	4	Z134
66	2283	2427	5	**********FAILURE CELL NO. 5										Z135
66	2283	2427	5	**********FAILURE CELL NO. 6										Z136
66	2283	2427	5	1	1	0	0	0	1	1	1	5	7	Z137
66	2283	2427	5	0	0	0			1	0	1	2	8	Z138
66	2283	2427	5	2	1	0	2	0	0	0	1	6	9	Z139
66	2283	2427	5	2	1	0	0	0	0	0	0	3	10	Z140
66	2469	2567	5	2	1	0	0	0	0	0	0	3	1	Z141
66	2469	2567	5	2	1	0	0	0	0	0	0	3	2	Z142
66	2469	2567	5	**********FAILURE CELL NO. 3										Z143
66	2469	2567	5	2	1	0	0	1	0	0	0	4	4	Z144
66	2469	2567	5	**********FAILURE CELL NO. 5										Z145
66	2469	2567	5	**********FAILURE CELL NO. 6										Z146
66	2469	2567	5	**********FAILURE CELL NO. 7										Z147
66	2469	2567	5	**********FAILURE CELL NO. 8										Z148
66	2469	2567	5	2	1	0	0	0	0	0	1	4	9	Z149
66	2469	2567	5	2	1	0	1	0	0	0	1	5	10	Z150
66	2644	2770	5	2	1	0	2	0	0	0	1	6	1	Z151
66	2644	2770	5	2	1	0	2	0	0	1	1	7	2	Z152
66	2644	2770	5	**********FAILURE CELL NO. 3										Z153
66	2644	2770	5	2	1	0	0	1	0	0	0	4	4	Z154
66	2644	2770	5	**********FAILURE CELL NO. 5										Z155
66	2644	2770	5	**********FAILURE CELL NO. 6										Z156
66	2644	2770	5	**********FAILURE CELL NO. 7										Z157
66	2644	2770	5	**********FAILURE CELL NO. 8										Z158
66	2644	2770	5	2	1	0	0	0	0	0	1	4	9	Z159
66	2644	2770	5	2	1	0	0	0	0	0	1	4	10	Z160
66	2831	2962	5	2	1	0	2	0	0	0	1	6	1	Z161
66	2831	2962	5	2	1	0	2	0	0	1	1	7	2	Z162
66	2831	2962	5	0	0				1	0	1	2	3	Z163
66	2831	2962	5	2	1	2	0	1	0	1	0	7	4	Z164
66	2831	2962	5	**********FAILURE CELL NO. 5										Z165
66	2831	2962	5	**********FAILURE CELL NO. 6										Z166
66	2831	2962	5	**********FAILURE CELL NO. 7										Z167
66	2831	2962	5	**********FAILURE CELL NO. 8										Z168
66	2831	2962	5	2	1	0	2	0	0	0	1	6	9	Z169
66	2831	2962	5	2	1	0	2	0	0	0	1	6	10	Z170
66	3065	3244	5	2	1	0	2	0	0	1	1	7	1	Z171
66	3065	3244	5	2	1	0	2	0	0	1	1	7	2	Z172
66	3065	3244	5	**********FAILURE CELL NO. 3										Z173
66	3065	3244	5	2	1	0	0	1	0	1	0	5	4	Z174
66	3065	3244	5	**********FAILURE CELL NO. 5										Z175
66	3065	3244	5	**********FAILURE CELL NO. 6										Z176

APPENDIX D

5 CYCLE-DELTA VOLT-HISTOGRAM PROGRAM

NAB-P1

5 CYCLE-DELTA VOLT-HISTOGRAM PROGRAM

Input to this program is Crane Battery Test Data.

Output is sets of five cycle tally histograms of first difference voltages on a per cell basis for both discharge and charge.

Each output card is identified by pack number. Each card contains the starting and ending cycle numbers of its cycle group. Each card contains the voltage first difference history, both discharge and charge, of one identified cell for the indicated cycle group.

Each card contains the minimum and maximum temperatures recorded, for its identified cell, for the cycle group.

The format of each output card is as follows:

C.C. 1 - X - Denoting ten cell pack.
V - Denoting five cell pack.

C.C. 3-5: Pack Number

C.C. 7-10: Group Starting Cycle Number

C.C. 12-15: Group Ending Cycle Number

C.C. 17-18: Number of Cycles Contained in this Cycle Group

C.C. 20-39: Ten, two digit fields starting with Delta volts equal zero to Delta Volts equal nine. Each of the two digit fields records the occurrences of Delta volt values for its respective level. For example--the first two digit field records the number of occurrences of the zero Delta volt level; the second two digit field records the number of occurrences of the one Delta volt level. This section is for discharge.

C.C. 41-43: Records the total number of Delta volt occurrences in the discharge section.

C.C. 44-63: The same as C.C. 20-39 but for charge.

C.C. 65-67: The same as C.C. 41-43 but for charge.

C.C. 70-76: Two, three digit fields recording the maximum and minimum temperatures for the cell for its cycle group.

C.C. 78-79: Records the individual cell number.

C.C. 80: The letter "P" denoting that this output was checked and found error free by the error checks within the program.

ERROR CHECKS AND ERROR OUTPUT:

1. Duplication and sequence errors:

This program checks the Crane Battery Test Data for proper sequence and duplicate card errors. When such errors are detected, the program, through switching options, notifies the operator, through card punch or console typewriter, which errors have occurred. The operator then has the chance to eliminate several types of errors.

These error messages are as follows:

Cycle number decreased.

Time Decreased--followed by a message stating that New Time Accepted.

Duplicate Time, Card 1.

No Card 1 Before (card #2)

No Card 2 Before (the next #1 card)

Duplicate 5 pack card.

One Misplaced Card
May Cause 2 or More
Error Messages: These error messages also contain pack, cycle, and time identification.

2. Other Error Types:

The following error messages are output the same as above.

Column 80 type wrong.

Trouble Card.

Wrong for this Pack.

3. "Reject" Cards:

These are caused by negative voltage differences in the charge cycle. No error messages are output.

Appendix E, Page 102 through 107 are examples of NAB-P1 output.

SUPERTALLY

Supertally is a dual purpose program that can output either one Delta volt histogram or a histogram of histograms.

Input to Supertally is NAB Pass 1 output.

Supertally computes the number of occurrences, from zero to twenty-four, of Delta volt values zero to nine. More than twenty-four occurrences is counted as twenty-four. Control cards specify from which cyclic group output is desired. Output is per cell with complete pack, cell, and cyclic group identification. Discharge and charge are separated and outputted concurrently.

If the input to Supertally is a single histogram in numerical form, the output is a physical representation of that histogram.

If the input to Supertally is many histograms in numerical form, the output is a distribution of occurrences of Delta volt values. From this distribution a mean can be calculated for use as a threshhold for certain indicator and other programs.

An example of "Supertally" is in Appendix E, Page108 through Page109 .

5 CYCLE
DELTA-VOLT
HISTOGRAM
PROGRAM

UNEDITED
OUTPUT

```
X 054 2850 2980 05  1 420 2 2 1 2 3 0 0   35 0 1 813 5 4 3 2 0 0   36    07 -01 05P
X 054 2850 2980 05  0 415 1 4 1 2 3 0 0   30 0 314 6 4 7 2 0 0 5   41    05 -01 06P
X 054 2850 2980 05  0 416 1 3 1 3 2 0 0   30 0 6 9 6 7 5 1 0 0 7   41    05 -01 07P
X 054 2850 2980 05  0 315 5 2 0 2 3 0 0   30 0 311 5 9 6 0 0 0 7   41    04 -03 08P
X 054 2850 2980 05  0 317 0 3 1 3 3 0 0   30 1 5 810 8 4 3 2 0 0   41    39 -03 09P
X 054 2850 2980 05  0 316 2 3 1 5 0 0 0   30 2 41012 6 4 2 1 0 0   41    05 -02 10P
X 054 3009 3140 05  1 116 6 3 0 1 4 0 0   32 4 1 21111 4 2 0 1 0   36    08 -19 01P
X 054 3009 3140 05  0 2 910 4 1 3 1 2 0   32 1 2 6 7 4 4 4 1 2 5   36    21 -03 02P
X 054 3009 3140 05  0 0 2 7 7 4 3 4 0 5   32 1 2 5 7 6 2 3 0 010   36    05 -03 03P
X 054 3009 3140 05  1 215 4 4 1 1 4 0 0   32 0 111 7 7 2 5 2 1 0   36    02 -19 04P
X 054 3009 3140 05  0 416 4 1 2 3 2 0 0   32 0 0 812 6 4 4 2 0 0   36    04 -03 05P
X 054 3009 3140 05  0 414 2 4 1 2 3 0 0   30 0 011 8 8 4 2 0 0 5   38    04 -03 06P
X 054 3009 3140 05  0 314 5 2 1 1 4 0 0   30 0 012 7 6 4 1 1 2 5   38    03 -02 07P
X 054 3009 3140 05  0 215 4 3 1 1 4 0 0   30 0 2 8 7 9 3 0 2 1 6   38    01 -03 08P
X 054 3009 3140 05  0 414 2 2 3 1 4 0 0   30 1 1 613 9 4 3 1 0 0   38    07 -02 09P
X 054 3009 3140 05  0 315 3 3 1 3 2 0 0   30 0 21015 4 3 4 0 0 0   38    02 -01 10P
   54 3172 0156 1238  251 -00  01 02 01 01 01 07 08 07 07 07      006 R 0008 22422
   259     821.   54  CYC.NO.DECREASEDZ                                      123538
   259     821.   54  NO CARD 2 BEFOREZ                                      123538
  1258    3312.   54  NO CARD 2 BEFOREZ                                      123548
X 054 3172 0821 05  2 212 4 2 0 2 3 0 0   27 0 0 4 9 7 3 1 0 1 0   25    00    00 01P
X 054 3172 0821 05  2 112 2 4 0 1 2 1 2   27 0 1 4 6 1 3 5 2 3 0   25    03    03 02P
X 054 3172 0821 05  0 1 1 6 4 5 1 3 2 4   27 0 0 2 8 3 2 2 2 1 5   25    01    01 03P
X 054 3172 0821 05  1 310 4 2 1 2 3 1 0   27 0 1 6 6 4 3 4 1 0 0   25    02    02 04P
X 054 3172 0821 05  1 4 9 6 1 2 2 2 0 0   27 0 0 5 7 6 6 1 0 0 0   25    02    02 05P
X 054 3172 0821 05  1 012 2 1 2 2 3 0 0   23 0 1 5 5 6 6 1 0 0 3   27   -99    99 06P
X 054 3172 0821 05  0 210 3 1 2 3 2 0 0   23 0 2 5 5 6 5 1 0 0 3   27   -99    99 07P
X 054 3172 0821 05  1 112 1 3 2 1 2 0 0   23 0 1 8 4 8 3 0 0 0 3   27   -99    99 08P
X 054 3172 0821 05  0 2 9 4 2 0 3 3 0 0   23 0 3 2 9 7 6 0 0 0 0   27   -99    99 09P
X 054 3172 0821 05  0 014 1 3 2 2 0 1 0   23 0 3 412 4 3 1 0 0 0   27   -99    99 10P
   862    3348.   54  TIME DECREASED  Z                                      123818
   862    3348.   54  NEW T ACCEPTED  Z                                      123818
  1059    3348.   54  NO CARD 1 BEFOREZ                                      123828
   54 3386 1059 1421  058 -02  02 02 02 02 02 00 01 23 01 00      010 R 0026 24172
X 054 3312 3458 05  1 313 3 1 1 0 2 0 0   24 1 2 611 6 4 1 1 0 0   32   -00 -19 01P
X 054 3312 3458 05  0 114 3 0 3 0 1 2 0   24 2 1 8 4 4 2 3 2 3 3   32   -00 -02 02P
X 054 3312 3458 05  0 0 0 7 6 1 4 1 0 5   24 0 2 3 9 1 7 1 1 2 6   32   -00 -04 03P
X 054 3312 3458 05  1 312 4 1 1 0 2 0 0   24 0 4 7 6 6 4 3 2 0 0   32   -00 -04 04P
X 054 3312 3458 05  1 412 3 2 0 0 2 0 0   24 0 1 8 8 5 7 2 0 1 0   32   -00 -04 05P
X 054 3312 3458 05  0 411 3 2 0 0 2 0 0   22 0 1 8 9 5 2 1 2 2 4   34    00 -04 06P
X 054 3312 3458 05  0 313 2 2 0 0 2 0 0   22 1 2 7 9 4 3 2 0 0 6   34   -00 -04 07P
X 054 3312 3458 05  0 312 2 1 1 1 1 0 1   22 0 110 5 5 3 1 2 0 7   34    01 -02 08P
X 054 3312 3458 05  0 412 2 1 1 0 2 0 0   22 0 3 9 8 6 5 1 1 1 0   34   -00 -04 09P
X 054 3312 3458 05  0 313 2 2 0 1 1 0 0   22 1 4 910 5 2 1 1 1 0   34    00 -04 10P
X 054 3525 4402 05  4 217 2 5 0 1 4 0 0   35 0 1 5 810 5 4 0 0 1   34    01 -01 01P
```

```
  121 2080 0807 0738  113 -02  00 93 00 00 00 00 28 00 00 00        293 R 0026 14682
  121 2113 0206 0613  246 -02 -01 59 00 00 00-01 76 00 00 00        858 R 0010 14802
  121 2113 0607 0709  136 -00  00 23 00 00 00 00 63 00 00 00        023 R 0022 14922
  121 2134 0157 0608  250 -03 -01 54 00 00 00-01 58 00 00 00        753 R 0008 15062
  121 2134 0406 0673  138 -03 -01 01 00 00 00-01 52 00 00 00        800 R 0018 15162
  121 2134 0707 0730  137 -02  00 35 00 00 00 00 70 00 00 00        035 R 0024 15222
X 121 1946 2134 05  0 516 4 3 2 0 0 0 0  30 2 4 5 610 3 0 0 0 0  30    02  00 01P
X 121 1946 2134 05  0 221 2 0 0 5 0 0 0  30 1 3 213 2 9 0 0 0 0  30    03  00 02P
X 121 1946 2134 05  0 220 3 0 1 4 0 0 0  30 0 2 3 513 7 0 0 0 0  30    02 -00 03P
X 121 1946 2134 05  0 513 7 0 2 2 1 0 0  30 1 5 5 7 4 8 0 0 0 0  30    04 -03 04P
X 121 1946 2134 05  0 317 5 0 2 2 1 0 0  30 0 4 1 512 8 0 0 0 0  30    02  00 05P
X 121 1946 2134 05 40 5 0 0 0 0 0 0 0 0  45 7 0 0 0 0 0 0 0 0 0   7    00  00 06P
X 121 1946 2134 05  0 0 0 0 2 0 2 0 041  45 0 0 0 0 0 1 0 0 0 6  07    00  00 07P
X 121 1946 2134 05 45 0 0 0 0 0 0 0 0 0  45 7 0 0 0 0 0 0 0 0 0  *7    00  00 08P
X 121 1946 2134 05 45 0 0 0 0 0 0 0 0 0  45 7 0 0 0 0 0 0 0 0 0   7    00  00 09P
X 121 1946 2134 05 45 0 0 0 0 0 0 0 0 0  45 7 0 0 0 0 0 0 0 0 0   7    00  00 10P
  121 2178 0208 0611  246 -03 -01 07 00 00 00-01 48 00 00 00        906 R 0010 15362
  121 2178 0606 0709  137 -01  00 00 00 00  *    29 00 00 00        000 R 0022 15482
   17   2202. 121  TIME DECREASED  Z                                          015568
   17   2202. 121  NEW T ACCEPTED  Z                                          015568
  121 2202 0056 0617  248 -02 -01 07 00 00 00-02 03 00 00 00        706 R 0005 15592
  121 2202 0708 0727  138 -02  00 70 00 00 00 00 11 00 00 00        070 R 0021 15752
  121 2236 0318 0647  000 -02  12 12 11 11 10 14 15 13 13 12        056 R 0015 15941
  121 2236 0318 0647  000 -02 -01 89 00 00 00-01 95 00 00 00        988 R 0016 15952
  121 2236 0709 0731  000 -03  00 82 00 00 00 00 06 00 00 00        082 R 0024 16032
  121 2257 0107 0633  248 -02 -01 19 00 00 00-01 59 00 00 00        718 R 0006 16132
  121 2257 0707 0733  138 -01  00 94 00 00 00 00 41 00 00 00        094 R 0024 16312
  121 2290 0209 0615  251 -00 -01 71 00 00 00-01 75 00 00 00        870 R 0010 16452
  121 2290 0715 0737  140 -01  00 29 00 00 00 00 99 00 00 00        129 R 0024 16592
X 121 2178 2290 05  0 416 3 3 2 0 0 0 0  28 3 6 1 610 2 0 0 1 0  29    02 -00 01P
X 121 2178 2290 05  0 216 4 1 3 2 0 0 0  28 0 4 4 6 5 8 1 0 1 0  29    02  00 02P
X 121 2178 2290 05  0 711 1 4 4 1 0 0 0  28 0 4 2 013 9 0 0 1 0  29    03  00 03P
X 121 2178 2290 05  0 216 4 1 4 1 0 0 0  28 2 4 2 9 4 7 0 0 1 0  29    02  00 04P
X 121 2178 2290 05  0 413 5 1 3 2 0 0 0  28 0 4 2 211 7 2 0 1 0  29    02  00 05P
X 121 2178 2290 05 38 7 1 0 0 0 0 0 0 0  46 4 0 0 0 0 0 0 0 0 0   4    00  00 06P
X 121 2178 2290 05  0 0 0 0 1 0 2 1 042  46 0 0 0 0 0 1 0 0 0 3  04    00  00 07P
X 121 2178 2290 05 46 0 0 0 0 0 0 0 0 0  46 4 0 0 0 0 0 0 0 0 0   4    00  00 08P
X 121 2178 2290 05 46 0 0 0 0 0 0 0 0 0  46 4 0 0 0 0 0 0 0 0 0   4    00  00 09P
X 121 2178 2290 05 46 0 0 0 0 0 0 0 0 0  46 4 0 0 0 0 0 0 0 0 0   4    00  00 10P
  121 2319 0257 0582  250 -03 -01 60 00 00 00-01 48 00 00 00        859 R 0012 16752
  121 2319 0709 0734  138 -01  00 41 00 00 00 00 70 00 00 00        141 R 0024 16872
  121 2351 0155 0622  250 -00 -01 12 00 00 00-01 51 00 00 00        811 R 0008 16992
  121 2351 0505 0700  138 -02 -01 24 00 00 00-01 76 00 00 00        823 R 0020 17112
  121 2351 0708 0736  139 -02  00 11 00 00 00 00 22 00 00 00        011 R 0024 17152
```

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X 062 0001 0125 05  0 512 3 4 0 2 1 0 0  27 2 2 3 6 9 5 3 0 0 0  30   03 -06  1P
X 062 0001 0125 05  1 3 9 6 4 2 2 0 0 0  27 0 0 1 9 7 3 4 3 2 1  30   01 -82  2P
X 062 0001 0125 05  0 410 6 4 1 2 0 0 0  27 1 0 2 9 8 6 0 0 0 4  30   03 -83  3P EDITED
X 062 0001 0125 05  0 311 5 3 2 1 2 0 0  27 0 0 1 6 9 1 3 1 1 8  30   26 -60  4P
X 062 0001 0125 05  0 215 2 3 2 1 2 0 0  27 1 0 2 5 6 5 2 0 3 6  30   02 -83  5F 5-CYCLE
X 062 0001 0125 05  1 3 9 7 2 2 1 1 0 0  26 0 1 112 5 5 2 0 4 0  30   75 -02  6P DELTA VOLT
X 062 0001 0125 05  0 410 5 4 1 1 1 0 0  26 0 1 2 8 9 4 1 1 4 0  30   04 -42  7P HISTOGRAM
X 062 0001 0125 05  1 311 5 2 1 1 1 0 1  26 2 2 2 8 7 4 2 2 1 0  30   75 -02  8P OUTPUT
X 062 0001 0125 05  0 511 4 2 1 2 0 0 1  26 0 2 4 7 9 4 4 0 0 0  30   03 -01  9P
X 062 0001 0125 05  0 211 7 4 1 1 0 0 0  26 0 2 2 610 3 4 1 0 2  30  -00 -85 10P
X 062 0158 0286 05  0 314 4 1 5 2 1 0 0  30 0 5 2 8 7 4 3 1 1 0  31   39 -37  1P
X 062 0158 0286 05  0 311 6 2 4 3 1 0 0  30 0 0 1 510 4 1 2 4 4  31   03 -01  2P
X 062 0158 0286 05  0 5 9 7 0 5 3 1 0 0  30 1 0 2 511 7 0 1 1 3  31   04 -03  3P
X 062 0158 0286 05  0 212 5 4 2 2 1 1 1  30 0 0 0 213 4 2 2 2 6  31   04 -11  4P
X 062 0158 0286 05  0 4 8 8 2 3 3 1 1 0  30 0 0 0 4 9 6 2 1 2 7  31   76  00  5P
X 062 0158 0286 05  1 412 5 3 3 4 1 0 0  33 0 0 3 7 6 4 0 4 1 1  26   06 -93  6P
X 062 0158 0286 05  2 312 6 1 5 3 1 0 0  33 0 0 4 6 7 3 2 1 2 1  26   77  02  7P
X 062 0158 0286 05  1 510 6 3 2 4 0 1 1  33 0 1 3 7 5 5 1 3 0 1  26   77 -82  8P
X 062 0158 0286 05  1 610 5 5 3 2 0 1 0  33 0 1 4 6 6 5 1 3 0 0  26   77 -91  9P
X 062 0158 0286 05  6 210 3 4 3 3 1 0 1  33 0 4 2 5 6 4 2 1 0 2  26   04 -86 10P
X 062 0318 0579 05  0 115 5 3 1 4 0 0 0  29 1 2 1 6 9 2 5 2 1 0  29   42 -13  1P
X 062 0318 0579 05  0 210 9 2 2 3 1 0 0  29 0 0 0 6 6 7 0 1 2 7  29   77 -03  2P
X 062 0318 0579 05  0 5 7 8 1 5 0 3 0 0  29 2 1 2 111 6 1 0 0 5  29   58 -20  3P
X 062 0318 0579 05  0 1 911 0 2 3 2 1 0  29 0 0 0 3 9 4 4 0 1 8  29   03 -85  4P
X 062 0318 0579 05  0 01110 2 2 1 3 0 0  29 0 0 0 015 0 5 0 2 7  29   03 -91  5P
X 062 0318 0579 05  0 114 6 2 3 1 2 0 0  29 0 0 2 412 6 0 2 1 2  29   39 -04  6P
X 062 0318 0579 05  0 015 6 2 3 2 1 0 0  29 1 2 1 410 6 0 1 3 1  29  -00 -86  7P
X 062 0318 0579 05  0 115 5 2 2 2 2 0 0  29 1 2 1 7 8 4 1 2 2 1  29   75 -03  8P

X 062 0318 0579 05  0 312 6 3 2 1 2 0 0  29 1 3 0 510 5 2 3 0 0  29   37 -03  9P
X 062 0318 0579 05  0 112 6 3 3 3 1 0 0  29 3 1 0 511 3 3 3 0 0  29   41 -82 10P
X 062 0610 0732 05  0 313 3 3 5 1 0 0 0  28 1 2 5 8 5 8 0 3 1 0  33   58 -03  1P
X 062 0610 0732 05  0 213 4 3 3 2 1 0 0  28 0 3 2 4 9 3 4 1 1 6  33   01 -93  2P
X 062 0610 0732 05  0 312 2 3 6 1 1 0 0  28 1 2 5 210 7 2 0 0 4  33   37 -82  3P
X 062 0610 0732 05  0 1 9 7 2 6 1 2 0 0  28 0 2 2 5 4 8 4 1 0 7  33   42 -02  4P
X 062 0610 0732 05  0 2 6 9 4 4 3 0 0 0  28 0 2 2 110 9 0 1 1 7  33   41 -03  5P
X 062 0610 0732 05  3 311 4 2 5 2 1 0 0  31 2 0 3 310 6 1 2 1 1  29   77 -82  6P
X 062 0610 0732 05  0 511 4 1 7 1 1 0 1  31 0 4 2 4 8 6 2 1 0 2  29   37 -93  7P
X 062 0610 0732 05  0 512 5 2 4 3 0 0 0  31 1 2 3 5 9 5 0 2 1 1  29   01 -86  8P
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X 062 2008 2125 05   0 118 1 5 0 1 3 1 0   30 1 1 0 4 312 2 1 2 2   28   07 -01  3P
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X 062 2008 2125 05   0 1 911 4 0 1 2 2 0   30 0 0 0 4 4 9 2 1 4 4   28   06 -07  5P
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```
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C 052      0001 2000 2001 5000                                            SDE
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   52 0001 1904  1 2 2 1 3. 0 1 0 0 0. 0 0 0 0 0. 0 0 0 0 0. 0 0 0 0 0. SDE4 03C
   52 0001 1904  1 4 1 2 2. 0 0 0 0 0. 0 0 0 0 0. 0 0 0 0 0. 0 0 0 0 0. SDE5 03C
   52 0001 1904  2 2 0 5 1. 0 0 0 0 0. 0 0 0 0 0. 0 0 0 0 0. 0 0 0 0 0. SDE6 03C
   52 0001 1904  3 5 0 1 1. 0 0 0 0 0. 0 0 0 0 0. 0 0 0 0 0. 0 0 0 0 0. SDE7 03C
   52 0001 1904  8 1 0 1 0. 0 0 0 0 0. 0 0 0 0 0. 0 0 0 0 0. 0 0 0 0 0. SDE8 03C
   52 0001 1904  9 1 0 0 0. 0 0 0 0 0. 0 0 0 0 0. 0 0 0 0 0. 0 0 0 0 0. SDE9 03C
C 052       0001 2000 2001 5000                                           SDE
   52 0001 1904  7 3 0 0 0. 0 0 0 0 0. 0 0 0 0 0. 0 0 0 0 0. 0 0 0 0 0. SDE0 04C
   52 0001 1904  2 2 2 2 1. 1 0 0 0 0. 0 0 0 0 0. 0 0 0 0 0. 0 0 0 0 0. SDE1 04C
   52 0001 1904  0 0 4 3 0. 1 2 0 0 0. 0 0 0 0 0. 0 0 0 0 0. 0 0 0 0 0. SDE2 04C
   52 0001 1904  0 0 0 0 0. 0 0 1 3 0. 1 0 3 1 1. 0 0 0 0 0. 0 0 0 0 0. SDE3 04C
   52 0001 1904  0 1 0 2 1. 1 3 0 1 0. 1 0 0 0 0. 0 0 0 0 0. 0 0 0 0 0. SDE4 04C
   52 0001 1904  0 2 1 2 1. 2 0 2 0 0. 0 0 0 0 0. 0 0 0 0 0. 0 0 0 0 0. SDE5 04C
   52 0001 1904  0 2 4 3 1. 0 0 0 0 0. 0 0 0 0 0. 0 0 0 0 0. 0 0 0 0 0. SDE6 04C
   52 0001 1904  6 2 1 1 0. 0 0 0 0 0. 0 0 0 0 0. 0 0 0 0 0. 0 0 0 0 0. SDE7 04C
   52 0001 1904  7 2 0 1 0. 0 0 0 0 0. 0 0 0 0 0. 0 0 0 0 0. 0 0 0 0 0. SDE8 04C
   52 0001 1904  9 1 0 0 0. 0 0 0 0 0. 0 0 0 0 0. 0 0 0 0 0. 0 0 0 0 0. SDE9 04C
C 052       0001 2000 2001 5000                                           SDE
   52 0001 1904  8 0 2 0 0. 0 0 0 0 0. 0 0 0 0 0. 0 0 0 0 0. 0 0 0 0 0. SDE0 05C
   52 0001 1904  1 2 3 3 0. 1 0 0 0 0. 0 0 0 0 0. 0 0 0 0 0. 0 0 0 0 0. SDE1 05C
   52 0001 1904  1 1 3 0 1. 1 2 1 0 0. 0 0 0 0 0. 0 0 0 0 0. 0 0 0 0 0. SDE2 05C
   52 0001 1904  0 0 0 0 0. 2 0 0 0 0. 3 3 0 2 0. 0 0 0 0 0. 0 0 0 0 0. SDE3 05C
   52 0001 1904  1 0 0 1 1. 0 1 2 0 0. 1 3 0 0 0. 0 0 0 0 0. 0 0 0 0 0. SDE4 05C
   52 0001 1904  0 1 3 4 0. 1 1 0 0 0. 0 0 0 0 0. 0 0 0 0 0. 0 0 0 0 0. SDE5 05C
   52 0001 1904  2 2 2 2 2. 0 0 0 0 0. 0 0 0 0 0. 0 0 0 0 0. 0 0 0 0 0. SDE6 05C
   52 0001 1904  8 2 0 0 0. 0 0 0 0 0. 0 0 0 0 0. 0 0 0 0 0. 0 0 0 0 0. SDE7 05C
   52 0001 1904  8 2 0 0 0. 0 0 0 0 0. 0 0 0 0 0. 0 0 0 0 0. 0 0 0 0 0. SDE8 05C
   52 0001 1904  8 0 2 0 0. 0 0 0 0 0. 0 0 0 0 0. 0 0 0 0 0. 0 0 0 0 0. SDE9 05C
C 052       0001 2000 2001 5000                                           SDE
   52 0001 1904  9 0 1 0 0. 0 0 0 0 0. 0 0 0 0 0. 0 0 0 0 0. 0 0 0 0 0. SDE0 06C
   52 0001 1904  2 2 4 1 1. 0 0 0 0 0. 0 0 0 0 0. 0 0 0 0 0. 0 0 0 0 0. SDE1 06C
   52 0001 1904  1 1 3 2 1. 1 0 1 0 0. 0 0 0 0 0. 0 0 0 0 0. 0 0 0 0 0. SDE2 06C
   52 0001 1904  0 0 0 0 0. 0 0 0 3 1. 4 1 0 0 0. 0 1 0 0 0. 0 0 0 0 0. SDE3 06C
   52 0001 1904  0 1 0 1 2. 0 1 2 1 0. 1 0 1 0 0. 0 0 0 0 0. 0 0 0 0 0. SDE4 06C
   52 0001 1904  0 1 2 3 1. 2 1 0 0 0. 0 0 0 0 0. 0 0 0 0 0. 0 0 0 0 0. SDE5 06C
   52 0001 1904  1 3 1 2 1. 1 1 0 0 0. 0 0 0 0 0. 0 0 0 0 0. 0 0 0 0 0. SDE6 06C
   52 0001 1904  7 2 1 0 0. 0 0 0 0 0. 0 0 0 0 0. 0 0 0 0 0. 0 0 0 0 0. SDE7 06C
   52 0001 1904  8 2 0 0 0. 0 0 0 0 0. 0 0 0 0 0. 0 0 0 0 0. 0 0 0 0 0. SDE8 06C
   52 0001 1904  7 2 1 0 0. 0 0 0 0 0. 0 0 0 0 0. 0 0 0 0 0. 0 0 0 0 0. SDE9 06C
C 052       0001 2000 2001 5000                                           SDE
```

APPENDIX E

FAILURE CHARTS

GLOSSARY

****** CODES ******

P = PACK NUMBER

M = MANUFACTURER

C = CAPACITY -- AMPERE HOUR

D = DEPTH OF DISCHARGE

1 = 15%
2 = 25%
4 = 40%
5 = 50%

T = TEMPERATURE -- CENTIGRADE

1 = 0 DEG.
2 = 25
4 = 40
5 = 50/40
6 = 25/40
7 = -20

O = ORBIT PERIOD

1 = 1.5 HOURS
2 = 3.0
3 = 24.0

* = CELL REPLACED DUE TO EARLY FAILURE

MANUFACTURER
1 = GENERAL ELECTRIC
2 = SONOTONE
3 = GULTON
4 = GOULD
5 = YARDNEY
6 = DELCO

TABLE A-1

FAILURE CYCLE

P	M	C	D	T	O	1	2	3	4	5	6	7	8	9	10
1	2	5.0	2	2	1	4423		11745	2995	11361	7782				11745
2	2	5.0	4	2	1	6671	4411			3992	5262	5262			3155
3	4	3.5	2	2	1		3090		4751	2785	4289	4401		4081	4751
4	4	3.5	4	2	1	2110		3029			2954	1609	1827		3164
5	2	5.0	2	2	2		3771	5272							
6	2	5.0	4	2	2				1161		5211	4608	1069	3798	1136
7	4	3.5	2	2	2	3130	3007	4173	3736	3483	3884				
8	4	3.5	4	2	2	1985	2494				1346	2138	1704	2494	1985
11	3	6.0	4	2	1	7743	7743	2753							
13	3	6.0	2	2	1	308	4021		3598	2969		3084			502
14	3	6.0	4	2	1	450	1113	1618	262	262		2086			
15	1	3.0	2	2	1				10382	8714		8065	8254	10382	10123
16	1	3.0	4	2	1	4741			5013	4917	4473	3985			4917
17	3	6.0	2	2	2	2375	2449	721		721				2885	1688
18	3	6.0	4	2	2	1550		608		1145	365	643		643	
20	1	3.0	4	2	2		4485	4889		3704	4485				
25	2	5.0	1	5	1	7758	9328	9070	7052	6348	9220				
26	2	5.0	2	5	1	2487		3344	3625		2993	2993		2902	
27	4	3.5	1	5	1		4485	2901				2998	2901	4102	3270
28	4	3.5	2	5	1	1811	408	1811	1811	860	1811	484	484	1811	1293
29	2	5.0	1	5	2	1418				5581	5975	4835	4380		
30	2	5.0	2	5	2	4141			3068			855	3684	3068	4141
31	4	3.5	1	5	2	2517	1696	2411			2517		2477	1500	1500
32	4	3.5	2	5	2	800		495	875		138	875		974	
33	5	12	5	4	3	152	126	58	210				197		210
37	3	6.0	1	5	1			238	2819		6064	4897	1566		2981
38	3	6.0	2	5	1		1377	225		1333	114		37	187	
39	1	3.0	1	5	1	7213	779			8109	2083	2523	8109		
40	1	3.0	2	5	1		2509	2073		2446	2509	2182	2182		2461
41	3	6.0	1	5	2		1132	1689			1062	1157	1157	649	
42	3	6.0	2	5	2	484			4133		3619	382	96	416	
43	1	3.0	1	5	2			1515	1182		1911	2515		2298	2656
44	1	3.0	2	5	2	3854	4487	3854			1672		3848		4487

TABLE A-2

FAILURE CYCLE

P	M	C	D	T	O	1	2	3	4	5	6	7	8	9	10
						CELL NUMBER									
47	3	6.0	2	2	1					5223					
49	2	5.0	1	1	1			10073						2010	
50	2	5.0	2	1	1			13500		12609					
51	4	3.5	1	1	1										14737
52	4	3.5	2	1	1			10994				9724	7858	9724	8367
57	5	12	5	1	3	162	162	166	166	166	166	166	166	166	162
59	3	6.0	2	1	1			3202							
61	3	6.0	1	1	1	10146	* 1	9760	4094	2762	4413		* 6		4285
62	3	6.0	2	1	1				4066	4441		8590			2995
65	3	6.0	1	1	2				5012		5706		6186		
66	3	6.0	2	1	2			1417	4414	1237	1045	2122	1173		
71	3	6.0	4	1	1				5070	2993					
73	3	20	2	2	1	6120		1776	7763						
74	3	20	2	2	2		1754	1302	1184						
76	3	20	1	5	1		7697	9348	7698						
77	3	20	1	4	2	5684	5510		6032						
79	3	6.0	5	2	3	149	545	164	545						
82	1	11	2	2	1	10878	7527			10624					
85	1	12	1	5	1		9710	8947	8888						
87	3	20	4	2	1	163	208	627	627	627					
88	3	20	4	2	2	151	151	358		358					
90	3	20	2	5	1			4045	2824	2824					
91	3	20	2	5	2	4480	4480	3385	2862						
93	1	12	5	6	3	349	266	349	349	349					
95	3	50	2	1	1	3227		2643		2938					
96	1	12	4	2	1		4020	3822	4020						
97	1	12	4	2	2		3894	3946	5002						
98	4	20	2	1	1	8619			10641	3556					
99	1	12	2	5	1	4853	3841	3841							
100	1	12	2	5	2	4424	4358	4170							
101	3	20	1	1	1		3111		3629	3111					
102	3	20	1	1	2		135								
104	4	20	2	2	1	2672		2980		2826					

TABLE A-3

FAILURE CYCLE

P	M	C	D	T	O	1	2	3	4	5	6	7	8	9	10
105	4	20	2	2	2	4306		5580	5690						
108	4	20	1	5	2		4003	4233							
112	4	20	1	5	1	5005	5005			5213					
113	1	5.0	1	4	1	4998	4998	4998	4998	4998					
115	3	20	2	1	1		2203	2107	2291						
118	4	20	4	2	1		1747		1963	2937					
119	4	20	4	2	2		1793	1793		222					
122	4	20	2	5	2		801	801		983					
123	3	50	1	4	1		1873	1873	1873						
124	1	12	2	1	1					3037					
126	4	20	2	5	1			1273	1509	1569					
127	3	5.0	1	4	1		7218								
128	3	5.0	2	4	1		5888	2422		6345 /NIMBUS/					
202	2	3.0	4	2	1			1630							
214	3	4.0	4	2	1	8474		7564		8474					
218	3	6.0	4	2	1		5364	7577	7577						
230	3	5.6	2	4	1	1275		1196		1195					
236	3	5.6	2	2	1	2743									
238	3	6.0	2	4	1		5184		5766	4350					
239	3	3.6	4	2	1						2038				
240	3	4.0	2	4	1		10360	10360	7900	10360					
242	3	5.6	2	4	1			3625		3795					
276	3	5.6	2	2	1		2025								
SHRF	3	3.6	4	2	1		2409	3190							3472
290	3	12	2	4	1			3318	3060	5124					
296	3	12	4	2	1		5152	5152	5036						
301	3	12	2	1	1				5586						
318	3	5.0	2	2	1		4863								
338	3	6.0	2	4	1						3835	3780		3835	3835
388	3	1.2	2	7	1					1897					
75	6	25		2		32 -			-						
89	6	25		2		80	- CYCLES		- ALL 3 PACKS RETURNED TO						
288	6	25		2		120	- COMPLETED -		MANUF. FOR ANALYSIS						
275	6	40		2		139	-- SAME AS ABOVE 3 PACKS								

TABLE A-4

INDIVIDUAL CELL FAILURES WITHIN 1000 CYCLE GROUPS

PACK	LESS THAN 1000 CYC.	LESS THAN 2000 CYC.	LESS THAN 3000 CYC.	LESS THAN 4000 CYC.	LESS THAN 5000 CYC.	LESS THAN 6000 CYC.	LESS THAN 7000 CYC.	LESS THAN 8000 CYC.	LESS THAN 9000 CYC.	LESS THAN 10000 CYC.	MORE THAN 10000 CYC.
				CELL	NUMBER						
1			4		1			6			3 5 10
2				5 10	2	6 7	1				
3			5	2	467910						
4		7 8	1 6	3 10							
5				2		3					
6		4 8 10		9	7	6					
7				1 2456	3						
8		1 6810	2 7 9								
11			3					1 2			
13	1 10		5	4 7	2						
14	1 4 5	2 3	7								
15									5 7 8		4 9 10
16				7	15610	4					
17	3 5	10	1 2 9								
18	3 6 79	1 5									
20				5	2 3 6						
25							5	1 4		2 3 6	
26			1 679	3 4							
27			3 7 8	10	2 9						
28	2 5 78	1346910									
29		1			7 8	5 6					
30	7			4 8 9	1 10						
31		2 9 10	1 368								
32	134679										
33	1234810										
37	3	8	4 10		7		6				
38	3 689	2 5									
39	2		6 7					1	5 8		
40		23567810									
41	9	2 3678									
42	1 789			6	4						

TABLE B-1

INDIVIDUAL CELL FAILURES WITHIN 1000 CYCLE GROUPS

PACK	LESS THAN 1000 CYC.	LESS THAN 2000 CYC.	LESS THAN 3000 CYC.	LESS THAN 4000 CYC.	LESS THAN 5000 CYC.	LESS THAN 6000 CYC.	LESS THAN 7000 CYC.	LESS THAN 8000 CYC.	LESS THAN 9000 CYC.	LESS THAN 10000 CYC.	MORE THAN 10000 CYC.
				CELL	NUMBER						
43		3 4 6	7 9 10								
44		6		1 3 8	2 10						
47						5					
49			9								3
50											3 5
51											10
52								8	10	7 9	3
57	ALL										
59				3							
61	2 8		5		4 6 10					3	1
62			10		4 5				7		
65						4 6	8				
66		3 5 68	7		4						
71			5			4					
73		3					1	4			
74		2 3 4									
76								2 4		3	
77						1 2	4				
79	ALL										
82								2			1 5
85									3 4	2	
87	ALL										
88	1 235										
90			4 5		3						
91			4	3	1 2						
93	ALL										
95			3 5	1							
96				3	2 4						
97				23		4					
98				5					1		4
99				2 3	1						
100					1 2 3						
101				2 4 5							
102	2										

TABLE B-2

INDIVIDUAL CELL FAILURES WITHIN 1000 CYCLE GROUPS

PACK	LESS THAN 1000 CYC.	LESS THAN 2000 CYC.	LESS THAN 3000 CYC.	LESS THAN 4000 CYC.	LESS THAN 5000 CYC.	LESS THAN 6000 CYC.	LESS THAN 7000 CYC.	LESS THAN 8000 CYC.	LESS THAN 9000 CYC.	LESS THAN 10000 CYC.	MORE THAN 10000 CYC.
				CELL	NUMBER						
104			1 3 5								
105					1	3 4					
108					2 3						
112						1 2 5					
113					ALL						
115			2 3 4								
118		2 4	5								
119	5	2 3									
122	2 3 5										
123		2 3 4									
124				5							
126		3 4 5									
127								2			
128			3			2	5				
202		3									
214								3	1 5		
218						2		3 4			
230		1 3 5									
236			1								
238					5	2 4					
239			6								
240								4			2 3 5
242				3 5							
276			2								
SHRF			2	3 10							
290				3 4		5					
296						2 3 4					
301						4					
318					2						
338				6 7910							
388		5									
75	RETURNED TO MANUF.										
89	RETURNED TO MANUF.										
288	RETURNED TO MANUF.										
275	RETURNED TO MANUF.										

TABLE B-3

FAILURE CHARACTERISTICS

A. Low Voltage Charge.

B. Low Voltage Discharge.

C. Separator: Deteriorated, Dissolved, Burned, Pinpoint Penetration, Short.

D. Plate Material Shorted Through Separator.

E. Separator Impregnated With Negative Plate Material.

F. Migration of Positive and/or Negative Plate Material.

G. Extraneous Material Between Plates.

H. Deposit on Positive and/or Negative Terminals.

I. Blistering on Positive Plate(s).

J. Plate(s) Stuck To Case.

K. Excess Scoring of Case.

L. High Pressure, Bulge, Convex Side(s).

M. Concave Side(s), Short(s) Due To Internal Shift.

N. Broken Seal(s): Ceramic, Glass.

O. Ceramic Short.

P. Electrolyte Leak, Weight Loss, Separator Dry, Electrolyte Shorted Out Cell.

Q. Tab(s): Burned, Broken, Welds Weak.

R. Third Electrode Shorted to Plate.

S. Cell Blew Up.

T. Circuit: Short, Open.

U. High Voltate Charge.

TABLE C-1

84	TOTAL NO. OF PACKS IN ORIGINAL PROGRAM
93	TOTAL NO. OF PACKS ADDED TO PROGRAM
177	TOTAL NO. OF PACKS IN PROGRAM
22	PARTIAL PACK FAILURES
77	TOTAL PACK FAILURES

FAILURE CHARACTERISTICS

PARTIAL PACK FAILURE --- 22 PACKS

	CELL NUMBER									
PACK	1	2	3	4	5	6	7	8	9	10
5 2		BUKFTC	BLQTKFC							
20 1		ABFCIQ	THFCI		ABIFC	ABFCIH				
47 3					TLFIDC					
49 2			TKCFD						ABC	
59 3			RFLP							
62 3				ABDIC	ABOIL		ABLCIO			BUPNLI
65 3				ABHLMFI		ABMTCI		ABMTDCI		
71 3			BUPFI		BUHPLFI					
102 3		AT								
108 4		TLGIC	TLGIC							
124 1										
127 3		BUDFC								
202 2			BPF							
236 3	BUPQFC									
239 3						BPFIC				
242 3			BHFCP		BHQFCP					
276 3		BUQC								
301 3				BULPFI						
318 3		TQFC								
338 3						ABHFDC	TLFC		TLFDC	BLFC
388 3					BUFIP					
SHRF3		ABPFC	BPQFIC							ABPFC

TABLE C-2

TOTAL PACK FAILURE --- 77 PACKS

PACK		CELL NUMBER 1	2	3	4	5	6	7	8	9	10
1	2	BUQKT		BQKFC	BUCP	BHKFC	BTKFC				BHQTKFC
2	2	BLKFC	ABKDQC			BPLCD	BEFCQL	ABDQKCE			TPLDCQ
3	4		ABPQ		BCEI	BUTGD	BPCD	BPCD		BPCTQ	BPE
4	4	ABCL		AC			ABPE	BPL	ABPL		ABPCF
6	2				DTQ		BQKFC	BKTQC	BE	BLKFC	ABCD
7	4	APNCFQ	APEFCQ	APQC		TPQEC	ABPCEQ	APFC			
8	4	ACE	ABPCEQ				ABPE	ABPQCE	APQ	ABPCEF	APQC
11	3	THFIC	BUHFICPROICP								
13	3	BUPL	ABOCEIL		ABOIC	ABOI		ABOI			BUPL
14	3	BUPL	BUO	ABO	BUPL	PMLN		BO			
15	1				BFCI	BHFIC		ABIFC	ABIFC	BFCI	BFCI
16	1	BDCET			ABEC	ABEC	BCDT	BQ			ABEC
17	3	ABOL	ABCIL	BULO		BUO				ABOIL	ABO
18	3	ABOIE		BPL		ABOI	BPMO	BULO		BUO	
25	2	ABKFC	ABFCQ	BCD	BLTKFC	AUCKT	BTCG				
26	2	D		TK	ABCD		BLQD	BLQKC		TCQD	
27	4		ACE	ABPCF				ALDF	APDCF	BUPCE	APDCQ
28	4	ABTD	APQ	BUQ	ABTIE	BUP	ABDQ	APL	APL	ABDQ	AUQ
29	2	TQDK				BHQKFC	BHPQKDC	ABCQ	BCK		
30	2	TC			ABCQK			CT	ABPTKFC	BCKQA	ABFC
31	4	ABPGCQ	BUDC	ABPDCEQ			ABDGECQ		BUPCEQ	ABPC	ABPDCQ
32	4	BPT		BP	ABPT		BQH	PTL		BUPDQ	
33	5	P	P	P	P				P		P
37	3			ABPO	ABOI		BUCEIO	BOPIC	ABPO		BOI
38	3		ABLO	BUP		BT	ABPO		ABO	BAHO	
39	1	BHQFC	BPTQUC			BPQFC	BTPQUC	BQU	BC		
40	1		BUPQT	BUTQC		BUQ	BUPTCQ	BUTCQ	BPF		BUFT
41	3		BO	BOI			BO	BOI	BO	BUO	
42	3	ABLOP			ABPIFCO		BPC	ABO	BO	BUO	
43	1			BUTCQ	BTCQA		Q	QTC		QCFE	QCFE
44	1	THC	BUHFCI	BFC			Q		BUCI		ABFCI
50	2			ABHKFT		ABDKF					
52	4			TGDFC				BUFCE	ABLEFC	ABFEC	BLCF
57	5	P	P	P	P	P	P	P	P	P	P

TABLE C-3

CELL NUMBER

PACK		1	2	3	4	5	6	7	8	9	10
61	3	HBMUQFP	ABM	ABLPDIO	ABOEIL	ABO	ABOIL		PL		ABOEIL
66	3			BOLMIP	BHLMTOF	BULHNIC	BULMNP	ABPEILM	ABMO		
73	3	ABPCFIL		BMNP	ABHMFCO						
74	3		BPNDMT	BP	ABPI						
75	6	S RETURNED TO MANUF.									
76	3		THNGC	TLCI	TLC						
77	3	TLFC	THMFC		THLFC						
79	3	BLHOFIC	BCI	ABLOIC	BCI						
82	1	BHC	BDFC			BC					
85	1		BLFC	ABLFC	ABLFC						
87	3	BULP	BUPO	BULHO	ABPHM	ABPLCO					
88	3	BULPN	BULPN	BULP		ABO					
89	6	RETURNED TO MANUF.									
90	3			OC	ABDLC	BDIL					
91	3	THLMCI	THLMCI	TLFC	TPNCFHO						
93	1	BHC	B	BHFC	BHC	BHFC					
95	3	BUEIJ		TPI		TPE					
96	1		ABDC	ABDC	ABDC						
97	1		ABHC	BLFIC	BLFC						
98	4	ABFCT			ABLFTC	ABCDQ					
99	1	ABCE	CE	TDCP							
100	1	TFC	TLFC	TLIC							
101	3		BUPL		BUPLMI	BUP					
104	4	ABTDL		ABCTL		ABDTGL					
105	4	ABLCI		ABHLFTC	ABLQFC						
112	4	ABTCL	ABTCL			ABTCI					
113	1	TLC	TLC	TLC	TLC	TLC					
115	3		LIT	BMPT	HLTIC						
118	4		ABTDL		ABTDL	ABDTL					
119	4		BDLI	BDLI		AT					
122	4		ABICFL	ABICFL		ABDIL					
123	3		BACTL	CJLH	CJL						
126	4			ABTDL	ABTDICL	ABTDL					
128	3		THOC	TGFCO		BUDFC					
214	3	ABLQFC		TLMQFC		ABLFC					
218	3		ABOCI	BFIC	BFIC						
230	3	BULQFC		BULQC		ABPQFC					
238	3		ABIQOFC		BQOFIC	ABLQFIC					

TABLE C-4

PACK	CELL NUMBER 1	2	3	4	5	6	7	8	9	10
240 3		BQFC	BQFC	TLQFC	BQFC					
275 6	RETURNED TO MANUF.									
288 6	RETURNED TO MANUF.									
290 3			TCI	BACI	BALCI					
296 3		TLICP	BAHLFTCBGCI							

TABLE C-5

GLOSSARY

Depth of Discharge:

The percent of the manufacturer specified ampere-hour capacity of each cell which is intended to be removed from each cell in the battery pack during discharge.

Orbit Period:

Total time, in hours, for one charge-discharge period during automatic cycling.

Ampere-hour Capacity:

The ampere-hour capacity of the individual cells in a battery pack as rated by the manufacturer.

Ambient Temperature:

The environmental temperature at which battery packs are cycled.

Charge or Voltage Limit:

The maximum intended average voltage, per cell, during the charge period. Expressed in volts.

Charge or Voltage Limiter:

A device which limits the voltage to which the entire battery pack is charged. It is set at the number of cells in the pack multiplied by the individual cell voltage limit.

NiCd:

Nickel - Cadmium

Histogram:

A chart showing, on its horizontal scale, a sequence of values or class intervals into which the data may fall, and on its vertical scale the frequency with which the data falls in each such class interval.

Threshold:

A predetermined numeric value having the function of an acceptance and/or cut-off point.

Indicator:

A symbol or level-number used in a data-division entry to indicate level or condition.

Cell Failure:

Any cell whose voltage level, at the end of discharge, is below 0.5 volts.

First Difference or Delta Voltage:

The positive or negative voltage quantity resulting when the measured cell voltage at a given monitoring point is subtracted from the measured voltage at the same monitoring point for the immediately previous time of data-taking within the same cycle. (Note that first observation time in a cycle has no prior observation in same cycle.)

Observed Cycle:

In the Crane test, every charge-discharge cycle is not recorded. The cycle recording frequency is dependent on pack orbit period. For example, in a 1.5 hour orbit regime, every 32nd cycle is recorded; in a 24 hour orbit regime, every 8th cycle is recorded. Observed cycle is synonymous with recorded cycle.