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INTRODUCTION TO COMPUTER-AIDED RELIABILITY DATA ANALYSIS

by Charles R. Toye

Electronics Research Center

Cambridge, Mass.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • FEBRUARY 1969

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INTRODUCTION

TO

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INTRODUCTION TO COMPUTER-AIDED RELIABILITY DATA ANALYSIS

By Charles R. Toye
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SUMMARY

This report is directed toward the areas of component quality control and reliability data analysis. The reader should have a sufficient knowledge of component evaluation to be familiar with the concepts of screening, life, burn-in, and environmental testing. The subject of Computer-Aided Reliability Data Analysis is presented through an illustration of the computer program library CARDA which is a mnemonic for the subject matter.

CARDA is specifically designed to fulfill the data collection, reduction, documentation, analysis, and presentation requirements found in high-reliability component specifications. The computer library is composed of numerous statistical routines prepared with quality control and reliability functions clearly in mind. It is actually a synthesis of much of the work that has been generated in the field of data analysis during the past several years. Although CARDA was originally developed at NASA/ERC, Cambridge, Mass., to be used for the analysis of semiconductor test data in conformance to MIL-S-19500, as indicated in this report, it can also be applied to many other components.

CARDA is written for third-generation electronic data processing equipment using advanced Fortran techniques. It has its own language, consisting of 21 statements and several syntax rules which, when properly mastered, allow the user to apply it to a great variety of data analysis situations. In the majority of cases, where data is recorded in either the decimal or scientific notation, the reader need not have any previous computer programming experience to understand how to use CARDA. However, CARDA is flexible enough to permit the user to insert his own data recording schemes, in which case, the user would be expected to have the capability of programming his special requirements.

Section I lists the various types of data analysis CARDA can perform; the areas in quality control and reliability where they most frequently appear, and its main features. Section II outlines the important aspects of a test report and presents an illustration from CARDA. Section III discusses such topics as classification of tests, data processing procedures, and data formating. Section IV gives a step-by-step procedure on how to arrange input data for use with CARDA. Section V describes how CARDA can be manipulated and gives further explanation of some of the topics discussed in Section IV.

I. INTRODUCTION

Computer-Aided Reliability Data Analysis relates to the use of electronic data processing equipment and procedures as an aid in the analysis of reliability data. It is a young and growing subject similar to Computer-Aided Circuit Design which produced such procedures as NET-1, ECAP, CIRCUS, and NASAP. At this stage of development, it is too early to prescribe fixed and governing rules as new generations of equipment and software are still being developed. The best that can be done at the present time is to present current examples of existing procedures, realizing that they could become obsolete within a very short period.

CARDA is given as one example, and the reader should examine it from this point of view.

The majority of reliability data that is collected in the aerospace industry relates to components. This is because many missions or systems functions are one-time affairs which result in a heavy emphasis placed on the use of highly qualified components. Consequently, qualification testing is well entrenched in the industry as being an important aspect of reliability.

The primary source of obtaining reliability information concerning components has been through the component manufacturer. High-reliability component specifications have required that the manufacturer provide the necessary quality and reliability assurance relating to his products. In the course of space programs, numerous part-improvement programs have generated a fantastic amount of part-reliability data. The efficient utilization of such data has been hindered by the lack of automated-data collection and reduction facilities. At the beginning of the Minuteman parts improvement program, there were virtually no automatic data recording facilities in the electronic-component industry, and certainly none in the semiconductor field adequate enough to fulfill the intent of the program. The voluminous amount of reliability data required by high-reliability specifications has been overwhelming. Consequently, the most exotic reliability data analysis has only required histogram plots, simple averages, and standard deviations to be calculated.

From an economic standpoint, the present state-of-the-art pertaining to semiconductor quality and reliability testing requires the use of automated data-logging techniques. The hand-recording of data is becoming obsolete.

Table 1 shows an estimated growth in the semiconductor industry of automated data-logging with respect to QC and

reliability-type test equipment. Some manufacturers of integrated-circuit test equipment are currently providing data-logging facilities on 100 percent of the equipment they are building.

In the development of data reduction and analysis procedures, the challenge to quality control and reliability engineering is to take advantage of the opportunities made available through the use of automated data-logging and electronic data processing. CARDA is oriented towards automated data-logging and is designed to handle the tremendous amounts of variable test data generated by highly complex component quality control and reliability specifications which often require such procedures as burn-in, step-stress, environmental and life tests.

TABLE 1

GROWTH OF QC DATA-LOGGING EQUIPMENT

Year	Growth (%)
1960	30
1963	50
1967	70
1970	90

Applications

The most common types of problems to which CARDA can be applied are as follows:

(1) To analyze component life test data when there are several measurements of different time intervals performed on the same unit during the course of the test.

(2) To analyze sequential environmental tests when the same units may be subjected periodically to a series of environmental tests and measurements.

(3) To analyze measurements taken before and after a specific environmental test.

(4) To compare several groups of data taken on different samples.

(5) To analyze any given array of measurements.

The foregoing items can be combined in a variety of ways in the following types of tests:

(1) Lot acceptance life tests

(2) Screening or burn-in tests

(3) Step-stress tests

(4) Long-term life tests

(5) Accelerated tests

(6) Qualification tests

Some of the various quality control and reliability areas where CARDA and other computer-aided procedures can be used are:

(1) Incoming inspection for the analysis of vendor test data or for a lot-to-lot variability study

(2) Inprocess control for engineering, manufacturing, and quality control sampling analysis

(3) Outgoing quality control for final product approval reports

(4) Environmental test for a comparison of measurements before and after test

(5) Life tests for analysis of distributions as a function of time

(6) Burn-in or screening tests for the elimination of maverick units

(7) Quality and reliability customer and internal reports

(8) Application and sales brochures

(9) Design review

(10) Specification changes and approvals

Features

The most significant features of CARDA are:

(1) A listing of all parameter measurements

(2) An average and standard deviation for each group of parameter measurements

(3) The smallest and largest value in each group of parameter measurements

(4) The failure rate and 10, 70, 80, and 90-percent confidence limits

(5) A check to (a) upper and/or lower specification limits, (b) pre- and/or post-test specification limits, (c) absolute and/or percent change specification limits

(6) A histogram or frequency distribution of parameter measurements

(7) The average, standard deviation and frequency distribution for the percent change of the parameters measurements

(8) A comparison of the number of rejects to an acceptance number.

Items (4) through (8) are program options. Item (4) pertains only to life tests. Item (5) gives the various specification limits that may be used. Item (6) is a visual display of the data, either in the form of a histogram or just the total number of units per cell interval. Item (7) is to be used only when there are more than one measurement per parameter per unit and the units are numbered.

II. DATA REDUCTION AND ANALYSIS

Certain fundamental principles are evident in most good quality and reliability test reports. These are:

(1) Product and specification identification

(2) Name of test condition or operation

(3) Listing of parameters measured

(4) Some form of data reduction (histograms, frequency distributions, etc.)

(5) Some form of data analysis (averages, standard deviations, etc.)

(6) Comparisons to standards (control or specification limits, etc.)

(7) An indication of compliance

For purposes of illustration, different sections of various semiconductor test reports will be presented. One data reduction and analysis method could not possibly be suitable in all cases. The examples presented herein demonstrate the above principles, and the format can be easily modified to particular needs. It is interesting to bear in mind that all the examples were generated by one computer program.

Figure 1 shows how the product identification and test codes can be displayed. Note how test codes are used to identify the measuring times. It is definitely advantageous to use test codes for such identification.

Figure 2 contains a listing of the parameters that were measured during the test. The first line gives the parameter name. The second line gives the parameter test condition. If necessary, third and fourth lines can be used for additional information. The parameter measurements are listed sequentially by test code within unit number. This is perhaps the most popular method of presenting component life-test measurements. Rejects are properly labeled as in the case of unit numbers 4 and 5.

Figure 3 illustrates a common form of data reduction, namely, by use of a histogram. Each X represents a measurement.

Figure 4 is used for the comparison of distributions at the various test intervals.

In Figures 3 and 4, the average, standard deviation, and largest and smallest number are shown.

Figure 5 shows the specification limits to which the devices were compared.

Figure 6 records the test results and presents the failure rate in terms of percent per thousand hours. It also contains confidence limits about the failure rate. The confidence limits were calculated from a special chi-square table modified for computer application.

The percent change distribution in Figure 4, the limits in Figure 5, and the failure rate calculation in Figure 6 are program options used to generate the data in Figures 1 through 6. Also, with this particular program, there is a choice of distribution presentation between Figure 3 and Figure 4.

When evaluating the merits of any computerized data reduction system, the ease of using the system; in other words, the interface between the using engineer and the computer must not be overlooked. If this interface requires the services of a professional computer programmer or even data set-up analysts who must acquire elaborate and detailed knowledge of the input data arrangement, then the use of such a data reduction system will become limited. Those who are saddled with rigid data format specifications like the ones imposed during the Minuteman I Parts Improvement Program can give testimony to the added complexity of using such formats and the high cost for their implementation. Unfortunately, the practice of rigid formating has continued in the industry until the present time when, in some cases, it costs more to prepare and check the tabulating card on which the test data is presented than it actually does to test the device. In the case of integrated circuits, where as many as sixty-five (65) parameters could be tested and recorded, rigid data format specifications imposed upon a manufacturer (who is using a different data format) may boost the cost of data preparation to astronomical heights. This is especially true where automatic data-logging equipment is being used to prepare the data-tabulating cards.

CARDA combats this problem by taking full advantage of the formatting procedures available in the latest state-of-the-art Fortran techniques. For example, the only data card requirement is that the test code must always precede the unit number. The test data can be recorded in a variety of ways. It can begin in any column, contain exponents if desired, and be prepared using any scale the user desires. CARDA was specifically designed to eliminate the great burden of data card preparations. It is orientated toward receiving hand-recorded or automatically-logged

data on a batch basis, so that items like specification limits, test conditions, and descriptive information can be changed easily and frequently.

REPORT FORMAT

SCREENING DATA(FOR ILLUSTRATION PURPOSES ONLY)

SCREENING PROCEDURE	TEST CODE
INITIAL READINGS	1
50 HOURS	
POST TEST MEASUREMENTS	2
125 HOURS	
POST TEST MEASUREMENTS	3
250 HOURS	
POST TEST MEASUREMENTS	4
500 HOURS	
POST TEST MEASUREMENTS	5

IN THE PERCENT CHANGE ANALYSIS,MINUS SIGNS DENOTE PARAMETER DECREASES,WHILE PLUS SIGNS DENOTE PARAMETER INCREASES.

COMPUTATIONS DO NOT INCLUDE REJECTED UNITS

Figure 1.- Display of product identification and test codes

COMPLETE LIST OF UNITS

UNIT NUMBER	TEST CODE	VZ 1 AT 16MA	VZ 2 AT 40MA	IR 1 AT 12V 100 C	IR 2 AT 12V 25 C
1	1	17.100	17.500	0.165	0.051
1	2	17.300	17.700	0.172	0.047
1	3	17.100	17.400	0.154	0.045
1	4	17.200	17.600	0.164	0.044
1	5	17.300	17.500	0.071	0.042
2	1	17.300	17.600	0.080	0.003
2	2	17.300	17.600	0.090	0.003
2	3	17.300	17.500	0.085	0.003
2	4	17.300	17.600	0.092	0.004
2	5	17.300	17.500	0.083	0.003
3	1	17.500	17.800	0.102	0.020
3	2	17.600	17.700	0.116	0.020
3	3	17.500	17.700	0.108	0.019
3	4	17.500	17.800	0.114	0.032
3	5	17.500	17.800	0.122	0.021
4	1	17.700	18.000	0.102	0.004
4	2	17.700	17.900	0.117	0.005
4	3	17.700	17.900	0.104	0.035
THE ABOVE UNIT IS A FAILURE ON PARAMETER NUMBER 4					
4	4	17.700	18.000	0.117	0.005
4	5	17.100	18.000	0.110	0.003
5	1	17.400	17.800	0.171	0.022
5	2	17.500	17.800	0.190	0.025
5	3	17.500	17.700	0.182	0.026
5	4	17.500	17.800	0.197	0.028
5	5	16.700	17.800	0.204	0.025
THE ABOVE UNIT IS A FAILURE ON PARAMETER NUMBER 1					
6	1	17.500	17.800	0.287	0.011
6	2	17.600	17.800	0.332	0.013

Figure 2.- List of parameters measured during test

PARAMETER NUMBER 2 VZ 2 AT 40MA MEASURED IN VOLTS

HISTOGRAM

UPPER CELL LIMIT		ACCUMULATIVE NUMBER OF UNITS/ CELL	ACCUMULATIVE PERCENTAGE / CELL
17.20000		0	0.0
17.30000		0	0.0
17.40000	XXXXXXXXX	9	2.6
17.50000	XXXXXXXXXXXXXXXXXXXXXXXXX	35	10.3
17.60000		35	10.3
17.70000	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	83	24.4
17.80000	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	135	39.7
17.90000	XXXXXXXXXXXXXXXXXXXX

PARAMETER NUMBER 1

VZ 1 AT 16MA MEASURED IN VOLTS

FREQUENCY DISTRIBUTIONS OF MEASUREMENTS
AT EACH READING PERIOD

CELL	INITIAL	50 HRS	125 HRS	250 HRS	500 HRS
16,90000	0	0	0	0	0
17,00000	0	0	0	0	0
17,10000	0	0	0	0	0
17,20000	1	0	1	0	0
17,30000	3	1	3	2	2
17,50000	23	20	22	20	21
17,40000	0	0	0	0	0
17,60000	0	0	0	0	0
17,70000	12	14	13	13	15
17,80000	7	10	7	7	7
17,90000	10	11	11	12	11
18,00000	1	1	0	3	1
18,10000	0	0	0	0	0
18,20000	0	0	0	0	0
18,30000	0	0	0	0	0
AVERAGE	17,547	17,591	17,554	17,607	17,579
STD.DEV.	0,2054	0,1957	0.2010	0,2103	0,1989
SMALLEST NO.	17.1000	17.2000	17.1000	17.2000	17,2000
LARGEST NO.	18.0000	18.0000	17.9000	18.0000	18,0000

FREQUENCY DISTRIBUTIONS OF PERCENT CHANGE VALUES

(THE PERCENT CHANGE HAS BEEN CALCULATED FROM THE FIRST TIME INTERVAL.)

CELL	INITIAL	50 HRS	125 HRS	250 HRS	500 HRS
-50,00000		0	0	0	0
-40,00000		0	0	0	0
-30,00000		0	0	0	0
-20,00000		0	0	0	0
-15,00000		0	0	0	0
-10,00000		0	0	0	0
-5,00000		0	0	0	0
-0,00000		33	49	23	40
5,00000		24	8	34	17
10,00000		0	0	0	0
15,00000		0	0	0	0
20,00000		0	0	0	0
30,00000		0	0	0	0
40,00000		0	0	0	0
50,00000		0	0	0	0
AVERAGE	0.000	0.251	0.041	0.340	0.181
STD.DEV.	0.0000	0.2948	0.2605	0.2868	0.2795

Figure 4.- Distribution comparisons

LIST OF PARAMETER LIMITS

PARAMETER NUMBER 1

VZ 1 AT 16MA MEASURED IN VOLTS

INITIAL UPPER LIMIT =	18.100
INITIAL LOWER LIMIT =	17.100
POST UPPER LIMIT =	18.100
POST LOWER LIMIT =	17.100
PERCENT CHANGE LIMIT =	25.000

PARAMETER NUMBER 2

VZ 2 AT 40MA MEASURED IN VOLTS

INITIAL UPPER LIMIT =	18.700
INITIAL LOWER LIMIT =	17.100
POST UPPER LIMIT =	18.700
POST LOWER LIMIT =	17.100
PERCENT CHANGE LIMIT =	25.000

PARAMETER NUMBER 3

IR 1 AT 12V AT 100 C MEASURED IN MICROAMPS

PERCENT CHANGE LIMIT =	100.000

PARAMETER NUMBER 4

IR 2 AT 12V AT 25 C MEASURED IN MICROAMPS

PERCENT CHANGE LIMIT =	100.000

Figure 5.- Parameter limits

REJECT TOTALS

1.00	REJECTED UNITS AT INITIAL HOUR
12.00	REJECTED UNITS DURING TEST
1.429	PERCENT REJECTS AT INITIAL HOUR
17.391	PERCENT REJECTS DURING TEST

TOTAL SAMPLE SIZE= 70 ACCEPTANCE NO.= 2

THIS TEST WAS REJECTED

FAILURE RATE (PERCENT PER 1000 HOURS)

HOURS	CUMULATIVE FAILURE RATE
50	0.0000
150	28.6041
250	48.4848
500	39.3443

CONFIDENCE LIMITS (PERCENT)

	60	70	80	90
FAILURE RATE	47.7193	51.2281	55.7895	62.4561

Figure 6.- Test results and failure rates (%/1000 hrs)

III. FUNDAMENTALS

The topics discussed in this section would be relevant to most computer-aided reliability data systems.

Classification of Tests

High-reliability component specifications commonly divide their testing requirements into three categories or groups labeled as A, B, and C.

Group A: - A device or unit is given a particular brand or label after it has been successfully processed through a series of manufacturing operations designated as a production line. Group A tests are the initial specifications a device must pass before it can be branded.

Group B: - Group B tests are usually the burn-in and/or the environmental conditions a device type must be capable of surviving. In the semiconductor industry, such conditions might be temperature cycling, centrifuge, high-temperature bake, operating burn-in, and shock.

Group C: - Group C is generally where the life test requirements are found. For semiconductor devices, the test time ranges from about 250 to 2000 hours, with the 1000-hour test being the most popular.

Testing costs money, and in some reliability specifications, it can constitute a higher portion of the total unit cost than does the actual manufacturing of the device. Group A tests are usually very extensive, while Group B and C tests are confined to those critical parameters that indicate failure modes and can be used as quality and reliability indicators. CARDA can be manipulated, through the use of program options, to produce specific types of analysis orientated toward each of the three Groups: A, B, and C.

Data Processing

The procedures for reporting test measurements and the results thereof should be clearly and concisely covered in a reliability specification. Most quality control and reliability organizations do not have their own EDP (Electronic Data Processing) departments. True, they may have automatic data-logging equipment, but the actual processing of data into a final acceptance report is usually performed by a separate EDP facility. In the process of transforming data from one format to another and

transmitting it between departments, many errors of omission and commission can occur. It is important that reliability specifications properly control the recording, collection, processing, and reporting of such information. Therefore, a brief review of some of the more pertinent data processing practices and procedures found in EDP and quality control installations is now presented.

Hash Total

In order to provide a means of controlling incoming and outgoing material, it is a common practice in EDP installations to sum up a particular data item that will appear in all the records that are received from outside sources. The sum-total value thus found will be compared to a similar one taken by the outside department; if in agreement, then it is assumed no data records have been lost or misplaced. Date code, unit number, and test code could be typical items that might be used for this purpose. While the outside department usually has to perform this function on a desk calculator, the EDP installation can use the computer. Data control practices of this kind become important when large numbers of hand-recorded data sheets are sent to be keypunched, or when large quantities of tabulating cards are to be processed.

Data Verification

The verification of keypunched data should be performed by the keypunch department. However, the submitting department should randomly sample the results using an appropriate sampling plan. The A.Q.L.* and L.T.P.D.** values of the sampling plan will be influenced by such factors as machine time availability, processing turn-around time, and the efficiency of the keypunch operation. The same sampling procedure holds true for data produced by automatic data-logging equipment.

Calibration

Care should be taken when specifying percent change and/or delta limits to consider the normal variation in the accuracy of the test equipment that will be used; the scale on which the measurements are to be read, and the number of significant digits to be used in the calculations.

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* Acceptance Quality Level
** Lot Tolerance Percent Defective

Signatures

To assure proper supervision during the testing of the devices, it is common practice to have the responsible test engineer or supervisor sign the test report.

Coded Data Cards

Reliability specifications that require tabulating cards to be included along with a test report should specify that a listing of the data cards must also be provided. In the case where the data on the tabulating cards is in a coded format, a decoded listing of the data is usually provided. However, to spot check the cards, a listing of the coded cards would also be convenient. The most preferable procedure is to specify only decoded cards and corresponding listings.

Data Storage

Reliability specifications requiring test data to be accessible for long periods of time should also specify the manner in which the corresponding data cards and/or tapes should be stored.

Coded Data

Data codes used in the transcribing of data should be constructed in as simple a manner as possible and a thorough explanation included in the reliability specification.

Data Card Shipment

When data cards are to be shipped, the packaging, labeling, and card arrangement should be adequately covered in the reliability specification.

Data Formatting

The medium for recording variable test data is either through some automatic data-logging system or simply by hand. The three most common methods of recording test measurements are the conventional decimal system, scientific, or by use of some arbitrary coded notation. The number one-hundred-twenty-three

would be written in the conventional decimal system as:

$$123$$

Reading from right to left, the digit 3 indicates units, the digit 2 indicates tens, and the digit 1 indicates hundreds. The number is said to be right justified; that is, the decimal point is understood to come after the digit 3, e.g.

$$123.$$

In scientific notation, the same number might be written as either:

$$1.23 \times 10^2$$

or

$$12.3 \times 10^1$$

or

$$123 \times 10^0$$

The scientific notation is useful in recording either extremely large or small numbers, e.g.:

$$123{,}000{,}000{,}000$$

could be recorded as: 123×10^9

or

the number: $.000{,}000{,}123$

could be recorded as: 123×10^{-9}

Some automatic data-logging equipment use range indicator codes to denote the scale on which the values are recorded. For example, the letter A after a number might indicate that the measurement was recorded on the 1 to 9 unit scale. The number

$$123A$$

would be interpreted as: 1.23

since no value can be less than 1 or greater than 9.

There seem to be as many coding schemes as there are data-logging systems. Nevertheless, CARDA can accommodate such schemes because it gives the user the flexibility of inserting his own data coding procedures into the computer program. One method of recording data for CARDA is to use the scientific notation with the term X10 understood, and the exponent, which is always considered negative in CARDA, placed after the last digit in the number. The following examples indicate the difference in the decimal notation and this scheme:

Decimal number	CARDA equivalent
.123	123$\underline{3}$
1.23	123$\underline{2}$
12.3	123$\underline{1}$
123.	123$\underline{0}$
.000,000,123	123$\underline{9}$

The underlined last digit in the CARDA equivalent column is the negative exponent. Other procedures which illustrate how the decimal point may be manipulated are given in subsequent paragraphs.

There are several methods of getting data into a computer and CARDA can be adapted to many of them. Perhaps the most common method is through the use of tabulating cards. Figure 7 shows a 12-row, 80-column, tabulating card on which data can be recorded. Only one character, either a letter, number, or special sign can be recorded in any single column. The rows numbered 0 to 9 are where the numbers 0 to 9 are recorded. Row zero is considered to be row number 10, and the subsequent two blank rows 11 and 12. Letters and special signs are produced by combinational punches in rows 10, 11, 12, and rows 1 to 9. Figure 8 shows a punched tabulating card.

When measurements of a particular device or item are being recorded, there is some additional information, such as the unit number and test code, that CARDA must have along with the parameter readings. This information must appear on each tabulating card in the following sequence: (1) test code, (2) unit number, and (3) parameter readings. The test code, preferably a number, is a means of identifying the operation, sequence interval, or time period that the measurements were recorded. For example, in a life test, the reading periods may be designated in sequence as 1, 2, 3, ... A unit number for each device measured must appear on the tabulating card(s). The parameter measurement

must appear on the tabulating cards in the same order from one device to another. Up to eight parameter readings may be recorded on a data card.

Suppose units were being selected at random for testing from lots of material according to a sampling plan and the sample size depended on the lot size. Now the lots of material could be sampled at any one of the three different operations and the sample size could range from 20 to 5000 units. The test codes could be assigned starting with number one. Three characteristics or parameters are recorded per unit and each one could range from 1000 to 1/1000 in value; e.g.

999.999 to .001

The following comparison shows the number of card columns required to record the above information

Data	Required Card Columns
Test Code	1
Unit Number	5
Each Measurement	6

Since no decimal points are recorded in the parameter measurements, the largest value would require 6 digits.

CARDA needs to know the card columns the above data will appear in and the number of columns required for each data item. This information is recorded on the Input Data Specification Card. One procedure that could accomplish this would be to use "T" to indicate the column the data starts in, and an "F" to indicate the number of columns and where the decimal point should be recorded by the computer. Figure 9 shows a card punched according to the requirements of the above example. The column in which the data items start was selected arbitrarily.

Item	Digits	Card Column	Field Width
Test Code	1	T 3	F 1.0
Unit Number	5	T 5	F 5.0
Parameter #1	6	T 10	F 6.3
Parameter #2	6	T 16	F 6.3
Parameter #3	6	T 22	F 6.3

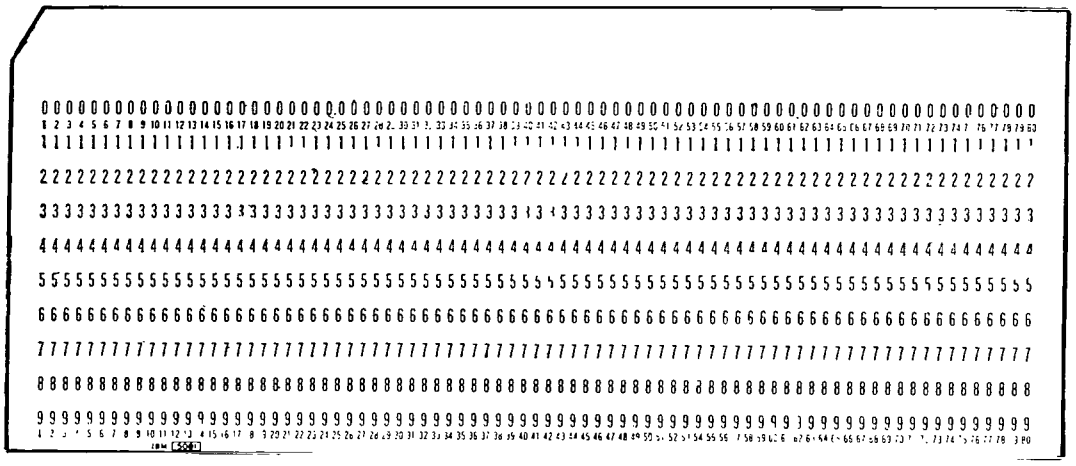


Figure 7.- Blank tabulating card

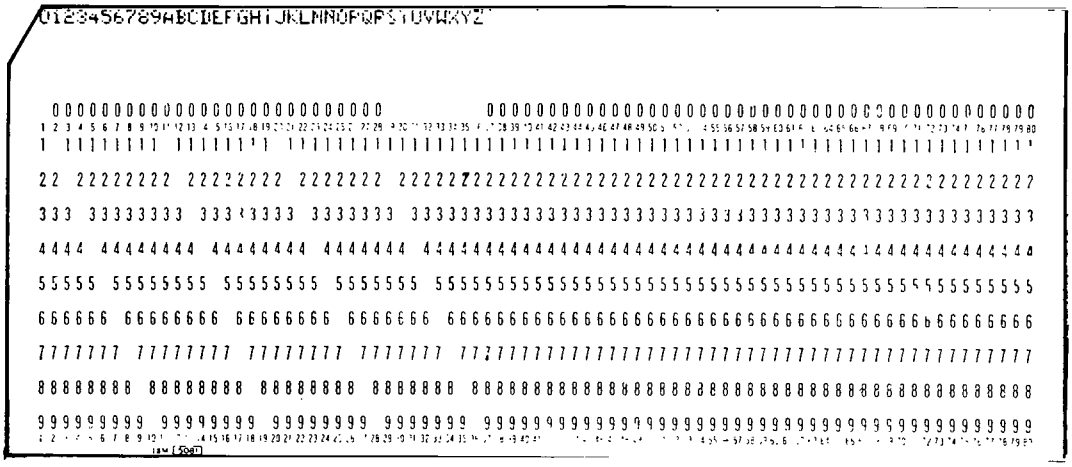


Figure 8.- Keypunched tabulating card

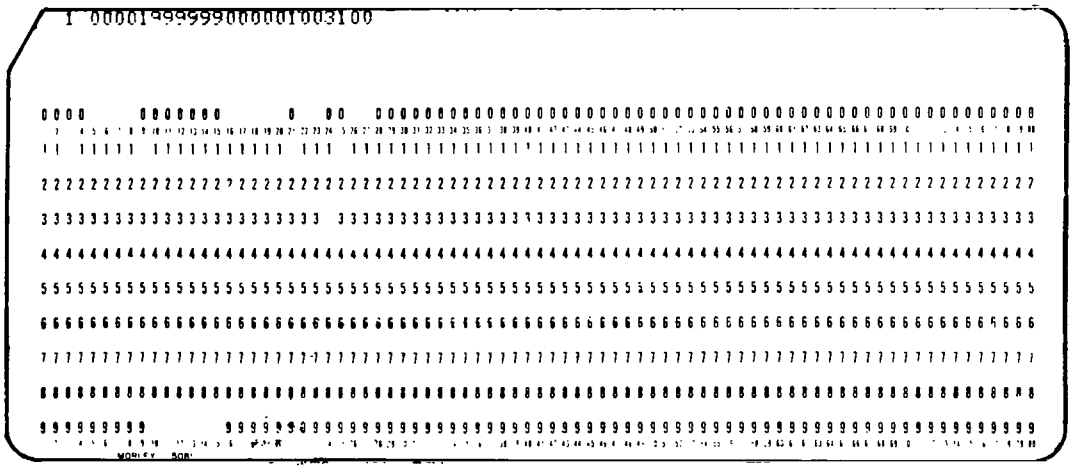


Figure 9.- Card with numeric data

In the "F" format, the digit before the decimal point indicates the total number of columns required, and the digit after the decimal point tells the computer where the decimal point belongs in the number. Figure 9 indicates measurements of 999.999, .001, and 3.1 for the first test code of unit number 1. The Input Data Specification Card begins with a parenthesis and ends with a parenthesis. For the data in Figure 9, the specification card would be:

(T3, F1.0, T5, F5.0, T10, F6.3, T16, F6.3, T22, F6.3)

When the negative exponent is not used, a blank space must be provided between parameter measurements. Test parameters usually do not require more than 6 columns each for recording data. Since the maximum number of parameters per card CARDA will allow is eight, then 6 x 8 = 48 card columns required out of 80. The remaining columns are used for the unit number, test code, and additional identifying information.

Each data card should be completely traceable to some documentation that governs its data format and interpretation. Some of the more common items that appear on test data cards are:

(1) Date of Test

(2) Specification Number

(3) Type of Device

(4) Manufacturer's Code

A typical hand recording data sheet is given in Figure 10.

TYPE_____ LOT NO._____ DATE_____ ORIGINATOR_____ PAGE_____of_____

PUNCHED IN CARD COLUMNS 1-18 OF ALL CARDS →	DEVICE TYPE								LOT NUMBER				TEST CODE			DATE		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18

ITEM COUNT					PARA 1			M		PARA 2			M		PARA 3			M		PARA 4			M		PARA 5			M	
19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48

Figure 10.- Typical hand recording data sheet

IV. CARDA INPUT DATA DECK

The Input Data Deck of the CARDA program is divided into five sections:

(1) General Test Information

(2) Specifications

(3) Headings and Labels

(4) Formats

(5) Parameter Readings

These categories are closely allied to the outline of fundamental principles for test reports that was given in Section II.

General Test Information

The first section of the input data deck should contain descriptive information that will identify the type of test and the test conditions. For proper identification this section should include, as in Figure 11;

(1)	Test Heading	RELIABILITY LIFE TEST REPORT ISSUED BY NASA (ERC-CQS) DATA COURTESY OF (Manufacturer)
(2)	Type of Unit	(Name and number, if applicable)
(3)	Lot and Sub-group	(If applicable)
(4)	Type of Test	(e.g. storage, operating, etc.)
(5)	Test Intervals and Codes	(e.g. pre-test, post-test, etc.)
(6)	Test Conditions	(If applicable)

This section must contain exactly fifteen (15) cards. If the desired information does not require fifteen cards, blank tabulating cards must be included to maintain the total number of fifteen. These blank cards may be placed either at the beginning, in between, or at the end of the information cards to obtain spacing.

Figure 12 shows an actual computer output. The blank space between the third and fourth lines of output was caused by the blank card.

Figure 13 shows the card setup for the sample output shown in Figure 12. In this setup, the fourth card, a blank, was inserted for spacing.

Although the descriptive information may begin in any column on the card, it is advisable to begin in column 15 in order to obtain a properly centered output.

RELIABILITY LIFE TEST REPORT ISSUED BY NASA (ERC-CQS) DATA COURTESY OF [ABC Co.] (Manufacturer)	TEST HEADING
ABC Co. SEMICONDUCTOR TEST	TEST NAME
CLOCKED FLIP-FLOP (6666)	UNIT NAME
TYPE Z22 6666 174X	UNIT CODE NAME
LOTS 5555,5556,5557	LOT NUMBER
SUBGROUP 7, SAMPLES 141-194	SUB-GROUP
OPERATING LIFE TEST TEST CODE PRETEST 1 POST TEST 3	TEST INTERVALS AND CODES
(POST TEST MEASURED AT 1000 HOURS)	TEST
TEST TEMPERATURE IS 125C TEST VOLTAGE IS 6.0V	CONDITIONS

Figure 11.- Sample data for information section

```
RELIABILITY LIFE TEST REPORT

ISSUED BY NASA(ERC-CQS)

DATA COURTESY OF AFC CO.


ABC CO. SEMICONDUCTOR TEST

CLOCKED FLIP-FLOP (6666)

TYPE  Z22 6666 174X

LOTS 5555, 5556, 5557

SUBGROUP 7, SAMPLES 141-194

OPERATING LIFE TEST        TEST CODE

PRETEST                        1

POST TEST                      3

(POST TEST MEASURED AT 1000 HOURS)

TEST TEMPERATURE IS 125 C

TEST VOLTAGE IS 6.0V

 IN THE PERCENT CHANGE ANALYSIS,MINUS SIGNS
DENOTE PARAMETER DECREASES,WHILE PLUS SIGNS
DENOTE PARAMETER INCREASES.

COMPUTATIONS DO NOT INCLUDE REJECTED UNITS
```

Figure 12.- Sample output of general test information section

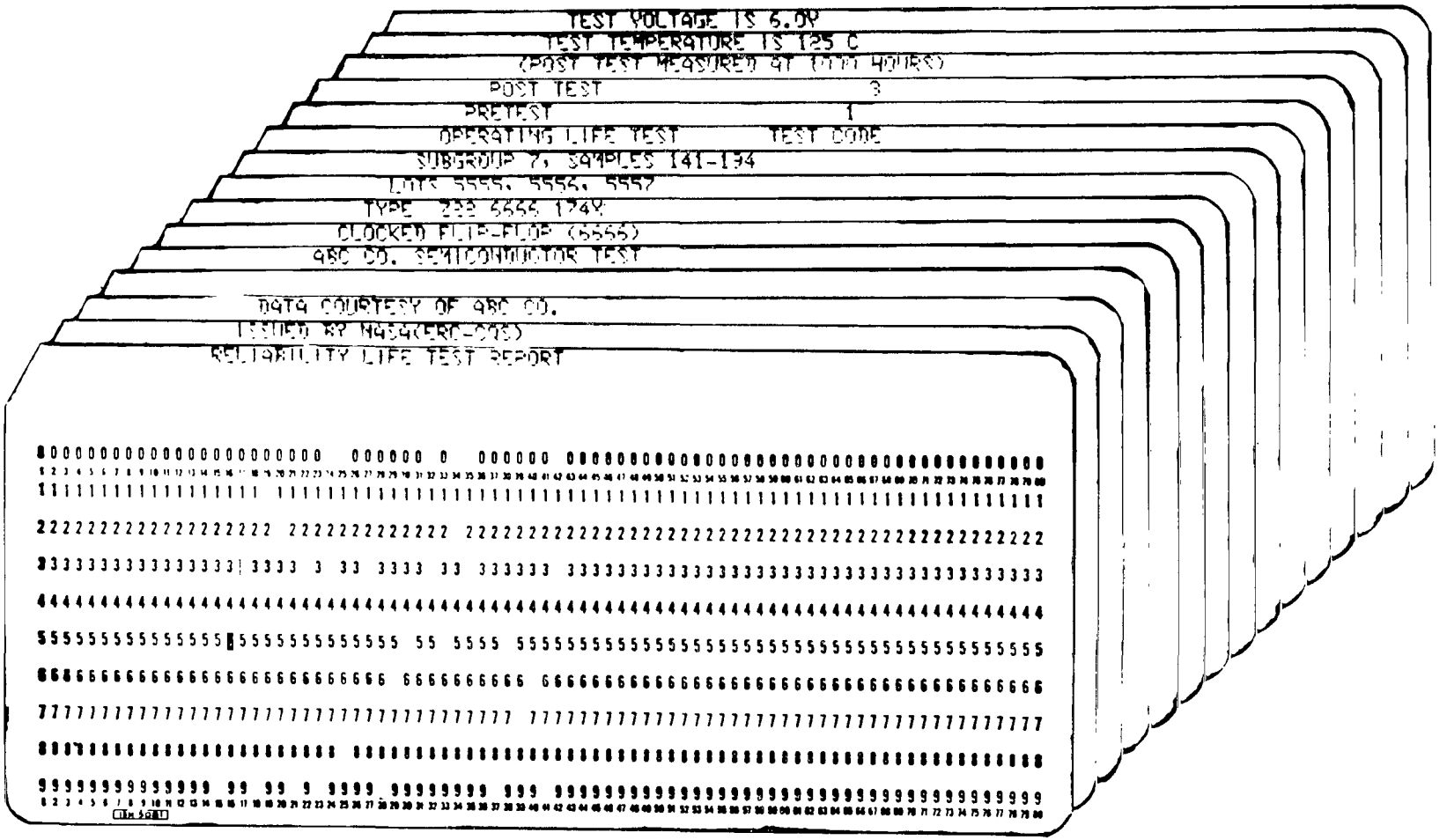


Figure 13.- Sample card setup of information section

Specifications

The second section of the data deck is the specification section which is called SPEC. This section is divided into four sub-sections:

(1) Numeric Variables

(2) Options

(3) Rules

(4) Restrictions

Definition of Numeric Variables

The following list is an explanation of the numeric variables contained in this section.

NOPARA is the number of parameter readings per data card (limited to a maximum of eight).

NACEPT is the number of rejects allowed before the test will be rejected.

NRTIME is the number of time periods or test sequences for which there are parameter readings.

TIME are the actual time periods after the initial time period.

XLOWER is the pre-test or initial time period minimum value which a parameter can attain before the unit is considered a reject.

XUPPER is the pre-test or initial time period maximum value which a parameter can attain before the unit is considered a reject.

YLOWER is the post-test minimum value which a parameter can attain before the unit is considered a reject.

YUPPER is the post-test maximum value which a parameter can attain before the unit is considered a reject.

CELLS are the predetermined interval limits used to establish the frequency distribution of the parameter readings.

CHANGE are the predetermined interval limits used to establish the percent change distribution of the parameter readings.

PCT is the absolute maximum percent change a parameter is permitted before the unit is considered a reject.

DELTA is the absolute maximum numeric deviation a parameter is permitted before the unit is considered a reject.

REED is the variable used to indicate the arrangement of the test measurements on the input data tabulating cards.

SCALE is the variable used to relate the parameter values to particular units of measure.

CURENT is the IC value used in the following formula for calculating the DC Beta of transistors.

$$\frac{IC}{IB} = HFE$$

Assignment of Values

Variables are assigned their appropriate values algebraically by means of an equal sign (=). The following examples illustrate the methods by which the variables are assigned values.

NOPARA For a set of readings which contain seven parameters for each time period NOPARA would be equated to seven, as in Figure 14.

NOPARA = 7,

NACEPT If two rejects are allowed before the test will be rejected, then NACEPT would be equated to two, as in Figure 14.

NACEPT = 2,

NRTIME Given a set of parameter readings for two time periods, initial and 1000 hours, NRTIME would be equated to two, as in Figure 14.

NRTIME = 2,

TIME Given a set of parameter readings for five time periods, 0, 50, 125, 250, and 500 hours, TIME would be equated to 50, 125, 250, and 500 as in Figure 14.

TIME = 50, 125, 250, 500,

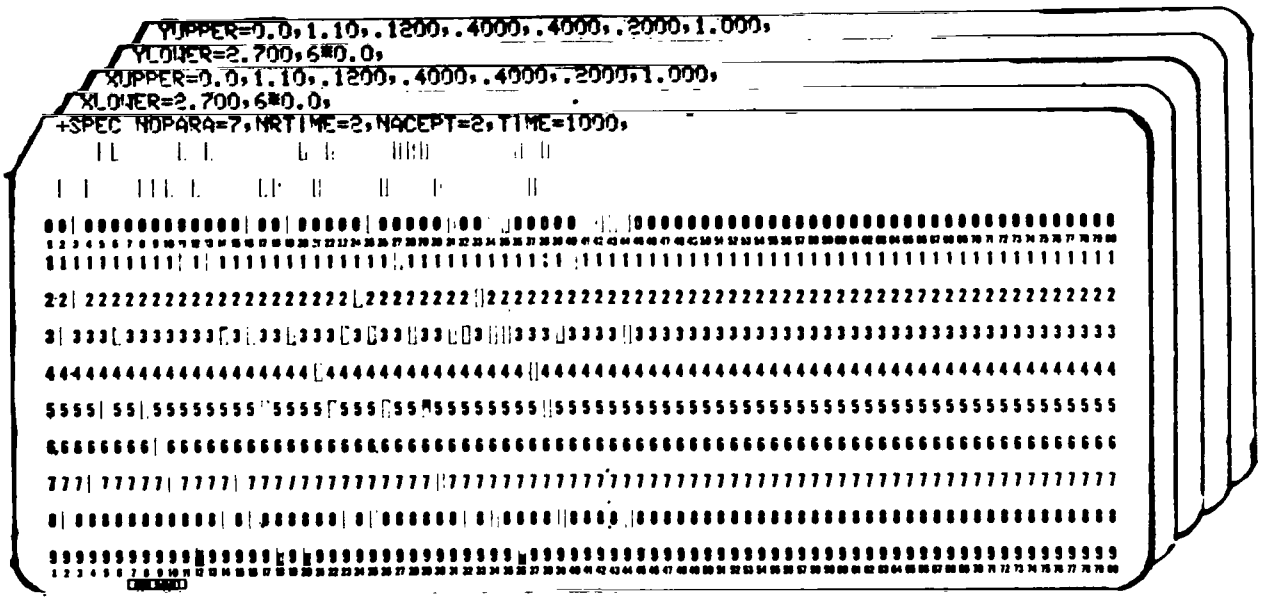


Figure 14.- Sample card set-up for several variables of the spec section

XLOWER
XUPPER
YLOWER
YUPPER

These four variables follow the same set-up procedures. Given a set of four parameters with upper limits of 18.1 and 18.7 for the third and fourth parameters respectively, XUPPER would be assigned as follows,

XUPPER = 0, 0, 18.1, 18.7

CELLS

Figure 15, contains a sample computer output of CELLS values. There must be a set of exactly fifteen (15) upper limit values for each parameter. Each set of values begins with the lowest value and concludes with the highest. The sets of values are then arranged according to the sequence of the parameters. Figure 16 provides a sample card set-up for seven parameters. In Figure 16 the first value of the first card, 3.040, represents the upper limit of the first cell interval of the first parameter. The last value of the second card, 3.250, represents the upper limit of the first cell interval of the first parameter. The first value on the third card, .068, is the upper limit of the first cell of the second parameter. The last value on the third card, 1.000, is the upper limit of the fifteenth cell interval of the second parameter. This procedure for assigning the values is repeated until fifteen values have been established for each parameter. (Note: Methods for determining cell limits can be found in most standard text books on quality control.)

CHANGE

Figure 15 contains a sample output of the CHANGE values. There must be a set of exactly fifteen (15) upper limit values for each parameter. Each set of values begins with the lowest value and concludes with the highest. The sets of values are arranged according to the sequence of the parameters.

In Figure 17, the first value on the first card, -50.0, represents the upper limit of the first cell interval of the first parameter. The last value of the second card, 50.0, represents the upper-limit of the fifteenth cell interval of the first parameter. The first value of the third card, -50.0, is the upper limit of the first cell interval of the second parameter. The last value on the fourth card, 50.0, is the upper limit of the fifteenth cell interval of the second parameter. This procedure for assigning the values is repeated until fifteen values have been established for each parameter. However, if the percent changes are not to be calculated, then the change values are omitted completely.

PARAMETER NUMBER 6

V9 MEASURED IN VOLTS

FREQUENCY DISTRIBUTIONS OF MEASUREMENTS
AT EACH READING PERIOD

	CELL	INITIAL	1000 HRS
CELLS	0.07200	0	0
	0.07750	0	0
	0.08300	0	0
	0.08850	5	4
	0.09400	4	5
	0.09950	4	4
	0.10500	7	7
	0.11050	5	5
	0.11600	3	3
	0.12150	5	5
	0.12700	3	3
	0.13250	3	3
	0.13950	1	1
	0.14900	1	1
	0.15300	0	0
	AVERAGE	0.108	0.108
	STD.DEV.	0.0153	0.0153
	SMALLEST NO.	0.0839	0.0840
	LARGEST NO.	0.1486	0.1484

FREQUENCY DISTRIBUTIONS OF PERCENT CHANGE VALUES

(THE PERCENT CHANGE HAS BEEN CALCULATED FROM THE FIRST TIME INTERVAL.)

	CELL	INITIAL	1000 HRS
CHANGE	-50.00000		0
	-40.00000		0
	-30.00000		0
	-20.00000		0
	-10.00000		0
	-5.00000		0
	-2.50000		0
	-0.00000		14
	2.50000		27
	5.00000		0
	10.00000		0
	20.00000		0
	30.00000		0
	40.00000		0
	50.00000		0
	AVERAGE	-0.000	0.110
	STD.DEV.	-0.0000	0.1524

Figure 15.- Sample output of CELLS and CHANGE values

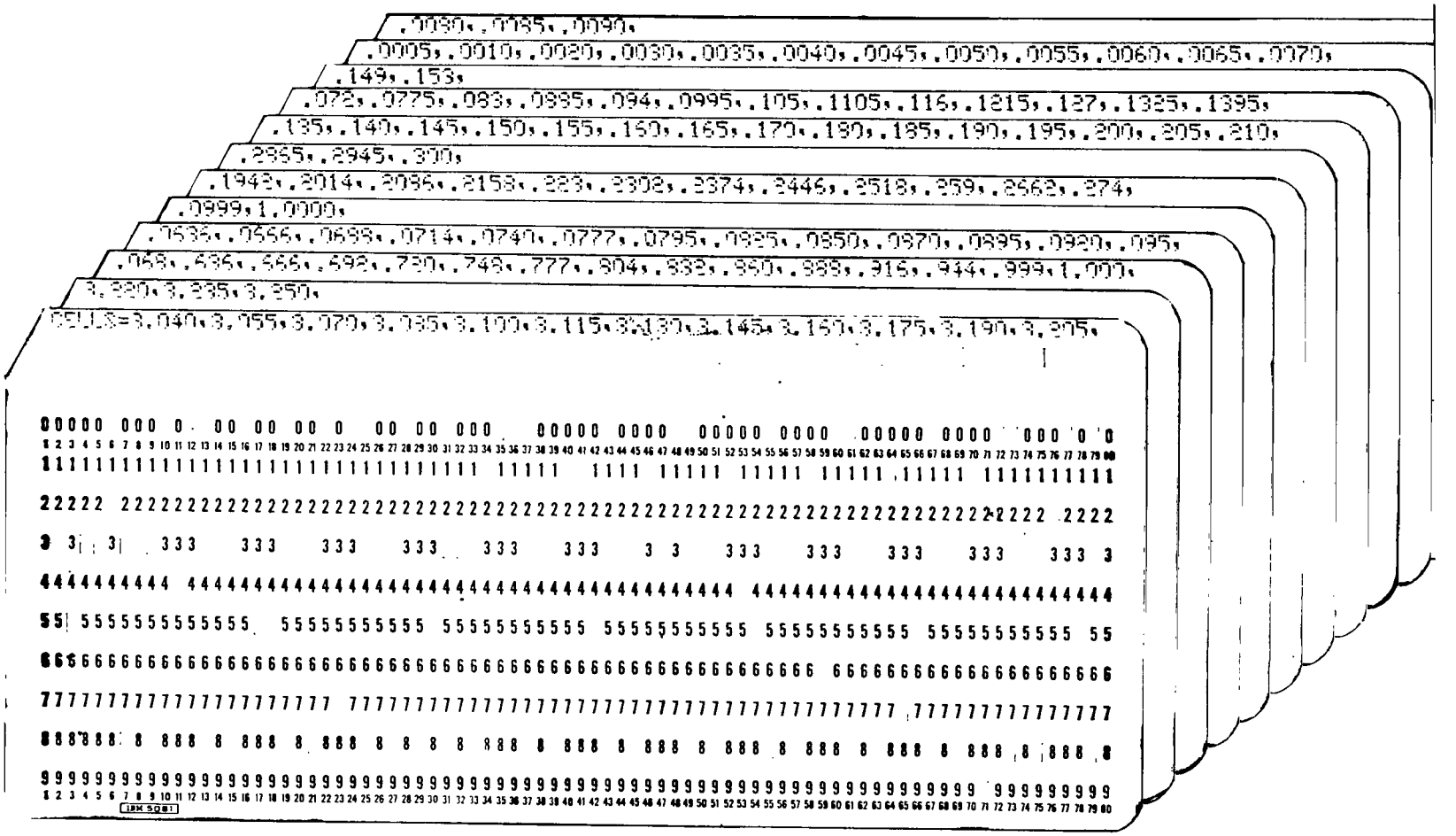


Figure 16.- Sample card setup of CELLS values

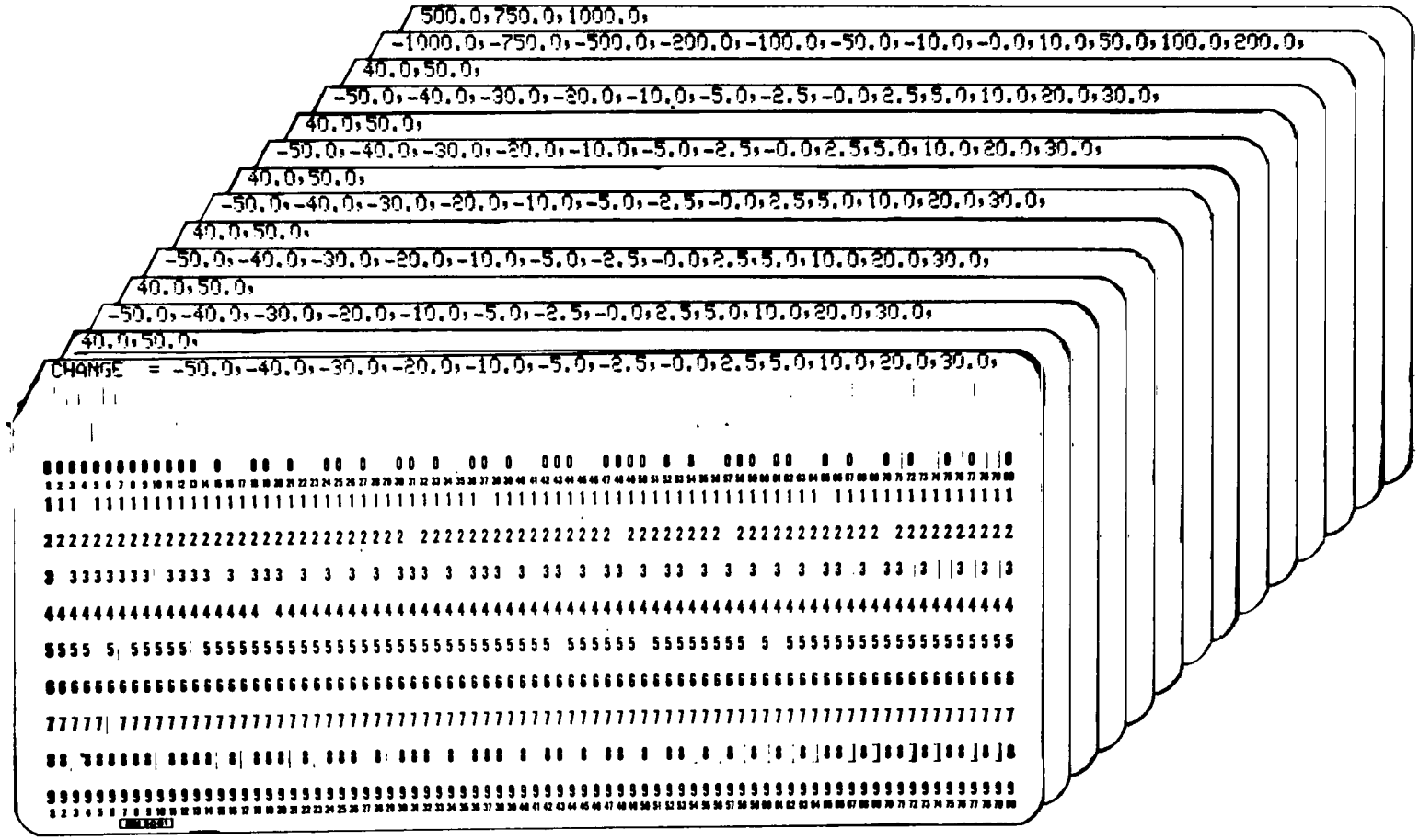


Figure 17.- Sample card setup of CHANGE values

PCT — The percent change can be calculated from either the initial or the previous time period. Calculation of the percent change from the initial time period is standard; however, if it is desired from the previous time period, then the IPCT option should be used as described in Sub-section 2, OPTIONS, of this section.

Given a set of readings for two parameters, with the restriction that the first parameter can vary by no more than 25% and that the second parameter can vary by no more than 100%, then PCT would be equated to 25 and 100.

PCT = 25, 100,

DELTA — Given a set of readings for two parameters, with the restriction that the first parameter can vary from the initial reading by no more than .5 and the second parameter can vary by no more than 1.0, then DELTA would be equated to .5 and 1.0.

DELTA = .5, 1.0,

However, DELTA cannot be used unless PCT and CHANGE have been defined.

REED — This variable is assigned its value dependent upon the arrangement of the input data.

Given input data arranged as follows:

TEST CODE, UNIT NUMBER, READING, EXPONENT,
READING, EXPONENT . . .

then REED would be equated to 1.

REED = 1,

Given input data arranged as follows:

TEST CODE, UNIT NUMBER, READING, READING . . .

then REED would be equated to 2.

REED = 2,

Other data arrangements are possible through the use of special input subroutines.

SCALE When exponents or range indicators are used with the parameter readings, SCALE is assigned a value which is used in the following formula to obtain the desired unit of measurement.

$$Z = Y \times 10^{(SCALE-X)}$$

where X represents the exponent or range indicator,
Y represents the parameter measurement given, and
Z represents the converted parameter reading.

Given a set of SCALE values of 3, 6, 3, and 9 for four parameters, the values, 3, 6, 3, and 9, would be equated to SCALE.

SCALE = 3, 6, 3, 9,

CURENT This variable is used only for transistors, i.e., when the base current, IB, is given and HFE must be calculated.

Options

The options allow variations to be made in the type of analysis and form of output. The option variables are assigned their values and are set up according to the rules previously defined for single valued variables. When the options are called for, the variables are included in the SPEC section. If a particular option is not desired, then that option variable is omitted completely. The following list is a brief description of the options available in the CARDA Program.

ILIST If just a listing of the parameter readings and specification limits is desired, set ILIST equal to one (1), i.e. ILIST = 1.

IHISTO If a histogram is called for, set IHISTO equal to one (1), i.e. IHISTO = 1.
Conditions: NRTIME must be equal to one (1).

IPCT If the percent change is to be computed from the previous time period, set IPCT equal to one (1), i.e. IPCT = 1.
Conditions: CHANGE must be defined.

ICONF If the confidence limits are called for, set ICONF equal to one (1), i.e. ICONF = 1.
Conditions: TIME must be defined.

IFAIL If a unit must fail both the absolute change value and the percent change value to be determined a failure, set IFAIL equal to two (2), i.e. IFAIL = 2. Conditions: PCT and DELTA must be defined.

All the options with the exception of ILIST can be combined in numerous ways to obtain a wide variety of reports.

RULES:

(1) All cards must start in column 2.

(2) The first card must start with a + in column 2.

(3) The section name, SPEC, must start in column 3 following the +.

(4) Each variable must be separated by a comma. (Spacing does not affect the numeric value.)

Sample set-up for:

(a) Single valued variable
Col 2
```
NOPARA = 7,
```

(b) Multiple valued variable on one card
Col 2
```
CELLS = 1, 2, 3 . . . . . 34, 35,
```

(c) Multiple valued variable on more than one card
Col 2
```
                                                Col 80
CELLS = 1, 2, 3 . . . . . .                     44, 45,
46, 47, 48, 49, 50,
```

(d) Combination of single and multiple valued variables
Col 2
```
                                                Col 80
NOPARA = 2, NRTIME = 2, NACEPT = 2, CELLS = 1, 2,
3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15,
1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15,
TIME = 1000,
```

(5) Each card must end with a comma.

Sample of illegal input:
Col 2
```
                                                Col 80
CELLS = 2.5, 3.0  . . . . . . . . .             6.0, 6.
5, 7.0, 7.5
```

The value, 6.5, cannot be continued from the first card to the second card. In this particular case the value, 6.5, must be written entirely on the second card.

Proper set-up:
Col 2

```
                                                    Col 80
CELLS = 2.5, 3.0 . . . . . . . . . . .                6.0,
6.5, 7.0, 7.5,
```

(6) The last card in this section must read +END starting in Column 2.
Last Card:
Col 2

```
+END
```

Restrictions

(1) Alphabetic information cannot be used in this section.

Sample illegal input:

NOPARA = N2 or CELLS = X, Y, Z,

Headings and Labels

The third section of the data deck contains the various output headings and labels. This section is subdivided into three sub-sections:

(1) Units of Measurement for Parameters

(2) Output Heading for Parameter Readings

(3) Cell Distribution Heading

Units of measurement for parameters.- This sub-section sets up the units of measurement labels for the parameters. The number of cards in this section corresponds exactly to the number of parameters as defined in the numeric variable section of Section II. The general format for this section is:

```
COLUMN
30
(Para I)...MEASURED IN...(Units)
```

where (Para I) are the actual parameter names which start in Column 30. The units of measure, (Units), will depend upon the actual parameter readings. However, the parameter names may begin in Column 5, if additional space is required.

Example 1. For seven parameters:

```
COLUMN
30
V6  MEASURED IN VOLTS
114 MEASURED IN MICRO-AMPS
12  MEASURED IN MICRO-AMPS
14  MEASURED IN MICRO-AMPS
I1  MEASURED IN MICRO-AMPS
V9  MEASURED IN VOLTS
112 MEASURED IN MICRO-AMPS
```

Example 2. For four parameters:

```
COLUMN
30
IR 1 AT 12V AT 100 C  MEASURED IN MICRO-AMPS
IR 2 AT 12V AT 25 C   MEASURED IN MICRO-AMPS
VZ 1 AT 16MA          MEASURED IN VOLTS
VZ 2 AT 40MA          MEASURED IN VOLTS
```

If there were, for example, seven parameters, there would be seven cards in this section, as in Example 1, and they would be set up as in Figure 18. If there were only four parameters, then there would be only four cards in this section, as in Example 2, and they would be set up as in Figure 19. Sample outputs which illustrate the use of these labels are given in Figures 20 and 21.

Output heading for parameter headings.- This sub-section sets up the heading which is used in the output of the COMPLETE LIST OF UNITS, as in Figure 22. The heading consists of four lines of output. Two tabulating cards must be used for each line of output. Therefore, there will be a total of eight cards in this section. The eight cards can be subdivided into four groups of two according to the four lines of output.

(a) Line 1

(b) Line 2

(c) Line 3

(d) Line 4

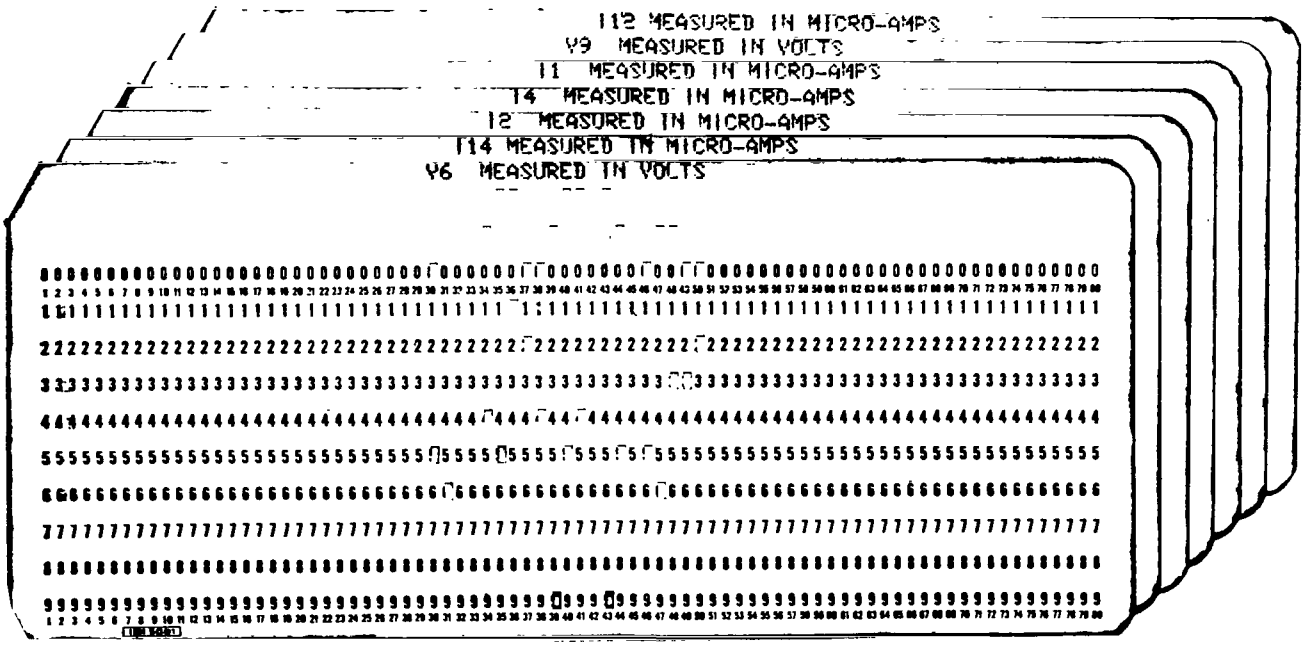


Figure 18.- Sample card setup of units of measurement section for seven parameters

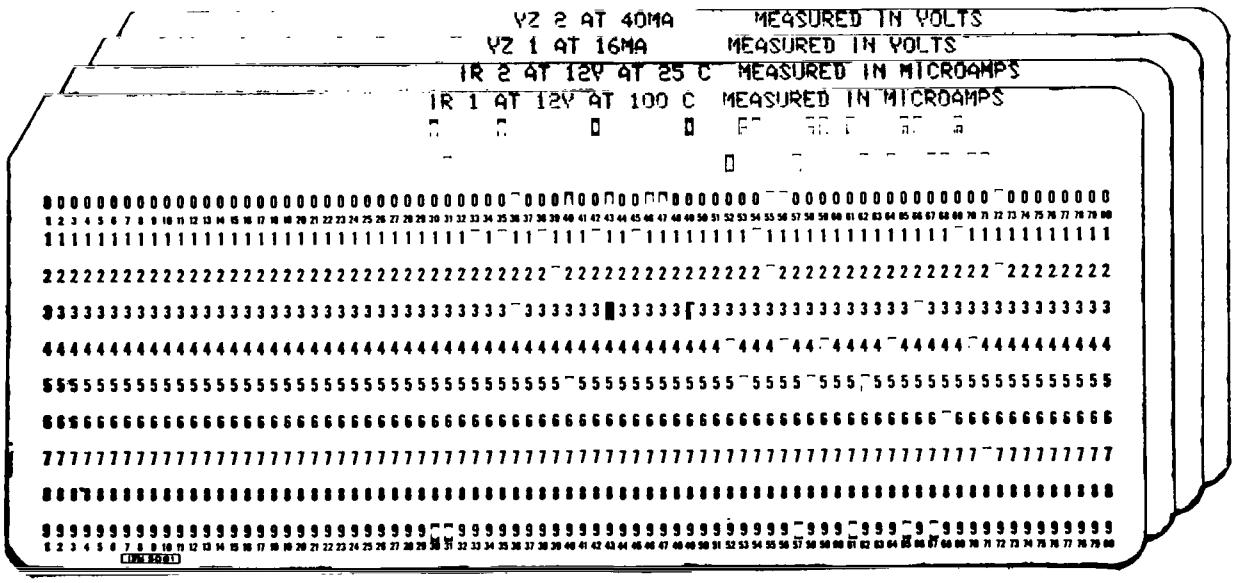


Figure 19.- Sample card setup of units of measurement section for four parameters

LIST OF PARAMETER LIMITS

PARAMETER NUMBER 1.

INITIAL LOWER LIMIT =	2.700
POST LOWER LIMIT =	2.700
PERCENT CHANGE LIMIT =	25.000

PARAMETER NUMBER 2

INITIAL UPPER LIMIT =	1.100
POST UPPER LIMIT =	1.100
PERCENT CHANGE LIMIT =	100.000

PARAMETER NUMBER 3

INITIAL UPPER LIMIT =	0.120
POST UPPER LIMIT =	0.120
PERCENT CHANGE LIMIT =	100.000

PARAMETER NUMBER 4

INITIAL UPPER LIMIT =	0.400
POST UPPER LIMIT =	0.400
PERCENT CHANGE LIMIT =	100.000

PARAMETER NUMBER 5

INITIAL UPPER LIMIT =	0.400
POST UPPER LIMIT =	0.400
PERCENT CHANGE LIMIT =	100.000

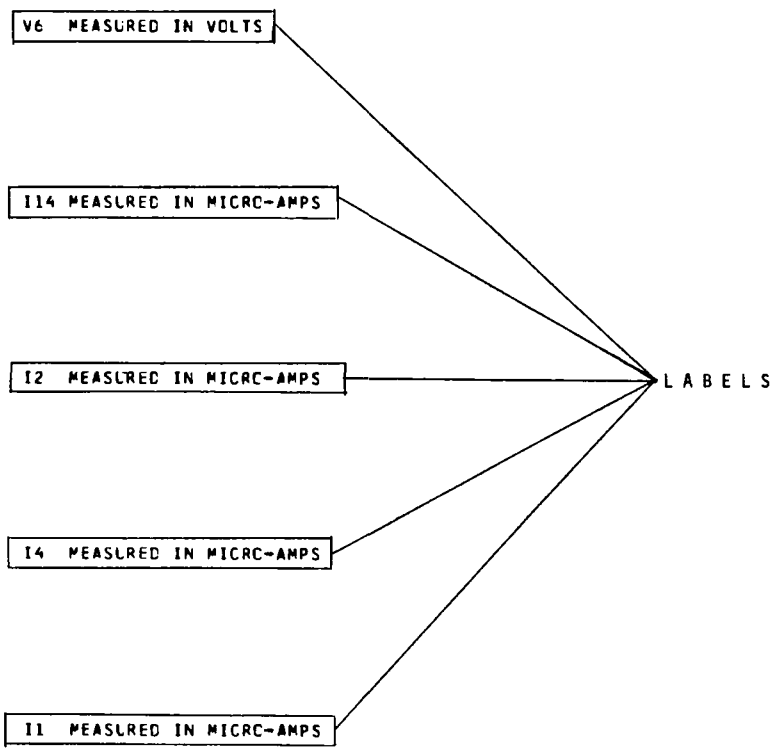


Figure 20.- Sample output illustrating the units of measurement section

PARAMETER NUMBER 7

I12 MEASURED IN MICRO-AMPS → LABEL

FREQUENCY DISTRIBUTIONS OF MEASUREMENTS
AT EACH READING PERIOD

CELL	INITIAL	1000 HRS
0.00050	0	0
0.00100	18	0
0.00200	22	0
0.00300	1	0
0.00350	0	0
0.00400	0	0
0.00450	0	0
0.00500	0	0
0.00550	0	0
0.00600	0	24
0.00650	0	0
0.00700	0	17
0.00800	0	0
0.00850	0	0
0.00900	0	0
AVERAGE	0.002	0.006
STD.DEV.	0.0005	0.0005
SMALLEST NO.	0.0010	0.0060
LARGEST NO.	0.0030	0.0070

FREQUENCY DISTRIBUTIONS OF PERCENT CHANGE VALUES

(THE PERCENT CHANGE HAS BEEN CALCULATED FROM THE FIRST TIME INTERVAL.)

CELL	INITIAL	1000 HRS
-1000.00000		0
-750.00000		0
-500.00000		0
-200.00000		0
-100.00000		0
-50.00000		0
-10.00000		0
-0.00000		0
10.00000		0
50.00000		0
100.00000		0
200.00000		8
500.00000		32
750.00000		1
1000.00000		0
AVERAGE	-0.000	350.813
STD.DEV.	-0.0000	141.3699

Figure 21.- Sample output illustrating the use of the units of measurement section

COMPLETE LIST OF UNITS

COLUMN HEADINGS

UNIT NUMBER	TEST CODE	V6 AT 4.5V	I14 AT 5.0V	I2 AT 5.5V	I4 AT 5.5V	I1 AT 5.5V	V9 AT 5.5V	I12 AT 4.5V
141	1	3.120	0.783	0.0691	0.1969	0.1426	0.1066	0.001
141	3	3.120	0.783	0.0692	0.1970	0.1429	0.1068	0.006
142	1	3.146	0.785	0.0834	0.2422	0.1717	0.1313	0.002
142	3	3.148	0.785	0.0834	0.2422	0.1718	0.1315	0.007
143	1	3.185	0.949	0.0998	0.2885	0.2032	0.1175	0.002
143	3	3.179	0.949	0.1000	0.2889	0.2036	0.1173	0.007
144	1	3.143	0.923	0.0870	0.2457	0.1773	0.1004	0.001
144	3	3.142	0.924	0.0871	0.2460	0.1775	0.1005	0.006
145	1	3.102	0.855	0.0730	0.2221	0.1685	0.1016	0.001
145	3	3.101	0.855	0.0731	0.2224	0.1689	0.1017	0.006
147	1	3.145	0.957	0.0892	0.2611	0.1851	0.0893	0.001
147	3	3.141	0.956	0.0894	0.2615	0.1856	0.0894	0.006
148	1	3.174	0.875	0.0750	0.2618	0.1830	0.1226	0.002
148	3	3.175	0.875	0.0751	0.2617	0.1830	0.1228	0.006
149	1	3.182	0.835	0.0889	0.2578	0.1791	0.0930	0.002
149	3	3.182	0.835	0.0890	0.2580	0.1791	0.0930	0.007
150	1	3.095	0.721	0.0752	0.2171	0.1521	0.1031	0.001
150	3	3.089	0.721	0.0752	0.2174	0.1523	0.1031	0.006
151	1	3.141	0.777	0.0833	0.2382	0.1674	0.1188	0.001
151	3	3.151	0.777	0.0831	0.2378	0.1671	0.1192	0.006
153	1	3.212	1.028	0.0972	0.2846	0.1947	0.1072	0.002
153	3	3.208	1.024	0.0973	0.2848	0.1949	0.1070	0.007
154	1	3.198	0.842	0.0844	0.2497	0.1730	0.0868	0.001
154	3	3.193	0.847	0.0846	0.2503	0.1733	0.0867	0.006
155	1	3.142	0.921	0.0815	0.2336	0.1690	0.0879	0.001
155	3	3.140	0.921	0.0816	0.2338	0.1692	0.0879	0.006
157	1	3.132	0.876	0.0935	0.2689	0.1843	0.1486	0.002

Figure 22.- Sample output illustrating the use of the column heading section

Line 1. This first group of cards sets up the first line of the heading in Figure 22.

The general format is:

Column	6	15	18	25	30	38	42	50	62	74
Card #1		UNIT		TEST		PN		PN	PN	PN
Card #2	PN		PN		PN		PN			

where PN represents the parameter names which can be no longer than ten (10) characters. These characters may be alphabetic, numeric, or a combination of both, e.g., I1, VR, 1B.

Example 1 (Line 1):

Column	6	15	18	25	30	38	42	50	62	74
Card #1		UNIT		TEST		V6		I14	I2	I4
Card #2	I1		V9		I12					

Example 2 (Line 1):

Column	6	15	18	25	30	38	42	50	62	74
Card #1		UNIT		TEST		IR1		IR2	VZ1	VZ2
Card #2	(blank)									

Line 2. The second group of cards sets up the second line of the heading in Figure 22. The general format is:

Column	6	15	18	25	30	38	42	50	62	74
Card #1		NUMBER		CODE		TC		TC	TC	TC
Card #2			TC		TC		TC			

where TC represents the test conditions expressed in numeric form or code.

Example 1 (Line 2):

Card #1

NUMBER CODE AT 4.5V AT 5.0V AT 5.5V AT 5.5V

Card #2

AT 5.5V AT 5.5V AT 4.5V

Lines 3 and 4. These two groups of cards are set up using the same format as Line 2 except that Columns 1 to 38 are left blank, and are used for additional test conditions, such as temperature, etc. If there is no need for them, then they must be inserted blank.

Example 1 (Line 3):

Column

6 15 18 25 30 38 42 50 62 74

Card #1

(blank) (blank) 100C 25C

Card #2

(blank)

If eight parameters are not used, then the parameters are listed according to the above set-up, and those which are not used are left blank, as in Example 1. If the second card is not used, it must be inserted blank in order to maintain the proper number of cards, as in Example 2. The same holds true for the test conditions. If eight parameters were not measured, then the conditions are listed for those which were measured and the other spaces are left blank. If the second card is not used, it must be inserted blank.

These four groups are illustrated in Figures 23 and 24. Figure 23 illustrates the set-up when there are seven parameters. Figure 24 illustrates the set-up when there are only four parameters.

Cell Distribution Heading. This sub-section sets up the frequency and percent change distribution headings, as in Figure 25. These lines are set up by two cards. The general format is:

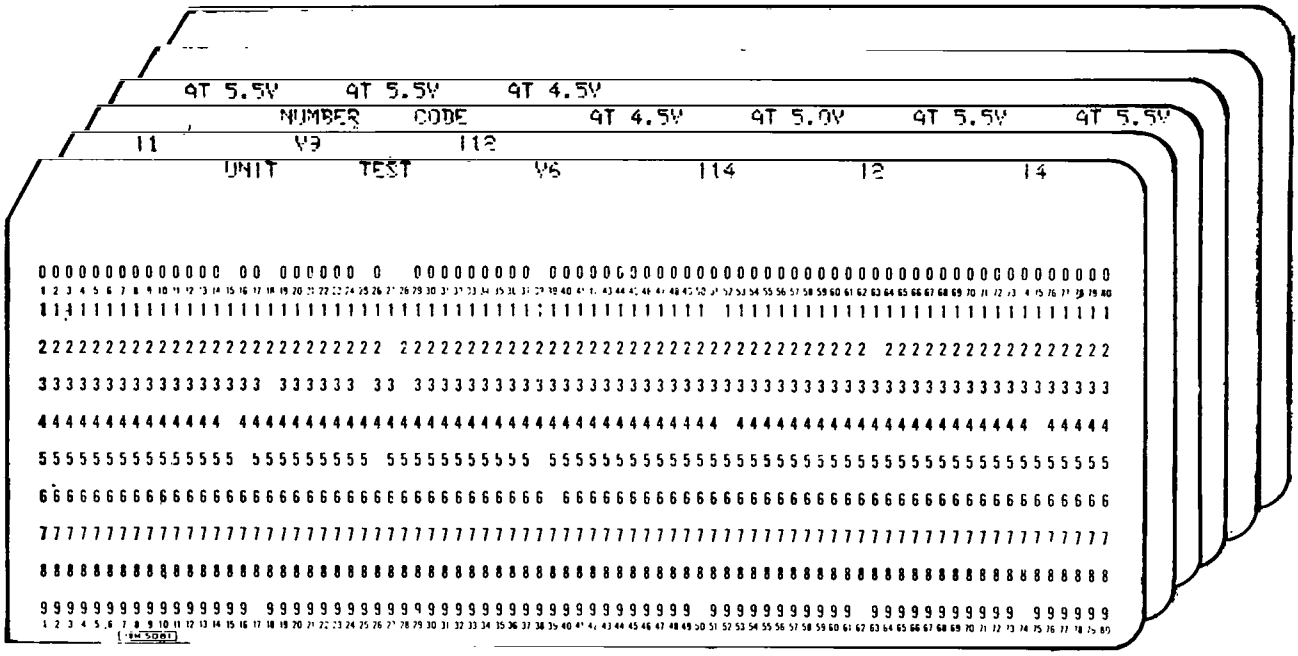


Figure 23.- Sample card setup of column heading section for seven parameters

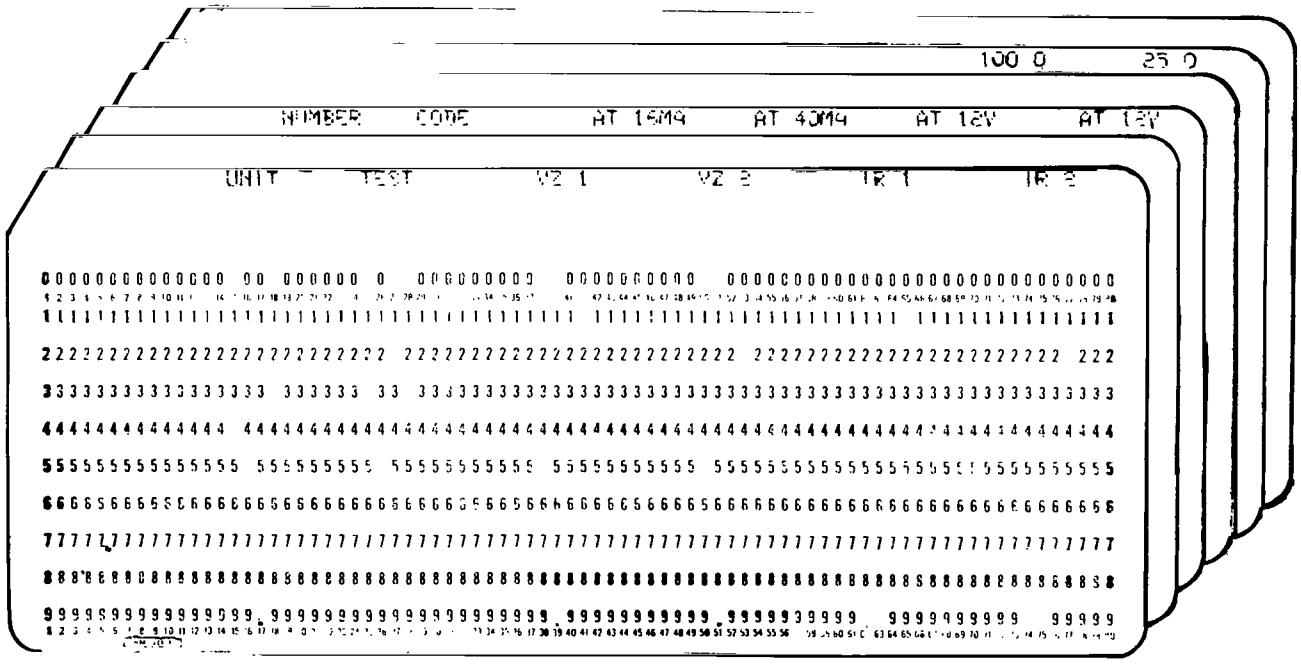


Figure 24.- Sample card setup of column heading section for four parameters

PARAMETER NUMBER 1

VZ 1 AT 16MA MEASURED IN VOLTS

FREQUENCY DISTRIBUTIONS OF MEASUREMENTS
AT EACH READING PERIOD

CELL	INITIAL	50 HRS	125 HRS	250 HRS	500 HRS
16.90000	0	0	0	0	0
17.00000	0	0	0	0	0
17.10000	1	0	1	0	0
17.20000	3	1	3	2	2
17.30000	7	9	6	6	8
17.40000	9	4	8	5	5
17.50000	7	7	8	9	8
17.60000	12	14	13	13	15
17.70000	7	10	7	7	7
17.80000	8	6	7	6	6
17.90000	2	5	4	6	5
18.00000	1	1	0	3	1
18.10000	0	0	0	0	0
18.20000	0	0	0	0	0
18.30000	0	0	0	0	0
AVERAGE	17.547	17.591	17.554	17.607	17.579
STD.DEV.	0.2055	0.1958	0.2011	0.2104	0.1990
SMALLEST NO.	17.1000	17.2000	17.1000	17.2000	17.2000
LARGEST NO.	18.0000	18.0000	17.9000	18.0000	18.0000

FREQUENCY DISTRIBUTIONS OF PERCENT CHANGE VALUES

(THE PERCENT CHANGE HAS BEEN CALCULATED FROM THE FIRST TIME INTERVAL.)

CELL	INITIAL	50 HRS	125 HRS	250 HRS	500 HRS
-50.00000		0	0	0	0
-40.00000		0	0	0	0
-30.00000		0	0	0	0
-20.00000		0	0	0	0
-15.00000		0	0	0	0
-10.00000		0	0	0	0
-5.00000		0	0	0	0
-0.00000		33	49	23	40
5.00000		24	8	34	17
10.00000		0	0	0	0
15.00000		0	0	0	0
20.00000		0	0	0	0
30.00000		0	0	0	0
40.00000		0	0	0	0
50.00000		0	0	0	0
AVERAGE	-0.000	0.251	0.041	0.340	0.181
STD.DEV.	-0.0000	0.2548	0.2605	0.2868	0.2796

CELL HEADING

Figure 25.- Sample output illustrating the use of cell distribution heading section

```
Column
     6   10      18     25   30      38          50      62          74
Card #1
         CELL           INITIAL     TP          TP      TP          TP
Card #2
     TP          TP          TP
```

where TP represents the time periods or time intervals, either expressed in numbers or in code, as in Figures 26 and 27. (Note: The number of TP's corresponds exactly to the NRTIME as defined in the numeric variable section of Section II since the zero (0) or initial time period is included in the heading already, INITIAL).

Example #1:

```
Column
     6   10      18     25   30      38          50      62          74
Card #1
         CELL           INITIAL     1000 HRS
Card #2
      (blank)
```

Example #2:

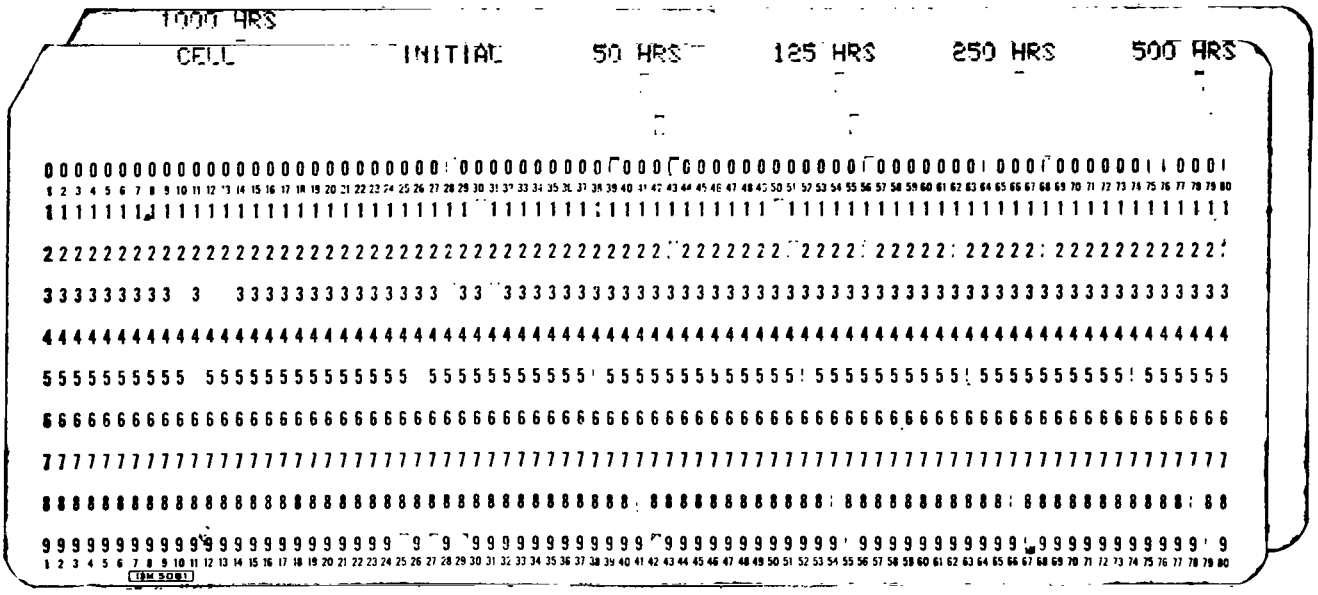
```
Card #1
         CELL           PRE-TEST    POST-TEST
Card #2
      (blank)
```

Example #3:

```
Card #1
         CELL           INITIAL     50 HRS      125 HRS 250 HRS  500 HRS
Card #2
      1000 HRS
```

FORMATS

This section of the data deck contains exactly two cards: the Input and Output Data Specification Cards. The first card specifies the format of the data cards which contain the actual parameter readings (see pp. 21 and 56). The second card specifies the format (see p. 56) for the output of the parameter readings which are shown in the sample output in Figure 28.



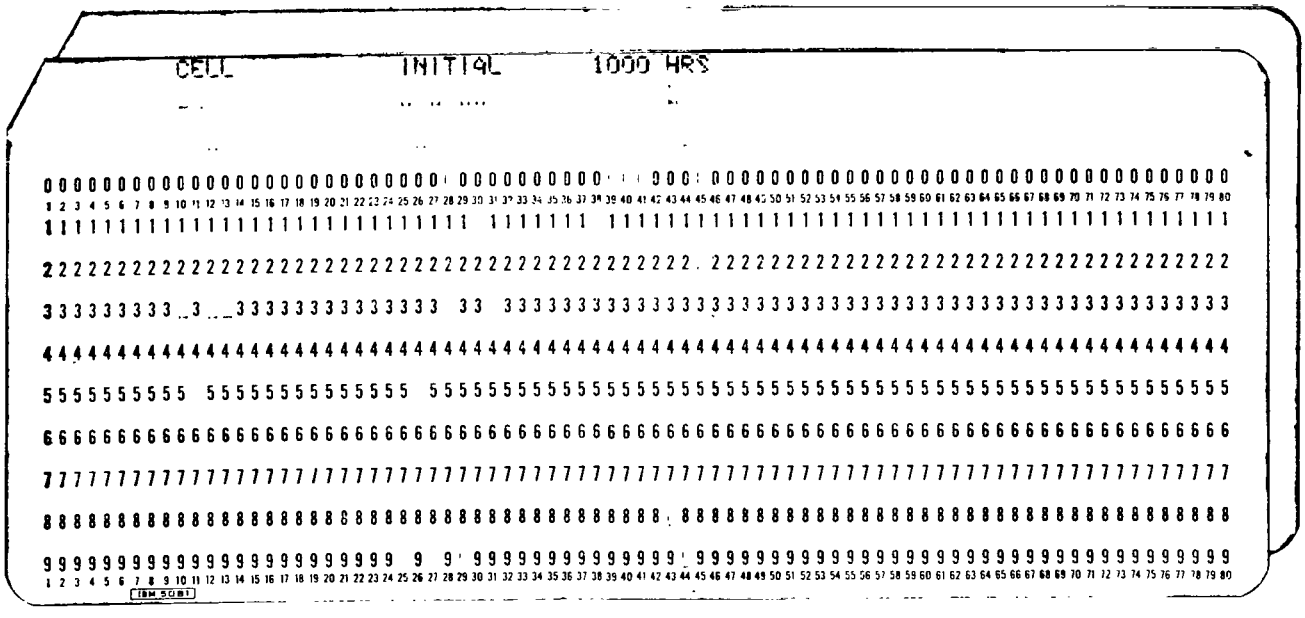


Figure 26.- Sample card set-up of cell distribution heading section

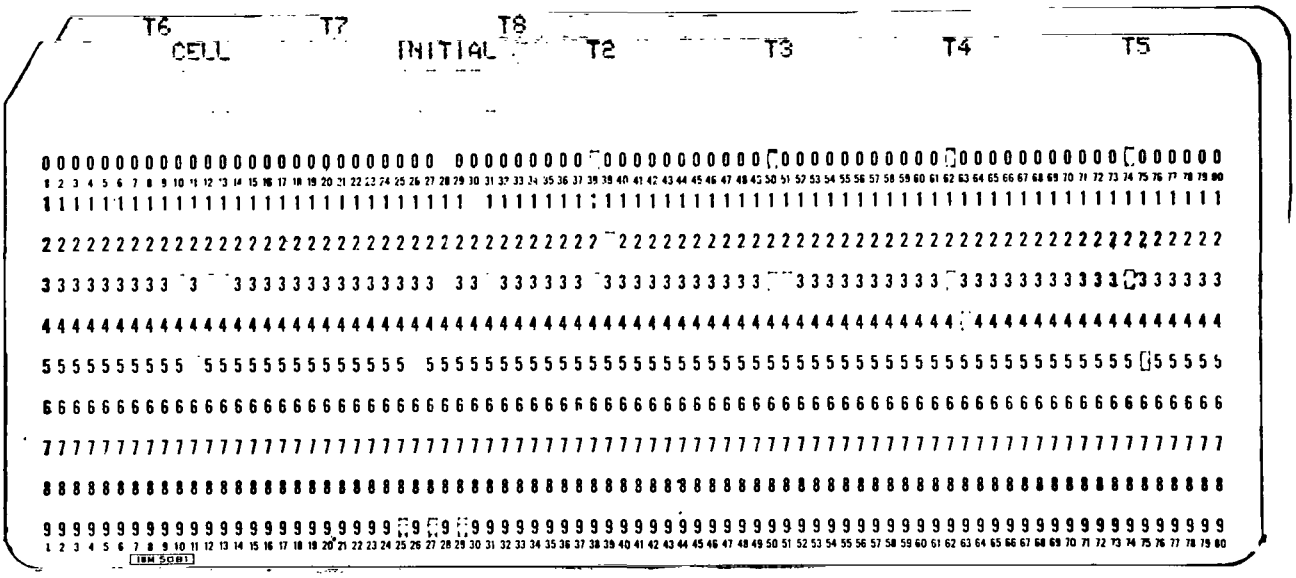


Figure 27.- Sample card set-up of cell distribution heading section

COMPLETE LIST OF UNITS

UNIT NUMBER	TEST CODE	VZ 1 AT 16MA	VZ 2 AT 40MA	IR 1 AT 12V 100 C	IR 2 AT 12V 25 C
65	5	17.700	17.900	0.662	0.041
66	1	17.400	17.700	0.152	0.013
66	2	17.500	17.600	0.170	0.012
66	3	17.500	17.600	0.175	0.018
66	4	17.500	17.700	0.180	0.020
66	5	17.500	17.700	0.164	0.014
67	1	17.600	17.900	0.237	0.009
67	2	17.700	17.800	0.278	0.010
67	3	17.600	17.800	0.257	0.010
67	4	17.700	17.900	0.277	0.012
67	5	17.600	17.800	0.276	0.009
68	1	17.700	18.000	0.168	0.006
68	2	17.700	18.000	0.194	0.007
68	3	17.700	17.900	0.190	0.007
68	4	17.800	18.000	0.213	0.009
68	5	17.700	18.000	0.201	0.006
69	1	17.400	17.700	0.815	0.011
69	2	17.500	17.600	0.093	0.012
69	3	17.400	17.600	0.081	0.011
69	4	17.500	17.700	0.089	0.013
69	5	17.400	17.700	0.092	0.012
70	1	17.800	18.000	0.680	0.037
70	2	17.800	18.000	0.772	0.038
70	3	17.800	17.900	0.683	0.037
70	4	17.900	18.200	0.745	0.044
70	5	17.800	18.000	0.718	0.032

Figure 28.- Sample output illustrating the output format

Parameter Readings

The fifth section of the data deck contains the actual parameter readings.

The following rules must be adhered to when preparing this section:

(1) On each data card, the test code, unit number, and parameter readings must appear in the following sequence:

Test Code, Unit Number, Parameter Readings

(2) No alphabetic characters are permitted in the columns allotted to the parameter readings.

(3) Parameter readings which contain exponents must have the exponent value located in the column(s) immediately following the columns allotted for each parameter.

(4) Parameter readings which do not contain exponents must be separated by leaving a blank column after each reading.

(5) The data cards which contain the parameter readings must be collated sequentially according to the unit numbers starting with the lowest unit number.

(6) Readings for each unit number must be arranged according to the sequence of the time periods.

V. APPLICATION

There are many instances in the course of quality control and reliability activities when a simple listing of parameter readings is sufficient (the parameters may or may not be checked to specification limits) instead of a detailed analysis. For this purpose, the variable ILIST is used.

With each and every output of CARDA, Figures 1, 5, and 6 are always given. If no descriptive data are required in Figure 1, then 15 blank cards are used as input.

The failure rate portion of Figure 6 is an option and is obtained by using ICONF along with the variable TIME. Failure rates are calculated for life tests only.

The various confidence limits presented are for informational purposes and seem to represent the most common ones requested. Data for up to eight time periods can be analyzed. As can be deduced from Figure 6, the time intervals in the life test do not have to be equally spaced.

A histogram similar to the one in Figure 3 can be obtained by using the variable IHISTO in conjunction with the variable CELL. The cell limits must be provided by the user. The maximum number of X's that will be printed out for any one cell is 74. However, the accumulative number of units/cell values will be correct. Histograms have numerous applications in the field of data analysis, and the ability to vary the cell limits is a highly desirable feature of CARDA.

The variable NRTIME along with the variable CELL was used to produce the frequency distributions of measurements at each reading period shown in Figure 4. Although this figure refers to a time sequence, CARDA can be used to display a sequence of "lots", time, manufacturing operations, environmental tests, etc. It also has use as a variable control chart.

The variable CHANGE is used in conjunction with the variables NRTIME and CELL to produce the frequency distributions of percent change values that are also shown in Figure 4. The percent change values are calculated from the first sequence interval, unless the variable IPCT is used, then it is calculated from the previous interval. The method of calculation depends upon the user's preference. If CHANGE is not specified, then the percent changes will not be calculated and no such distributions given.

NACEPT should equal the required acceptance number as indicated in Figure 6. An acceptance number of zero is understood unless a value is specified. In a sequential test, CARDA always

separates the initial (which is usually the pre-test measurement) rejects from the subsequent rejects as indicated in Figure 6.

The variables DELTA, PCT, XLOWER, XUPPER, YLOWER, and YUPPER are specification limits. If a unit must be beyond both a maximum deviation and a percent change limit, IFAIL should be used. IFAIL allows for the case when the percent change of a parameter might be large from one reading period to another but the actual amount of change relatively insignificant.

Reed

The variable REED can be used in the special case where the input data is in a coded form. It allows the user to write his own input subroutine and insert it into CARDA. Figure 29 shows the fixed statements that must be included in the subroutine. The decoded test data must be transferred to CARDA by means of the Y (I, J) array, where I is equal to NRTIME and J is equal to NOPARA. The variables UN and TESTY are the FORTRAN names referring to the unit number and test codes, respectively.

Scale

The variable SCALE can be used in conjunction with parameter measurement exponents to shift the decimal point. For example, a measurement of .003 may be punched on a data tabulating as $3\underline{3}$, where the underlined or second 3 is the negative exponent. If SCALE were set to 3 for this particular parameter, the printed computer output would be a 3 instead of .003. This would save printed output space. With the same scale setting a value of:

.030 recorded as $3\underline{2}$ would print out as 30.
.3 recorded as $3\underline{1}$ would print out as 300.
3.0 recorded as $3\underline{0}$ would print out as 3000.
.00003 recorded as $3\underline{4}$ would print out as .3.
.000003 recorded as $3\underline{5}$ would print out as .03.
.0000003 recorded as $3\underline{6}$ would print out as .003.

Error Messages

Most EDP installations have built-in machine and programming checks to monitor the computer input for invalid data. For example, when a letter appears in a card column that had been specified for a number, it is common practice to abort the program. Why process mispunched data? Likewise, CARDA has its own checking scheme that safeguards against some of the more common data recording and processing errors it encounters.

```
                SUBROUTINE RED3 (NOPARA,NTIME,Y,TESTY,UN,FMT2)
                DIMENSION Y(8,8),UN(8),TESTY(8),FMT2(20)
DIMENSION       •••••
SECTION         •••••
FOR USER        •••••
SUPPLIED        •••••
VARIABLES       •••••
                DO 50 J=1,NTIME
                READ(9,FMT2) TESTY(J),UN(J), (••••• , I=1,NOPARA)
                •••••
                •••••
                •••••
 BODY OF        •••••
                •••••
  USER          •••••
                •••••
SUPPLIED        •••••
                •••••
INPUT SUB-      •••••
                •••••
 ROUTINE        •••••
                •••••
                •••••
                •••••
                Y(I,J) = •••••
             50 CONTINUE
                RETURN
                END
```

Figure 29.- Fixed statements in a user-supplied input subroutine

Initial Readings

In any given sequence of tests, the initial reading of a parameter cannot be zero. If it is, then the unit will be removed from the report and the following error message printed.

Unit No. XXXXX Is Not Included In This Report

Data Cards

In any given sequence of tests, a data card for each unit at every time interval must be included in the input data deck, or else either of the following error messages might be printed.

Card Goof

or

Check Input Data for Illegal Card Procedure

Devices that contain zeros for parameter measurements are counted as failures. This is done to include catastrophic failures in the reject count and to assure that all devices are measured during the course of a test.

Parameter Reading Data Cards

It is a common procedure at some test installations to remove devices that are found to be outside specification limits at the particular test interval or sequence when the failure was detected. Consequently, some devices that start a particular sequence of tests may not complete all the tests because they were classified as failures during the sequence, and others may not complete a sequence of tests because they were misplaced or lost. In such cases, tabulating cards for the missing portion of the test sequence containing at least the test code and device unit number must be inserted at their appropriate location in the Input Data Deck.

Every device that starts a series of tests must have a data card corresponding to each test in the series. The parameter readings may be blank, but the test code and unit number must be present.

In the Input Data Deck, the parameter reading data cards are arranged by test code within unit number starting with the lowest unit number and the first test code.

Format Specifications

An introduction as to how to prepare the Input Data Specification Card was described in Section II. The Output Data Specification Card is prepared in a similar manner except that the field width in the "F" format must be made large enough to include a decimal point and plus sign (which is always understood for positive numbers). For example, the number

99.99

might appear on a data card in four columns as

9999

and be specified on the input format specification card as

F4.2

To print out the same number

99.99

the "F" format would have to appear on the output format specification card as

F6.2

to include printing columns for the sign, 4 digits, and decimal point.

The test code precedes the unit number on the input data card, but the unit number precedes the test code for printed output. This must be reflected on the Input and Output Data Specification Cards.

Test Codes

If test codes are composed of alphanumeric characters then the "A" format must be specified on the input and output format specification cards. The "A" format consists of the letter A followed by the number of card columns on the data card or printed columns required to describe the test code. For example, test codes such as

T1 would be specified as A2,
T13 would be specified as A3,
G191 would be specified as A4,

The "A" format cannot contain more than four characters. Since in any test sequence there cannot be more than eight testing intervals, the numbers one to eight specified by the "F" format are recommended for use in CARDA.

Unit Number

CARDA will accept any number of devices. The unit number should be specified in the "F" format.

Automatic Collating

The emphasis thus far concerning the arrangement of the test measurement input data cards obtained from sequential testing has stressed the fact that they should be collated sequentially by test code within unit number as the output in Figure 2 indicates. However, in the more general type of component environmental and life testing, data is not collected in this required manner. Usually, in the course of a given series of tests, the data is collected by test code. All the data from test code No. 1 is collected before the data from test code No. 2, and all the data from test code No. 3 is collected before the data from test code No. 4, etc. Thus, at the conclusion of a given sequence of tests, there may be several groups of data, each group relating to a particular test code.

Such data must be collated according to the procedures previously described. This can be accomplished either manually, or automatically by the use of a collator. Because both of these procedures are susceptible to certain errors, extreme care must be taken. Errors most frequently arise when rejects have occured and the data cards for the rejects have either not been completely filled out, or they have been removed, and appropriate cards have not been replaced in the data deck. Sometimes, when tests are temporarily interrupted, duplicate data cards inadvertantly become produced for the device that was being tested at the time of the interruption. This is especially true in the case where automatic data-logging equipment is being used to record the test measurements.

To aid in the proper arrangement of the test measurement data cards, a sort and merger routine was especially designed for CARDA. This collating procedure was given the variable name COLATE spelled with one "L". It can be used by assigning the value one to the variable, e.g.:

COLATE = 1,

and placing it in the specification section, (SPEC), of the input data deck.

By using COLATE, the test measurement data cards can be inputed in any arrangement. For example, they could be arranged by groups according to test codes as is the most natural way of conducting tests, or they could be intermingled in some random manner. Of course, this sort and merge routine requires computer time and the more closely the data is arranged according to the proper sequence the less computer time will be required.

In addition to arranging cards, this routine will check to make sure that each device tested has the proper amount of data cards. If test cards are missing for various test codes, then these missing cards will be simulated with the proper unit number and test code. However, all the test measurements corresponding to the simulated card(s) will be assigned the value(s) of zero. For example, suppose unit number 10 was tested 4 times during a life test for parameters A, B, and C, and all the measurements had the value of 8, then the output listing might appear as follows:

Unit Number	Test Code	A	B	C
10	1.	8.	8.	8.
10	2.	8.	8.	8.
10	3.	8.	8.	8.
10	4.	8.	8.	8.

However, if data cards for test codes 2 and 3 were missing and COLATE were being used, then the output listing would appear as follows:

Unit Number	Test Code	A	B	C
10	1.	8.	8.	8.
10	2.	0.0	0.0	0.0
10	3.	0.0	0.0	0.0
10	4.	8.	8.	8.

Data cards for test codes 2 and 3 would have been simulated. In addition, if a lower specification limit of greater than zero, but less than 8 had been specified, the unit would have also been labeled and counted as a reject. COLATE should never be used as a substitute for the data handling and screening procedures previously mentioned. It should be considered as a safeguard feature, and used accordingly.

The restrictions on the use of COLATE are as follows:

(1) Test Codes must be numbered from 1 to 8. The "F" format must be used on the Input and Output Data Specification Card.

(2) All the data cards for test code number 1 must be present, or else erroneous calculations will occur.

(3) COLATE cannot be used to check or arrange more than 10,000 data cards.

Data Storage and Retrieval

Some of the more common media used for the storage of test data are paper tape, magnetic tape, discs, drums, tabulating cards, printed material, and microfilm. The selection of one or more types of media will depend upon the quantity of data to be stored, and the number of times it is to be retrieved for usage. In certain cases, one printed report might be sufficient with the data cards stored for a certain period of time and then destroyed. When large quantities of data are to be considered for storage, frequent retrieval, and distribution of results, then either discs or magnetic tapes combined with microfilm might provide an efficient and economical solution.

Third-generation computer hardware can be easily configured with high-speed printing plotting peripheral equipment to produce a very versatile system. In such a configuration, the output of CARDA can be either in the standard printed format or on photographic paper which is excellent for reproduction. At the same time, either 35mm or 16mm microfilm slides are easily obtainable for data storage. An example of output from high-speed printing and plotting equipment is shown in Figures 30 and 31. These figures indicate the actual size of the printed output.

Hardware Facilities

General purpose computers are usually classified as small, medium, or large depending upon their speed and core storage size. Greater flexibility in the programming language is obtained by a progression from the smaller to the larger types of computers. This is especially true in FORTRAN, the language in which CARDA is written. Therefore, there is a trade-off between machine cost (or rental) and programming costs. Consideration of these factors resulted in the selection of a large-scale computer system for the development of CARDA on which programming and operating costs could be minimized. CARDA requires approximately 500,000 core

COMPLETE LIST OF UNITS

TEST CODE	UNIT NUMBER	FSC2	IFN	IFN	IPOL
25	3.	3.905	120.300	119.500	291.500
25	4.	4.113	120.100	119.300	291.200
25	5.	4.120	120.100	119.300	291.600
26	1.	4.052	99.150	100.200	241.200
26	2.	4.055	99.250	100.300	241.700
26	3.	3.834	99.300	100.400	241.600
26	4.	4.054	99.160	100.200	241.300
26	5.	4.055	99.170	100.200	241.600
27	1.	4.127	97.970	98.590	238.700
27	2.	4.130	98.040	104.500	248.500
27	3.	3.900	97.980	98.620	238.700
27	4.	4.130	97.950	98.550	238.700
27	5.	4.132	97.970	98.580	238.900
28	1.	4.024	103.900	103.500	252.000
28	2.	4.025	103.900	103.500	252.400
28	3.	3.805	104.000	103.600	252.400
28	4.	4.025	103.900	103.500	252.100
28	5.	4.024	103.800	103.500	252.300
30	1.	3.974	97.980	99.180	238.200
30	2.	3.974	98.020	99.210	238.400
30	3.	3.753	98.010	99.220	238.300
30	4.	3.972	97.930	99.120	238.100
30	5.	3.973	97.950	99.120	238.400
31	1.	3.381	77.380	77.090	186.500
31	2.	3.283	77.480	77.200	187.000
31	3.	3.117	77.470	77.180	186.700
THE ABOVE UNIT IS A FAILURE ON PARAMETER NUMBER 1					
31	4.	3.318	77.370	77.070	186.600
31	5.	3.295	77.390	77.110	186.800

Figure 30.- Printed output on photo paper (actual size)

PARAMETER NUMBER 1

FSC2 (PIN 14 AT 4.5V) MEASURED IN MILLI-AMPS

FREQUENCY DISTRIBUTIONS OF MEASUREMENTS
AT EACH READING PERIOD

CELL	INITIAL	100HRS	500HRS	1000HRS	2000HRS
3.10000	0	0	0	0	0
3.20000	0	0	0	0	0
3.30000	0	0	2	0	0
3.40000	0	0	2	0	0
3.50000	0	2	1	1	0
3.60000	4	3	6	3	4
3.70000	1	0	6	1	1
3.80000	4	5	13	4	4
3.90000	6	7	15	8	8
4.00000	12	11	3	10	10
4.10000	14	14	1	14	14
4.20000	7	6	0	7	7
4.30000	0	0	0	0	0
4.40000	1	1	0	1	1
4.50000	0	0	0	0	0
AVERAGE	3.948	3.934	3.724	3.941	3.942
STD.DEV.	0.1718	0.1803	0.1757	0.1799	0.1748
SMALLEST NO.	3.5540	3.4710	3.2490	3.4740	3.5280
LARGEST NO.	4.3170	4.3150	4.0730	4.3160	4.3170

FREQUENCY DISTRIBUTIONS OF PERCENT CHANGE VALUES

(THE PERCENT CHANGE HAS BEEN CALCULATED FROM THE FIRST TIME INTERVAL.)

CELL	INITIAL	100HRS	500HRS	1000HRS	2000HRS
-1000.00000		0	0	0	0
-750.00000		0	0	0	0
-500.00000		0	0	0	0
-200.00000		0	0	0	0
-100.00000		0	0	0	0
-50.00000		0	0	0	0
-10.00000		0	0	0	0
-0.0		37	49	38	41
10.00000		12	0	11	8
50.00000		0	0	0	0
100.00000		0	0	0	0
200.00000		0	0	0	0
500.00000		0	0	0	0
750.00000		0	0	0	0
1000.00000		0	0	0	0
AVERAGE	0.0	-0.373	-5.705	-0.193	-0.168
STD.DEV.	0.0	0.8725	0.8064	0.6110	0.4045

Figure 31.- Printed output on photo paper (actual size)

storage locations, thereby placing it in the large-scale computer category. It was developed on an IBM-360 Model-75 computer. A typical configuration with various peripheral equipment is shown in Figure 32.

The Stromberg-Carlson SC-4020 high-speed printer/plotter shown in Figure 33 is the type of peripheral equipment that is used in data reduction activities for the purpose of producing microfilm. This equipment is capable of printing 7000 lines per minute. One page of computer output can be put on one microfilm frame or slide at the commercial price of 5 cents, thus making it one of the most economical data reduction systems available.

A computer controlled integrated circuit tester that can be easily adapted for either card or tape data logging is shown in Figure 34 . For economical high-speed volume testing and data logging, such systems are far more reliable than hand testing and recording procedures. In many cases, the CARDA program provides the interface for a computer-to-computer operation, that is, from the computer that controls the integrated circuit tester to the general purpose computer that reduces the test data.

With the advent of real-time testing and remote control terminals the CARDA program could be integrated into an overall testing scheme that could attain the full potential that the subject of Computer-Aided Reliability Data Analysis offers.

Operational System Concepts

As stated in Section II, the CARDA program has been presented in the batch processing mode; that is, the program and all required information and data described herein are inputted to the computer in one batch or at the same time. Initially, in trying to establish computer-aided reliability data analysis procedures, this is quite necessary. However, as one becomes proficient in the art and gains experience on third-generation equipment, the idea of operating continuously and under all circumstances in the batch processing mode is not very appealing.

In some circumstances, for example, when repetitive data from various lots of material are to be analyzed, the specifications, test conditions and source may remain the same. In other words, the Input Data Deck, as explained in Section IV, virtually becomes static and the only required change might be that of lot number and date code; then, the process of submitting the entire Input Data Deck for each analysis might seem to be a cumbersome procedure in light of third-generation hardware capabilities.

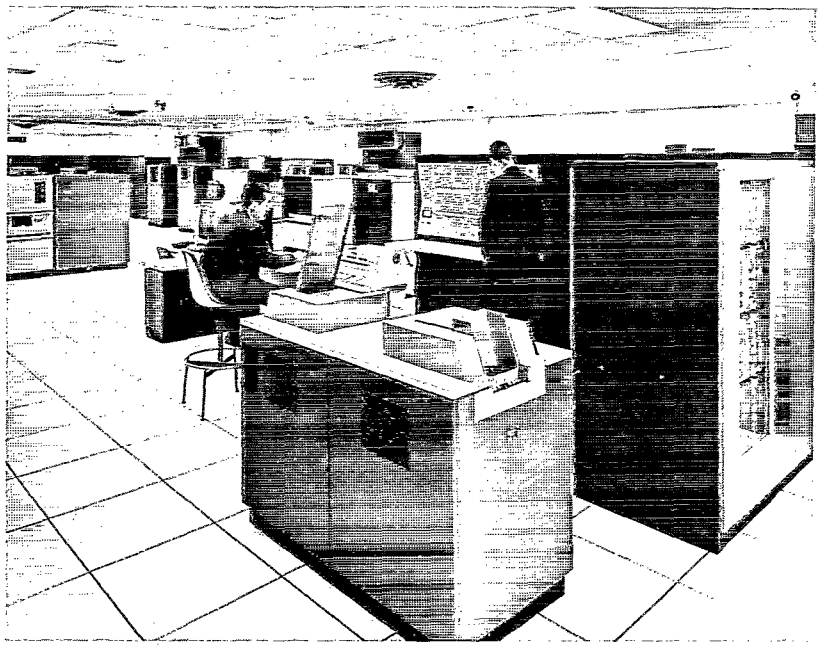


Figure 32.- The IBM 360/75 system

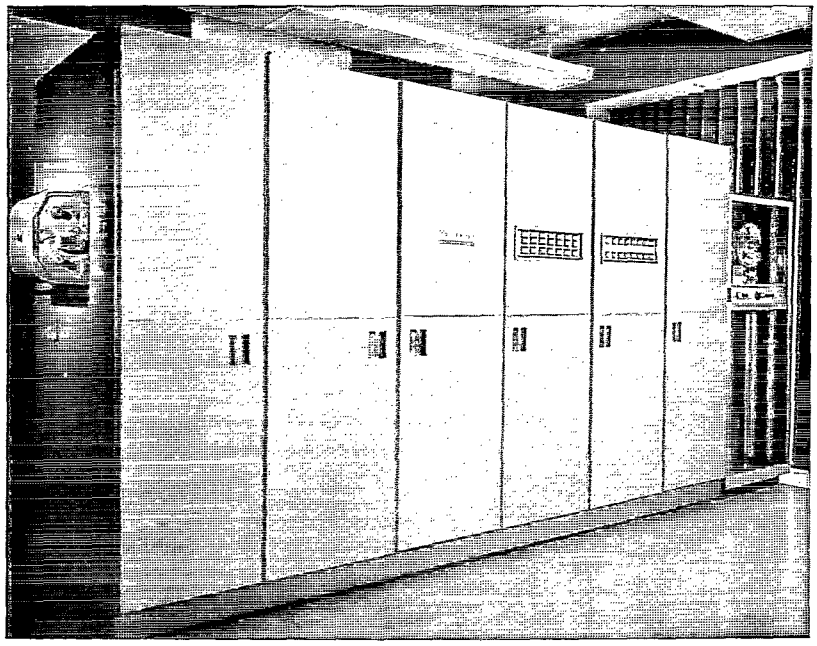


Figure 33.- The SC-4020 high-speed printer/plotter

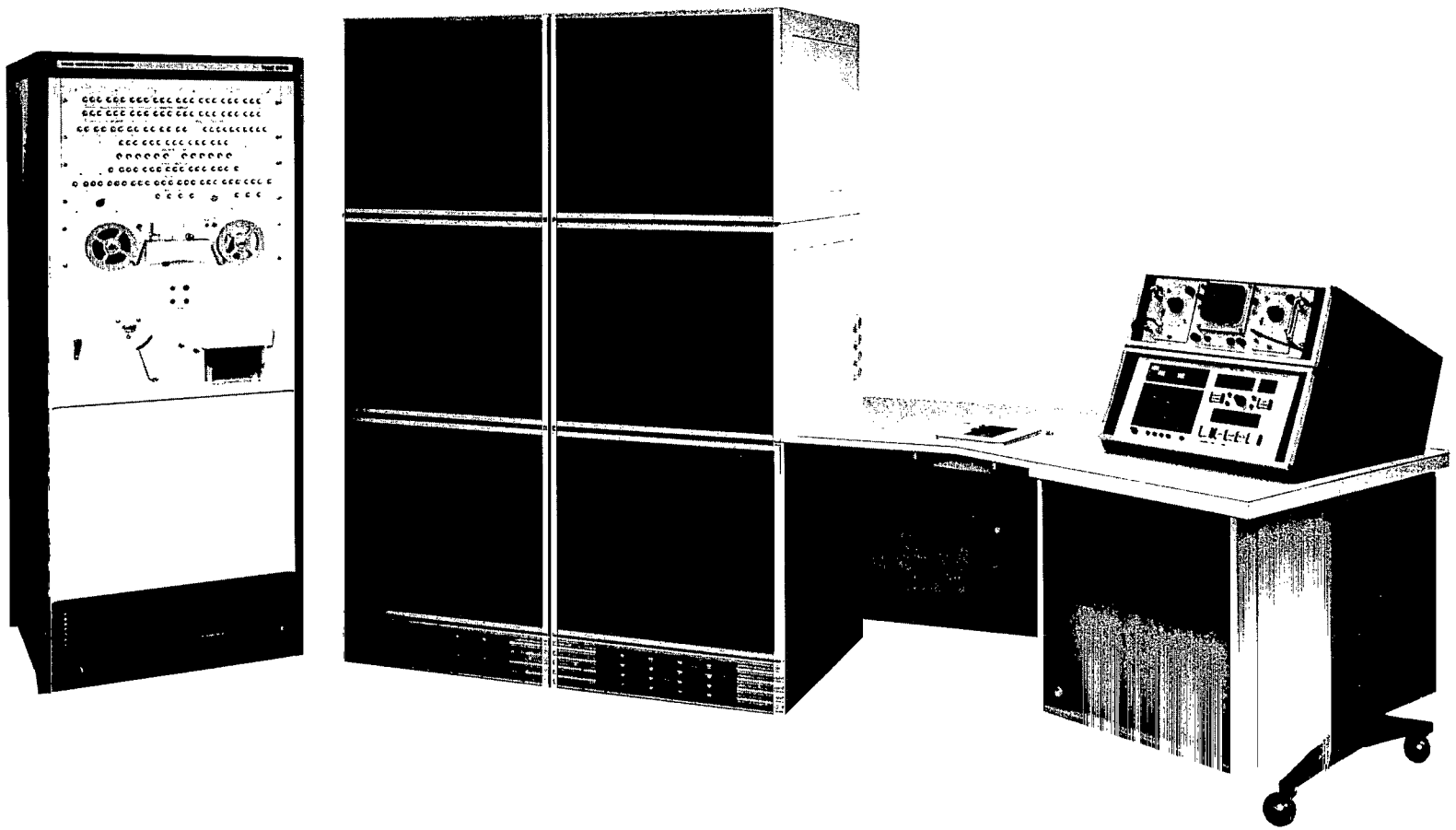


Figure 34.- Automatic integrated circuit tester and data logging device

Another example of what might become an inefficient procedure is the shipment of data cards for analysis when a data tape might be more easily and simply prepared. Therefore, to take CARDA out of the batch processing mode and to eliminate some of what might appear at various times to be awkward procedures, three interface programs: TEST, LØAD, and LIB can be combined with CARDA for operation in a "system" mode.

The interface programs, TEST and LØAD, provide access to CARDA from remote locations. They pre-screen the test data, provide preliminary reports, and load the data on tapes for shipment to the EDP installation that operates the CARDA program.

There are many ways in which a CARDA system can be configured. The following is a general procedure which can be easily modified to the user's particular needs:

(a) An installation issues a testing specification to a commercial testing or manufacturing facility.

(b) The tester records the measurements and sends them to a predetermined EDP installation.

(c) The EDP installation uses the TEST program to screen the data and the LØAD program to prepare the tape for shipment to the installation that operates CARDA.

(d) CARDA processes the tape and the results are sent to the appropriate installation for disposition.

Parameter specification limits which are used to indicate rejects, control statements that are used to designate various data analysis functions, and histogram cell limits can be stored in the CARDA specification Library called, LIB, which is attached to the CARDA program. LIB provides an efficient and economical procedure for analyzing repeated tests.

Figure 35 illustrates the above concepts. The components to be tested are produced by the vendor or source industry. They are tested at a test facility which could represent the manufacturer's quality control or reliability group, a commercial testing agency, or the user's own facilities. The output data (usually tabulating cards) are sent to an EDP facility for preliminary analysis and screening. This is accomplished by the computer program TEST which is given in Appendix A. The setup procedures for TEST are identical to those of CARDA, so that it can be used to check CARDA's Input Data Deck Card Setup. In addition, TEST provides a listing of the parameter measurements and checks for rejects. Figures 1, 2, and 5 show the types of data that are found in an output from TEST. This program is used as a primer

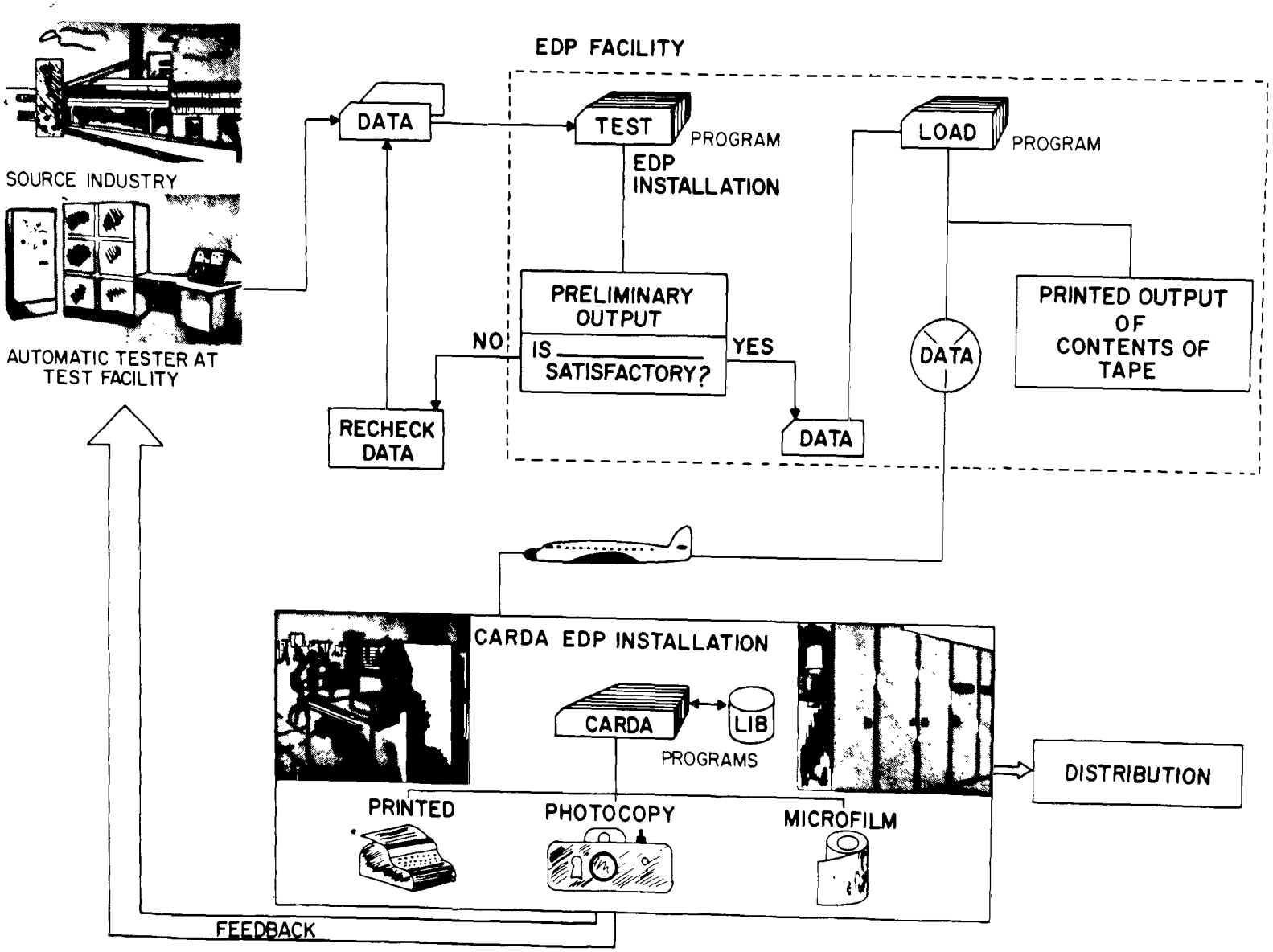


Figure 35.- The CARDA system

for CARDA and assures that data accepted by it will also be accepted by CARDA. The EDP installation could be that of a commercial service bureau, the tester, vendor, or user.

The LØAD program is an optional program that is used to load the test data onto magnetic tape for shipment to the CARDA EDP installations. It is easier from a packaging and handling standpoint to ship tapes rather than cards. The EDP installation that operates CARDA analyzes the test data in accordance with the appropriate CARDA procedures. The output can be a printed, photocopied, or a microfilm report. Distribution of the report is in accordance with the user's objectives; however, it is a good practice to provide a feedback loop to the device source or tester.

The program LIB is a file maintenance program used to prepare a specification library containing Input Data Decks employed for repetitive data analysis.

Therefore, by pre-screening the data, providing for better handling procedures, and reducing clerical operators involved in program setup procedures, TEST, LØAD, and LIB can provide a more efficient CARDA system operation.

Future Developments

The possible areas where future development of CARDA might be directed are as follows:

(a) Expanding the number of parameters

(b) Providing for data storage and management

(c) Adding curve fitting techniques.

In certain quality control applications, the need to handle 100 parameters is apparent. For example, the Final Test station for many microelectronic devices requires the checking of parameters close to that number and is growing all the time. During the course of certain types of sequential testing, it would be desirable to have the data from the various test intervals actually put in a storage file for future collating rather than collating data cards after each test interval as is presently required. With respect to repetitive-type testing, it might be desirable to accumulate certain information. For example, where several lots of the same type device are to be life-tested, it might be desirable to keep a running account of the number of hours accumulated and the failure rate statistic. This could be

accomplished by the addition of a data management file. Correlation and regression analysis along with distribution "goodness of fit" testing could be easily added to the existing statistical routines.

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Cambridge, Massachusetts, October 1968
125-25-04-91

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APPENDIX

TEST PROGRAM

```
      INTEGER REED, SCALE
      REAL IFAIL
      REAL NDELTA
      CØMMØN UN(8)
      CØMMØN ADY(8,8),CFR(8),FR(8),        SMLYS(3,8),XH(8),VNY(8),ACCR(8)
     1,YRCIPN(8),RXJ(8),PERC(50),VNT(50),ASELX(8,8)
      CØMMØN    CELLS(15,8),CHANGE(15,8),XLØWER(8),XUPPER(8),
     1YLØWER(8), YUPPER(8),PLIMIT(8)
      CØMMØN    PARA(20,8) ,            TESTSQ(32),Y(8,8),L(8,8),NY(8),
     1PCTY(15,8)
      CØMMØN    PLIMC(100),VNUD(8),TIME(8)
      CØMMØN    FMTI(20),FMT2(20),FMT3(20),ADELX(8,8)
      CØMMØN    TØTAC(8),NPAR(100),T(200),VND(3,8)
      CØMMØN    SCØUNT(8),COUNT(8),SELX(8,8),DELX(8,3)
      CØMMØN    TESTY(8),XNUM(10),Y1(8,8),NCFRY(15,8) ,YYE(8,8)
      CØMMØN    L1(8),L2(8),L3(8),L4(8),NY5(8)
      CØMMØN    PCT(8),DELTA(8),CURENT(8)
      CØMMØN    XLINE1(32),XLINE2(32),XLINE3(32),XLINE4(32)
      CØMMØN EXM (8,8)
      CØMMØN FRT(5), ATA(15,20)
      CØMMØN SCALE (8),NØPARA
       CØMMØN  J,K17,I,NTIVE
      DIMENSIØN NAME(18)
      NAMELIST /SPEC/ DELTA,PCT,XUPPER,XLØWER,YUPPER,YLØWER,CURENT,TIME,
     1SCALE,CELLS,CHANGE,CØLATE,
     1NØPARA,NRTIME,NACEPT,IPCT,ICØNF,IHISTØ,REED,ILIST,IFAIL,FINAL
 1002 FØRMAT(1H1)
 1003 FØRMAT(20A4)
  622 FØRMAT(30I2)
  500 FØRMAT(2I1)
 5301 FØRMAT(32A4)
 3206 FØRMAT(1HØ,34X,45HIN THE PERCENT CHANGE ANALYSIS,MINUS SIGNS   )
 3207 FØRMAT(34X,45HDENØTE PARAMETER DECREASES,WHILE PLUS SIGNS   )
 3208 FØRMAT(34X,45HDENØTE PARAMETER INCREASES.                   )
 3209 FØRMAT(/34X,42HCØMPUTATIØNS DØ NØT INCLUDE REJECTED UNITS)
 9907 FØRMAT(1H1,40X,22HCØMPLETE LIST ØF UNITS,//)
 1625 FØRMAT(10X,47HTHE ABØVE UNIT IS A FAILURE ØN PARAMETER NUMBER,I2)
 5093 FØRMAT(1H1,20X,16HPARAMETER NUMBER,I2)
 5004 FØRMAT(1HØ,17X,39HFREQUENCY DISTRIBUTIØNS ØF MEASUREMENTS)
 3007 FØRMAT(1H ,23X,22HAT EACH READING PERIØD,//)
 3010 FØRMAT (1H ,8X,F11.5,6X,I4,8(6X,I4))
 4790 FØRMAT(/8X,7HAVERAGE,7X,9(F10.3,2X))
 7778 FØRMAT(8(F3.0,F1.0))
 4791 FØRMAT(/8X,8HSTD.DEV.,7X,9(F10.4,2X))
 2974 FØRMAT(/8X,12HSMALLEST NO.,3X,9(F10.4,2X))
 1974 FØRMAT(/8X,11HLARGEST NO.,4X,9(F10.4,2X),//)
 3011 FØRMAT(1HØ,17X,48HFREQUENCY DISTRIBUTIØNS ØF PERCENT CHANGE VALUES
     1)
 3020 FØRMAT(1H ,8X,F11.5,18X,7(I4,8X))
 3021 FØRMAT(1H1,7777735X,24HLIST ØF PARAMETER LIMITS///)
 1603 FØRMAT(I5,15(F3.0,I1))
 3023 FØRMAT(1HØ,15X,16HPARAMETER NUMBER,I2)
 3028 FØRMAT(1HØ,18X,21HINITIAL UPPER LIMIT =,5X,F16.3)
 3032 FØRMAT(1H ,18X,21HINITIAL LØWER LIMIT =,5X,F16.3)
 3036 FØRMAT(1HØ,18X,18HPØST UPPER LIMIT =,5X,F16.3)
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 3040 FØRMAT(1HØ,18X,18HPØST LØWER LIMIT =,8X,F16.3)
 3044 FØRMAT(1HØ,18X,23HABSØLUTE CHANGE LIMIT =,3X,F16.3)
19056 FØRMAT(15F5.0)
 3049 FØRMAT(1HØ,25X,48HNØ LIMITS HAVE BEEN SPECIFIED FØR THIS PARAMETER
     1)
 3050 FØRMAT(1HØ,18X,22HPERCENT CHANGE LIMIT =,4X,F16.3)
 2030 FØRMAT(1H1,33X,13HREJECT TØTALS)
 2031 FØRMAT(1HØ,17X,F5.2,5X,30HREJECTED UNITS AT INITIAL HØUR)
 2032 FØRMAT(1HØ,17X,F5.2,5X,26HREJECTED UNITS DURING TEST)
 2033 FØRMAT(1HØ,16X,F7.3,4X,31HPERCENT REJECTS AT INITIAL HØUR)
 2034 FØRMAT(1HØ,16X,F7.3,4X,27HPERCENT REJECTS DURING TEST)
  495 FØRMAT(1HØ12X,18HTØTAL SAMPLE SIZE=,2X,I6,13X,15HACCEPTANCE NØ.=,I
     15)
 9313 FØRMAT(////35X,22HTHIS TEST WAS ACCEPTED)
 9319 FØRMAT(////35X,22HTHIS TEST WAS REJECTED)
  213 FØRMAT(1HØ,12X,F11.5,2X,75A1,8X,I4,10X,F6.1)
  322 FØRMAT(3I2,6I1,F1.0,I1,F1.0,F1.0,I5)
 2171 FØRMAT(1HØ,40X,9HHISTØGRAM)
  212 FØRMAT(1HØ,10X,10HUPPER CELL,81X,12HACCUMULATIVE,4X,
     112HACCUMULATIVE)
 2137 FØRMAT(13X,5HLIMIT,87X,9HNUMBER ØF,8X,10HPERCENTAGE)
 2138 FØRMAT(105X,11HUNITS/ CELL,6X,6H/ CELL)
 3212 FØRMAT(///)
18391 FØRMAT(34X,20A4)
 7136 FØRMAT(8F9.4)
 5267  FØRMAT(20A4/20A4)
 7777 FØRMAT(8(F3.0,I3))
17029 FØRMAT(1H ,10X,I5,9X,A3,4X,8(F10.3,2X))
 2047 FØRMAT(1X,18HCARD GØØF UNIT NØ.,I5)
18060 FØRMAT(1HØ,19X,20A4)
C
C        PRØGRAM STARTS
      FINAL = 0.0
 1197 NTR=0
      IL=0
      NCT=0
      CØLATE=0
       NW=0
      TØTAC(1)=0
      INF=0
      VNX=0
      VNUM=0
      NØPARA=0
      NRTIME=0
      NACEPT=0
      ILIST=0
      IHISTØ=0
      IPCT=0
      IFAIL=0
      ICØNF=0
      DØ 3000 I=1,6
      XH(I)=0.0
      NYS(I)=0
      PLIMC(I)=0
      SCØUNT(I)=0
      CØUNT(I)=0
      XUPPER(I)=0.0
      XLØWER(I)=0.0
      YUPPER(I)=0.0
```

APPENDIX

```
          YLØWER(I)=0.0
          TIME(I)=0.0
          CURENT(I)=0.0
          PCT(I)=0.0
          DELTA(I)=0.0
          SCALE(I)=0.0
          UN(I)=0.0
          NY(I)=0
    3000  CØNTINUE
          DØ 15020 I=1,8
          DØ 15020 J=1,15
          NCFRY(J,I)=0
          CELLS(J,I)=0.0
          CHANGE(J,I)=0.0
   15020  CØNTINUE
          K17=0
          XR=0.
          LL=0
          YR=0
          CTR=27.
          JM=0
          FAIL=0
          WRITE (6,1002)
    2839  CØNTINUE
   98765  FØRMAT(I7,F1.0,18A4)
           READ(9,98765) NJØB,FINAL, (NAME(I),I=1,18)
          IF(NJØB) 1755,1753,1755
    1753  CØNTINUE
          DØ 1754 J=1,15
          READ(5,1003) (ATA(J,M),M=1,20)
          WRITE(6,18060) (ATA(J,M),M=1,20)
    1754  CØNTINUE
    1754  CØNTINUE
   19063  READ(5,SPEC)
          CALL MIBCØM
          DØ 1637 I=1,NØPARA
           READ(5,1003) (PARA(J,I),J=1,20)
    1637   CØNTINUE
   19001  CØNTINUE
   19057  READ(5,5267)(XLINE1(J),J=1,32)
   19058  READ(5,5267)(XLINE2(J),J=1,32)
   19059  READ(5,5267)(XLINE3(J),J=1,32)
   19060  READ(5,5267)(XLINE4(J),J=1,32)
   19061  READ(5,5267)(TESTSQ(I),I=1,32)
   19064  READ (5,1003)(FMT2(I),I=1,20)
   19065  READ(5,1003)(FMT3(I),I=1,20)
    1755  CØNTINUE
           IF(NJØB) 3867,4321,3867
    3867  CØNTINUE
           READ(9,98765) NJØB,FINAL, (NAME(I),I=1,18)
   98765  FØRMAT(I7,F1.0,16A4)
    4321  CØNTINUE
          IF(NDELTA)4082,4081,4082
    4082  WRITE (6,3206)
          WRITE (6,3207)
          WRITE(6,3208)
    4081  WRITE(6,3209)
          WRITE(6,3212)
    1111  CØNTINUE
```

APPENDIX

```
      J=1
C
C     CHECK FØR READ IN STATEMENTS                                      60
C
      GØ TØ (3271,5107,2003),REED
 2003 CALL RED3          (NØPARA,NRTIME,Y,TESTY,UN,FMT2)
      GØ TØ 7313
C
 3271 CØNTINUE
 7314 CØNTINUE
 7315 CØNTINUE
      DØ 5000 J=1,NTIME
      READ(5,FMT2) TESTY(J),UN(J),(Y(I,4),L(I,J),I=1,NØPARA)
      IF(UN(J)) 5000,7313,5000
 5000 CØNTINUE
       GØ TØ 7313
 5107 CØNTINUE
      DØ 30 J=1,NTIME
      READ(5,FMT2) TESTY(J),UN(J),(Y(I,J),L(I,J),I=1,NØPARA)
       IF(UN(J))30,7313,30
   30 CØNTINUE
C
C
C        UNIT CØUNT   CHECK FØR PERCENTAGE                              70
C
 7313 DØ 89999 J=1,NRTIME
      NY(J)=UN(J)
 89999 CØNTINUE
  7414 CØNTINUE
      IF (NY(1)) 4096,31,4096
 4096 CØNTINUE
      IF(NRTIME.EQ.1) GØ TØ 32
 4037 CØNTINUE
      DØ 33 I=2,NRTIME
      IF(NY(1)-NY(I))32,33,32
   32 WRITE (6,2047) NY(I)
      IL=1
      GØ TØ 1111
   33 CØNTINUE
C        REDUCE EXPØNENTS                                               80
C
 3362 NTR=NTR+1
      GØ TØ (14016,14014,14016),REED
14014 DØ 11013 J=1,NRTIME
 3333 DØ 11013 I=1,NØPARA
    4 Y(I,J)=Y(I,J)*10.**(SCALE(I)-L(I,J))
11013 CØNTINUE
C
C
C     CHECK INITIAL READINGS FØR ZERØ
C
14016 CØNTINUE
      DØ 14017 J=1,NRTIME
      DØ 14017 I=1,NØPARA
      IF(Y(I,J))14019,14017,14019
14019 IF(CURENT(I))14018,14017,14018
14018 Y(I,J)=(CURENT(I)*10.**XH(I))/Y(I,J)
14017 CØNTINUE
 7420 CØNTINUE
```

APPENDIX

```
      DØ 5317 I=1,NØPARA
      IF(Y(I,1))5317,5311,5317
 5311 WRITE(6,5312)NY(1),I
 5312 FØRMAT(10X,8HUNIT NØ.,1X,I5,1X,34HHAS NØ INITIAL READING FØR PAR.N
     10.,I3)
      NTR=NTR-1
      K17=K17+1
      NY5(K17)=NY(1)
      CTR=CTR+1.0
       IF(NCT-1)1111,7420,31
 5317 CØNTINUE
C
C
C        CHECK INITIAL LIMITS                                          90
C
14015. DØ 7021 J=1,NRTIME
 3363 DØ 7024 I=1,NØPARA
      IF(J-1)10009,10008,10009
10008 IF(XUPPER(I))37,38,37
   37 IF(Y(I,1)-XUPPER(I))38,38,41
   38 IF(XLØWER(I))39,6313,39
   39 IF(Y(I,1)-XLØWER(I))41,6313,6313
   41 XR=XR+1.
      LL=LL+1
      FAIL=1.
      GØ TØ 1624
C
C
C        CHECK FØR CATASTRØPHIC FAILURES                              100
C
10009 IF(Y(I,J))43,8891,43
   43 CØNTINUE
C
C
C        CHECK PØST TEST LIMITS                                       110
C
      IF(YUPPER(I))50,51,50
   50 IF(Y(I,1)-YUPPER(I))51,51,8891
   51 IF(YLØWER(I))52,53,52
   52 IF(Y(I,J)-YLØWER(I))8891,53,53
   53 CØNTINUE
C
C
C        CHECK FØR PERCENTAGE AND DELTA CHANGE CALCULATIØN            120
C
      IF(CHANGE(15,1))9053,6313,9053
 9053 IF(IPCT)9561,9560,9561
 9560 M1=1
      GØ TØ 9562
 9561 M1=J-1
 9562 SELX(I,J)=Y(I,J)-Y(I,M1)
      IF(SELX(I,J))54,90,54
   54 DELX(I,J)=SELX(I,J)/Y(I,M1)*100.
      ADELX(I,J)=ABS(DELX(I,J))
      IF(PCT(I))55,55,8173
 8173 IF(ADELX(I,J)-PLIMIT(I))555,555,558
  555 IF(IFAIL-1.)55,55,60
  558 IF(IFAIL-1.)8891,8891,55
   55 ASELX(I,J)=ABS(SELX(I,J))
```

APPENDIX

```
      IF(DELTA(I))60,60,5502
 5502  IF(ASDELX(I,J)-DELTA(I))60,60,8891
   90 DELX(I,J)=0
   60 CONTINUE
      GO TO 6313
 8891 SCOUNT(J)=SCOUNT(J)+1.
      JJ=J
      YR=YR+1.
      DO 57 K=JJ,NRTIME
      COUNT(K)=COUNT(K)+1.
   57 CONTINUE
      LL=LL+1
      T(LL)=TIME(J-1)
      FAIL=1.
      GO TO 1624
 6313 CONTINUE
 7024 CONTINUE
C
C
C        WRITE OUT COMPLETE LIST OF UNITS HEADINGS                    150
C
 1624 CONTINUE
 5263 IF(CTR-27.)17021,17040,17040
17040 CONTINUE
      WRITE(6,9907)
      WRITE(6,5301)(XLINE1(K),K=1,32)
      WRITE(6,5301)(XLINE2(K),K=1,32)
      WRITE(6,5301)(XLINE3(K),K=1,32)
      WRITE(6,5301)(XLINE4(K),K=1,32)
C
C
C        WRITE OUT INPUT DATA                                         160
C
      CTR=0
17021 CONTINUE
17033 WRITE(6,FMT3) UN(J),TESTY(J),(Y(N,J),N=1,NOPARA)
      CTR=CTR+1.
16033 IF(FAIL)17022,7021,17022
17022 WRITE(6,1625) I
      FAIL=0
      IF(J-NRTIME) 5261,6627,6627
 5261 LM=J+1
      DO 1626 K=LM,NRTIME
16041 WRITE(6,FMT3) UN(K),TESTY(K),(Y(I,K),I=1,NOPARA)
16043 CTR=CTR+1.
 1626 CONTINUE
      GO TO 6627
 7021 CONTINUE
 6627 CONTINUE
      WRITE(6,5132)
 5132 FORMAT(/)
      IF(NCT-1)111,7420,31
  111 CONTINUE
      GO TO  1111
C
C        END OF COMPUTATIONS FOR ONE UNIT                             180
C
```

APPENDIX

```
C
C
C     ØUTPUT ØF SPEC. LIMITS                                          240
C
   31 CØNTINUE
 1203 WRITE (6,3021)
      JM=0
      DØ 8261 I=1,NØPARA
      WRITE (6,3023) I
      WRITE (6,18591)(PARA(J,I),J=1,20)
 1147 CØNTINUE
      IF(XUPPER(I))3026,3027,3026
 3026 WRITE(6,3028) XUPPER(I)
 3027 IF(XLØWER(I))3030,3031,3030
 3030 WRITE(6,3032) XLØWER(I)
 3031 IF(YUPPER(I))3034,3035,3034
 3034 WRITE(6,3036) YUPPER(I)
 3035 IF(YLØWER(I))3038,3039,3038
 3038 WRITE(6,3040) YLØWER(I)
 3039 IF(DELTA(I))3042,3043,3042
 3042 WRITE(6,3044) DELTA(I)
 3043 IF(PCT(I))3046,3045,3046
 3045 LJ=XUPPER(2)+XLØWER(I)+YLØWER(I)+YUPPER(I)+DELTA(I)+PCT(I)
 3445 IF(UJ)3022,3048,3022
 3048 WRITE(6,3049)
      GØ TØ 1973
 3046 WRITE(6,3050) PCT(I)
 3022 CONTINUE
 1973 JM=JM+1
      IF(JM-5)8261,8262,8261
 8262 WRITE (6,3021)
      JM=0
 8261 CØNTINUE
 3286 CØNTINUE
C
C
C     ØUTPUT ØF REJECT TØTALS                                         245
C
      XNTRR=NTR
      PXR=XR/XNTRR*100.
      PPL=YR/(XNTRR-XR)*100.
      WRITE (6,2030)
      WRITE (6,2031)XR
      WRITE (6,2032) YR
      WRITE (6,2033) PXR
      WRITE (6,2034) PPL
      WRITE(6,495) NTR,NACEPT
      IF(NACEPT-LL) 9311,9312,9312
 9312 WRITE (6,9313)
      GØ TØ 5321
 9311 WRITE (6,9319)
 5321 IF(K17)5314,9314,5314
 5314 WRITE (6,3212)
      DØ 5316 J=1,K17
      WRITE (6,5315) NY5(J)
 5315 FØRMAT(7X,8HUNIT NØ.,1X,I5,1X,30HIS NØT INCLUDED IN THIS REPØRT)
 5316 CØNTINUE
```

APPENDIX

```
 9314 CONTINUE
   75 IF(FINAL)15634,1192,15634
15634 WRITE(6,1002)
      STOP
      END
```

INTRODUCTION TO COMPUTER-AIDED RELIABILITY DATA ANALYSIS

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ABSTRACT

This report describes the significant features required for the collection, coding, and documentation of hi-rel test data. It also contains a user's manual for the CARDA program, a third-generation computer program designed to fulfill the data reduction, analysis, and presentation requirements found in high-reliability component specifications.

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