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COMPUTERIZED ARRHENIUS RELIABILITY EXTRAPOLATION TECHNIQUES

by Charles R. Toye

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Cambridge, Mass.

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SUMMARY

This paper presents computerized mathematical techniques and algorithms that are useful in obtaining extrapolated component failure rates derived from the Arrhenius equation. The mathematics of the Arrhenius equation is first reviewed. A computer program for the calculation of an important constant in the equation is then given, and finally, a computerized extrapolation procedure is illustrated.

INTRODUCTION

The Arrhenius relation plays a significant role in the theory of physical-chemical reaction kinetics and has been used extensively for the prediction of chemical reaction rates as a function of temperature. In the semiconductor industry it is the most commonly used statistical technique for the extrapolation of failure rates. To the extent that semiconductor failures are traceable to temperature-generated, physical-chemical reactions of the device materials involved, the Arrhenius relation provides an adequate basis for failure rate extrapolation.

In its exponential form the relation is given by

$$F_2 = F_1 e^{-C/T} \qquad (1)$$

where

$F_1 \equiv$ the failure rate (expressed as a decimal per 1000 hours) at maximum test temperature T_1

$F_2 \equiv$ the failure rate (similarly expressed) at some lower temperature T_2

$C \equiv$ the Arrhenius acceleration factor related to the particular device considered, measured in degrees Kelvin.

$\frac{1}{T} \equiv \frac{1}{T_2} - \frac{1}{T_1} = \frac{T_1 - T_2}{T_1 T_2}$. where T_1 and T_2 are measure in degrees Kelvin.

By taking common logarithms of Eq. (1), it can be shown that the logarithm of the unknown failure rate can be expressed as a linear function of $1/T$. Thus, we have:

$$\log F_2 = \log \left(F_1 e^{-C/T}\right)$$

$$\log F_2 = \log F_1 + \log e^{-C/T} .$$

Now:

$$\log e^{-C/T} = \ln e^{-C/T} \left(\frac{1}{2.303}\right)$$

$$\log e^{-C/T} = - \frac{C}{2.303} \left(\frac{1}{T}\right)$$

and

$$\log F_2 = \log F_1 - \frac{C}{2.303} \left(\frac{1}{T}\right) . \qquad (2)$$

A sample problem is now given to illustrate its application.

PROBLEM: Suppose 100 units of a particular device are tested for 1000 hours at 300°C and a failure rate of 10%/1000 hours is observed. A second sample is tested at 125°C with an observed failure rate of 0.01%/1000 hours. Determine the failure rate (%/1000 hours) at 60°C.

SOLUTION: To use the Arrhenius relation a value for C (Arrhenius acceleration factor) must first be determined. For this, the logarithmic form of the relation given by Eq. (2) is best suited:

$$\log F_2 = \log F_1 - \frac{C}{2.303} \left(\frac{1}{T}\right)$$

$$-C = 2.303\, T \left(\log F_2 - \log F_1\right)$$

$$C = 2.303\, T \left(\log F_1 - \log F_2\right)$$

$$C = 2.303 \left(\frac{T_1 T_2}{T_1 - T_2}\right)\left(\log F_1 - \log F_2\right) .$$

Substituting known values:

$F_1 = 0.1$ $\qquad$ $T_1 = 300^\circ C = 573^\circ K^*$

$F_2 = 0.0001$ $\qquad$ $T_2 = 125^\circ C = 398^\circ K^*$

* In changing from Centigrade to Kelvin scales it is necessary to add 273 to the Centigrade reading.

we have:

$$C = 2.303 \left(\frac{573 \times 398}{573 - 398}\right) \left(\log 1 - \log .0001\right)$$

$$C = 2.303 \left(\frac{573 \times 398}{573 - 398}\right) \left(-1 + 4\right)$$

$$C \approx 9003.57^{\circ}K$$

Once a value for C is obtained, the extrapolated failure fate at $60^{\circ}C$ can be determined by either of the following two methods. Let $F_1 = 0.1$ and $T_1 = 573^{\circ}K$, with $C = 9003.57^{\circ}K$ and $T_2 = 60^{\circ}C = 330^{\circ}K$.

METHOD 1

Using Eq. (1) and substituting known values we have:

$$F_2 = F_1 e^{-C/T} = F_1 e^{-C \left(\frac{T_1 - T_2}{T_1 T_2}\right)}$$

$$F_2 = 0.1 \left[e^{-9003.57 \left(\frac{573 - 333}{573 \times 333}\right)}\right]$$

$$F_2 = 0.1 \left(e^{-11.32471}\right)$$

$$F_2 = 0.1 \left(e^{-10}\right) \left(e^{-1.32471}\right)$$

$$F_2 \approx 0.1 \ (.0000454) \ (.265883)$$

$$F_2 \approx 0.0000012071 \approx .00012\%/1000 \text{ hours.}$$

METHOD 2

Using Eq. (2) and substituting known values we have:

$$\log F_2 = \log F_1 - \frac{C}{2.303} \left(\frac{T_1 - T_2}{T_1 T_2}\right)$$

$$\log F_2 = \log .1 - \frac{9003.57}{2.303} \left(\frac{573 - 333}{573 \times 333}\right)$$

$$\log F_2 = -1 - \frac{9003.57}{2.303} \left(\frac{573 - 333}{573 \times 333}\right)$$

$$\log F_2 \approx -1 \ -4.9174 = -5.9174 = \bar{6}.0826 \equiv 4.0826 - 10$$

$$F_2 \approx 1.209 \times 10^{-6} = 0.000001209 \approx 0.00012\%/1000 \text{ hours.}$$

FACTOR PROGRAM

The Arrhenius relation in its logarithmic form (Eq. (2)) is graphically presentable on semi-logarithmic paper as a linear curve. Linear curve fitting techniques, e.g., the "Least Squares Method," would require data derived from several test temperature conditions. However, because of the high cost in the semiconductor industry, the experimental design is generally limited to two test conditions.

Contained herein (Figure 1) is a computer program (FACTOR) using the IBM 7090/7094 IBSYS Operating System, FORTRAN IV language; it is designed to calculate the value of the Arrhenius acceleration factor C necessary for the extrapolation of failure rates. In essence, the program utilizes the same method used in the sample problem above to calculate C. Given any two test temperatures (^{o}C) and their respective failure rates (%/1000 hours), or the information necessary to determine these failure rates, i.e., number of failures, sample size, and length of test (hours), the program used the Arrhenius relation (Eq. (2)) and the computer's logarithm subroutine to calculate the Arrhenius acceleration factor C (^{o}K) for the particular device under test.

The program is set up to accept test data in either of two forms. Form I consists of two test temperature (^{o}C) and their respective failure rates (%/1000 hours). Form II consists of two test temperatures (^{o}C) and their respective number of failures, sample sizes, and hours tested.

INPUT SETUP AND PROCEDURE

All input data must be keypunched on tabulating cards. The data deck consists of at least two data cards for each device for which an acceleration factor is to be calculated. For each device, the first card(s) contains actual test data; the last card, descriptive information, i.e., the kind of device and its type number.

To input test data of the kind in either Form I or Form II, the first data card(s) for each device considered, except the last, must be either of the form

```
Column 23
     $SPEC TEMP1=300, TEMP2=200, FR1=10, FR2=.7$
```

or

```
Column 23
     $SPEC TEMP1=300, TEMP2=200, REJ1=10, REJ2=7, SIZE1=100, SIZE2=1000,
     HRS1=1000, HRS2=1000$
```

depending on whether test data is of Form I or Form II, respectively. The meaning of the variables is as follows: TEMP1 is the higher of the two test temperatures (^{o}C); TEMP2 is the lower of the two; FR1, REJ1, SIZE1 and HRS1 are, respectively, the observed failure rate (%/1000 hours), number of failures, sample size and hours tested at TEMP1; FR2, REJ2, SIZE2, and HRS2 are similarly defined for TEMP2.

In setting up the "SPEC" data card(s), column 1 is left blank; a $ must appear in column 2, immediately followed by the word "SPEC", immediately followed by one or more blank characters. The variable names are then assigned constant values, with all data items separated by commas. Use of a comma following the last item is optional. If more than one card is needed for "SPEC" data, data items begin in column 2 and the last item of each card, except the last, must be a constant followed by a comma. The end of a group of "SPEC" data is signaled by a $ either in the same card as the word "SPEC", or anywhere in any succeeding card except in the column 1 position.

The descriptive data card for each device considered is of the form

```
Column 1                  18
        TRANSISTOR  2N2651
```

Columns 1-12 are reserved for the kind of device, e.g., transistor, diode, etc., entered left-justified; columns 13-18 are reserved for the type number, e.g., 2N2651, 1N696, etc., entered right-justified.

Calculation of an acceleration factor for more than one device is accomplished by simply supplying additional "SPEC" and related descriptive data cards. Input data for the last device for which an acceleration factor is to be calculated must be prepared in either of the following forms:

```
Column 123                 18
         $SPEC TEMP1=300,TEMP2=200,FR1=10,FR2=.7,FINAL=1$
        TRANSISTOR  2N2651
```

or

```
Column 123      18
         $SPEC TEMP1=300,TEMP2=200,REJ1=10,REJ2=7,SIZE1=100,
        SIZE2=1000,HRS1=1000,HRS2=1000,FINAL=1$
        TRANSISTOR  2N2651
```

again depending on whether test data is of Form I or Form II, respectively. Note that the input setup for the last device differs from that for previous devices only in the addition of "FINAL=1" to the "SPEC" card(s); this causes execution to terminate.

Output is the form:

DEVICE	TYPE	ACCELERATION FACTOR
TRANSISTOR	2N345	9234.71369288
TRANSISTOR	2N2651	7208.66473389
|	|	|
|	|	|
|	|	|

The following is a listing of the program proper (Figure 1) followed by sample input (Figure 2) and output (Figure 3) listings and a sample input card setup (Figure 4).

FIGURE 1.

ACCELERATION FACTOR (FACTOR)

PROGRAM LISTING

```
$JOB                    CABRAL-NASA
$EXECUTE        IBJOB
$IBJOB
$IBFTC FACTOR
      NAMELIST/SPEC/TEMP1,TEMP2,FR1,FR2,REJ1,REJ2,SIZE1,SIZE2,HRS1,HRS2,
     1FINAL
      WRITE(6,5)
    5 FORMAT(1H1,30X,6HDEVICE,10X,4HTYPE,20X,19HACCELERATION FACTOR)
      WRITE(6,12)
   12 FORMAT(1H0)
    9 TEMP1=0
      TEMP2=0
      FR1=0
      FR2=0
      REJ1=0
      REJ2=0
      SIZE1=0
      SIZE2=0
      HRS1=0
      HRS2=0
      FINAL=0
      READ(5,SPEC)
      READ(5,2)DEV1,DEV2,TYPE
    2 FORMAT(3A6)
      IF(FR1)3,4,3
    3 FR1=FR1/100.
      FR2=FR2/100.
    4 FR1=REJ1/(SIZE1*HRS1)*10.**5
      FR2=REJ2/(SIZE2*HRS2)*10.**5
      X=TEMP1+273.
      Y=TEMP2+273.
      T=(X-Y)/(X*Y)
      W=((ALOG10(FR2)-ALOG10(FR1))*2.303)/T
      C=-1.*W
      WRITE(6,6)DEV1,DEV2,TYPE,C
    6 FORMAT(30X,A6,A6,4X,A6,18X,F18.8)
      IF(FINAL-1.)9,8,9
    8 STOP
      END
```

FIGURE 2.

SAMPLE INPUT LISTING

```
$DATA
 $SPEC TEMP1=300,TEMP2=200,FR1=10,FR2=.7$
TRANSISTOR  2N2651
 $SPEC TEMP1=300,TEMP2=200,REJ1=10,REJ2=7,SIZE1=100,SIZE2=1000,HRS1=1000,
 HRS2=1000,FINAL=1$
TRANSISTOR  2N2651
$STOP
```

FIGURE 3.

SAMPLE OUTPUT LISTING

DEVICE	TYPE	ACCELERATION FACTOR
TRANSISTOR	2N2651	7208.66473389
TRANSISTOR	2N2651	7208.66473389

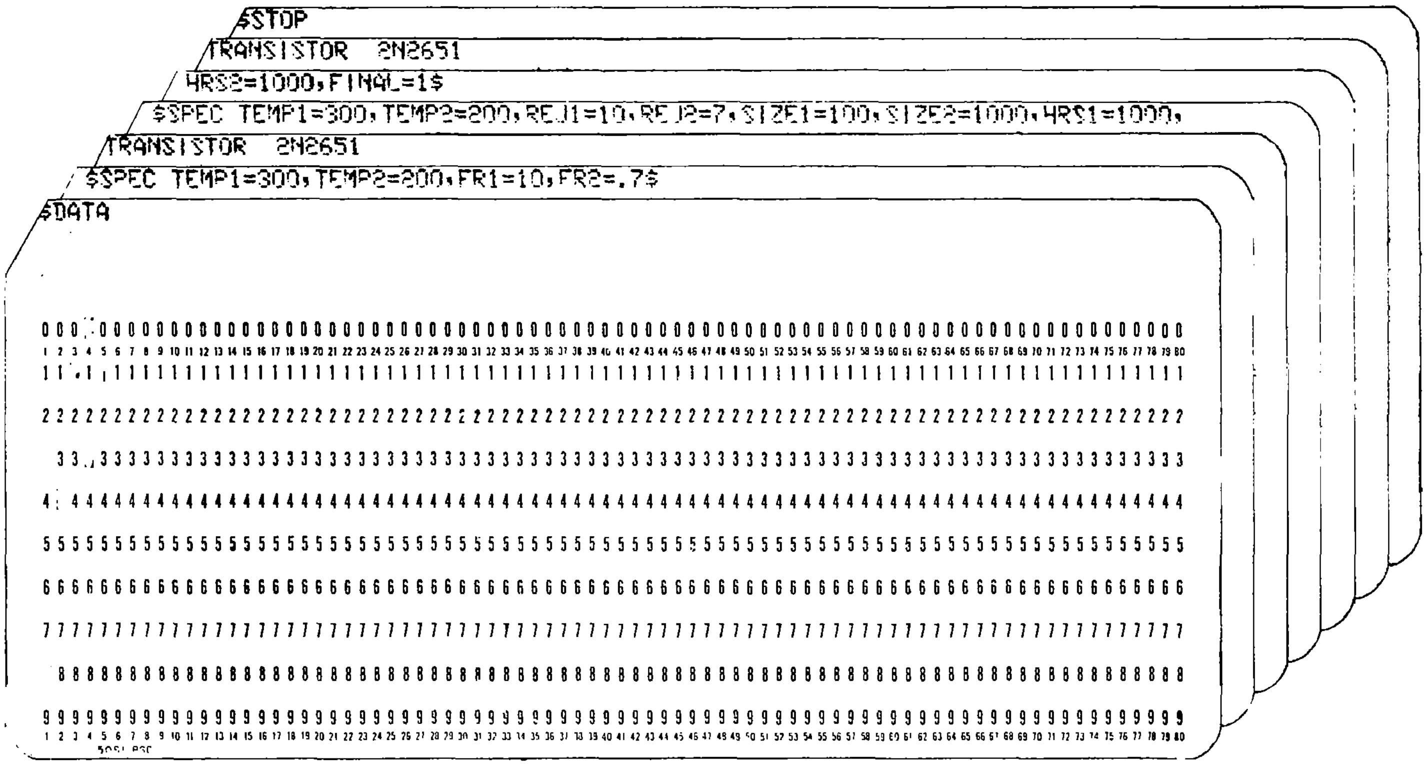

FIGURE 4.

SAMPLE INPUT CARD SETUP

The two acceleration factors outputted (Figure 3) are identical and are, in fact, for the same device. Checking the input data (Figure 2), one finds that the first of the two identical lines of output corresponds to input data of the kind described by Form I, while the other corresponds to that described by Form II. Data inputted the second way required the computer to first calculate failure rates (which, in this case, matched exactly those failure rates just previously inputted directly) before determining an acceleration factor. The duplication of output lines was purposely arranged in the data deck to illustrate the program's duality of input modes.

EXTRAP PROGRAM

The purpose of the above FACTOR program (Figure 1) is to calculate the value of the Arrhenius acceleration factor C, which in turn can be used in the extrapolation of failure rates for the device under test. A program (EXTRAP) has been written to perform this latter task. As with FACTOR, EXTRAP uses the IBM 7090/7094 IBSYS Operating System, FORTRAN IV language.

Specifically, given data based on performance under high temperature testing, i.e., temperature (^{o}C), sample size, length of test hours, number of failures and acceleration factor (^{o}K), the EXTRAP program will output an extrapolation table(s) which lists temperatures (^{o}C) in descending order, beginning with the given high test temperature and decreasing by decrements of 5^{o}C. The program is written to accommodate any high test temperature not greater than 200^{o}C (the temperature at which low- and medium-power silicon transistors are perhaps most frequently life-tested). For each temperature between, and including this maximum test temperature and a minimum temperature not lower than 25^{o}C, the table includes a failure rate (%/1000 hours) for each of five confidence limits of 10, 60, 70, 80 and 90 per cent. (These limits were calculated by means of the "Chi-square distribution".) Thus, on the basis of high temperature performance test data, the reliability of components under "in-use" conditions, through the Arrhenius extrapolation procedure contained within this program, can be predicted and presented in tabular form.

INPUT SETUP AND PROCEDURE

Input data is keypunched on tabulating cards and is set up as outlined below.

The first nine cards are reserved for general descriptive and/or identifying information, punched in columns 1-72. Data presented on these first nine cards will appear alone on the first page of output and serve as a title page for the extrapolation table(s) to follow.

The next card contains the actual test data that forms the basis for the extrapolation of failure rates. The same general procedure is followed that has been described for setting up the "SPEC" cards in the preceding FACTOR program, i.e., starting with a $ in column 2, etc. Test data is thus presented in the following form:

```
Column 23
        $SPEC SAMPLE=332, HRS=1000, TEMP=200, NF=11, C=7500, N=6$ .
```

The meaning of the variables is as follows: SAMPLE refers to the sample size or number of units of the device tested, HRS refers to the length of the test (hours), TEMP refers to the temperature (^{o}C) in the range 25^{o}C to 200^{o}C at which the test was conducted, NF is the number of failures observed, C is the acceleration factor (^{o}K) and N is simply a number, the value of which controls the continuation or termination of execution. When N is less than or greater than zero, execution continues; when N equals zero, execution is terminated.

The next three cards are reserved for descriptive information, punched in columns 1-72. These data will supply a heading for the extrapolation table based on the immediately preceding "SPEC" card.

The EXTRAP program can accommodate more than one set of test data and related descriptive information and can thus output more than one extrapolation table on a single run. If this is desired, one need only supply the additional "SPEC" cards each followed by three descriptive cards. The last "SPEC" card must assign to N a value of zero (see Figures 5 and 6).

The following is a sample input listing (Figure 5), its corresponding card setup (Figure 6), and its output (Figure 7). The tables in Figures 7b and 7c correspond to sampling plans in Table C-I of the MIL-S-19500, indexed according to the lambda value, sample size, and number of failures permitted (acceptance number). In Figure 7b, lambda equals 10, the sample size is 178, and the acceptance number is 12. In Figure 7c, lambda equals 5, the sample size is 332, and the acceptance number is 11.

In Figures 5 and 6, cards 13 and 17 are blank because only two lines of descriptive information were sufficient to identify each table and three descriptive cards are required by the program as it is written. In output (Figures 7b and 7c), the blank card causes a space between the two lines which head each table.

If it is so desired, one may use blank cards similarly in the first set of nine descriptive cards used as a title page for the tables, as long as the number of cards in this set (blank and/or punched) totals nine.

The Arrhenius equation was developed by S. Arrhenius in 1889 as an expression for the influence of temperature on reaction velocity. A derivation of this relationship may be found in Reference 1.

Variations of the Arrhenius relation for use in semiconductor reliability may be found in Reference 2.

A brief discussion of the Arrhenius equation and its limitations may be found in Reference 3

REFERENCES

1. Glasstone, S.: Textbook of Physical Chemistry. Second ed., D. Van Nostrand Co., Inc., New York, pp. 1088-1091, 1946.

2. Pershing, A.V., and Hollingsworth, G.C.: Derivation of Delbruck's Model for Random Failure (for Semiconductor Materials): Its Identification with the Arrhenius Model; and Its Experimental Verification from Physics of Failure in Electronics. Vol. 2, pp. 61-67, Reliability Series, Rome Air Development Center, Research and Technology Division, Air Force Systems Command, Griffis Air Force Base, New York, 1964.

3. Toye, C.R.: Extrapolating Component Life Tests. Electro-Technology, Industrial Research, Inc., Beverly Shores, Ind., pp. 36-39, October 1964.

FIGURE 5.

SAMPLE INPUT LISTING

```
$DATA
RELIABILITY EXTRAPOLATION BASED ON ARRHENIUS RELATION
SEMICONDUCTOR DEVICES
FAILURE RATE VARIATION WITH TEMPERATURE
EXTRAPOLATION - 5 CONFIDENCE LIMITS (10, 60, 70, 80, 90 PERCENT)
INFORMATION KNOWN - NUMBER OF FAILURES, MAXIMUM TEMPERATURE,
     SAMPLE SIZE, LENGTH OF TEST (HRS.), ACCELERATION FACTOR
INFORMATION LEARNED - 5 FAILURE RATE CONFIDENCE LIMITS FOR EACH TEMPERA-
     TURE WITH TEMPERATURES DECREASING BY DECREMENTS OF 5 DEGREES
NASA-ERC (CQS)        DATE - AUGUST 1, 1967
 $SPEC SAMPLE=178,HRS=1000,TEMP=200,NF=12,C=7500,N=6$
LAMBDA = 10
                   blank card
MIL-S-19500 SAMPLING PLAN - TABLE C-I
 $SPEC SAMPLE=332,HRS=1000,TEMP=200,NF=11,C=7500,N=0$
LAMBDA = 5
                   blank card
MIL-S-19500 SAMPLING PLAN - TABLE C-I
$STOP
```

FIGURE 6.

SAMPLE INPUT CARD SETUP

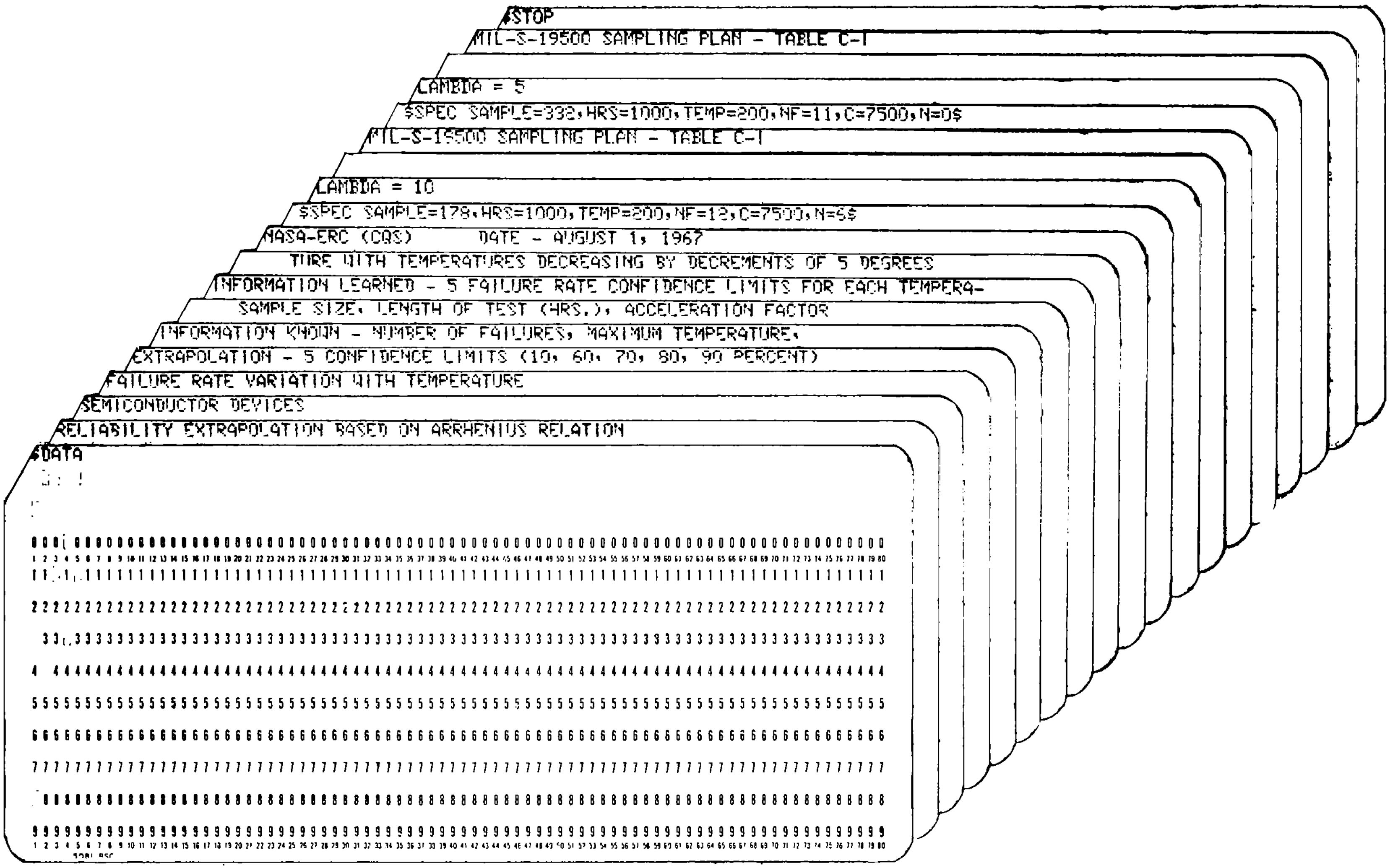

FIGURE 7.

SAMPLE OUTPUT

RELIABILITY EXTRAPOLATION BASED ON ARRHENIUS RELATION

SEMICONDUCTOR DEVICES

FAILURE RATE VARIATION WITH TEMPERATURE

EXTRAPOLATION - 5 CONFIDENCE LIMITS (10, 60, 70, 80, 90 PERCENT)

INFORMATION KNOWN - NUMBER OF FAILURES, MAXIMUM TEMPERATURE,

SAMPLE SIZE, LENGTH OF TEST (HRS.), ACCELERATION FACTOR

INFORMATION LEARNED - 5 FAILURE RATE CONFIDENCE LIMITS FOR EACH TEMPERA-

TURE WITH TEMPERATURES DECREASING BY DECREMENTS OF 5 DEGREES

NASA-ERC (CQS)   DATE - AUGUST 1, 1967

FIGURE 7a.

LAMBDA = 10

MIL-S-19500 SAMPLING PLAN - TABLE C-I

LENGTH OF TEST (HRS.)	SAMPLE SIZE	NO. OF FAILURES	MAXIMUM TEMPERATURE	ACCELERATION FACTOR
1000.	178.	12	200.	7500.

RELIABILITY EXTRAPOLATION - FAILURE RATE (PERCENT/1000 HOURS)

TEMPERATURE DEGREES CENTIGRADE	CONFIDENCE LIMITS (PERCENT) 10	60	70	80	90
200.	4.859550	7.640449	8.202247	8.932584	10.000000
195.	4.102275	6.449820	6.924071	7.540598	8.441676
190.	3.450360	5.424844	5.823729	6.342281	7.100163
185.	2.891100	4.545544	4.879775	5.314275	5.949315
180.	2.413050	3.793928	4.072893	4.435548	4.965582
175.	2.005937	3.153843	3.385743	3.687214	4.127824
170.	1.660569	2.610836	2.802810	3.052375	3.417124
165.	1.368746	2.152017	2.310254	2.515961	2.816610
160.	1.123183	1.765929	1.895777	2.064579	2.311290
155.	0.917427	1.442429	1.548490	1.686370	1.887885
150.	0.745788	1.172569	1.258787	1.370871	1.534685
145.	0.603264	0.948484	1.018225	1.108889	1.241398
140.	0.485477	0.763293	0.819418	0.892380	0.999016
135.	0.388613	0.610999	0.655926	0.714330	0.799690
130.	0.309363	0.486398	0.522162	0.568656	0.636609
125.	0.244867	0.384994	0.413302	0.450103	0.503889
120.	0.192668	0.302923	0.325197	0.354153	0.396473
115.	0.150662	0.236880	0.254297	0.276940	0.310033
110.	0.117061	0.184049	0.197582	0.215175	0.240888
105.	0.090348	0.142050	0.152495	0.166073	0.185918
100.	0.069248	0.108876	0.116882	0.127289	0.142500
95.	0.052694	0.082849	0.088940	0.096860	0.108434
90.	0.039797	0.062570	0.067171	0.073152	0.081894
85.	0.029821	0.046886	0.050334	0.054816	0.061366
80.	0.022164	0.034848	0.037410	0.040741	0.045610
75.	0.016333	0.025680	0.027569	0.030023	0.033611
70.	0.011930	0.018757	0.020136	0.021929	0.024549
65.	0.008633	0.013573	0.014571	0.015869	0.017765
60.	0.006187	0.009727	0.010442	0.011372	0.012731
55.	0.004389	0.006901	0.007408	0.008068	0.009032
50.	0.003081	0.004843	0.005200	0.005663	0.006339
45.	0.002138	0.003362	0.003609	0.003931	0.004400
40.	0.001467	0.002307	0.002476	0.002697	0.003019
35.	0.000994	0.001563	0.001678	0.001828	0.002046
30.	0.000665	0.001046	0.001123	0.001223	0.001369
25.	0.000439	0.000691	0.000741	0.000807	0.000904

FIGURE 7b.

LAMBDA = 5

MIL-S-19500 SAMPLING PLAN - TABLE C-I

LENGTH OF TEST (HRS.)	SAMPLE SIZE	NO. OF FAILURES	MAXIMUM TEMPERATURE	ACCELERATION FACTOR
1000.	332.	11	200.	7500.

RELIABILITY EXTRAPOLATION - FAILURE RATE (PERCENT/1000 HOURS)

TEMPERATURE DEGREES CENTIGRADE	CONFIDENCE LIMITS (PERCENT) 10	60	70	80	90
200.	2.364458	3.780120	4.081325	4.457831	5.000000
195.	1.995999	3.191055	3.445322	3.763157	4.220838
190.	1.678804	2.683947	2.897808	3.165133	3.550082
185.	1.406690	2.248913	2.428109	2.652104	2.974657
180.	1.174091	1.877050	2.026615	2.213573	2.482791
175.	0.976007	1.560367	1.684699	1.840114	2.063912
170.	0.807965	1.291714	1.394640	1.523296	1.708562
165.	0.665976	1.064713	1.149550	1.255597	1.408305
160.	0.546495	0.873695	0.943313	1.030334	1.155645
155.	0.446383	0.713643	0.770507	0.841587	0.943943
150.	0.362870	0.580130	0.626355	0.684137	0.767343
145.	0.293523	0.469263	0.506655	0.553394	0.620699
140.	0.236213	0.377640	0.407731	0.445345	0.499508
135.	0.189083	0.302292	0.326380	0.356488	0.399845
130.	0.150523	0.240646	0.259821	0.283789	0.318304
125.	0.119142	0.190476	0.205653	0.224625	0.251945
120.	0.093744	0.149872	0.161813	0.176741	0.198236
115.	0.073306	0.117196	0.126535	0.138208	0.155017
110.	0.056957	0.091059	0.098314	0.107384	0.120444
105.	0.043960	0.070279	0.075879	0.082879	0.092959
100.	0.033693	0.053867	0.058159	0.063524	0.071250
95.	0.025639	0.040989	0.044255	0.048338	0.054217
90.	0.019363	0.030957	0.033423	0.036507	0.040947
85.	0.014510	0.023197	0.025045	0.027356	0.030683
80.	0.010784	0.017241	0.018615	0.020332	0.022805
75.	0.007947	0.012705	0.013718	0.014983	0.016805
70.	0.005805	0.009280	0.010019	0.010944	0.012275
65.	0.004200	0.006715	0.007250	0.007919	0.008882
60.	0.003010	0.004813	0.005196	0.005675	0.006366
55.	0.002135	0.003414	0.003686	0.004026	0.004516
50.	0.001499	0.002396	0.002587	0.002826	0.003170
45.	0.001040	0.001663	0.001796	0.001962	0.002200
40.	0.000714	0.001141	0.001232	0.001346	0.001509
35.	0.000484	0.000773	0.000835	0.000912	0.001023
30.	0.000324	0.000518	0.000559	0.000610	0.000685
25.	0.000214	0.000342	0.000369	0.000403	0.000452

FIGURE 7c.

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