OPTIMUM GUN TUBE SAFE-LIFE

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by

George Schlenker

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Technical Note 67-2

Weapons Operations Research Office
U. S. Army Weapons Command
Rock Island Arsenal
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ABSTRACT

A method for determining an optimum safe-life is presented. This life is optimal in the sense that the combined expected costs associated with catastrophic failure and total life inventory are a minimum.

An associated question that is addressed is that of determining the optimum number of tubes to be life-tested. This decision is resolved by minimizing the combined cost of testing and the monetary penalty of imperfect information.

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TABLE OF CONTENTS

INTRODUCTION

The question of how long to retain gun tubes in service (in terms of cumulative usage) has historically been settled by determining the number of rounds at a given zone that a gun would fire with acceptable accuracy. Due to several factors, nearly all the cannon tubes in our inventory now become dangerously liable to a fatigue failure before wear causes an unacceptable loss of accuracy.

Thus, the question of current concern is how many rounds may be fired before the risk of a fatigue failure becomes excessive. Unfortunately the variability associated with failure by fatigue is quite large. With no precise, non-destructive way of ascertaining when a tube will fail, one only has recourse to determining tube life on the basis of failure data gathered on the tube. Further the large cost of tubes, used expendably in testing, precludes large sample sizes. Thus the risk that one is running must itself be obtained by statistical inference.

Stated more precisely, from a small sample of failure data, one must decide what the nature of the failure distribution is and what the parameters of this distribution* are. Only when the latter are obtained, can one predict the chances of failure when operating a tube to a certain life.

Presently, statistical data on thick-walled cannon tubes indicates that the distribution of cycles to failure is log-normal. Altho some other distributions cannot be definitively rejected by chi-squared and Kolmogorov-Smirnov tests, graphical analysis using maximum likelihood estimates offers persuasive evidence that the distribution is log-normal rather than, say, Weibull. Most of the failure data from which this inference is drawn come from one tube--the M113 cannon used on the M107, 175mm gun. However, because of the similarity in geometry of tubes with changes in caliber, it is presently felt that the distribution of tube

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* Even to talk about a failure distribution implies immutability of expected values over time. This in turn requires that the process generating the tubes does not change over time. For example the same materials must be used and the same requirements for strength, hardness, toughness, etc. must persist. The same fraction of tubes must be procured from each supplier. The same inspection standards must apply, etc. Doubtless over the life of the system some characteristics of the process will change with possible change in the nature of the product. This prospect adds another element of uncertainty to an already uncertain situation. However, we shall assume statistical stationarity, mainly because the problem would become completely intractable without this assumption, but also because we feel that changes deliberately introduced in the process would only tend to improve the quality of the product and therefore that the fictitious failure distribution obtained from early sampling would be a conservative estimate of the present quality of the product.

life would be log-normal for all cannons. In this report we assume that tube life is log-normally distributed. The failure data for the M113 cannon and graphical evidence for the log-normality of the underlying distribution are presented in the appendix.

Therefore, only the parameters of this distribution need be estimated from early failure data. The primary purpose of these tests is viewed as particularizing the distribution of tube life. This distribution will be called $F(t)$ and its estimate will be $\hat{F}(t)$. After this has been done a decision must be made, in the light of $F(t)$, as to what is a reasonable safe-life. One way of doing this is to decide what a maximum acceptable risk of failure is, say, α; and find the value of t such that $F(t) = \alpha$.

Altho this suggestion has the merit of conceptual simplicity, it fails to address how one decides upon a max acceptable risk. Since determination of the latter is the heart of the problem, it is not helpful to answer the question of tube safe-life by deferring the question of risk to executive fiat.

DETERMINING OPTIMUM SAFE-LIFE

The authors believe that a clearer picture of the consequences of selecting a certain life as "safe" is obtained by examining the future costs associated with a selection--the only costs germane to this decision. These costs are (1) inventory costs and (2) expected costs imputed to catastrophic failures. The first of these decreases as tube safe-life is increased whereas the second increases with tube life. This situation suggests that the sum of these costs may have a minimum for a particular life. This life is, then, regarded as optimal. To find it, we proceed as follows.

Let c = the average cost of acquiring and maintaining a tube in inventory

$(A)(c)$ = the average cost of an operational failure of a tube including all costs imputed thereto such as liabilities, cost of investigation, value loss of operational opportunity, value loss of troop confidence, value loss of military prestige, etc.

NOTE: A is the ratio of cost of failure to tube cost.

u = the expected total utilization of the system over its operational life in number of rounds

t_L = condemnation limit (safe-life) for a tube

$F(t)$ = failure distribution for tube life

Then the total, undiscounted, expected future cost affected by a decision on t_L is given by

$$\text{total variable cost} = [A\ c\ u\ F(t_L) + c\ u]/t_L \qquad (1)$$

We call

$$U(t_L) = \text{variable cost} / (c\ u) \quad , \tag{2}$$

hence $$U(t_L) = [A\ F(t_L) + 1]/t_L \tag{3}$$

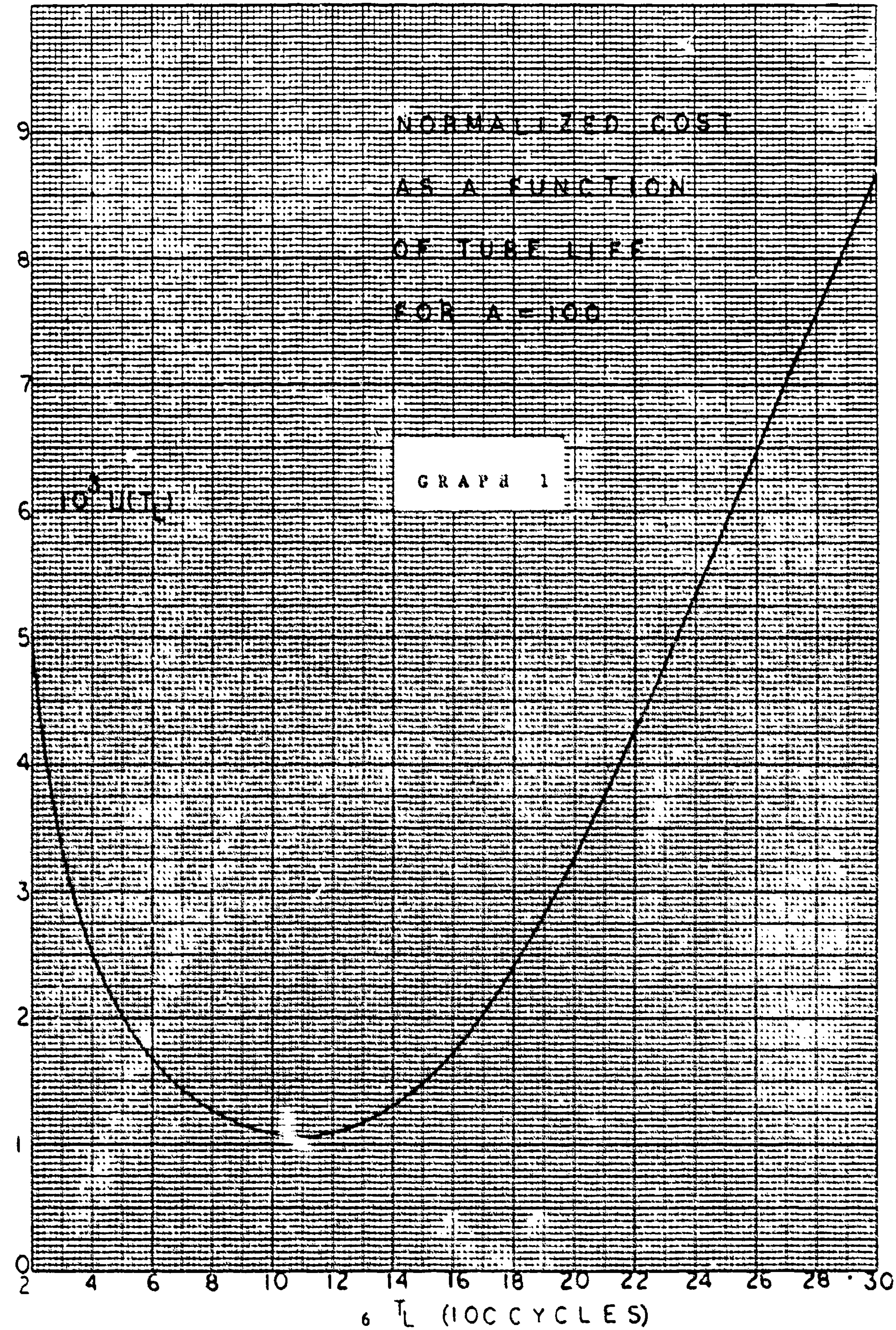
It is clear that minimization of $U(t_L)$ with respect to t_L is equivalent to minimization of the total variable cost. In graphs 1 and 2 we have plotted $U(t_L)$ vs t_L for two values of the parameter A. For this purpose we chose $F(t_L)$ as log-normal with parameters $\mu = 8.3065$ and $\sigma = 0.4425$, this being representative of the M113 gun tube.

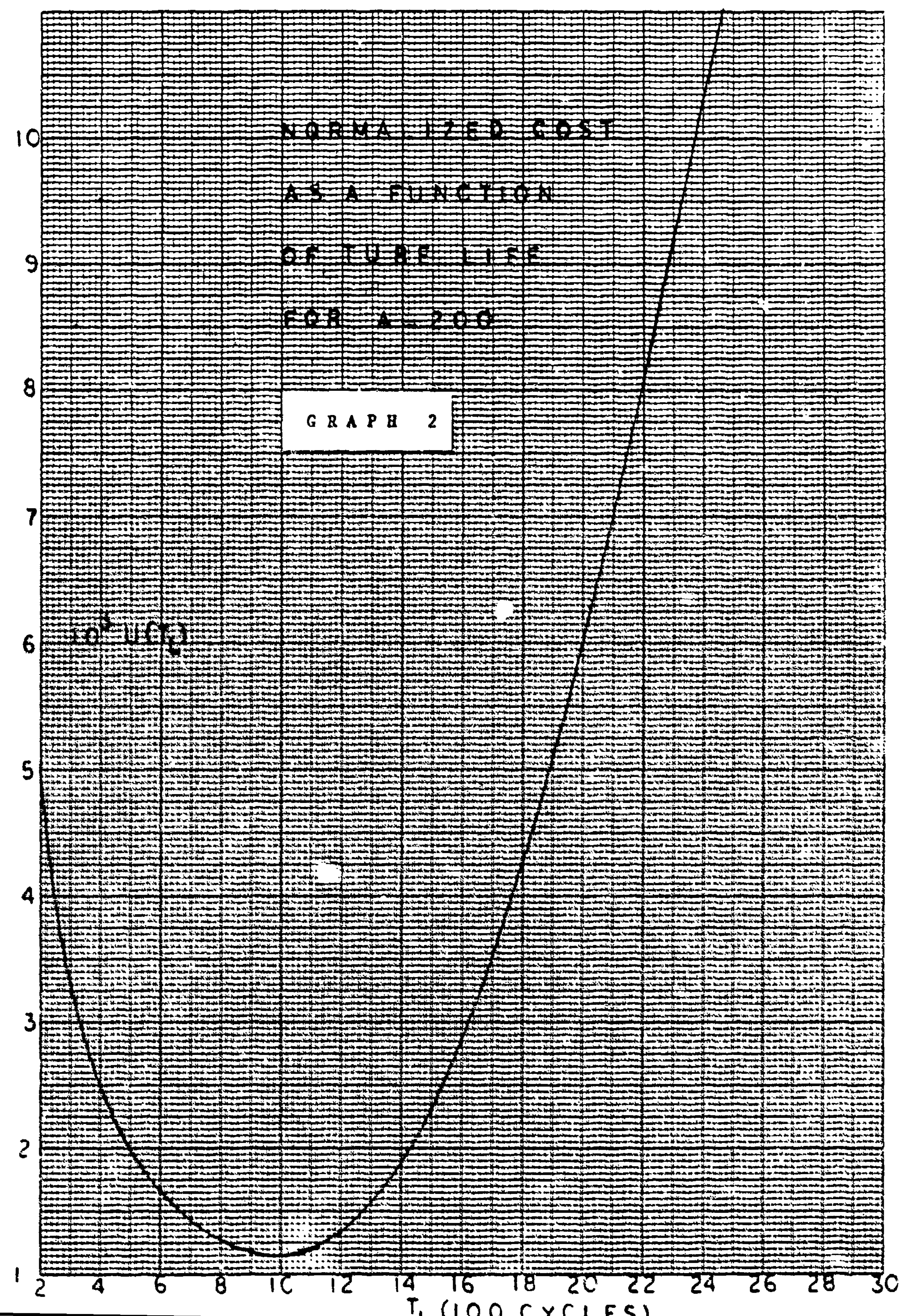
$$F(t_L) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{z} e^{-t^2/2}\, dt \quad , \text{ where}$$

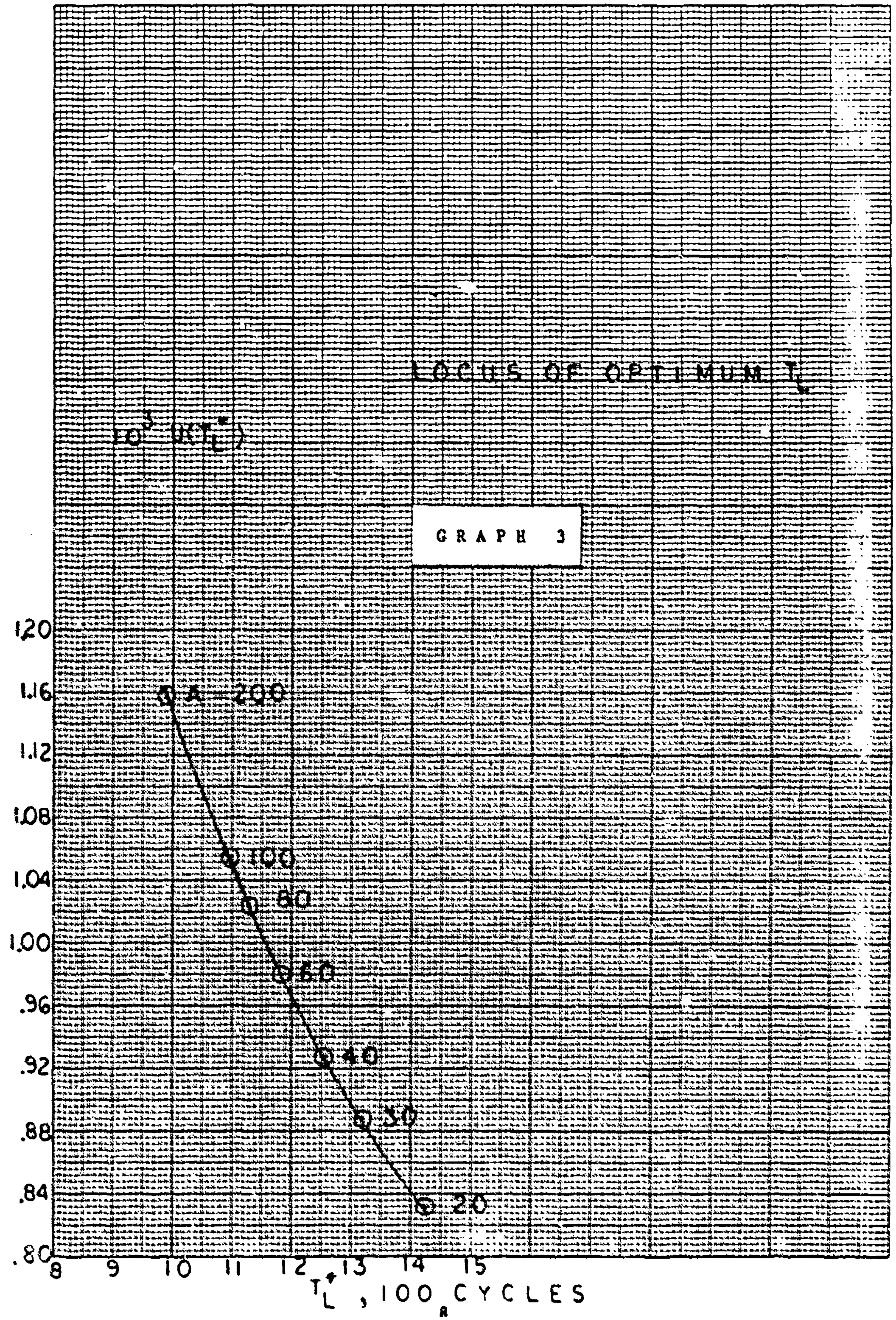
$$z = \frac{\ln t_L - \mu}{\sigma} \tag{4}$$

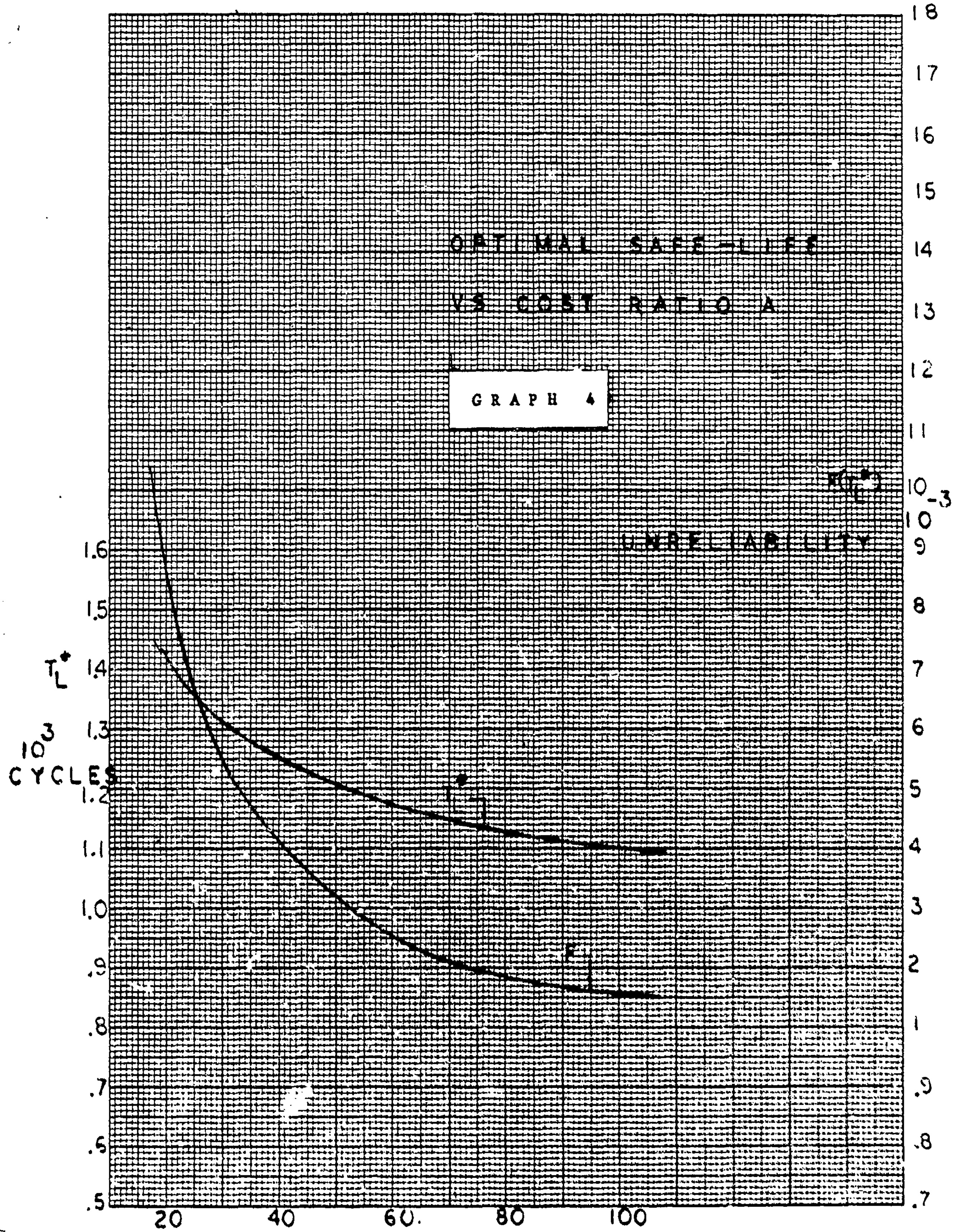
In graph 3 is shown the locus of optimum t_L. In graph 4 we have cross-plotted the optimum value of t_L, t_L^*, vs the parameter A. The unreliability, $F(t_L^*)$, is also shown. It is clear from this graph that the optimal value of tube safe-life becomes progressively less sensitive to incremonts in A as A increases.

For the case shown, a tube cost of $25,000 has been given while the total imputed cost of a catastrophic failure of $2.5 million is not unreasonable. Thus a reasonable value of A is 100. At this value the tube safe-life is 1100 cycles and is quite insensitive to changes in A. It should be noted that this optimal safe life is considerably above the 400 cycles currently in use for the M113 cannon.


NORMALIZED COST
AS A FUNCTION
OF TUBE LIFE
FOR A = 100
GRAPH 1
$10^3 U(T_L)$
9
8
7
6
5
4
3
2
1
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
T_L (10^6 CYCLES)


NORMALIZED COST
AS A FUNCTION
OF TUBE LIFE
FOR A-200
GRAPH 2
10
9
8
7
6
5
4
3
2
1
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
T_L (100 CYCLES)


LOCUS OF OPTIMUM T_L
$10^3\, U(T_L^*)$
GRAPH 3
1.20
1.16
1.12
1.08
1.04
1.00
.96
.92
.88
.84
.80
A = 200
100
80
60
40
30
20
8
9
10
11
12
13
14
15
T_L^*, 100 CYCLES



OPTIMAL SAFE-LIFE
VS COST RATIO A
GRAPH 4
UNRELIABILITY
$F(T_L^*)$
10^{-3}
T_L^*
10^3 CYCLES
T_L^*
F
A
1.6
1.5
1.4
1.3
1.2
1.1
1.0
.9
.8
.7
.6
.5
20
40
60
80
100
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
.9
.8
.7

9

PROBLEM OF TEST SAMPLE SIZE

The executive will choose a tube safe-life on the basis of the best information he has available after testing. To use the method described above, he must act as if his estimate of the failure distribution $\hat{F}(t_L)$ is the one which actually obtains. He would then proceed to obtain his estimated optimal safe life $\hat{t}_L^*$.

However, because of inevitable sampling error, the value of his "optimum" will not in general be the correct one. That is, in general $\hat{t}_L^* \neq t_L^*$. Because of this the total variable cost of subsequent operation will be higher than it might have been had he chosen t_L^* .

Letting $U^* = U(t_L^*)$, the monetary penalty associated with choosing $\hat{t}_L^*$ is given by

$$\text{penalty} = c\ u\ (U(\hat{t}_L^*) - U^*) \tag{5}$$

This is the loss incurred because of imperfect information.

Now one can reduce the expected difference in $\hat{t}_L^*$ and t_L^* by testing more units. The question as to how many units one should test can then be posed, for it is clear that one cannot go on testing indefinitely in an attempt to reduce his uncertainty concerning $F(t_L)$.

We answer this question by insisting that the rational decision-maker will want to minimize the expected aggregate cost of testing and penalty. This total cost for n units in a total life test is

$$\text{total cost} = \text{penalty} + B\ c\ n\ , \tag{6}$$

where B is the ratio of cost of testing one tube to the cost of a tube in inventory, c . This value of B is about 12 for existing systems and methods.

We define

$$V(n) = \text{total cost} / c \quad . \tag{7}$$

Thus

$$V(n) = u\, G(n,t) + B\, n,$$

where

$$G(n,t) = U(t) - U^* \quad . \tag{8}$$

It is clear that the expected value of $V(n)$, which we shall minimize, is given by

$$\overline{V}(n) = u\, \overline{G}(n) + B\, n \tag{9}$$

To find the value of n for which $\overline{V}(n)$ is a minimum, we proceed as follows.

Let n^* be such that

$$\begin{aligned} \overline{V}(n^*) &\le \overline{V}(n^* + 1) \\ &\le \overline{V}(n^* - 1) \end{aligned} \tag{10}$$

But,

$$\overline{V}(n^* + 1) = u\, \overline{G}(n^* + 1) + B\,(n^* + 1)$$

or

$$\overline{V}(n^* + 1) = u[\, \overline{G}(n^* + 1) - \overline{G}(n^*)\,] + B + \overline{V}(n^*) \quad . \tag{11}$$

Similarly,

$$\overline{V}(n^* - 1) = u\,[\, \overline{G}(n^* - 1) - \overline{G}(n^*)\,] - B + \overline{V}(n^*) \tag{12}$$

From (10), (11), and (12), we can write

$$\boxed{\overline{G}(n^* - 1) - \overline{G}(n^*) \ge \frac{B}{u} \ge \overline{G}(n^*) - \overline{G}(n^* + 1)} \tag{13}$$

The last expression is interesting in that it shows that the optimum sample size depends only on the ratio of B to u , *i.e.*, only on the ratio of non-dimensional test cost to utilization. Further at the optimum n , the forward difference in $\bar{G}(n)$ straddles B/u .

To determine $\bar{G}(n)$, the authors found it necessary to resort to MONTE CARLO techniques. In doing this, we attempted to duplicate as closely as possible the conditions facing the tester.

Sample of n failure times are drawn from a log-normal distribution whose parameters are unknown to the tester. From these t_i (i = 1 ...n), he uses maximum likelihood to obtain parameter estimates $\hat{\mu}$ and $\hat{\sigma}$

$$\hat{\mu} = \Sigma_{i=1}^{n} \ln (t_i) / n$$

$$\hat{\sigma} = \text{sqrt} [(\Sigma_{i=1}^{n} \ln^2 (t_i) - n\hat{\mu}^2)/(n-1)] \quad (14)$$

The estimates form the basis of his estimated failure distribution $\hat{F}(t)$. Using this in place of $F(t_L)$ in (3) and minimizing with respect to t_L produces $\hat{t}_L^*$ from which one can compute

$$G(n) = U(\hat{t}_L^*) - U^* \text{ , (repeated here from (8)) .}$$

This procedure was repeated 1000 times for each n and then replicated. Examples of distributions* of G(n) are shown in graphs 10 and 11 in the Appendix. The results were averaged obtaining point estimates

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* It was noted that the distribution of G(n) is well fit by a Weibull distribution. The variance of the distribution increases with the parameter A .

of $\overline{G}(n)$. A smooth curve was passed thru these points using the function

$$\overline{G}(n) = \exp[\, a + b\, \ln(n)] \quad .$$

The result is shown plotted in graph 5. Finally forward differences in $\overline{G}(n)$ were taken, $\Delta\, \overline{G}(n)$. These are shown in graph 6 for $A = 100$ and in graph 7 for $A = 200$. As an illustration of the utility of these graphs in finding n^* , we take the following example:

testing cost/tube = \$300,000

cost of tube = \$25,000

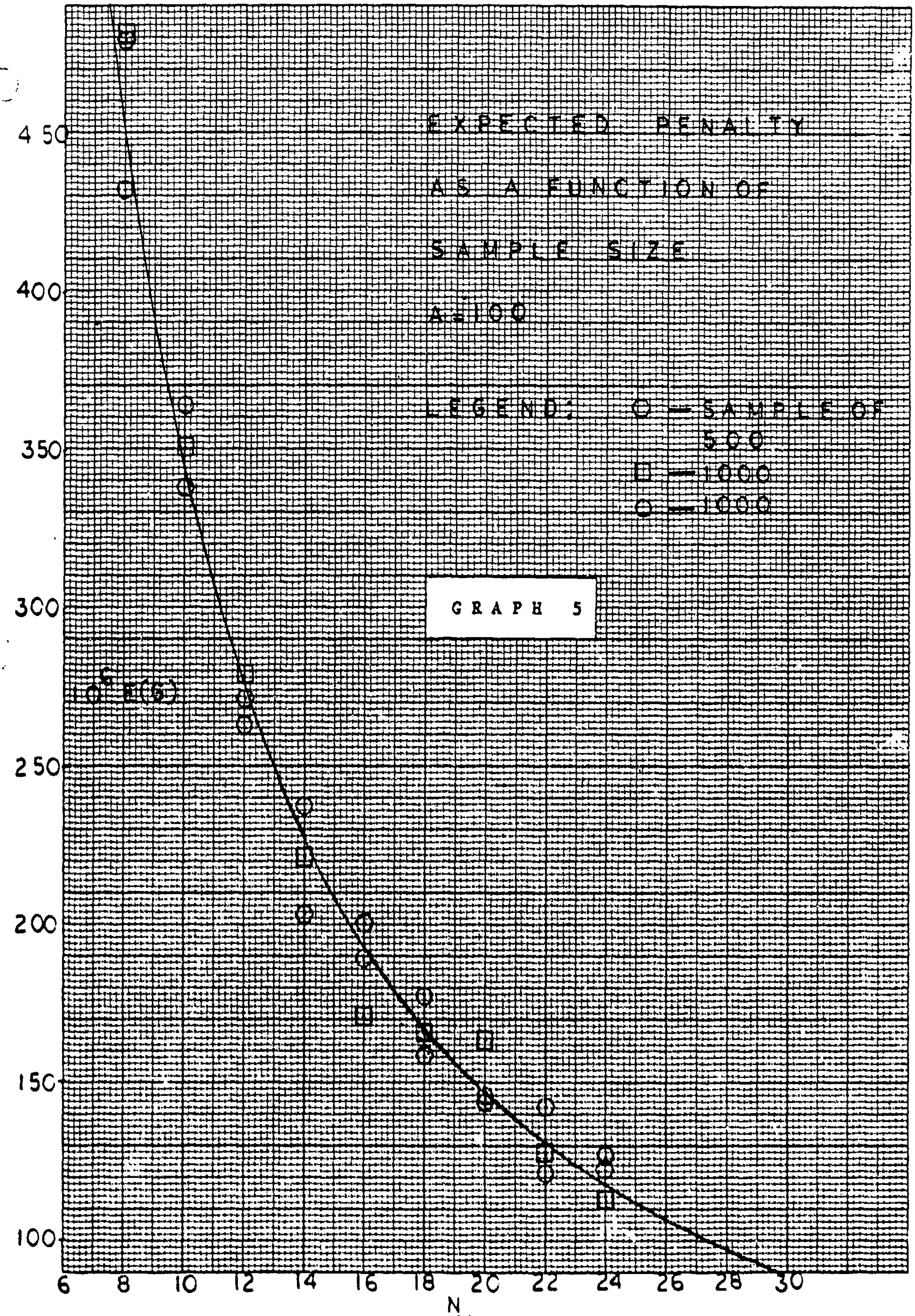
total expected utilization of the system = 1 million rnds.

Thus, $B = 300{,}000/25{,}000 = 12$ and $10^6\, B/u = 12$.

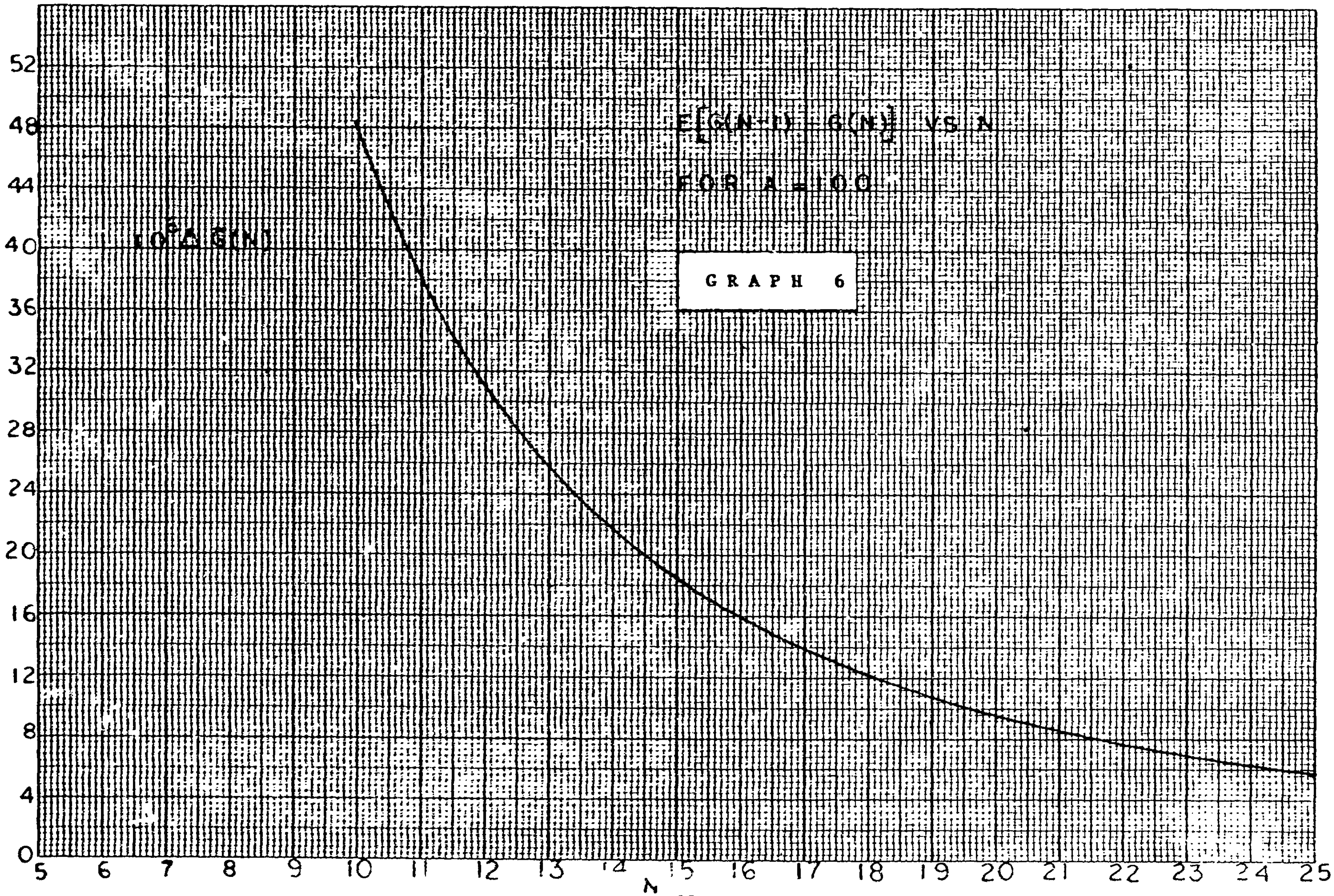
From graph 5, we see that $10^6 \Delta\, \overline{G}(n) > 12$ for $n = 18$ and

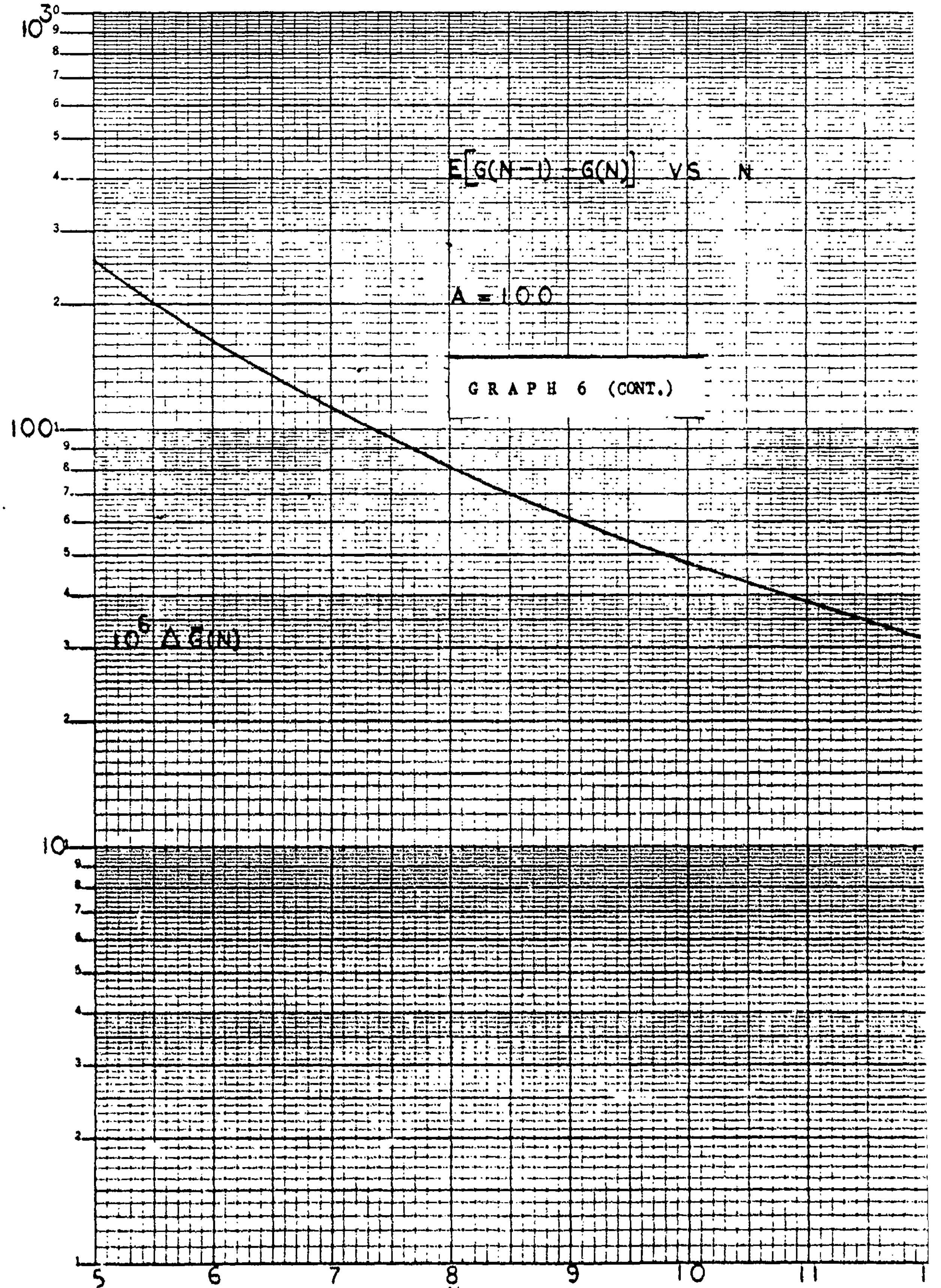
$10^6 \Delta\, \overline{G}(n) < 12$ for $n = 19$.

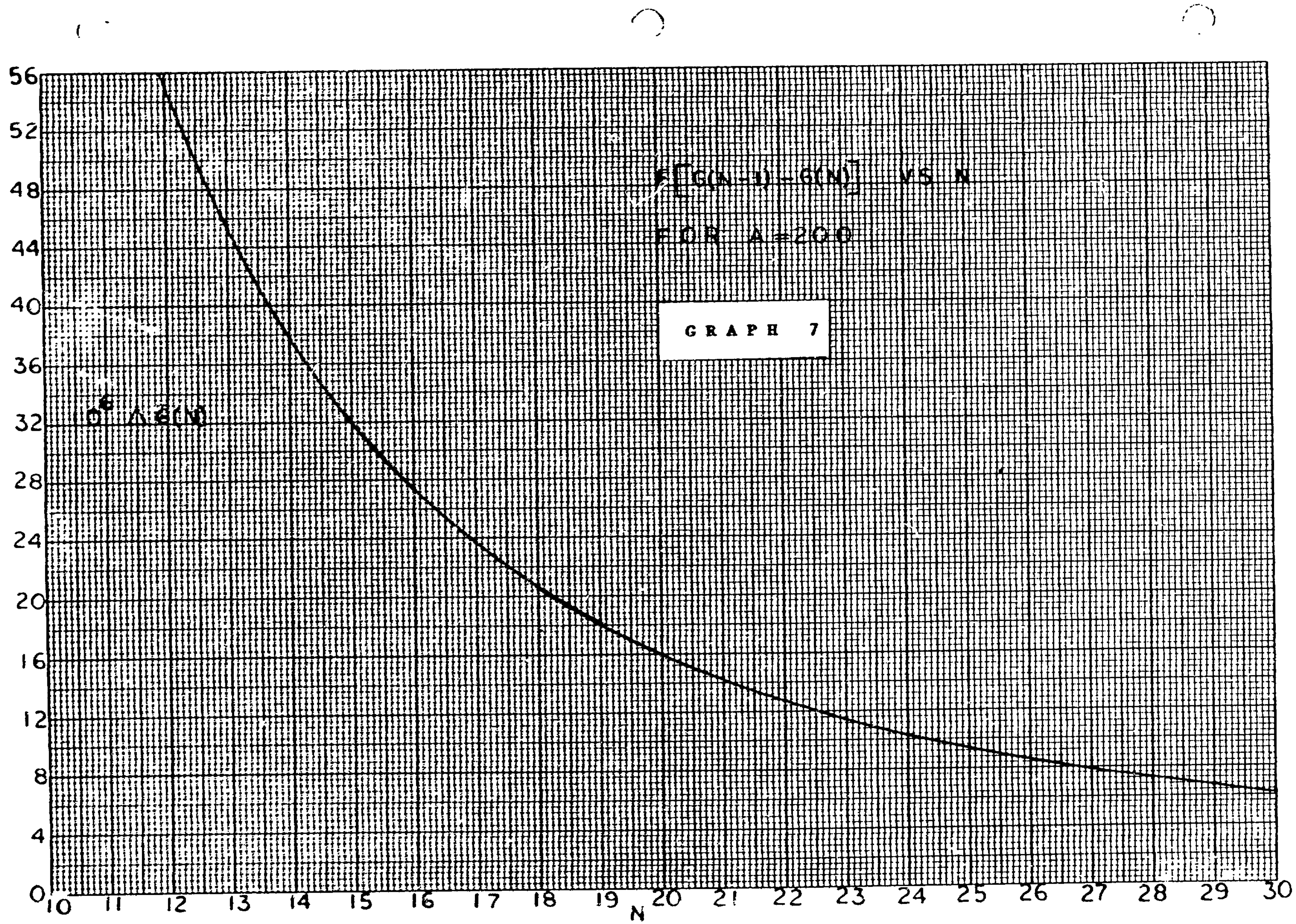
Therefore $n^* = 18$.

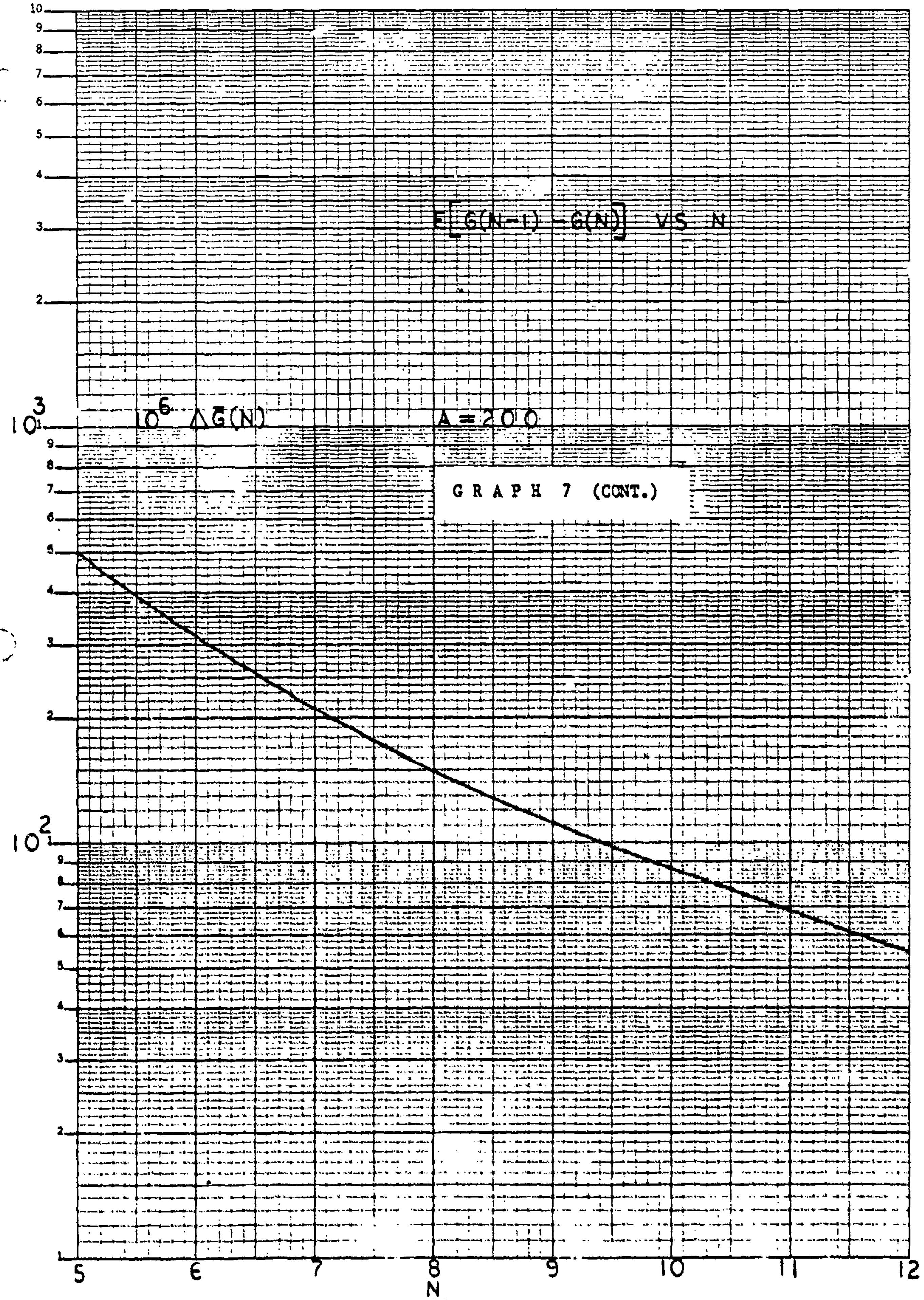


EXPECTED PENALTY
AS A FUNCTION OF
SAMPLE SIZE
A=100
LEGEND: ○ — SAMPLE OF 500
□ — 1000
⊖ — 1000
GRAPH 5
10^6 E(G)
450
400
350
300
250
200
150
100
6
8
10
12
14
16
18
20
22
24
26
28
30
N


E[G(N+1) - G(N)] VS N
FOR A = 100
GRAPH 6
ΔG(N)
52
48
44
40
36
32
28
24
20
16
12
8
4
0
5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
N


E[G(N-1) - G(N)] VS N
A = 100
GRAPH 6 (CONT.)
$10^6 \Delta \bar{G}(N)$
10^3
100
10
5
6
7
8
9
10
11
N


GRAPH 7
$E[G(A-1)-G(N)]$ VS N
FOR A=200
$10^6 \Delta E(N)$
N
56
52
48
44
40
36
32
28
24
20
16
12
8
4
0
10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30


E[G(N-1) - G(N)] VS N
$10^6 \Delta\bar{G}(N)$
A = 200
GRAPH 7 (CONT.)
10^3
10^2
5
6
7
8
9
10
11
12
N

SUMMARY

Two problems are addressed in this paper: determination of the optimum tube safe-life and determination of the optimum size of sample to be life tested. These problems are related in that the method by which the decision-maker would choose a "safe" life after tests are completed affects the penalty associated with imperfect information. This has a bearing on the number of samples taken. Stated succinctly, the way in which the information is used affects the amount of effort productively spent in its acquisition. In an obvious way, the information concerning failure— once acquired—should be used with all of the pertinent cost factors to choose an optimum safe-life. In this note we have shown how this can be done. We have also shown that three principle parameters are involved in these decisions: A, B, and u .
Further, since the decision-making models involve future (and uncertain) variables, we have described the sensitivity of the decision to the parameters.

Finally one might conjecture that the decisions themselves affect the future values of some of the variables. For example, a decision to lower the safe-life raises the total inventory requirement. In an attempt to meet the added requirement usage may decrease due to rationing of tubes. In some cases this reciprocal relationship between a decision and its data base may not be negligible.

COMPUTER PROGRAMS

The computer program implementation of the analysis is simple and direct. Basically, the program finds the expectation of G(n), $\overline{G}(n)$, for values of n from a set read in as parameter data. Other values treated as parameters are E1, E2, E3 and A. E1, E2 and E3 are, respectively, values of t in F(t) for which F(t) = .16, .50, and .84 . Thus, for F(t) a log-normal distribution with parameters μ and σ , $\mu = \ln E2$ and $\sigma = 1/2 \ln (E3/E1)$.

The program was written in the FORTRAN-II language for implementation on a FORTRAN-IV compiler. The program uses several standard library programs developed by this office. Since these programs are not part of a basic FORTRAN system, their source listings will appear in this note for completeness. The programs used are

(1) SUBROUTINE MIN1D (XØ, YØ, Y, DX, EPX, EPY)

Y is a function name which is given in the EXTERNAL statement of the calling program. The program minimizes Y(X), a user-written function, by the method of interval-halving. A starting value XØ , hopefully near the optimum, is given. The steps in X of DX are used until the search is terminated when changes in both X <u>and</u> Y iterates are less than the given epsilon values EPX and EPY , respectively. The optimum point is passed back to the calling program thru XØ and YØ.

(2) SUBROUTINE OPEN (IHIST, XMIN, INTER, DX, D1, D2, D3, XMAX)

SUBROUTINE DIST (IHIST, XMIN, INTER, DX, D1, D2, D3, X)

SUBROUTINE CLOSE (IHIST, XMIN, INTER, DX, D1, D2, D3, N)

This set of programs is used to construct a histogram for the FORTRAN random variable X . IHIST is the name of a one-dimensional array used for storing the frequency-of-occurrence of X . XMIN is the lower bound of the histogram. INTER is the number of intervals in the histogram. DX is the interval width. D1, D2 and D3 are dummy variables used by the subroutines. Note that DX, D1, D2 and D3 are computed and used only by the histogram package. XMAX is the upper limit of the histogram. X is the random variable to be DIST-ributed and N is the number of random variables that were distributed for final summary computations in CLOSE.

(3) FUNCTION SNORM (Z)

The program computes the integral from $-\infty$ to Z of the standard-normal probability function. The error, $/\epsilon(\chi)/ \leq 1.5 \times 10^{-7}$.

(4) RANDOM (N)

This function subprogram was written in MAP language for the IBM-7044. Each time it appears and is called, a random number is produced. That number is the sum of N uniform, random deviates from (0,1) . It is used in this study to generate normal deviates using the Central Limit theorem technique as explained in OR Technical Note 66-1 by Stuart Olson.

The main program begins by reading a set of constants, identification and parameters. The FORTRAN symbols and their meaning are given,

Symbol	Meaning
TITLE	An array used to store 80 characters of run identification.
NS	Number of iterations to be used in Monte Carlo simulation (1000).
NPAR	Number of parameter cards in the set.
IDL	A number changed for each run so that the random number sequence does not start with the same number.
NVNT	Number of intervals in the $G(n)$ histogram IVN.
NTNT	Number of intervals in the $\hat{t}_L^*$ histogram ITS.
NUNT	Number of intervals in the $U(\hat{t}_L^*)$ histogram IUS.
TSØ	An estimate of t_L^* (1100).
DT	An increment used in the search for optimum t_L^* (25).
ET,EU	Maximum fractional error levels for $U(t_L)$ minimization used by MIN1D (.002 and .001).
VL,VH	Lower and upper limits, respectively, for $G(n)$ histogram (0.0 and 0.01).
TL,TH	Lower and upper limits, respectively, for $\hat{t}_L^*$ histogram (0.0 and 10000.).
UL,UH	Lower and upper limits, respectively, for $U(\hat{t}_L^*)$ histogram (0.001 and 0.005).

(The following are repeated NPAR times.)

AV(I)	i-th value of A in the parameter set
E1V(I),E2V(I),E3V(I)	i-th values of E1, E2 and E3 (2600, 4050 and 6300, for all i)
NV(I,J)	For the i-th set of parameters, the values of n to be used

Using the parameters given, the program computes μ and σ. These are used to find t_L^* by the MIN1D search. A loop counter is initialized to sweep thru all the n's given on the i-th parameter card. The histogram files are OPEN-ed and the Monte Carlo loop is initialized. Within the loop, $\hat{\mu}$ and $\hat{\sigma}$ are obtained from equation (14). When these are computed, the value of $\hat{t}_L$ must be found such that $U(\hat{t}_L)$ is a minimum. This is accomplished by a special search subroutine called MINFH which searches on the variable $z = (\ell n\ t_L - \hat{\mu})/\hat{\sigma}$. When $\hat{t}_L^*$ is found, $GN = U(\hat{t}_L^*) - U(t_L^*)$ is computed and distributed in the IVN histogram. Other interesting quantities are also distributed in other histograms. After NS repetitions, the current operating parameters are printed and the histogram files are CLOSE-d and printed. Then the n-loop is repeated, followed by the NPAR loop.

The program source listings, sample input and output are given.

SOURCE LISTINGS

```
$IBSYS
$JOB                      AWCOR-SO
$TIME           40
$PAGE           300
$IBJOB UCC      MAP,DECK
$IBFTC GUNSS
C      JUNE 5,1967
C      GUN TUBE SAMPLE SIZE STUDY  S C H L E N K E R  -  O L S O N
       EXTERNAL U
       DIMENSION AV(20),E1V(20),E2V(20),E3V(20),NV(20,10),TITLE(16),
      1 IVN(1002),ITS(502),IUS(202),IZ(102)
       COMMON A,EMU,SIG,EMUH,SIGH,TLO,UHS,Z,ZSTAR
C      READ PARAMETERS FOR SIMULATIONS
       READ 1,TITLE,NS,NPAR,IDL,NVNT,NTNT,NUNT,TSO,DT,ET,EU,VL,VH,TL,
      1 TH,UL,UH,(AV(I),E1V(I),E2V(I),E3V(I),(NV(I,J),J=1,10),I=1,NPAR)
     1 FORMAT (16A5/I5,I2,I3,3I5,5X4F10.0/6F10.0/(4F10.0,10I2))
C      IDLE RANDOM NUMBER GENERATOR TO START NEW SEQUENCE
       DO 9 I=1,IDL
     9 RAND=RANDOM(1)
C      SET LIMITS OF Z HISTOGRAM
       ZL=-3.5
       ZH=-2.5
C      INITIALIZE PARAMETER-SET COUNTER
       DO 2 IPAR=1,NPAR
C      GET WORKING VALUES OF PARAMETERS FROM READ-IN ARRAY
       A=AV(IPAR)
       E1=E1V(IPAR)
       E2=E2V(IPAR)
       E3=E3V(IPAR)
C      COMPUTE MU AND SIGMA FOR U(TL) FUNCTION
       EMU=ALOG(E2)
       SIG=.5*ALOG(E3/E1)
C      COMPUTE SIGMA WITH CORRECTION FACTOR FOR VARIANCE IN
C      CENTRAL LIMIT SAMPLING SCHEME TO BE USED BELOW
       SIGC=.70710678*SIG
C      INITIALIZE TL TO BE USED IN SEARCH FOR MIN-U
       TLS=TSO
C      COMPUTE EPSILON VALUES TO BE USED IN GENERAL ONE-DIMENSIONAL
C      SEARCH FOR MIN-U
       EPT=ET*TLS
       EPU=EU*U(TLS)
C      CALL ONE-DIMENSIONAL SEARCH TO MINIMIZE U(TL) FUNCTION AND
C      STORE RESULT IN TLS AND USTAR
       CALL MIN1D(TLS,USTAR,U,DT,EPT,EPU)
       ZSTAR=(ALOG(TLS)-EMU)/SIG
C      PRINT RESULTS OF SEARCH PLUS A TABLE OF U(TL)
       PRINT 11,TLS,USTAR
    11 FORMAT (31H1TABLE OF U(TL). MINIMUM AT TL=F8.2,3X7HU-STAR=F11.8/
      1 1H013X2HTL10X5HU(TL))
       TLT=0.
```

```
      DO 12 I=1,50
      TLT=TLT+100.
      UTL=U(TLT)
   12 PRINT 13,TLT,UTL
   13 FORMAT (1H F15.2,F15.8)
C     INITIALIZE COUNTER FOR N-VALUES
      DO 2 NN=1,10
      N=NV(IPAR,NN)
C     PERFORM SIMULATION USING N-VALUE GIVEN
      IF (N-1)2,2,3
    3 FN=N
C     OPEN HISTOGRAM DATA FILES
      CALL OPEN(IZ,ZL,100,Z41,Z42,Z43,ZH)
      CALL OPEN(IVN,VL,NVNT,Z11,Z12,Z13,VH)
      CALL OPEN(ITS,TL,NTNT,Z21,Z22,Z23,TH)
      CALL OPEN(IUS,UL,NUNT,Z31,Z32,Z33,UH)
C     INITIALIZE SIMULATION COUNTER
      DO 4 I=1,NS
C     COMPUTE MU-HAT AND SIGMA-HAT VALUES
      EMUH=0.
      SIGH=0.
      DO 5 J=1,N
      X=EMU+SIGC*(RANDOM(24)-12.)
      EMUH=EMUH+X
    5 SIGH=SIGH+X*X
      EMUH=EMUH/FN
      SIGH=SQRT ((SIGH-FN*EMUH*EMUH)/(FN-1.))
C     USING EMUH AND SIGH, MINIMIZE U(TL) FUNCTION
      CALL MINFH
C     USING EMU AND SIG VALUES WITH THE OPTIMUM TL VALUE, TLO, JUST
C     OBTAINED, COMPUTE U(TLO)
      UTS=U(TLO)
      GN=UTS-USTAR
C     DISTRIBUTE COMPUTED VALUES IN THEIR RESPECTIVE HISTOGRAMS
      CALL DIST(IVN,VL,NVNT,Z11,Z12,Z13,GN)
      CALL DIST(IZ,ZL,100,Z41,Z42,Z43,Z)
      CALL DIST(ITS,TL,NTNT,Z21,Z22,Z23,TLO)
    4 CALL DIST(IUS,UL,NUNT,Z31,Z32,Z33,UTS)
C     END OF A SIMULATION-PRINT RESULTS
      PRINT 6,TITLE,A,E1,E2,E3,EMU,SIG,N
    6 FORMAT (1H116A5/1H014X1HA13X2HE113X2HE213X2HE3/1H 4F15,2/1H013X
     1 2HMU10X5HSIGMA14X1HN/1H 2F15.4,I15)
      PRINT 14
   14 FORMAT (16H1G(N) STATISTICS)
C     CLOSE HISTOGRAM FILES AND PRINT RESULTS
      CALL CLOSE(IVN,VL,NVNT,Z11,Z12,Z13,NS)
      PRINT 7
    7 FORMAT (19H1TL-STAR STATISTICS)
      CALL CLOSE(ITS,TL,NTNT,Z21,Z22,Z23,NS)
      PRINT 8
```

```
 8 FORMAT (18H1U-STAR STATISTICS)
   CALL CLOSE(IUS,UL,NUNT,Z31,Z32,Z33,NS)
   PRINT 10
10 FORMAT (13H1Z-STATISTICS)
   CALL CLOSE(IZ,ZL,100,Z41,Z42,Z43,NS)
 2 CONTINUE
   CALL EXIT
   END
```

```
$IBFTC UTL
      FUNCTION U(TL)
      COMMON A,EMU,SIG
C     SNORM COMPUTES THE STANDARD-NORMAL INTEGRAL FOR ANY Z VALUE. IT IS
C     ACCURATE TO 1.5 PARTS IN THE 7-TH DECIMAL
      U=(A*SNORM((ALOG(TL)-EMU)/SIG)+1.)/TL
      RETURN
      END
```

```
$IBFTC MINFH
C      THIS ROUTINE MINIMIZES U[TL] BY SEARCHING ON THE VARIABLE Z
       SUBROUTINE MINFH
       COMMON A,EMU,SIG,EMUH,SIGH,T2,U2,Z,ZSTAR
       Z=ZSTAR
       T=EXP [SIGH*Z+EMUH]
       U=[A*SNORM[Z]+1.]/T
       DZ=.1
     8 Z2=Z+DZ
       T2=EXP [SIGH*Z2+EMUH]
       F=SNORM[Z2]
       U2=[A*F+1.]/T2
       IF [ABS [T-T2]-1.0]4,4,5
     4 IF [ABS [U-U2]-U*1.E-3]9,9,5
     5 IF [U2-U]6,6,7
     7 DZ=-.5*DZ
     6 U=U2
       Z=Z2
       T=T2
       GO TO 8
     9 RETURN
       END
```

```
$IBFTC MIN1D
C     MIN1D IS A SIMPLE ONE-DIMENSIONAL FUNCTION MINIMIZER
      SUBROUTINE MIN1D(XS,YS,FUNC,DXS,EPX,EPY)
      X=XS
      Y=FUNC(X)
      DX=DXS
  105 X2=X+DX
      Y2=FUNC(X2)
      IF (ABS (DX)-EPX)101,101,102
  101 IF (ABS (Y-Y2)-EPY)100,100,102
  102 IF (Y2-Y)103,104,104
  104 DX=-.5*DX
  103 Y=Y2
      X=X2
      GO TO 105
  100 XS=X2
      YS=Y2
      RETURN
      END
```

```
$IBFTC OPEN
      SUBROUTINE OPEN[IP,XMIN,JNT,DX,DS,DSSQ,XMAX]
      DIMENSION IP[2502]
      DS=0.
      DSSQ=0.
      LIM=JNT+2
      DO 1 I=1,LIM
    1 IP[I]=0
      DX=[XMAX-XMIN]/FLOAT [JNT]
      RETURN
      END
```

```
$IBFTC DIST
      SUBROUTINE DIST(IP,XMIN,JNT,DX,DS,DSSQ,X)
      DIMENSION IP(2502)
      DS=DS+X
      DSSQ=DSSQ+X*X
      Y=X-XMIN
      K=Y/DX+.5
      IF (K)1,2,3
    3 IF(K-JNT)6,4,5
    6 IF (Y-FLOAT (K)*DX)2,4,2
    2 K=K+1
    4 IP(K)=IP(K)+1
      RETURN
    1 K=JNT+1
      GO TO 4
    5 K=JNT+2
      GO TO 4
      END
```

```
$IBFTC CLOSE
      SUBROUTINE CLOSE(IP,XMIN,INTER,DX,SS,SSSS,N)
      DIMENSION IP(2502)
      FN=N
      DS=SS/FN
      DSSQ=SQRT (ABS ((SSSS-FN*DS*DS)/(FN-1.)))
      SX=0.
      SIGX=0.
      V=XMIN-DX/2.
      DO 1 I=1,INTER
      V=V+DX
      DEN=FLOAT (IP(I))*V
      SX=SX+DEN
    1 SIGX=SIGX+DEN*V
      SX=SX/FN
      SIGX=SQRT (ABS (SIGX/FN-SX*SX-DX*DX/12.))
      PRINT 2,N,DS,DSSQ,SX,SIGX
    2 FORMAT  (1H010X26HHISTOGRAM GENERATOR OUTPUT /1H 9X6HSAMPLE6X
     1 9HSAMP MEAN3X12HSAMP STD DEV6X9HHIST MEAN3X12HHIST STD DEV/1H
     2 I15,1P4E15.6/9H0INTERVAL4X11HUPPER LIMIT5X10HCLASS MARK3X4HFREQ8X
     3 7HDENSITY5X10HCUMULATIVE)
      LINE=-40
      UL=XMIN
      CUM=FLOAT (IP(INTER+1))/FN
      PRINT 8,UL,IP(INTER+1),CUM,CUM
    8 FORMAT (1H 7X1H01PE15.4,15XI7,0P2F15.8)
      CM=UL+DX/2.
      UL=UL+DX
      DO 3 I=1,INTER
      IF (IP(I))10,11,10
   10 DEN=FLOAT (IP(I))/FN
      CUM=CUM+DEN
      LINE=LINE+1
      IF (LINE)5,5,6
    6 IF (INTER-I-05)5,5,15
   15 K=0
      DO 12 J=I,INTER
      IF (IP(J))12,12,13
   13 K=K+1
   12 CONTINUE
      IF (K-05)5,5,14
   14 PRINT 7
    7 FORMAT (1H18HINTERVAL4X11HUPPER LIMIT5X10HCLASS MARK3X4HFREQ8X
     1 7HDENSITY5X10HCUMULATIVE)
      LINE=-55
    5 PRINT 4,I,UL,CM,IP(I),DEN,CUM
    4 FORMAT (1H I8,1P2E15.4,I7,0P2F15.8)
   11 UL=UL+DX
    3 CM=CM+DX
      K=INTER+2
```

```
  I=K-1
  DEN=FLOAT (IP(K))/FN
  CUM=CUM+DEN
  PRINT 9,I,IP(K),DEN,CUM
9 FORMAT (1H I8,30XI7,2F15.8)
  RETURN
  END
```

```
$IBFTC SNORM
      FUNCTION SNORM[Z]
      IF [ABS [Z]-7.]1,1,2
    1 SNORM=.5+SIGN [.5,Z]*ERRFX[ABS [Z]*.70710678]
      RETURN
    2 SNORM=.5+SIGN [.5,Z]
      RETURN
      END
$IBFTC ERRFX
      FUNCTION ERRFX[X]
      T=1./[1.+.3275911*X]
      SUM=1.06140543*T
      SUM=[SUM-1.45315203]*T
      SUM=[SUM+1.42141374]*T
      SUM=[SUM-.284496736]*T
      SUM=[SUM+.254829592]*T
      ERRFX=1.-SUM*EXP [-X*X]
      RETURN
      END
```

```
$IBMAP RANDOM
       ENTRY   RANDOM
RANDOM SAVE    1,2,4
       TZE     NEWUO
       TPL     START
       CHS
       STO     UO
       RETURN  RANDOM
NEWUO  CLA     UO
       RETURN  RANDOM
START  CLA     =0
       STO     SUM
       CLA*    3,4
GENER  PAX     ,1
       LDQ     UO
       ZAC
       MPY     X
       LLS     8
       ZAC
       LLS     27
       STO     UO
       ORA     MASK
       FAD     MASK
       FAD     SUM
       STO     SUM
       TIX     GENER+1,1,1
       RETURN  RANDOM
SUM    BSS     1
UO     OCT     000425071643
MASK   OCT     200000000000
X      DEC     11587
       END
```

SAMPLE INPUT

```
0123456789012345678901234567890123456789012345678901234567890123456789  COL. SCALE

GUN TUBE SAMPLE SIZE STUDY  ANC-OR   SCHLENKER - OLSON JUNE.20,1967
 1000 3 11 1000  500  200     1100.      25.        .002       ,001
0.         .01        .0      10000.    0.001      0.005
200.       2600.      4050.    6300.      81012141618202224
200.       2600.      4050.    6300.      81012141618202224  NPAR = 3 SETS
100.       2600.      4050.    6300.      81012141618202224
```

TABLE OF U(TL). MINIMUM AT TL= 989.06 U-STAR= 0.00115709

TL	U(TL)
100.00	0.01000000
200.00	0.00500000
300.00	0.00333334
400.00	0.00250004
500.00	0.00200046
600.00	0.00166933
700.00	0.00143898
800.00	0.00128092
900.00	0.00118630
1000.00	0.00115735
1100.00	0.00120230
1200.00	0.00133180
1300.00	0.00155625
1400.00	0.00188393
1500.00	0.00231984
1600.00	0.00286522
1700.00	0.00351750
1800.00	0.00427067
1900.00	0.00511584
2000.00	0.00604189
2100.00	0.00703621
2200.00	0.00808532
2300.00	0.00917547
2400.00	0.01029313
2500.00	0.01142533
2600.00	0.01256002
2700.00	0.01368620
2800.00	0.01479408
2900.00	0.01587513
3000.00	0.01692206
3100.00	0.01792882
3200.00	0.01889055
3300.00	0.01980343
3400.00	0.02066467
3500.00	0.02147235
3600.00	0.02222534
3700.00	0.02292321
3800.00	0.02356613
3900.00	0.02415473
4000.00	0.02469011
4100.00	0.02517368
4200.00	0.02560712
4300.00	0.02599234
4400.00	0.02633139
4500.00	0.02662646
4600.00	0.02687977
4700.00	0.02709362
4800.00	0.02727029
4900.00	0.02741205
5000.00	0.02752115

GUN TUBE SAMPLE SIZE STUDY AWC-OR SCHLENKER - OLSON JUNE,20,1967

A	E1	E2	E3
200.00	2600.00	4050.00	6300.00

MU	SIGMA	N
8.3065	0.4425	8

G(N) STATISTICS

HISTOGRAM GENERATOR OUTPUT

SAMPLE	SAMP MEAN	SAMP STD DEV	HIST MEAN	HIST STD DEV
1000	8.122838E-04	1.703063E-03	7.437439E-04	1.360227E-03

INTERVAL	UPPER LIMIT	CLASS MARK	FREQ	DENSITY	CUMULATIVE
0	0.		0	0.00000000	0.00000000
1	1.0000E-05	5.0000E-06	73	0.07300000	0.07300000
2	2.0000E-05	1.5000E-05	60	0.06000000	0.13300000
3	3.0000E-05	2.5000E-05	38	0.03800000	0.17100000
4	4.0000E-05	3.5000E-05	27	0.02700000	0.19800000
5	5.0000E-05	4.5000E-05	31	0.03100000	0.22900000
6	6.0000E-05	5.5000E-05	19	0.01900000	0.24800000
7	7.0000E-05	6.5000E-05	18	0.01800000	0.26600000
8	8.0000E-05	7.5000E-05	21	0.02100000	0.28699999
9	9.0000E-05	8.5000E-05	24	0.02400000	0.31099999
10	1.0000E-04	9.5000E-05	21	0.02100000	0.33199999
11	1.1000E-04	1.0500E-04	14	0.01400000	0.34599999
12	1.2000E-04	1.1500E-04	20	0.02000000	0.36599999
13	1.3000E-04	1.2500E-04	9	0.00900000	0.37499999
14	1.4000E-04	1.3500E-04	13	0.01300000	0.38799998
15	1.5000E-04	1.4500E-04	17	0.01700000	0.40499998
16	1.6000E-04	1.5500E-04	15	0.01500000	0.41999998
17	1.7000E-04	1.6500E-04	12	0.01200000	0.43199997
18	1.8000E-04	1.7500E-04	14	0.01400000	0.44599997
19	1.9000E-04	1.8500E-04	9	0.00900000	0.45499997
20	2.0000E-04	1.9500E-04	9	0.00900000	0.46399997
21	2.1000E-04	2.0500E-04	16	0.01600000	0.47999997
22	2.2000E-04	2.1500E-04	9	0.00900000	0.48899997
23	2.3000E-04	2.2500E-04	10	0.01000000	0.49899997
24	2.4000E-04	2.3500E-04	11	0.01100000	0.50999997
25	2.5000E-04	2.4500E-04	13	0.01300000	0.52299996
26	2.6000E-04	2.5500E-04	9	0.00900000	0.53199996
27	2.7000E-04	2.6500E-04	6	0.00600000	0.53799996
28	2.8000E-04	2.7500E-04	2	0.00200000	0.53999995
29	2.9000E-04	2.8500E-04	9	0.00900000	0.54899995
30	3.0000E-04	2.9500E-04	7	0.00700000	0.55599995
31	3.1000E-04	3.0500E-04	11	0.01100000	0.56699995
32	3.2000E-04	3.1500E-04	3	0.00300000	0.56999995
33	3.3000E-04	3.2500E-04	6	0.00600000	0.57599995
34	3.4000E-04	3.3500E-04	3	0.00300000	0.57899994
35	3.5000E-04	3.4500E-04	7	0.00700000	0.58599994
36	3.6000E-04	3.5500E-04	7	0.00700000	0.59299994
37	3.7000E-04	3.6500E-04	6	0.00600000	0.59899994
38	3.8000E-04	3.7500E-04	7	0.00700000	0.60599994
39	3.9000E-04	3.8500E-04	11	0.01100000	0.61699994
40	4.0000E-04	3.9500E-04	5	0.00500000	0.62199993

NTERVAL	UPPER LIMIT	CLASS MARK	FREQ	DENSITY	CUMULATIVE
41	4.1000E-04	4.0500E-04	4	0.00400000	0.62599993
42	4.2000E-04	4.1500E-04	6	0.00600000	0.63199992
43	4.3000E-04	4.2500E-04	5	0.00500000	0.63699992
44	4.4000E-04	4.3500E-04	4	0.00400000	0.64099991
45	4.5000E-04	4.4500E-04	2	0.00200000	0.64299991
46	4.6000E-04	4.5500E-04	4	0.00400000	0.64699990
47	4.7000E-04	4.6500E-04	5	0.00500000	0.65199990
48	4.8000E-04	4.7500E-04	3	0.00300000	0.65499990
49	4.9000E-04	4.8500E-04	4	0.00400000	0.65899989
50	5.0000E-04	4.9500E-04	4	0.00400000	0.66299988
51	5.1000F-04	5.0500E-04	5	0.00500000	0.66799988
52	5.2000E-04	5.1500E-04	4	0.00400000	0.67199987
53	5.3000E-04	5.2500E-04	2	0.00200000	0.67399987
54	5.4000E-04	5.3500E-04	3	0.00300000	0.67699987
55	5.5000E-04	5.4500E-04	7	0.00700000	0.68399987
56	5.6000E-04	5.5500E-04	4	0.00400000	0.68799986
57	5.7000E-04	5.6500E-04	1	0.00100000	0.68899985
58	5.8000E-04	5.7500E-04	1	0.00100000	0.68999985
60	6.0000E-04	5.9500E-04	3	0.00300000	0.69299985
61	6.1000E-04	6.0500E-04	2	0.00200000	0.69499984
62	6.2000E-04	6.1500E-04	2	0.00200000	0.69699984
63	6.3000E-04	6.2500E-04	5	0.00500000	0.70199984
64	6.4000E-04	6.3500E-04	6	0.00600000	0.70799983
65	6.5000E-04	6.4500E-04	1	0.00100000	0.70899983
66	6.6000E-04	6.5500E-04	5	0.00500000	0.71399982
68	6.8000E-04	6.7500E-04	3	0.00300000	0.71699982
69	6.9000E-04	6.8500E-04	2	0.00200000	0.71899982
70	7.0000E-04	6.9500E-04	5	0.00500000	0.72399981
71	7.1000E-04	7.0500E-04	5	0.00500000	0.72899981
72	7.2000E-04	7.1500E-04	3	0.00300000	0.73199981
73	7.3000E-04	7.2500E-04	1	0.00100000	0.73299980
74	7.4000E-04	7.3500E-04	2	0.00200000	0.73499980
75	7.5000E-04	7.4500E-04	4	0.00400000	0.73899979
76	7.6000E-04	7.5500E-04	4	0.00400000	0.74299978
77	7.7000E-04	7.6500E-04	3	0.00300000	0.74599978
78	7.8000E-04	7.7500E-04	1	0.00100000	0.74699978
79	7.9000E-04	7.8500E-04	2	0.00200000	0.74899977
80	8.0000E-04	7.9500E-04	2	0.00200000	0.75099977
81	8.1000E-04	8.0500E-04	1	0.00100000	0.75199977
82	8.2000E-04	8.1500E-04	2	0.00200000	0.75399976
83	8.3000E-04	8.2500E-04	3	0.00300000	0.75699976
84	8.4000E-04	8.3500E-04	3	0.00300000	0.75999976
85	8.5000E-04	8.4500E-04	2	0.00200000	0.76199976
86	8.6000E-04	8.5500E-04	1	0.00100000	0.76299975
88	8.8000E-04	8.7500E-04	2	0.00200000	0.76499975
89	8.9000E-04	8.8500E-04	1	0.00100000	0.76599974
90	9.0000E-04	8.9500E-04	2	0.00200000	0.76799974
91	9.1000E-04	9.0500E-04	4	0.00400000	0.77199973
92	9.2000E-04	9.1500E-04	4	0.00400000	0.77599972
93	9.3000E-04	9.2500E-04	1	0.00100000	0.77699972
94	9.4000E-04	9.3500E-04	2	0.00200000	0.77899972
95	9.5000E-04	9.4500E-04	1	0.00100000	0.77999971
96	9.6000E-04	9.5500E-04	2	0.00200000	0.78199971
98	9.8000E-04	9.7500E-04	2	0.00200000	0.78399970
100	1.0000E-03	9.9500E-04	2	0.00200000	0.78599970
101	1.0100E-03	1.0050E-03	3	0.00300000	0.78899970

INTERVAL	UPPER LIMIT	CLASS MARK	FREQ	DENSITY	CUMULATIVE
102	1.0200E-03	1.0150E-03	3	0.00300000	0.79199970
103	1.0300E-03	1.0250E-03	1	0.00100000	0.79299969
104	1.0400E-03	1.0350E-03	3	0.00300000	0.79599969
105	1.0500E-03	1.0450E-03	1	0.00100000	0.79699969
107	1.0700E-03	1.0650E-03	2	0.00200000	0.79899968
108	1.0800E-03	1.0750E-03	1	0.00100000	0.79999968
109	1.0900E-03	1.0850E-03	2	0.00200000	0.80199967
111	1.1100E-03	1.1050E-03	1	0.00100000	0.80299967
112	1.1200E-03	1.1150E-03	3	0.00300000	0.80599967
113	1.1300E-03	1.1250E-03	3	0.00300000	0.80899967
115	1.1500E-03	1.1450E-03	1	0.00100000	0.80999966
116	1.1600E-03	1.1550E-03	3	0.00300000	0.81299966
117	1.1700E-03	1.1650E-03	2	0.00200000	0.81499965
118	1.1800E-03	1.1750E-03	1	0.00100000	0.81599965
120	1.2000E-03	1.1950E-03	1	0.00100000	0.81699964
121	1.2100E-03	1.2050E-03	5	0.00500000	0.82199964
122	1.2200E-03	1.2150E-03	3	0.00300000	0.82499964
124	1.2400E-03	1.2350E-03	2	0.00200000	0.82699963
126	1.2600E-03	1.2550E-03	1	0.00100000	0.82799963
130	1.3000E-03	1.2950E-03	1	0.00100000	0.82899962
132	1.3200E-03	1.3150E-03	1	0.00100000	0.82999962
133	1.3300E-03	1.3250E-03	1	0.00100000	0.83099961
134	1.3400E-03	1.3350E-03	1	0.00100000	0.83199961
135	1.3500E-03	1.3450E-03	2	0.00200000	0.83399960
136	1.3600E-03	1.3550E-03	1	0.00100000	0.83499960
137	1.3700E-03	1.3650E-03	1	0.00100000	0.83599959
138	1.3800E-03	1.3750E-03	1	0.00100000	0.83699959
139	1.3900E-03	1.3850E-03	1	0.00100000	0.83799958
140	1.4000E-03	1.3950E-03	1	0.00100000	0.83899958
141	1.4100E-03	1.4050E-03	1	0.00100000	0.83999957
142	1.4200E-03	1.4150E-03	1	0.00100000	0.84099957
144	1.4400E-03	1.4350E-03	1	0.00100000	0.84199956
145	1.4500E-03	1.4450E-03	1	0.00100000	0.84299956
148	1.4800E-03	1.4750E-03	2	0.00200000	0.84499955
149	1.4900E-03	1.4850E-03	4	0.00400000	0.84899954
151	1.5100E-03	1.5050E-03	3	0.00300000	0.85199954
152	1.5200E-03	1.5150E-03	3	0.00300000	0.85499954
153	1.5300E-03	1.5250E-03	1	0.00100000	0.85599954
157	1.5700E-03	1.5650E-03	1	0.00100000	0.85699953
159	1.5900E-03	1.5850E-03	3	0.00300000	0.85999953
160	1.6000E-03	1.5950E-03	1	0.00100000	0.86099952
162	1.6200E-03	1.6150E-03	1	0.00100000	0.86199952
165	1.6500E-03	1.6450E-03	1	0.00100000	0.86299951
166	1.6600E-03	1.6550E-03	2	0.00200000	0.86499951
167	1.6700E-03	1.6650E-03	3	0.00300000	0.86799951
169	1.6900E-03	1.6850E-03	2	0.00200000	0.86999951
170	1.7000E-03	1.6950E-03	2	0.00200000	0.87199950
171	1.7100E-03	1.7050E-03	1	0.00100000	0.87299950
176	1.7600E-03	1.7550E-03	1	0.00100000	0.87399949
180	1.8000F-03	1.7950E-03	1	0.00100000	0.87499949
181	1.8100E-03	1.8050E-03	1	0.00100000	0.87599948
183	1.8300E-03	1.8250E-03	2	0.00200000	0.87799948
184	1.8400E-03	1.8350E-03	1	0.00100000	0.87899947
185	1.8500E-03	1.8450E-03	1	0.00100000	0.87999947
186	1.8600E-03	1.8550E-03	1	0.00100000	0.88099946
188	1.8800E-03	1.8750E-03	2	0.00200000	0.88299946

INTERVAL	UPPER LIMIT	CLASS MARK	FREQ	DENSITY	CUMULATIVE
189	1.8900E-03	1.8850E-03	3	0.00300000	0.88599946
190	1.9000E-03	1.8950E-03	1	0.00100000	0.88699945
191	1.9100E-03	1.9050E-03	1	0.00100000	0.88799945
192	1.9200E-03	1.9150E-03	1	0.00100000	0.88899944
194	1.9400E-03	1.9350E-03	2	0.00200000	0.89099944
195	1.9500E-03	1.9450E-03	2	0.00200000	0.89299943
196	1.9600E-03	1.9550E-03	2	0.00200000	0.89499943
198	1.9800E-03	1.9750E-03	1	0.00100000	0.89599942
199	1.9900E-03	1.9850E-03	1	0.00100000	0.89699942
200	2.0000E-03	1.9950E-03	3	0.00300000	0.89999942
202	2.0200E-03	2.0150E-03	1	0.00100000	0.90099941
205	2.0500E-03	2.0450E-03	1	0.00100000	0.90199941
207	2.0700E-03	2.0650E-03	1	0.00100000	0.90299940
208	2.0800E-03	2.0750E-03	1	0.00100000	0.90399940
209	2.0900E-03	2.0850E-03	2	0.00200000	0.90599939
211	2.1100E-03	2.1050E-03	1	0.00100000	0.90699939
213	2.1300E-03	2.1250E-03	1	0.00100000	0.90799938
214	2.1400E-03	2.1350E-03	1	0.00100000	0.90899938
215	2.1500E-03	2.1450E-03	1	0.00100000	0.90999937
216	2.1600E-03	2.1550E-03	1	0.00100000	0.91099937
218	2.1800E-03	2.1750E-03	1	0.00100000	0.91199936
226	2.2600E-03	2.2550E-03	1	0.00100000	0.91299935
227	2.2700E-03	2.2650E-03	1	0.00100000	0.91399935
235	2.3500E-03	2.3450E-03	1	0.00100000	0.91499934
240	2.4000E-03	2.3950E-03	1	0.00100000	0.91599934
241	2.4100E-03	2.4050E-03	1	0.00100000	0.91699933
243	2.4300E-03	2.4250E-03	2	0.00200000	0.91899933
244	2.4400E-03	2.4350E-03	1	0.00100000	0.91999932
248	2.4800E-03	2.4750E-03	1	0.00100000	0.92099932
252	2.5200E-03	2.5150E-03	3	0.00300000	0.92399932
254	2.5400E-03	2.5350E-03	2	0.00200000	0.92599931
256	2.5600E-03	2.5550E-03	1	0.00100000	0.92699931
257	2.5700E-03	2.5650E-03	1	0.00100000	0.92799930
258	2.5800E-03	2.5750E-03	1	0.00100000	0.92899930
265	2.6500E-03	2.6450E-03	1	0.00100000	0.92999929
266	2.6600E-03	2.6550E-03	1	0.00100000	0.93099929
272	2.7200E-03	2.7150E-03	1	0.00100000	0.93199928
275	2.7500E-03	2.7450E-03	1	0.00100000	0.93299928
283	2.8300E-03	2.8250E-03	1	0.00100000	0.93399927
284	2.8400E-03	2.8350E-03	1	0.00100000	0.93499926
292	2.9200E-03	2.9150E-03	1	0.00100000	0.93599926
296	2.9600E-03	2.9550E-03	1	0.00100000	0.93699925
302	3.0200E-03	3.0150E-03	1	0.00100000	0.93799925
309	3.0900E-03	3.0850E-03	1	0.00100000	0.93899924
317	3.1700E-03	3.1650E-03	1	0.00100000	0.93999924
329	3.2900E-03	3.2850E-03	1	0.00100000	0.94099923
332	3.3200E-03	3.3150E-03	1	0.00100000	0.94199923
333	3.3300E-03	3.3250E-03	1	0.00100000	0.94299922
340	3.4000E-03	3.3950E-03	3	0.00300000	0.94599922
348	3.4800E-03	3.4750E-03	1	0.00100000	0.94699921
354	3.5400E-03	3.5350E-03	1	0.00100000	0.94799921
356	3.5600E-03	3.5550E-03	1	0.00100000	0.94899920
357	3.5700E-03	3.5650E-03	1	0.00100000	0.94999920
361	3.6100E-03	3.6050E-03	1	0.00100000	0.95099919
362	3.6200E-03	3.6150E-03	1	0.00100000	0.95199919
365	3.6500E-03	3.6450E-03	1	0.00100000	0.95299918

INTERVAL	UPPER LIMIT	CLASS MARK	FREQ	DENSITY	CUMULATIVE
366	3.6600E-03	3.6550E-03	1	0.00100000	0.95399918
369	3.6900E-03	3.6850E-03	1	0.00100000	0.95499917
370	3.7000E-03	3.6950E-03	1	0.00100000	0.95599917
376	3.7600E-03	3.7550E-03	1	0.00100000	0.95699916
379	3.7900E-03	3.7850E-03	1	0.00100000	0.95799915
385	3.8500E-03	3.8450E-03	1	0.00100000	0.95899915
386	3.8600E-03	3.8550E-03	1	0.00100000	0.95999914
393	3.9300E-03	3.9250E-03	1	0.00100000	0.96099914
405	4.0500E-03	4.0450E-03	1	0.00100000	0.96199913
417	4.1700E-03	4.1650E-03	1	0.00100000	0.96299913
444	4.4400E-03	4.4350E-03	1	0.00100000	0.96399912
448	4.4800E-03	4.4750E-03	1	0.00100000	0.96499912
453	4.5300E-03	4.5250E-03	1	0.00100000	0.96599911
458	4.5800E-03	4.5750E-03	1	0.00100000	0.96699911
463	4.6300E-03	4.6250E-03	1	0.00100000	0.96799910
478	4.7800E-03	4.7750E-03	1	0.00100000	0.96899910
489	4.8900E-03	4.8850E-03	1	0.00100000	0.96999909
522	5.2200E-03	5.2150E-03	1	0.00100000	0.97099908
525	5.2500E-03	5.2450E-03	1	0.00100000	0.97199908
528	5.2800E-03	5.2750E-03	1	0.00100000	0.97299907
529	5.2900E-03	5.2850E-03	1	0.00100000	0.97399907
537	5.3700E-03	5.3650E-03	1	0.00100000	0.97499906
575	5.7500E-03	5.7450E-03	1	0.00100000	0.97599906
579	5.7900E-03	5.7850E-03	1	0.00100000	0.97699905
597	5.9700E-03	5.9650E-03	1	0.00100000	0.97799905
610	6.1000E-03	6.0950E-03	1	0.00100000	0.97899904
633	6.3300E-03	6.3250E-03	1	0.00100000	0.97999904
644	6.4400E-03	6.4350E-03	1	0.00100000	0.98099903
668	6.6800E-03	6.6750E-03	1	0.00100000	0.98199902
690	6.9000E-03	6.8950E-03	1	0.00100000	0.98299902
702	7.0200E-03	7.0150E-03	1	0.00100000	0.98399901
716	7.1600E-03	7.1550E-03	1	0.00100000	0.98499901
735	7.3500E-03	7.3450E-03	1	0.00100000	0.98599900
750	7.5000E-03	7.4950E-03	1	0.00100000	0.98699900
844	8.4400E-03	8.4350E-03	1	0.00100000	0.98799899
870	8.7000E-03	8.6950E-03	1	0.00100000	0.98899899
902	9.0200E-03	9.0150E-03	1	0.00100000	0.98999898
932	9.3200E-03	9.3150E-03	1	0.00100000	0.99099898
971	9.7100E-03	9.7050E-03	1	0.00100000	0.99199897
973	9.7300E-03	9.7250E-03	1	0.00100000	0.99299897
982	9.8200E-03	9.8150E-03	1	0.00100000	0.99399896
983	9.8300E-03	9.8250E-03	1	0.00100000	0.99499895
1001			5	0.00500000	0.99999895

FL-STAR STATISTICS

HISTOGRAM GENERATOR OUTPUT

SAMPLE	SAMP MEAN	SAMP STD DEV	HIST MEAN	HIST STD DEV
1000	1.121490E 03	4.134041E 02	1.131360E 03	4.128561E 02

INTERVAL	UPPER LIMIT	CLASS MARK	FREQ	DENSITY	CUMULATIVE
0	0.		0	0.00000000	0.00000000
20	4.0000E 02	3.9000E 02	2	0.00200000	0.00200000
21	4.2000E 02	4.1000E 02	1	0.00100000	0.00300000
22	4.4000E 02	4.3000E 02	2	0.00200000	0.00500000
23	4.6000E 02	4.5000E 02	3	0.00300000	0.00800000
24	4.8000E 02	4.7000E 02	6	0.00600000	0.01400000
25	5.0000E 02	4.9000E 02	5	0.00500000	0.01900000
26	5.2000E 02	5.1000E 02	7	0.00700000	0.02600000
27	5.4000E 02	5.3000E 02	9	0.00900000	0.03500000
28	5.6000E 02	5.5000E 02	11	0.01100000	0.04600000
29	5.8000E 02	5.7000E 02	12	0.01200000	0.05800000
30	6.0000E 02	5.9000E 02	9	0.00900000	0.06700000
31	6.2000E 02	6.1000E 02	8	0.00800000	0.07500000
32	6.4000E 02	6.3000E 02	10	0.01000000	0.08500000
33	6.6000E 02	6.5000E 02	9	0.00900000	0.09400000
34	6.8000E 02	6.7000E 02	17	0.01700000	0.11100000
35	7.0000E 02	6.9000E 02	15	0.01500000	0.12600000
36	7.2000E 02	7.1000E 02	15	0.01500000	0.14100000
37	7.4000E 02	7.3000E 02	17	0.01700000	0.15799999
38	7.6000E 02	7.5000E 02	21	0.02100000	0.17899999
39	7.8000E 02	7.7000E 02	21	0.02100000	0.19999999
40	8.0000E 02	7.9000E 02	21	0.02100000	0.22099999
41	8.2000E 02	8.1000E 02	19	0.01900000	0.23999999
42	8.4000E 02	8.3000E 02	20	0.02000000	0.25999999
43	8.6000E 02	8.5000E 02	25	0.02500000	0.28499999
44	8.8000E 02	8.7000E 02	23	0.02300000	0.30799999
45	9.0000E 02	8.9000E 02	19	0.01900000	0.32699998
46	9.2000E 02	9.1000E 02	22	0.02200000	0.34899998
47	9.4000E 02	9.3000E 02	17	0.01700000	0.36599998
48	9.6000E 02	9.5000E 02	18	0.01800000	0.38399998
49	9.8000E 02	9.7000E 02	23	0.02300000	0.40699998
50	1.0000E 03	9.9000E 02	21	0.02100000	0.42799998
51	1.0200E 03	1.0100E 03	23	0.02300000	0.45099998
52	1.0400E 03	1.0300E 03	18	0.01800000	0.46899997
53	1.0600E 03	1.0500E 03	25	0.02500000	0.49399997
54	1.0800E 03	1.0700E 03	20	0.02000000	0.51399997
55	1.1000E 03	1.0900E 03	15	0.01500000	0.52899996
56	1.1200E 03	1.1100E 03	22	0.02200000	0.55099996
57	1.1400E 03	1.1300E 03	12	0.01200000	0.56299996
58	1.1600E 03	1.1500E 03	27	0.02700000	0.58999995
59	1.1800E 03	1.1700E 03	15	0.01500000	0.60499994

INTERVAL	UPPER LIMIT	CLASS MARK	FREQ	DENSITY	CUMULATIVE
60	1.2000E 03	1.1900E 03	25	0.02500000	0.62999994
61	1.2200E 03	1.2100E 03	12	0.01200000	0.64199994
62	1.2400E 03	1.2300E 03	24	0.02400000	0.66599993
63	1.2600E 03	1.2500E 03	13	0.01300000	0.67899993
64	1.2800E 03	1.2700E 03	13	0.01300000	0.69199993
65	1.3000E 03	1.2900E 03	14	0.01400000	0.70599993
66	1.3200E 03	1.3100E 03	17	0.01700000	0.72299992
67	1.3400E 03	1.3300E 03	11	0.01100000	0.73399992
68	1.3600E 03	1.3500E 03	16	0.01600000	0.74999992
69	1.3800E 03	1.3700E 03	5	0.00500000	0.75499991
70	1.4000E 03	1.3900E 03	7	0.00700000	0.76199991
71	1.4200E 03	1.4100E 03	12	0.01200000	0.77399991
72	1.4400E 03	1.4300E 03	11	0.01100000	0.78499991
73	1.4600E 03	1.4500E 03	10	0.01000000	0.79499990
74	1.4800E 03	1.4700E 03	9	0.00900000	0.80399990
75	1.5000E 03	1.4900E 03	10	0.01000000	0.81399990
76	1.5200E 03	1.5100E 03	15	0.01500000	0.82899989
77	1.5400E 03	1.5300E 03	3	0.00300000	0.83199989
78	1.5600E 03	1.5500E 03	11	0.01100000	0.84299989
79	1.5800E 03	1.5700E 03	13	0.01300000	0.85599989
80	1.6000E 03	1.5900E 03	9	0.00900000	0.86499988
81	1.6200E 03	1.6100E 03	9	0.00900000	0.87399988
82	1.6400E 03	1.6300E 03	13	0.01300000	0.88699988
83	1.6600E 03	1.6500E 03	14	0.01400000	0.90099987
84	1.6800E 03	1.6700E 03	10	0.01000000	0.91099987
85	1.7000E 03	1.6900E 03	3	0.00300000	0.91399987
86	1.7200E 03	1.7100E 03	6	0.00600000	0.91999987
87	1.7400E 03	1.7300E 03	9	0.00900000	0.92899986
88	1.7600E 03	1.7500E 03	3	0.00300000	0.93199986
89	1.7800E 03	1.7700E 03	3	0.00300000	0.93499986
90	1.8000E 03	1.7900E 03	3	0.00300000	0.93799986
91	1.8200E 03	1.8100E 03	2	0.00200000	0.93999986
92	1.8400E 03	1.8300E 03	3	0.00300000	0.94299985
93	1.8600E 03	1.8500E 03	4	0.00400000	0.94699985
94	1.8800E 03	1.8700E 03	9	0.00900000	0.95599984
95	1.9000E 03	1.8900E 03	4	0.00400000	0.95999984
96	1.9200E 03	1.9100E 03	2	0.00200000	0.96199983
97	1.9400E 03	1.9300E 03	1	0.00100000	0.96299983
99	1.9800E 03	1.9700E 03	4	0.00400000	0.96699982
100	2.0000E 03	1.9900E 03	2	0.00200000	0.96899982
101	2.0200E 03	2.0100E 03	1	0.00100000	0.96999981
103	2.0600E 03	2.0500E 03	5	0.00500000	0.97499981
105	2.1000E 03	2.0900E 03	1	0.00100000	0.97599980
106	2.1200E 03	2.1100E 03	2	0.00200000	0.97799980
107	2.1400E 03	2.1300E 03	1	0.00100000	0.97899979
108	2.1600E 03	2.1500E 03	1	0.00100000	0.97999979
109	2.1800E 03	2.1700E 03	1	0.00100000	0.98099978
110	2.2000E 03	2.1900E 03	1	0.00100000	0.98199978
111	2.2200E 03	2.2100E 03	2	0.00200000	0.98399977
112	2.2400E 03	2.2300E 03	1	0.00100000	0.98499977
113	2.2600E 03	2.2500E 03	1	0.00100000	0.98599976
114	2.2800E 03	2.2700E 03	1	0.00100000	0.98699976
118	2.3600E 03	2.3500E 03	1	0.00100000	0.98799975
119	2.3800E 03	2.3700E 03	1	0.00100000	0.98899975
120	2.4000E 03	2.3900E 03	1	0.00100000	0.98999974
122	2.4400E 03	2.4300E 03	1	0.00100000	0.99099974

INTERVAL	UPPER LIMIT	CLASS MARK	FREQ	DENSITY	CUMULATIVE
123	2.4600E 03	2.4500E 03	1	0.00100000	0.99199973
124	2.4800E 03	2.4700E 03	3	0.00300000	0.99499973
128	2.5600E 03	2.5500E 03	2	0.00200000	0.99699973
141	2.8200E 03	2.8100E 03	1	0.00100000	0.99799972
163	3.2600E 03	3.2500E 03	1	0.00100000	0.99899971
177	3.5400E 03	3.5300E 03	1	0.00100000	0.99999971
501			0	0.00000000	0.99999971

U-STAR STATISTICS

HISTOGRAM GENERATOR OUTPUT

SAMPLE	SAMP MEAN	SAMP STD DEV	HIST MEAN	HIST STD DEV
1000	1.969375E-03	1.703065E-03	1.634699E-03	8.221258E-04

INTERVAL	UPPER LIMIT	CLASS MARK	FREQ	DENSITY	CUMULATIVE
0	1.0000E-03		0	0.00000000	0.00000000
9	1.1800E-03	1.1700E-03	128	0.12800000	0.12800000
10	1.2000E-03	1.1900E-03	66	0.06600000	0.19400000
11	1.2200E-03	1.2100E-03	50	0.05000000	0.24400000
12	1.2400E-03	1.2300E-03	40	0.04000000	0.28399999
13	1.2600E-03	1.2500E-03	47	0.04700000	0.33099999
14	1.2800E-03	1.2700E-03	29	0.02900000	0.35999999
15	1.3000E-03	1.2900E-03	26	0.02600000	0.38599999
16	1.3200E-03	1.3100E-03	31	0.03100000	0.41699999
17	1.3400E-03	1.3300E-03	23	0.02300000	0.43999999
18	1.3600E-03	1.3500E-03	23	0.02300000	0.46299998
19	1.3800E-03	1.3700E-03	25	0.02500000	0.48799998
20	1.4000E-03	1.3900E-03	22	0.02200000	0.50999998
21	1.4200E-03	1.4100E-03	22	0.02200000	0.53199998
22	1.4400E-03	1.4300E-03	8	0.00800000	0.53999998
23	1.4600E-03	1.4500E-03	16	0.01600000	0.55599997
24	1.4800E-03	1.4700E-03	14	0.01400000	0.56999997
25	1.5000E-03	1.4900E-03	8	0.00800000	0.57799996
26	1.5200E-03	1.5100E-03	15	0.01500000	0.59299996
27	1.5400E-03	1.5300E-03	10	0.01000000	0.60299996
28	1.5600E-03	1.5500E-03	18	0.01800000	0.62099995
29	1.5800E-03	1.5700E-03	10	0.01000000	0.63099995
30	1.6000E-03	1.5900E-03	7	0.00700000	0.63799995
31	1.6200E-03	1.6100E-03	7	0.00700000	0.64499995
32	1.6400E-03	1.6300E-03	10	0.01000000	0.65499995
33	1.6600E-03	1.6500E-03	7	0.00700000	0.66199995
34	1.6800E-03	1.6700E-03	10	0.01000000	0.67199995
35	1.7000E-03	1.6900E-03	4	0.00400000	0.67599994
36	1.7200E-03	1.7100E-03	12	0.01200000	0.68799993
37	1.7400E-03	1.7300E-03	2	0.00200000	0.68999993
38	1.7600E-03	1.7500E-03	3	0.00300000	0.69299993
39	1.7800E-03	1.7700E-03	4	0.00400000	0.69699992
40	1.8000E-03	1.7900E-03	11	0.01100000	0.70799992
41	1.8200E-03	1.8100E-03	4	0.00400000	0.71199992
42	1.8400E-03	1.8300E-03	4	0.00400000	0.71599991
43	1.8600E-03	1.8500E-03	7	0.00700000	0.72299991
44	1.8800E-03	1.8700E-03	9	0.00900000	0.73199990
45	1.9000E-03	1.8900E-03	2	0.00200000	0.73399990
46	1.9200E-03	1.9100E-03	8	0.00800000	0.74199989
47	1.9400E-03	1.9300E-03	5	0.00500000	0.74699989
48	1.9600E-03	1.9500E-03	4	0.00400000	0.75099988

INTERVAL	UPPER LIMIT	CLASS MARK	FREQ	DENSITY	CUMULATIVE
49	1.9800E-03	1.9700E-03	2	0.00200000	0.75299988
50	2.0000E-03	1.9900E-03	6	0.00600000	0.75899988
51	2.0200E-03	2.0100E-03	3	0.00300000	0.76199988
52	2.0400E-03	2.0300E-03	2	0.00200000	0.76399987
53	2.0600E-03	2.0500E-03	4	0.00400000	0.76799987
54	2.0800E-03	2.0700E-03	8	0.00800000	0.77599986
55	2.1000E-03	2.0900E-03	3	0.00300000	0.77899986
56	2.1200E-03	2.1100E-03	3	0.00300000	0.78199986
57	2.1400E-03	2.1300E-03	2	0.00200000	0.78399985
58	2.1600E-03	2.1500E-03	2	0.00200000	0.78599985
59	2.1800E-03	2.1700E-03	6	0.00600000	0.79199985
60	2.2000E-03	2.1900E-03	3	0.00300000	0.79499985
61	2.2200E-03	2.2100E-03	2	0.00200000	0.79699984
62	2.2400E-03	2.2300E-03	3	0.00300000	0.79999984
63	2.2600E-03	2.2500E-03	2	0.00200000	0.80199984
64	2.2800E-03	2.2700E-03	3	0.00300000	0.80499984
65	2.3000E-03	2.2900E-03	4	0.00400000	0.80899983
66	2.3200E-03	2.3100E-03	3	0.00300000	0.81199983
67	2.3400E-03	2.3300E-03	4	0.00400000	0.81599982
69	2.3800E-03	2.3700E-03	9	0.00900000	0.82499982
70	2.4000E-03	2.3900E-03	1	0.00100000	0.82599981
71	2.4200E-03	2.4100E-03	2	0.00200000	0.82799981
73	2.4600E-03	2.4500E-03	1	0.00100000	0.82899980
74	2.4800E-03	2.4700E-03	1	0.00100000	0.82999980
75	2.5000E-03	2.4900E-03	2	0.00200000	0.83199979
76	2.5200E-03	2.5100E-03	3	0.00300000	0.83499979
77	2.5400E-03	2.5300E-03	2	0.00200000	0.83699979
78	2.5600E-03	2.5500E-03	2	0.00200000	0.83899979
79	2.5800E-03	2.5700E-03	2	0.00200000	0.84099978
80	2.6000E-03	2.5900E-03	1	0.00100000	0.84199978
81	2.6200E-03	2.6100E-03	1	0.00100000	0.84299977
82	2.6400E-03	2.6300E-03	2	0.00200000	0.84499977
83	2.6600E-03	2.6500E-03	4	0.00400000	0.84899976
84	2.6800E-03	2.6700E-03	5	0.00500000	0.85399976
85	2.7000E-03	2.6900E-03	2	0.00200000	0.85599975
87	2.7400E-03	2.7300E-03	1	0.00100000	0.85699975
88	2.7600E-03	2.7500E-03	4	0.00400000	0.86099974
90	2.8000E-03	2.7900E-03	1	0.00100000	0.86199974
91	2.8200E-03	2.8100E-03	3	0.00300000	0.86499973
92	2.8400E-03	2.8300E-03	3	0.00300000	0.86799973
93	2.8600E-03	2.8500E-03	2	0.00200000	0.86999973
94	2.8800E-03	2.8700E-03	3	0.00300000	0.87299973
97	2.9400E-03	2.9300E-03	1	0.00100000	0.87399972
99	2.9800E-03	2.9700E-03	2	0.00200000	0.87599972
100	3.0000E-03	2.9900E-03	3	0.00300000	0.87899972
101	3.0200E-03	3.0100E-03	2	0.00200000	0.88099971
102	3.0400E-03	3.0300E-03	2	0.00200000	0.88299971
103	3.0600E-03	3.0500E-03	4	0.00400000	0.88699970
104	3.0800E-03	3.0700E-03	2	0.00200000	0.88899970
105	3.1000E-03	3.0900E-03	2	0.00200000	0.89099970
106	3.1200E-03	3.1100E-03	4	0.00400000	0.89499969
107	3.1400E-03	3.1300E-03	1	0.00100000	0.89599968
108	3.1600E-03	3.1500E-03	4	0.00400000	0.89999968
109	3.1800E-03	3.1700E-03	1	0.00100000	0.90099967
111	3.2200E-03	3.2100E-03	1	0.00100000	0.90199967
112	3.2400E-03	3.2300E-03	2	0.00200000	0.90399966

INTERVAL	UPPER LIMIT	CLASS MARK	FREQ	DENSITY	CUMULATIVE
113	3.2600E-03	3.2500E-03	2	0.00200000	0.90599966
114	3.2800E-03	3.2700E-03	1	0.00100000	0.90699966
115	3.3000E-03	3.2900E-03	1	0.00100000	0.90799965
116	3.3200E-03	3.3100E-03	2	0.00200000	0.90999965
117	3.3400E-03	3.3300E-03	2	0.00200000	0.91199964
121	3.4200E-03	3.4100E-03	1	0.00100000	0.91299964
122	3.4400E-03	3.4300E-03	1	0.00100000	0.91399963
126	3.5200E-03	3.5100E-03	1	0.00100000	0.91499963
128	3.5600E-03	3.5500E-03	1	0.00100000	0.91599962
129	3.5800E-03	3.5700E-03	1	0.00100000	0.91699962
130	3.6000E-03	3.5900E-03	3	0.00300000	0.91999961
132	3.6400E-03	3.6300E-03	1	0.00100000	0.92099961
134	3.6800E-03	3.6700E-03	2	0.00200000	0.92299961
135	3.7000E-03	3.6900E-03	2	0.00200000	0.92499960
136	3.7200E-03	3.7100E-03	2	0.00200000	0.92699960
137	3.7400E-03	3.7300E-03	2	0.00200000	0.92899960
141	3.8200E-03	3.8100E-03	2	0.00200000	0.93099959
144	3.8800E-03	3.8700E-03	1	0.00100000	0.93199959
146	3.9200E-03	3.9100E-03	1	0.00100000	0.93299958
150	4.0000E-03	3.9900E-03	2	0.00200000	0.93499958
154	4.0800E-03	4.0700E-03	1	0.00100000	0.93599957
156	4.1200E-03	4.1100E-03	1	0.00100000	0.93699957
159	4.1800E-03	4.1700E-03	1	0.00100000	0.93799956
163	4.2600E-03	4.2500E-03	1	0.00100000	0.93899956
167	4.3400E-03	4.3300E-03	1	0.00100000	0.93999955
173	4.4600E-03	4.4500E-03	1	0.00100000	0.94099955
174	4.4800E-03	4.4700E-03	1	0.00100000	0.94199954
175	4.5000E-03	4.4900E-03	1	0.00100000	0.94299953
178	4.5600E-03	4.5500E-03	3	0.00300000	0.94599953
182	4.6400E-03	4.6300E-03	1	0.00100000	0.94699953
185	4.7000E-03	4.6900E-03	1	0.00100000	0.94799952
186	4.7200E-03	4.7100E-03	1	0.00100000	0.94899952
187	4.7400E-03	4.7300E-03	1	0.00100000	0.94999951
189	4.7800E-03	4.7700E-03	2	0.00200000	0.95199951
191	4.8200E-03	4.8100E-03	2	0.00200000	0.95399950
193	4.8600E-03	4.8500E-03	2	0.00200000	0.95599950
197	4.9400E-03	4.9300E-03	1	0.00100000	0.95699950
198	4.9600E-03	4.9500E-03	1	0.00100000	0.95799949
200	5.0000E-03	4.9900E-03	2	0.00200000	0.95999949
201			40	0.04000000	0.99999949

Z-STATISTICS

HISTOGRAM GENERATOR OUTPUT

SAMPLE	SAMP MEAN	SAMP STD DEV	HIST MEAN	HIST STD DEV
1000	-3.206379E 00	1.024886E-01	-3.187429E 00	2.253406E-01

INTERVAL	UPPER LIMIT	CLASS MARK	FREQ	DENSITY	CUMULATIVE
0	-3.5000E 00		4	0.00400000	0.00400000
1	-3.4900E 00	-3.4950E 00	1	0.00100000	0.00500000
3	-3.4700E 00	-3.4750E 00	1	0.00100000	0.00600000
4	-3.4600E 00	-3.4650E 00	1	0.00100000	0.00700000
5	-3.4500E 00	-3.4550E 00	3	0.00300000	0.01000000
6	-3.4400E 00	-3.4450E 00	7	0.00700000	0.01700000
7	-3.4300E 00	-3.4350E 00	2	0.00200000	0.01900000
8	-3.4200E 00	-3.4250E 00	3	0.00300000	0.02200000
9	-3.4100E 00	-3.4150E 00	6	0.00600000	0.02800000
10	-3.4000E 00	-3.4050E 00	5	0.00500000	0.03300000
11	-3.3900E 00	-3.3950E 00	6	0.00600000	0.03900000
12	-3.3800E 00	-3.3850E 00	9	0.00900000	0.04800000
13	-3.3700E 00	-3.3750E 00	10	0.01000000	0.05800000
14	-3.3600E 00	-3.3650E 00	8	0.00800000	0.06600000
15	-3.3500E 00	-3.3550E 00	14	0.01400000	0.08000000
16	-3.3400E 00	-3.3450E 00	15	0.01500000	0.09500000
17	-3.3300E 00	-3.3350E 00	13	0.01300000	0.10800000
18	-3.3200E 00	-3.3250E 00	13	0.01300000	0.12100000
19	-3.3100E 00	-3.3150E 00	24	0.02400000	0.14499999
20	-3.3000E 00	-3.3050E 00	18	0.01800000	0.16299999
21	-3.2900E 00	-3.2950E 00	35	0.03500000	0.19799999
22	-3.2800E 00	-3.2850E 00	22	0.02200000	0.21999999
23	-3.2700E 00	-3.2750E 00	22	0.02200000	0.24199999
24	-3.2600E 00	-3.2650E 00	31	0.03100000	0.27299999
25	-3.2500E 00	-3.2550E 00	28	0.02800000	0.30099999
26	-3.2400E 00	-3.2450E 00	44	0.04400000	0.34499999
27	-3.2300E 00	-3.2350E 00	33	0.03300000	0.37799999
28	-3.2200E 00	-3.2250E 00	34	0.03400000	0.41199999
29	-3.2100E 00	-3.2150E 00	30	0.03000000	0.44199998
30	-3.2000E 00	-3.2050E 00	40	0.04000000	0.48199998
31	-3.1900E 00	-3.1950E 00	56	0.05600000	0.53799998
32	-3.1800E 00	-3.1850E 00	31	0.03100000	0.56899998
33	-3.1700E 00	-3.1750E 00	43	0.04300000	0.61199997
34	-3.1600E 00	-3.1650E 00	40	0.04000000	0.65199997
35	-3.1500E 00	-3.1550E 00	36	0.03600000	0.68799997
36	-3.1400E 00	-3.1450E 00	46	0.04600000	0.73399997
37	-3.1300E 00	-3.1350E 00	24	0.02400000	0.75799996
38	-3.1200E 00	-3.1250E 00	22	0.02200000	0.77999996
39	-3.1100E 00	-3.1150E 00	18	0.01800000	0.79799996
40	-3.1000E 00	-3.1050E 00	35	0.03500000	0.83299996
41	-3.0900E 00	-3.0950E 00	19	0.01900000	0.85199995

INTERVAL	UPPER LIMIT	CLASS MARK	FREQ	DENSITY	CUMULATIVE
42	-3.0800E 00	-3.0850E 00	31	0.03100000	0.88299995
43	-3.0700E 00	-3.0750E 00	19	0.01900000	0.90199994
44	-3.0600E 00	-3.0650E 00	20	0.02000000	0.92199994
45	-3.0500E 00	-3.0550E 00	14	0.01400000	0.93599994
46	-3.0400E 00	-3.0450E 00	13	0.01300000	0.94899993
47	-3.0300E 00	-3.0350E 00	11	0.01100000	0.95999993
48	-3.0200E 00	-3.0250E 00	6	0.00600000	0.96599993
49	-3.0100E 00	-3.0150E 00	12	0.01200000	0.97799993
50	-3.0000E 00	-3.0050E 00	9	0.00900000	0.98699992
51	-2.9900E 00	-2.9950E 00	4	0.00400000	0.99099991
52	-2.9800E 00	-2.9850E 00	4	0.00400000	0.99499991
54	-2.9600E 00	-2.9650E 00	2	0.00200000	0.99699990
55	-2.9500E 00	-2.9550E 00	2	0.00200000	0.99899990
57	-2.9300E 00	-2.9350E 00	1	0.00100000	0.99999990
101			0	0.00000000	0.99999990

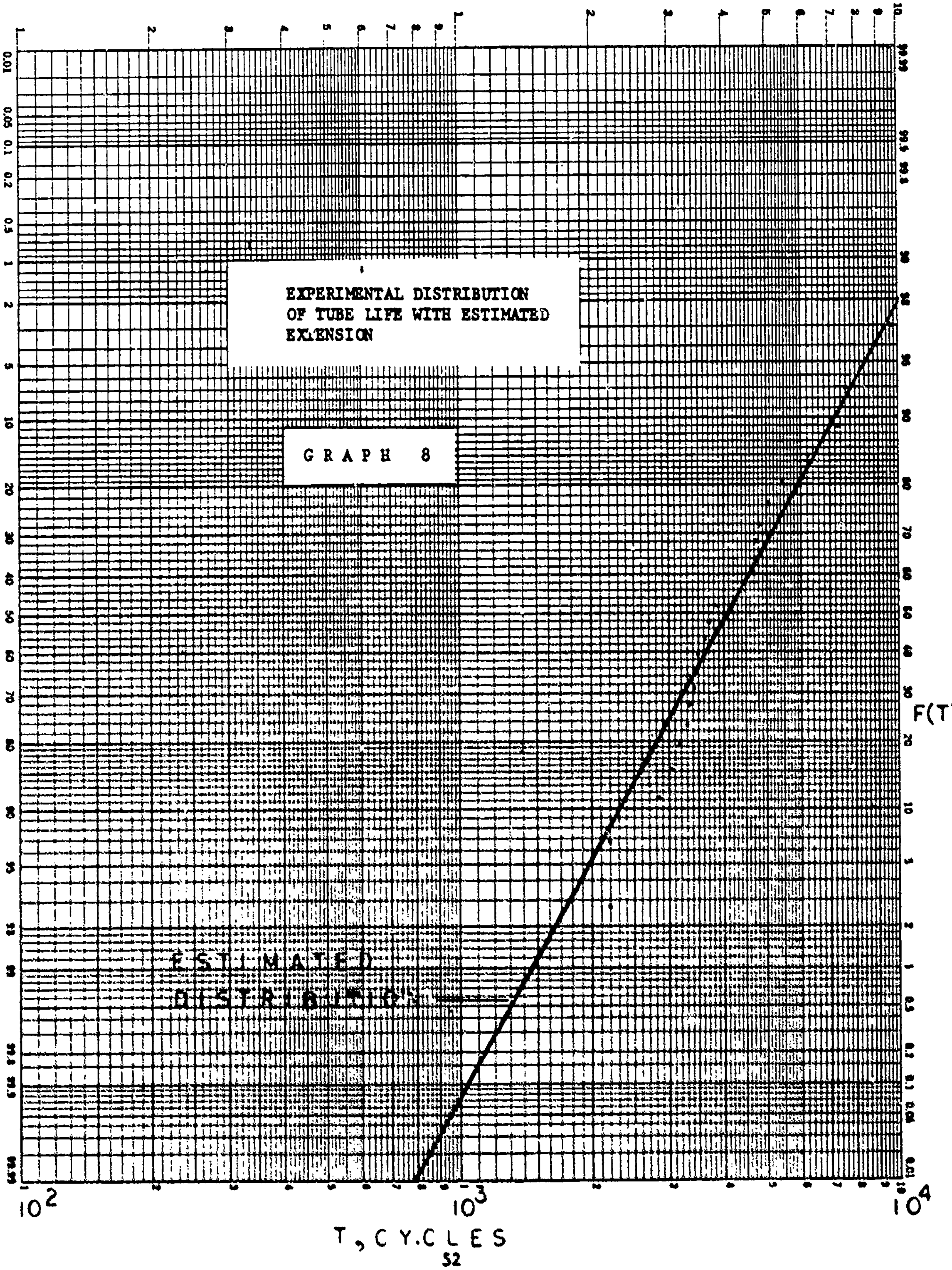
APPENDIX

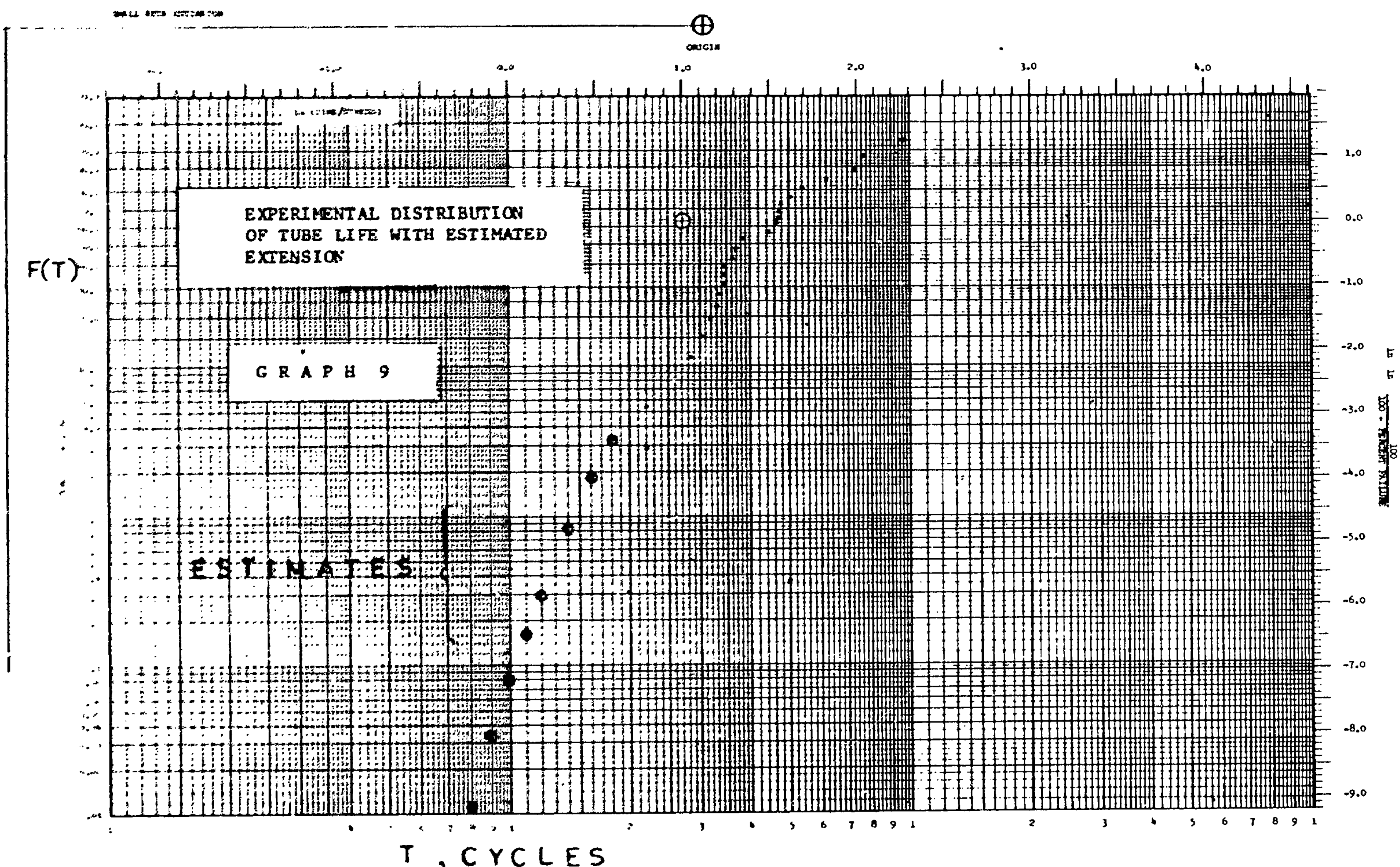
The primary data on tube life which forms the basis of the assertion that $F(t)$ is log-normal was obtained for the M113 cannon. This is given in table 1. The 24 failure times (cycles of max rated pressure) are listed by rank together with the median rank statistic for a sample of 24.

The median ranks were plotted versus failure times on log-normal graph paper and on Weibull graph paper in graphs 8 and 9, respectively. As suggested by the appearance of the data on log-normal graph paper, a conservative estimate of the underlying distribution was drawn thru the data. Points from the lower tail of estimated distribution were plotted on Weibull paper with the experimental data to provide additional visual indication of the tenability of the log-normality assumption versus alternative assumptions. For example, the estimated points seem to fair more smoothly with the experimental points than would a straight line on Weibull paper.

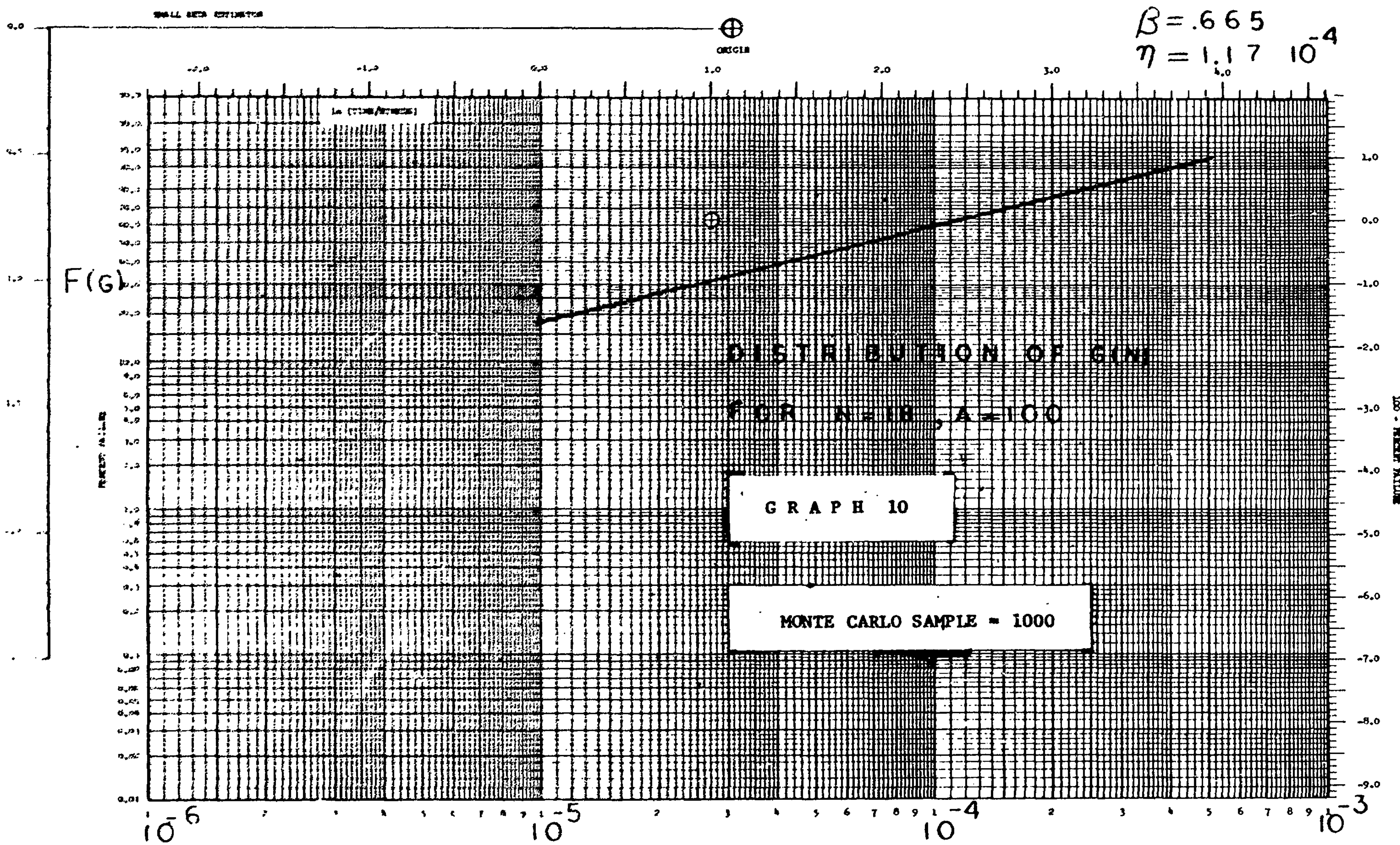
TABLE 1

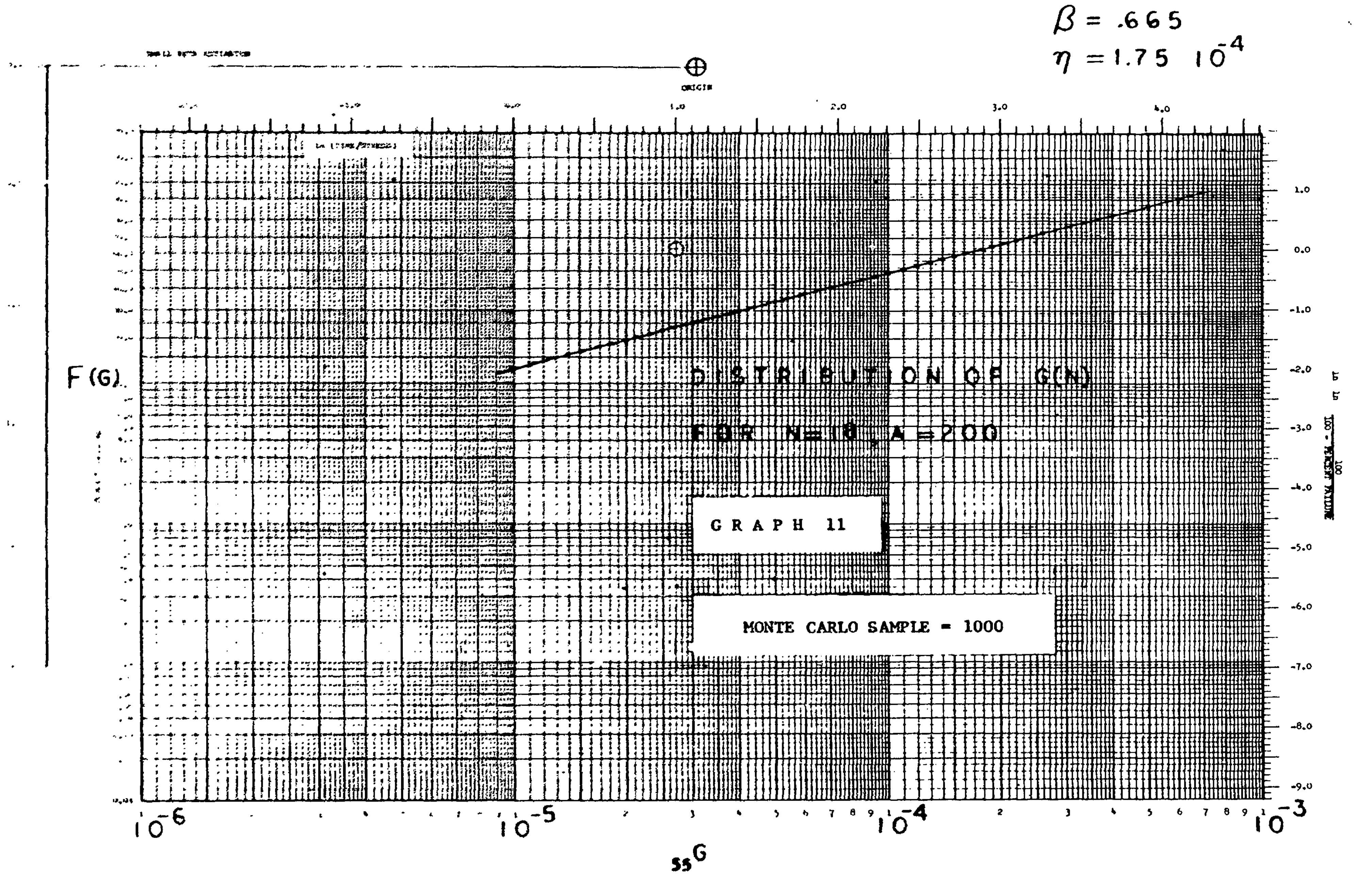
	Failure Times	Median Rank
1	2194	.0289
2	2196	.0698
3	2826	.1108
4	3025	.1518
5	3169	.1927
6	3309	.2337
7	3323	.2747
8	3438	.3156
9	3449	.3566
10	3476	.3976
11	3606	.4385
12	3698	.4795
13	3847	.5205
14	4451	.5615
15	4671	.6024
16	4685	.6434
17	4697	.6844
18	4768	.7253
19	5035	.7663
20	5397	.8073
21	6192	.8482
22	7238	.8892
23	7631	.9302
24	9652	.9711
aver	4272.68	


EXPERIMENTAL DISTRIBUTION OF TUBE LIFE WITH ESTIMATED EXTENSION
GRAPH 8
ESTIMATED DISTRIBUTION
F(T
10^2
10^3
10^4
T, CYCLES



ORIGIN
EXPERIMENTAL DISTRIBUTION
OF TUBE LIFE WITH ESTIMATED
EXTENSION
GRAPH 9
ESTIMATES
F(T)
T , CYCLES
ln ln $\frac{100}{100 - \text{PERCENT FAILURE}}$


$\beta = .665$
$\eta = 1.17 \quad 10^{-4}$
DISTRIBUTION OF G(N)
FOR N=18, A=100
GRAPH 10
MONTE CARLO SAMPLE = 1000
F(G)
G
ORIGIN
SMALL BETA ESTIMATOR
10^{-6}
10^{-5}
10^{-4}
10^{-3}


$\beta = .665$
$\eta = 1.75 \; 10^{-4}$
DISTRIBUTION OF G(N)
FOR N=10, A=200
GRAPH 11
MONTE CARLO SAMPLE = 1000
F(G)
ORIGIN
10^{-6}
10^{-5}
10^{-4}
10^{-3}
${}_{55}G$
1.0
2.0
3.0
4.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0
-5.0
-6.0
-7.0
-8.0
-9.0