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ARMY MATERIEL SYSTEMS ANALYSIS ACTIVITY ABERDEEN PROV--ETC F/G 12/1
SIMULATION OF SEQUENTIAL TESTS.(U)

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AMSAA-TR-241

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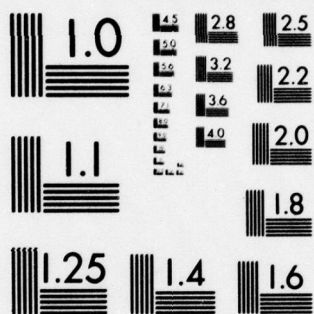
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) A computer program is presented which simulates a Probability Ratio Sequential Test (PRST) plan from MIL-STD 781C. Upon selection of an applicable test plan and a lower test MTBF (6), the simulation determines, for a chosen range of true MTBFs, (1) the probability of reaching maximum (total) test time before making a decision (to either accept or reject equipment) and (2) the probability of reaching the last failure in the test plan. Examples are available from selected test plans.		

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I wish to thank Harry B. Tanner for his ideas concerning the several "weighting schemes" and for his helpful suggestions regarding the CALCOMP plotting subroutines. I also wish to thank Gregory J. Gibson for getting me started on the project.

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SIMULATION OF SEQUENTIAL TESTS

1. INTRODUCTION

The computer program presented in this paper is offered as an aid to test planners and those who are concerned with the application of the Reliability Design Qualification and Production Acceptance Tests (Exponential Distribution), more specifically, the Probability Ratio Sequential Test (PRST) plans from MIL-STD-781C.

The PRST plans, which come under the category of statistical test plans, should be employed when a sequential test plan with minimal decision risks (10 to 20 percent) is desired. In the main, the PRST plans would be preferred to the fixed length test plans when the objective of the test is to accept material with a high mean-time-between-failures (MTBF) or reject material with a very low MTBF as quickly as possible.¹

In view of these considerations, the utilization of the methodology proposed should permit the test planner, equipped with a reasonable amount of practical experience with the PRST plans, to make certain probabilistic statements regarding termination points in the plans, namely (1) the likelihood of reaching the last failure and (2) the likelihood of reaching the maximum test time.

Historically, the PRST plans have no provision for establishing a definitive estimate of the true MTBF of an item prior to testing. Therefore, the expected time required for test completion may vary significantly. Consequently, program costs and schedules have to be planned to compensate for this range of uncertainty. However, with the help of the methodology delineated herein, one may be able to choose an appropriate test plan from MIL-STD-781C, select a lower test MTBF (θ_1), specify a realistic range of true MTBFs for consideration, implement the simulation, and finally obtain measures of the two likelihood estimates aforementioned, all of this in order to reduce the range of uncertainty and therefore, minimize program cost overruns.

2. APPLICATION OF MIL-STD-781C AND THEORETICAL CONSIDERATIONS

A typical PRST plan from MIL-STD-781C, regardless of the total number of failures and the total test time in the plan, will basically assume an appearance as depicted in Figure 1. Given that the decision risks, discrimination ratio, total number of failures, and accept-reject criteria are all in harmony, of concern is not the general shape or length of the PRST arrow (shaded area) but the two termination vectors located in the arrowhead. For simplicity, we may designate the last failure as F_L and the maximum total test time as T_M . The problem, then,

¹Proposed MIL-STD-781C Reliability Design Qualification and Production Acceptance Tests: Exponential Distribution.

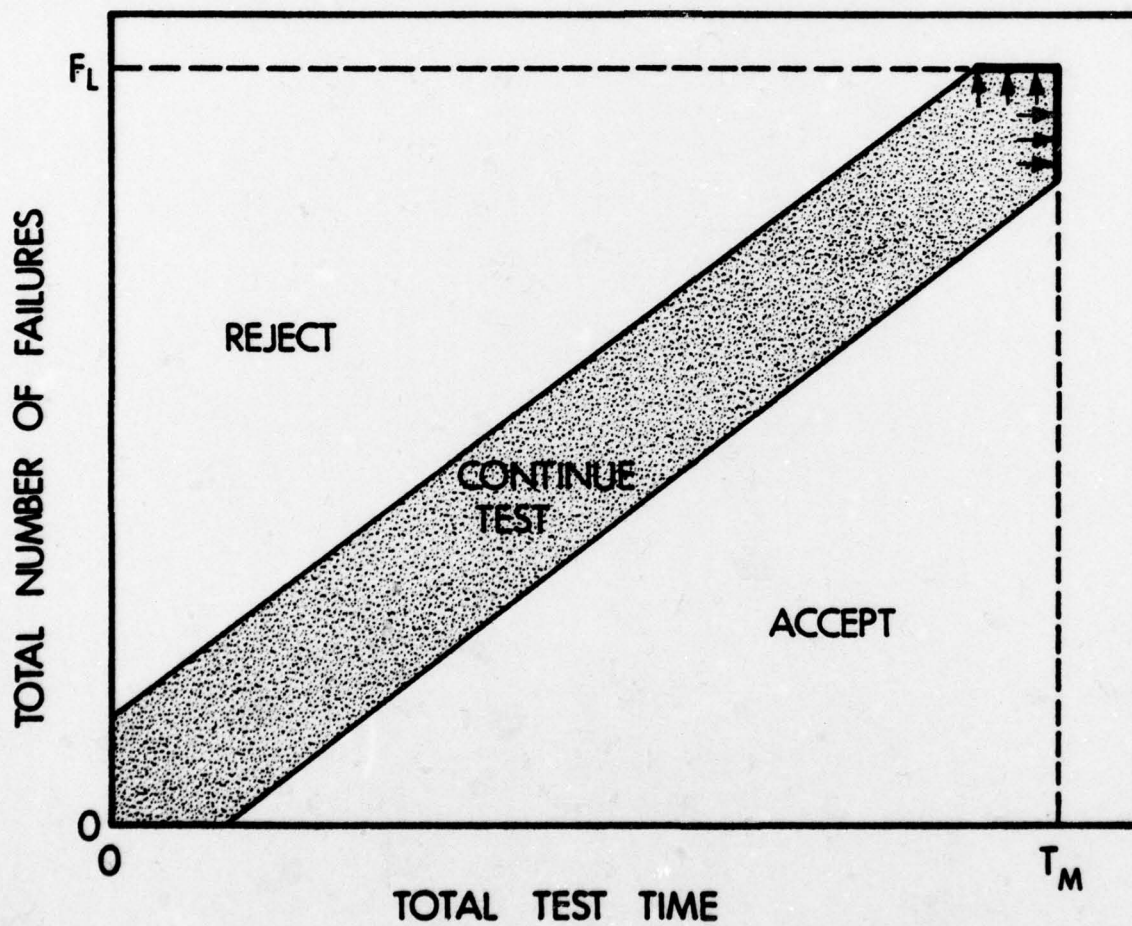


Figure 1. A Generalized PRST Plan.

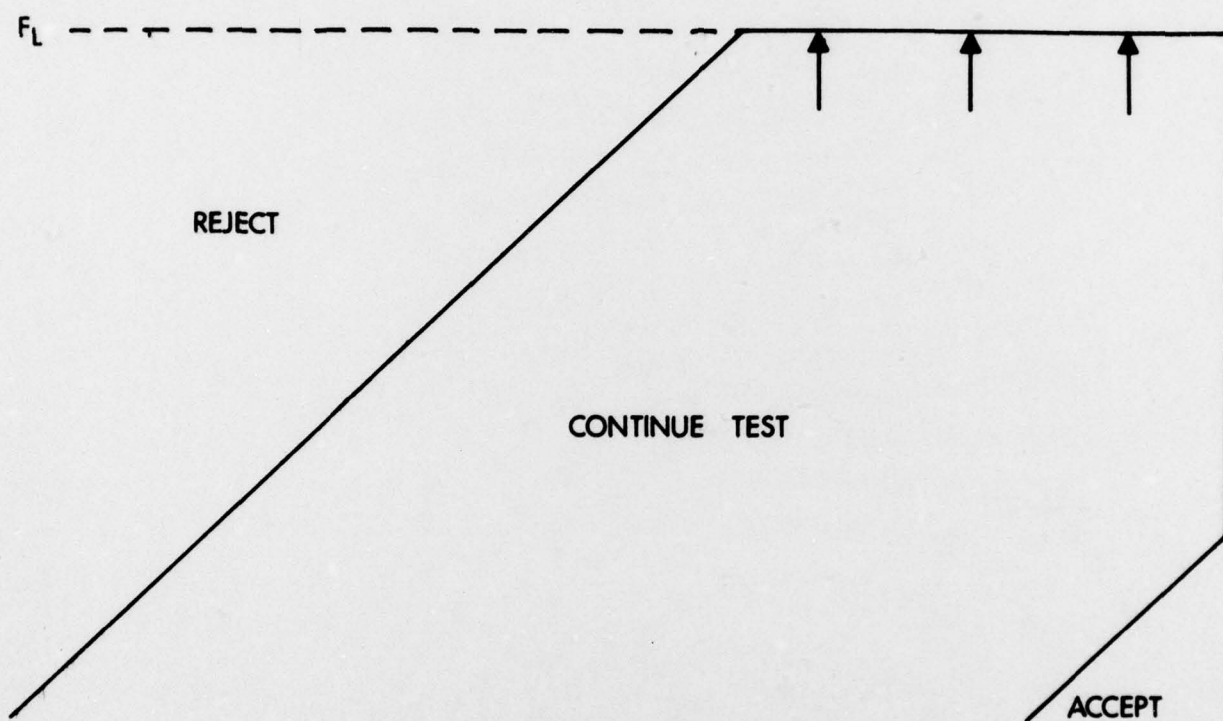


Figure 2. Last Failure Consideration.

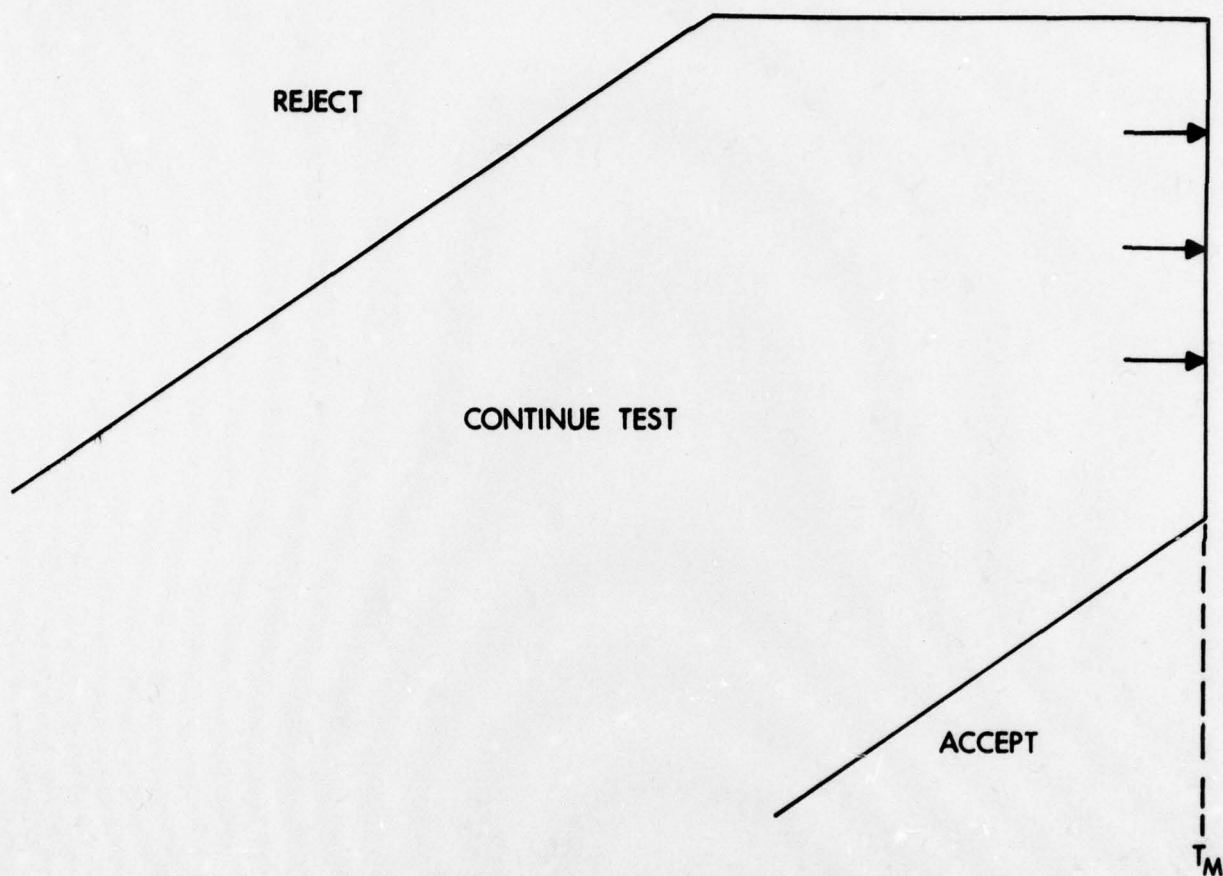


Figure 3. Maximum Test Time Consideration.

$$\begin{array}{c}
 \frac{1}{16n} + \frac{1}{8n} + \frac{1}{4n} + \underbrace{\left(\frac{1}{2n} + \frac{1}{n} + \frac{1}{2n} \right)}_{3 \text{ PTS}} + \frac{1}{4n} + \frac{1}{8n} + \frac{1}{16n} = 1 \\
 \underbrace{\hspace{10em}}_{5 \text{ PTS}} \\
 \underbrace{\hspace{10em}}_{7 \text{ PTS}} \\
 \underbrace{\hspace{10em}}_{9 \text{ PTS}}
 \end{array}$$

Figure 4. Weighting Scheme.

SUBROUTINE SUB3

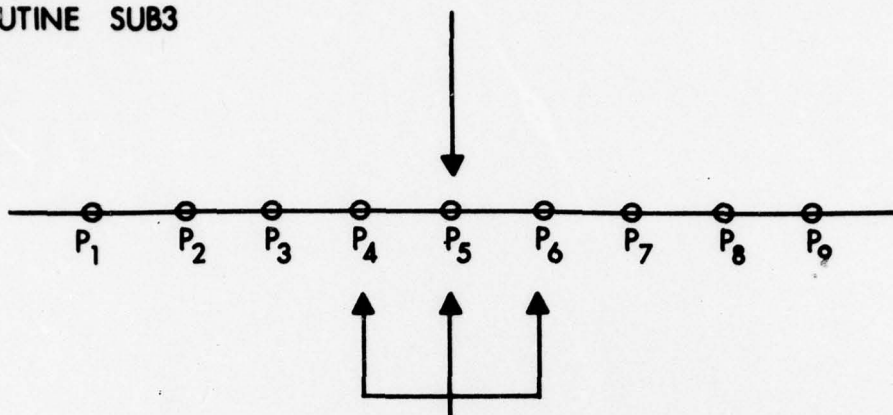


Figure 5. Curve Smoothing Scheme (3-Point)

SUBROUTINE SUB9

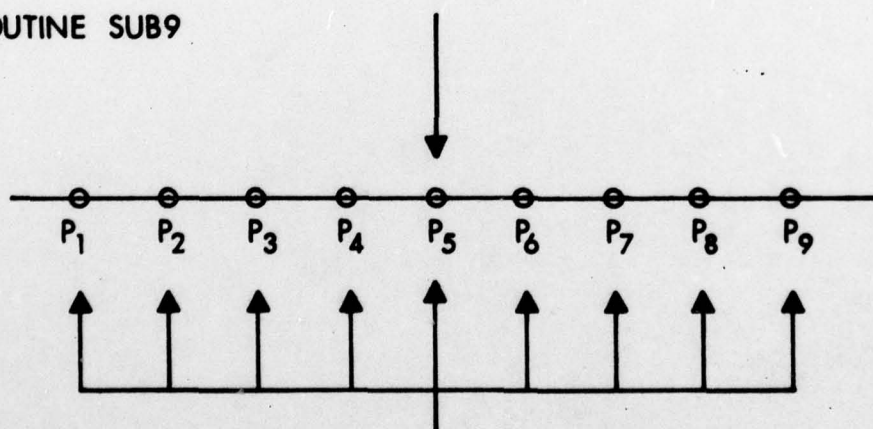


Figure 6. Curve Smoothing Scheme (9-Point)

becomes the following: When testing an item of equipment with the PRST plans, how often is the last failure reached? In other words, what is the likelihood of reaching F_L ?

In a similar manner, when testing an item of equipment with the PRST plans, how often is the maximum test time reached? That is, what is the likelihood of reaching T_M ? With these thoughts in mind, the purpose of the simulation, then, is to ascertain how often F_L and T_M are reached. (Figures 2, 3).

Once arrays of these likelihood estimates are determined for a representative range of true MTBFs, it may be feasible, strictly for the benefit of the CALCOMP plots, to effect minor changes to these arrays by employing a simple weighting scheme (Figure 4). By allowing a particular data point to have a weight of $1/n$, successive neighboring data points in either direction can be assigned weights of $1/2n$, $1/4n$, $1/8n$ and so on. This scheme essentially permits valuable information to be used from data points in proximity (Figure 5, 6). If one is not so inclined toward implementing such curve-smoothing techniques, the unsanitized raw data points are still available.

3. PROCEDURE FLOWCHART

All that the user of the computer program (henceforth, referred to as program MS 781C) need be concerned with is contained in this section. An adherence to the principles set forth in the procedure flowchart (Figure 7) and the preparation of the data input cards for program MS 781C (Table 2) should permit the user to investigate a wide variety of options. There are two areas regarding input, though, that may require clarification - (1) the test plan matrix and (2) the accept-reject criteria.

A summary of the test plan matrix for MIL-STD-781C is shown below.

TABLE 1. MILITARY STANDARD 781 C

Test Plan Number	Maximum Number of Failures	Maximum Test Time (Theta One Multiple)	The Minimum Number of Failures From Which To Reach Maximum Test Time
1	41	49.50	36
2	19	21.90	15
3	16	20.60	12
4	8	9.74	5
5	7	10.35	4
6	3	4.50	2
7	6	6.80	3
8	3	4.50	2

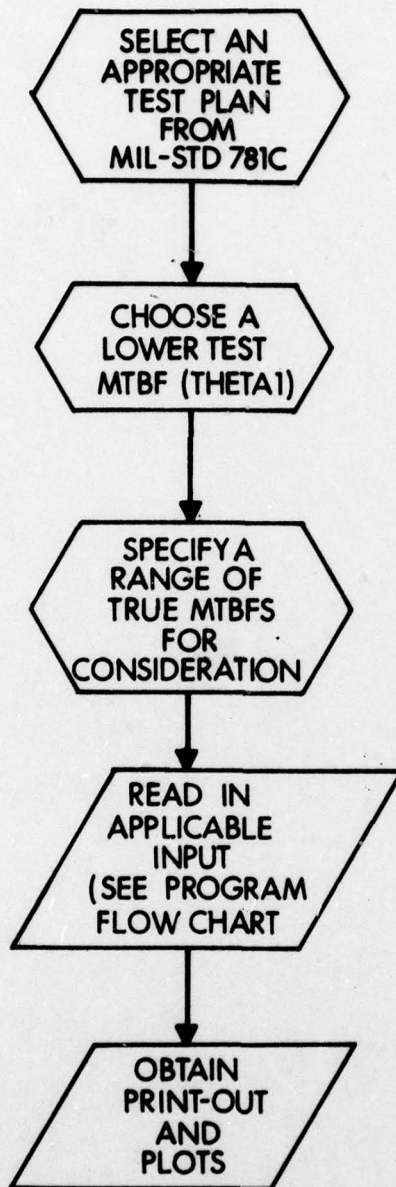


Figure 7. Procedure Flow Chart.

The test plan matrix (Table 1) is one of the required inputs to program MS 781C. It was defined in this way so that the user could specify the number of entries in the matrix (up to 25 entries as established in the program logic). Moreover, the test plan matrix was relegated to input status in order to provide flexibility for any user who chooses to submit a modified version of the test plan matrix, a version based on innovative truncation points perhaps.

Since the accept-reject criteria must be in accordance with the test plan matrix, it has also been placed in the domain of user-supplied input information. Care must be exercised, though, that the values for the reject line be input prior to the values for the accept line.

4. DESCRIPTION OF THE ALGORITHM

The essence of program MS 781C resides in a section of code (the algorithm) in the heart of the program. This set of instructions simulates the testing of an item of equipment using a typical PRST plan. The code, that is, set of instructions, makes use of two program counters. One counter corresponds to the last failure, F_L , and the other counter corresponds to the maximum test time, T_M . During each iteration of the simulation, an item of equipment can be either rejected, accepted, or put to further test (as exemplified by the continue test strip, Figure 1). If the item is rejected or accepted prior to reaching truncation, then no counters are incremented, and a new iteration is begun. If the item falls within the continue strip without a rejection or an acceptance, then another failure time is called for, and the above process is repeated.

In order to test against the maximum test time value, a particular failure time is compared with the T_M value. If that particular failure time is greater than or equal to the T_M value, then the T_M counter is incremented by one and a new iteration is begun. If that particular failure time is less than the T_M value, then another failure time is called for and queried in the same manner.

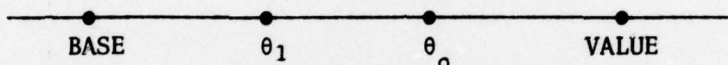
Similarly, in order to test against the last failure, a particular failure number is compared with the maximum failure number, F_L , to determine equality. If equality exists, then the F_L counter is incremented by one and a new iteration is begun. If equality does not exist; that is, if the particular failure number is less than the F_L value, then another failure is called for and queried in the same manner.

Now, if we allow each iteration to be an independent event, and if we conduct a large number of these trials, then the F_L and T_M

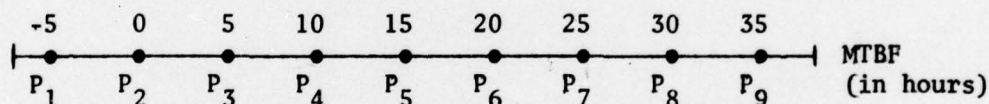
counters can be shown to be likelihood estimates for reaching the last failure and the maximum total test time, respectively. Furthermore, these likelihood estimates can be viewed in probabilistic terms.

5. RECOMMENDATIONS FROM COMPUTATIONAL EXPERIENCE

Once a PRST plan has been chosen and a value for the lower test MTBF (THETA ONE) has been designated, the only values that may require prudent selection are the three input parameters BASE, VALUE, and DELTAX (see Table 2, Appendix 1). Clearly, one would be interested in examining a range of true MTBFs encompassing both the lower test MTBF and the upper test MTBF (THETA ZERO). Something like the following might be of interest:



A problem may surface toward the lower end of the range of true MTBFs, though, if a value for the increment (DELTAX) is chosen too large. This problem could arise in subroutine SUB 9 where a neighborhood of nine (9) points is operated on:



For example, with a BASE MTBF of 15 hours and a DELTAX increment of 5 hours, the "lower-end" MTBF could attain a negative value, thereby creating a failure mode. However, the program logic is set up to handle this problem and will respond with a diagnostic to the user.

6. ILLUSTRATIVE EXAMPLES

In order to exemplify the range of possibilities that exists among the PRST plans, consider test plans II and VI (Table 3).

TABLE 3. COMPARISON OF TEST PLANS II AND VI

	<u>Decision Risks</u>	<u>Discrimination Ratio</u>	<u>Total Number of Failures</u>	<u>Total Test Time</u>
Test Plan II	20%	1.5:1	19	$21.90 \cdot \theta_1$
Test Plan VI	20%	3.0:1	3	$4.50 \cdot \theta_1$

Both test plans are based on the same risks. However, they differ in at least two respects: Test Plan VI has twice the discrimination ratio as Test Plan II, while Plan II is based on approximately six times as many failures as Plan VI.

Table IV below demonstrates simulation results for both plans at two specific data points - THETA ONE and THETA ZERO. In each cell, the top number gives the probability of reaching the maximum test time, $P(T_M)$, while the bottom number gives the probability of reaching the last failure, $P(F_L)$.

TABLE 4. SIMULATION RESULTS FOR TEST PLANS II AND VI

TEST PLAN	@ THETA ONE		@ THETA ZERO	
II	$P(T_M)$	= .12	$P(T_M)$	= .21
	$P(F_L)$	= .12	$P(F_L)$	= .08
VI	$P(T_M)$	= .13	$P(T_M)$	= .39
	$P(F_L)$	= .86	$P(F_L)$	= .38

7. SUMMARY

The purpose of this study has been to develop an algorithm that, with the aid of Monte Carlo simulation techniques, would allow one to formulate certain probabilistic statements regarding termination points in the PRST plans. The information derived from program MS 781C coupled with empirical data from practical field experience with the plans should permit the test planner to obtain a grasp on the likelihood of arriving at the concluding points in the plans. With this kind of information, the test planner may be able to minimize program costs due to personnel and materials and perhaps get a better handle on structuring test schedules.

APPENDIX I
TABLE 2. DATA INPUT CARDS

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APPENDIX I

TABLE 2. DATA INPUT CARDS

Data Card 1

Field 1	MAXNRF (I10)	The maximum number of failures for the test plan.
Field 2	NRITER (I10)	The number of iterations for the simulation e.g., 2000 or 10,000.
Field 3	NRTP (I10)	The number of the test plan being implemented.
Field 4	NRPLNS (I10)	The number of plans in the test plan matrix (not to exceed 25).
Field 5	BASE (F10.2)	The lowest MTBF in the range of MTBFs considered e.g., if an MTBF range of 50-250 is desired, then BASE would be 50.
Field 6	VALUE (F10.2)	The highest MTBF in the range of MTBFs considered.
Field 7	DELTA (F10.2)	The increment value between successive MTBFs.
Field 8	THETA1 (F10.2)	The lower test MTBF.

Data Card 2

This data card consists of the array containing the values for the reject line. Data must be arranged sequentially, eight (8) values per card, not to exceed 200 values, i.e. 25 cards.

Data Card 3

This data card consists of the array containing the values for the accept line. Data must be arranged sequentially, eight (8) values per card, not to exceed 200 values, i.e. 25 cards.

Data Card 4

Field 1	MATRIX (K, 1) (F10.2)	The maximum number of failures for the test plan.
Field 2	MATRIX (K, 2) (F10.2)	The maximum test time (THETA ONE Multiple) for the test plan.
Field 3	MATRIX (K, 3) (F10.2)	The minimum number of failures from which to reach maximum test time.

Note: For data card 4, the data cards must be arranged sequentially, i.e. the first card must begin with test plan 1, the second card must begin with test plan 2, and so on. Data must be arranged three (3) values per card, not to exceed 25 cards.

APPENDIX II
TABLE 5. DICTIONARY OF PROGRAM VARIABLES

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APPENDIX II

TABLE 5. DICTIONARY OF PROGRAM VARIABLES

	Variable	Type	Definition
1	NOF (I)	Program/Output	The number of failures in the test plan.
2	TMTBF (I)	Program/Output	The array of true MTBFs considered.
3	D (I)	Program	An array containing the lowest and highest true MTBF. Finds utility in the Fix Scale (FIXSCA) plotting subroutine.
4	TITLE (I)	Program	The arrays containing the symbol strings for the plotting subroutines.
5	AKOUNT (I) BKOUNT (I) CKOUNT (I) DKOUNT (I)	Program " " "	Arrays used for holding values from the counters.
6	MAXNRF	Input	The maximum number of failures for the test plan.
7	NRITER	Input	The number of iterations for the simulation.
8	NRTP	Input	The number of the test plan being implemented.
9	NRPLNS	Input	The number of plans in the test plan matrix.
10	BASE	Input	The lowest MTBF in the range of MTBFs considered.
11	VALUE	Input	The highest MTBF in the range of MTBFs considered.
12	DELTA	Input	The increment value between successive MTBFs.
13	THETA1	Input	The lower test MTBF.

APPENDIX II

TABLE 5. DICTIONARY OF PROGRAM VARIABLES (CONTINUED)

	Variable	Type	Definition
14	INTVLS	Program	The number of intervals for the accept-reject criteria.
15	NRMTBF	Program	The number of MTBFs in the range of MTBFs considered.
16	UPPER	Program	The value used for maximum test time.
17	LIMIT	Program	The minimum number of failures from which to reach maximum test time.
18	KOUNT	Program	A local counter used to store the number of times maximum test time is reached.
19	KNT	Program	A local counter used to store the number of times the last failure is reached.
20	NCASE	Program	A local counter for tracking the number of cases in the simulation.
21	ACCUM	Program	An accumulator used for storing an (exponential) time to failure.
22	NFAIL1	Program	The number of the failure being scrutinized in the simulation.
23	RLINE (I)	Input/Output	The array containing the values for the reject line.
24	ALINE (I)	Input/Output	The array containing the values for the accept line.
25	MATRIX (I)	Input/Output	An array containing the test plan matrix.

APPENDIX III

FIGURE 8. CURVE SMOOTHING SCHEME (5-POINT)

FIGURE 9. CURVE SMOOTHING SCHEME (7-POINT)

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SUBROUTINE SUB5

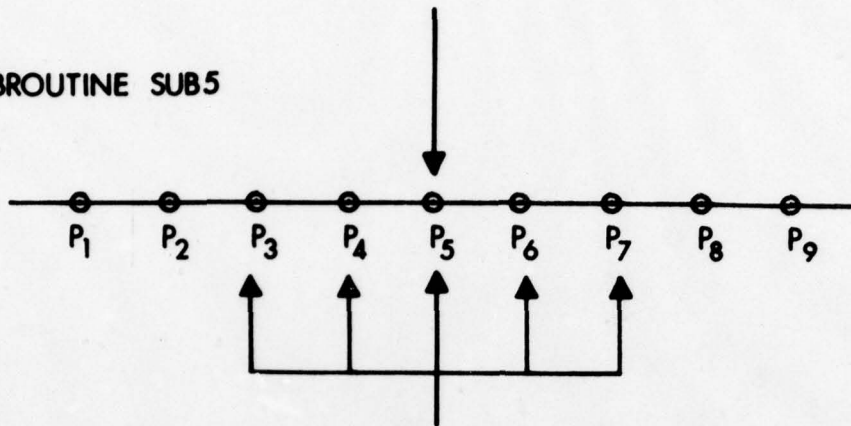


Figure 8. Curve Smoothing Scheme (5- Point)

SUBROUTINE SUB7

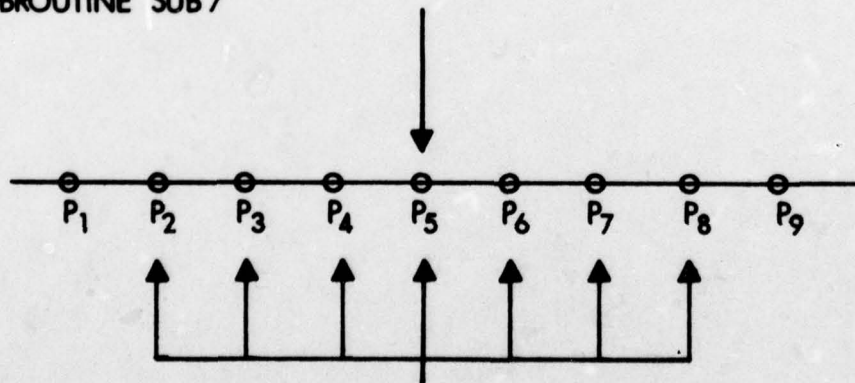


Figure 9. Curve Smoothing Scheme (7-Point)

APPENDIX IV
FIGURE 10. PROGRAM FLOW CHART

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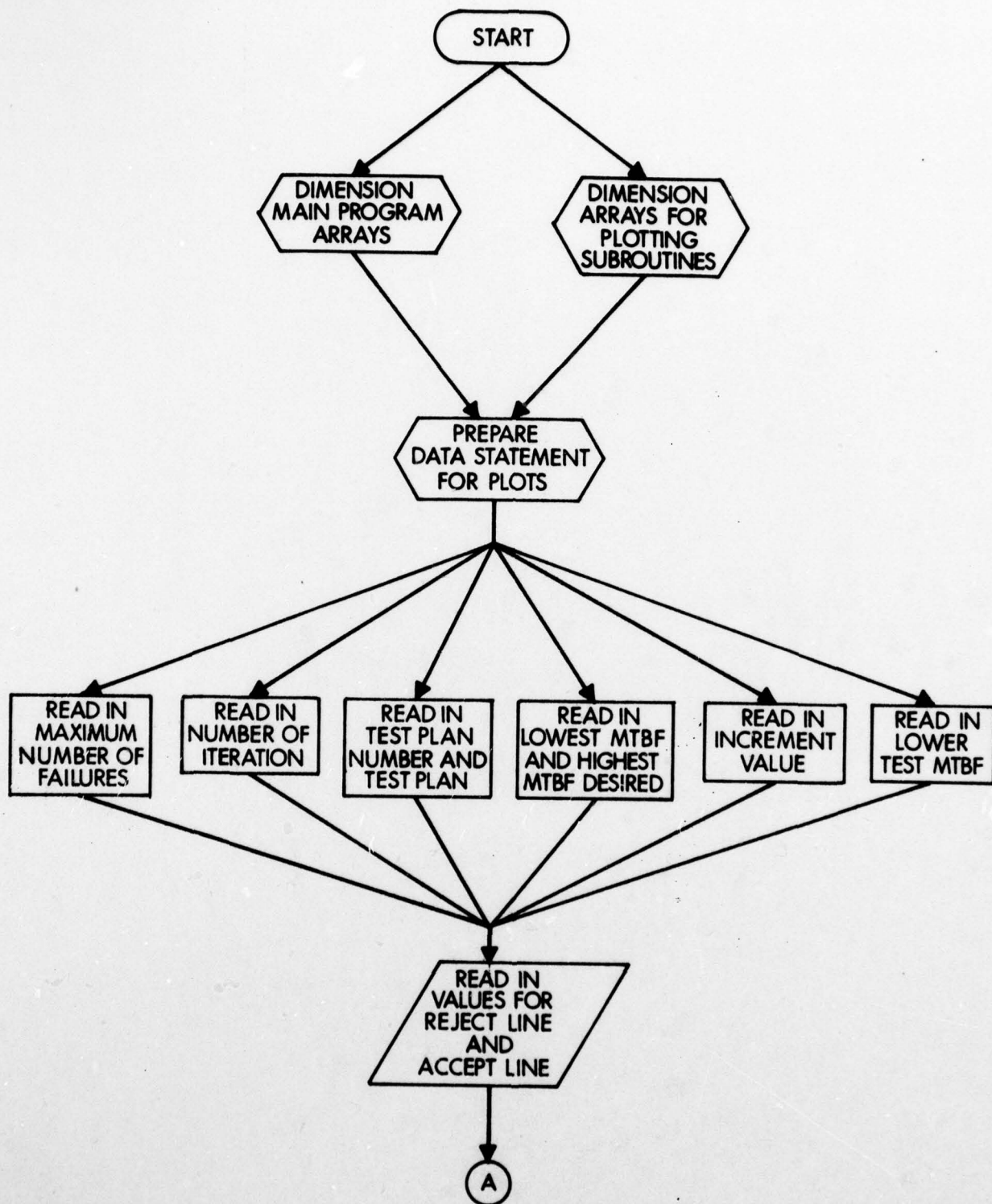
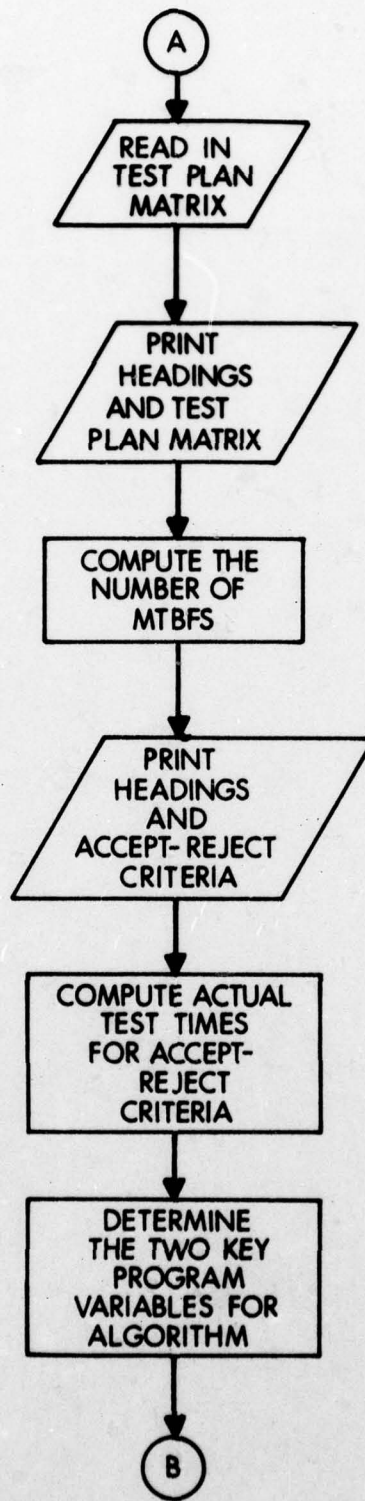
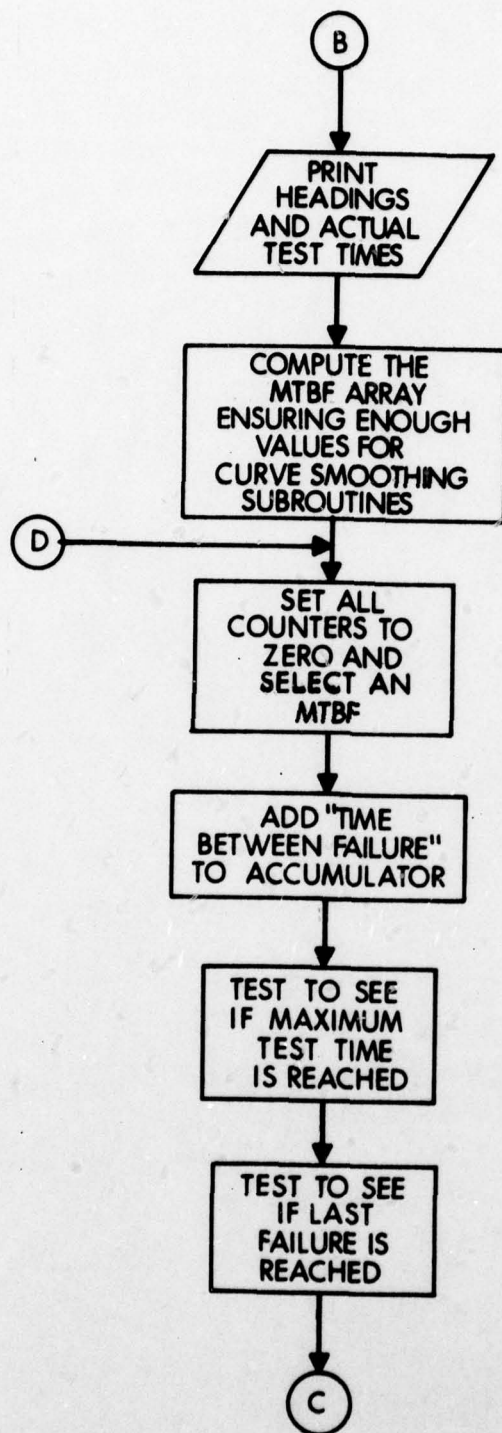
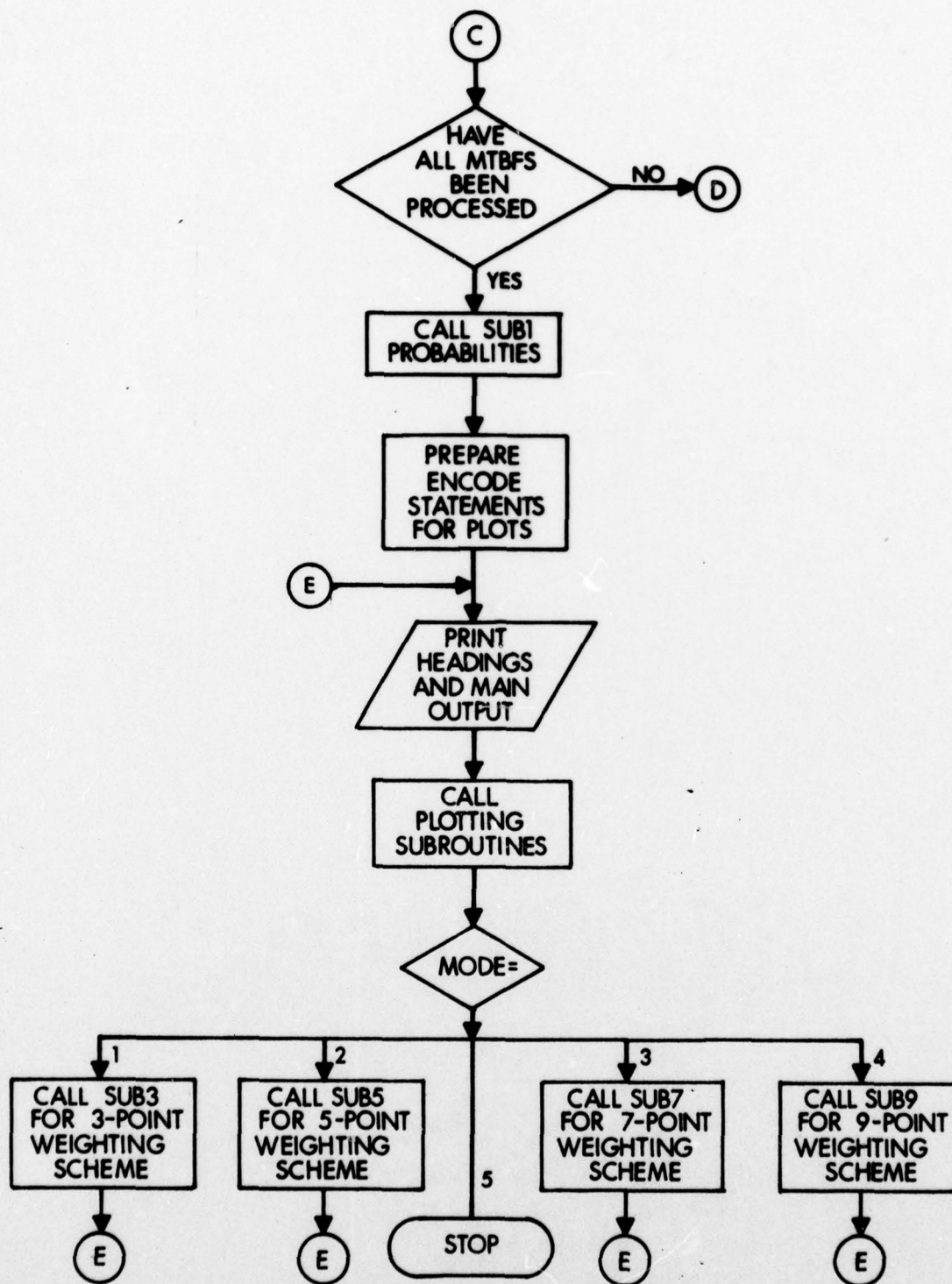


Figure 10. Program Flow Chart.







APPENDIX V
SUMMARY OF RESULTS - TEST PLANS I - VIII

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APPENDIX V

SUMMARY OF RESULTS - TEST PLANS I - VIII

The following table and figures give a brief summary of results for test plans I through VIII. In each case, THETA ONE has been chosen as 100 hours MTBF. Figures Ia - VIIIa depict the probability of reaching the last failure, $P(F_L)$, while Figures Ib - VIIIb depict the probability of reaching the maximum test time, $P(T_M)$.

TABLE 6

SUMMARY OF RESULTS

Test Plan PRST	Decision Risks	Discrimination Ratio	Probability of Reaching Last Failure $P(F_L)$	Probability of Reaching Maximum Test Time $P(T_M)$
1	10%	1.5:1	.16 @ θ_1 .07 @ θ_0	.05 @ θ_1 .16 @ θ_0
2	20%	1.5:1	.12 @ θ_1 .08 @ θ_0	.12 @ θ_1 .21 @ θ_0
3	10%	2.0:1	.08 @ θ_1 .04 @ θ_0	.07 @ θ_1 .20 @ θ_0
4	20%	2.0:1	.10 @ θ_1 .07 @ θ_0	.10 @ θ_1 .28 @ θ_0
5	10%	3.0:1	.15 @ θ_1 .07 @ θ_0	.07 @ θ_1 .37 @ θ_0
6	20%	3.0:1	.86 @ θ_1 .38 @ θ_0	.13 @ θ_1 .39 @ θ_0
7	30%	1.5:1	.44 @ θ_1 .33 @ θ_0	.26 @ θ_1 .52 @ θ_0
8	30%	2.0:1	.80 @ θ_1 .49 @ θ_0	.09 @ θ_1 .26 @ θ_0

MIL-STD 781 C TEST PLAN 1 C

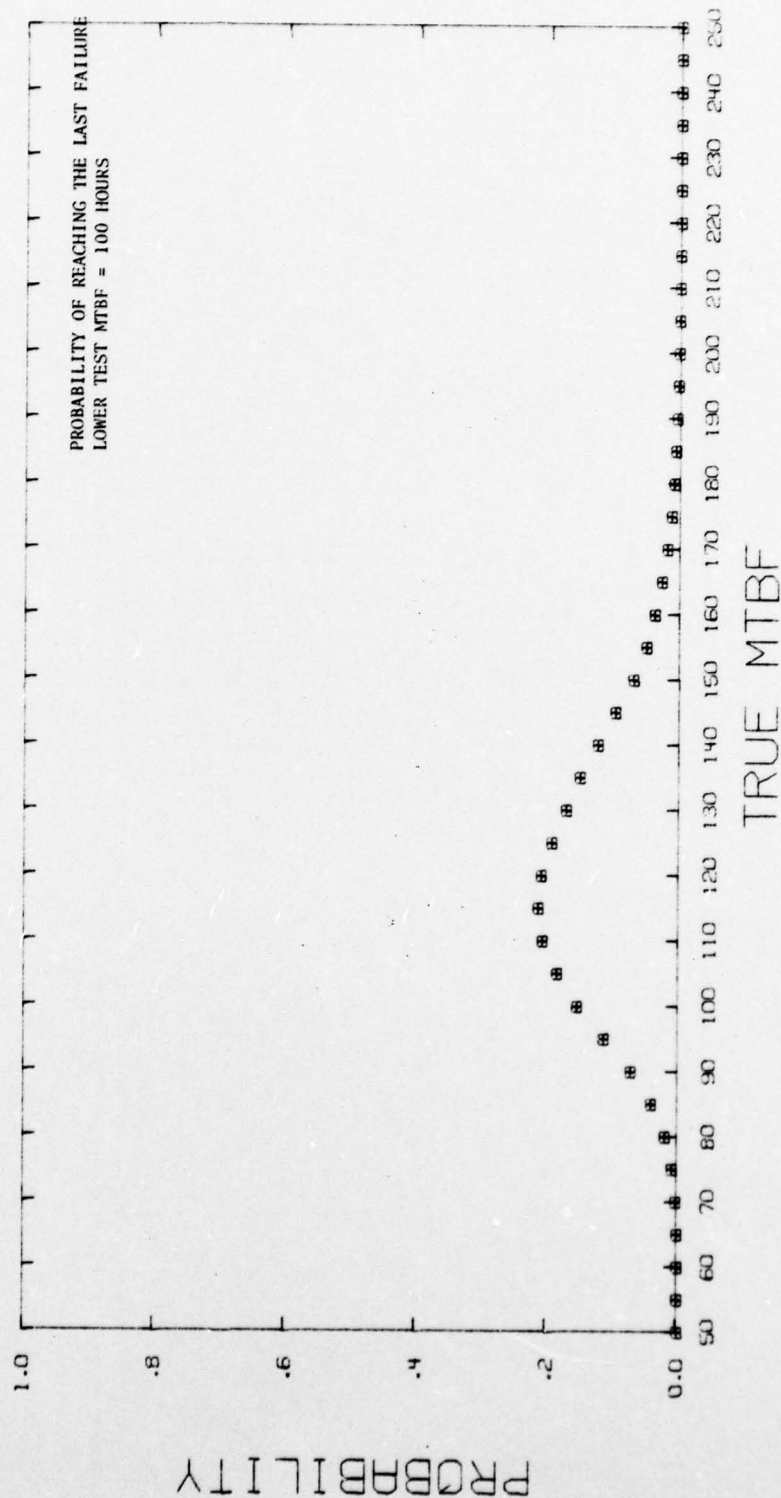


FIGURE 1A

MIL-STD 781 C TEST PLAN 2 C

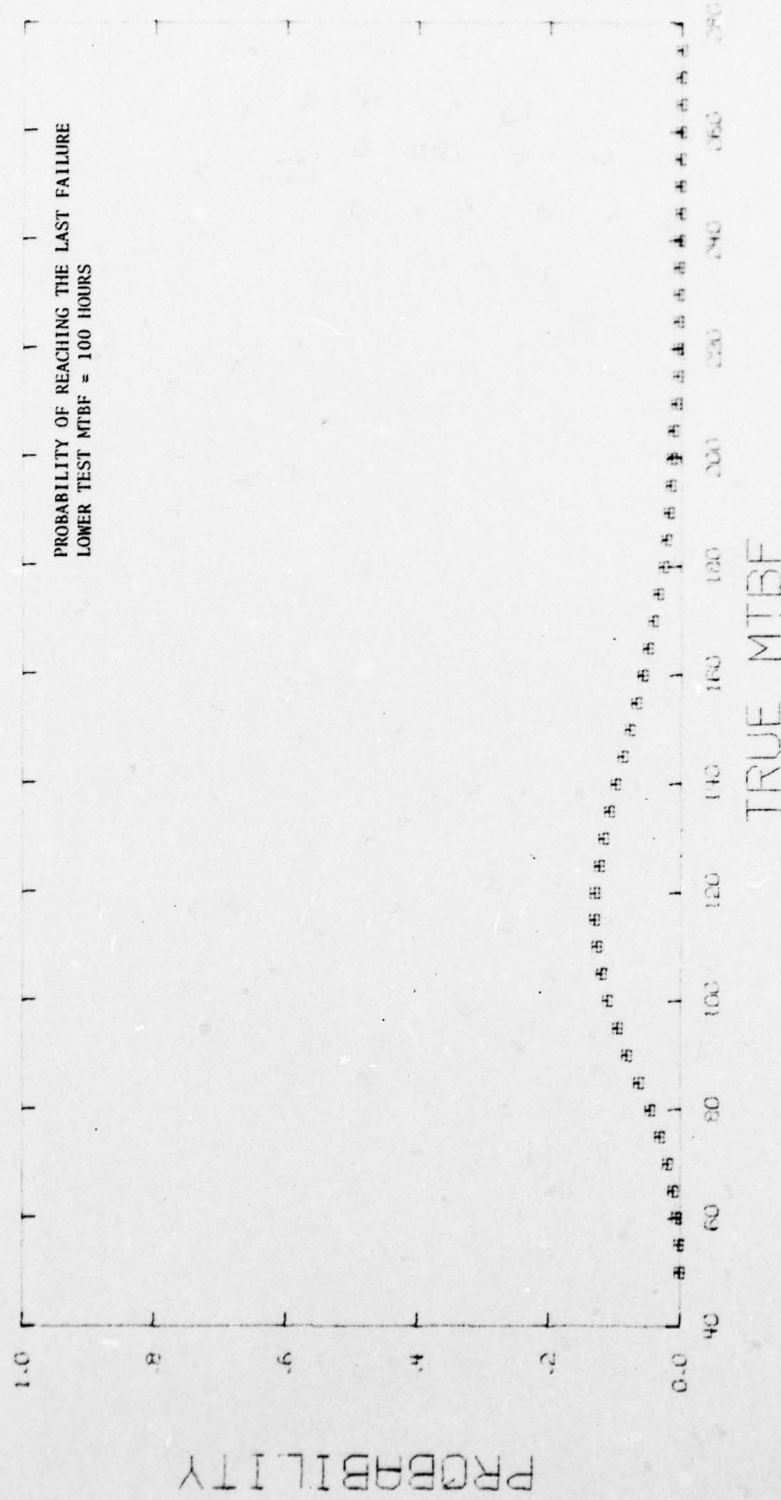


FIGURE 2A

MIL-STD 781 C TEST PLAN 3 C

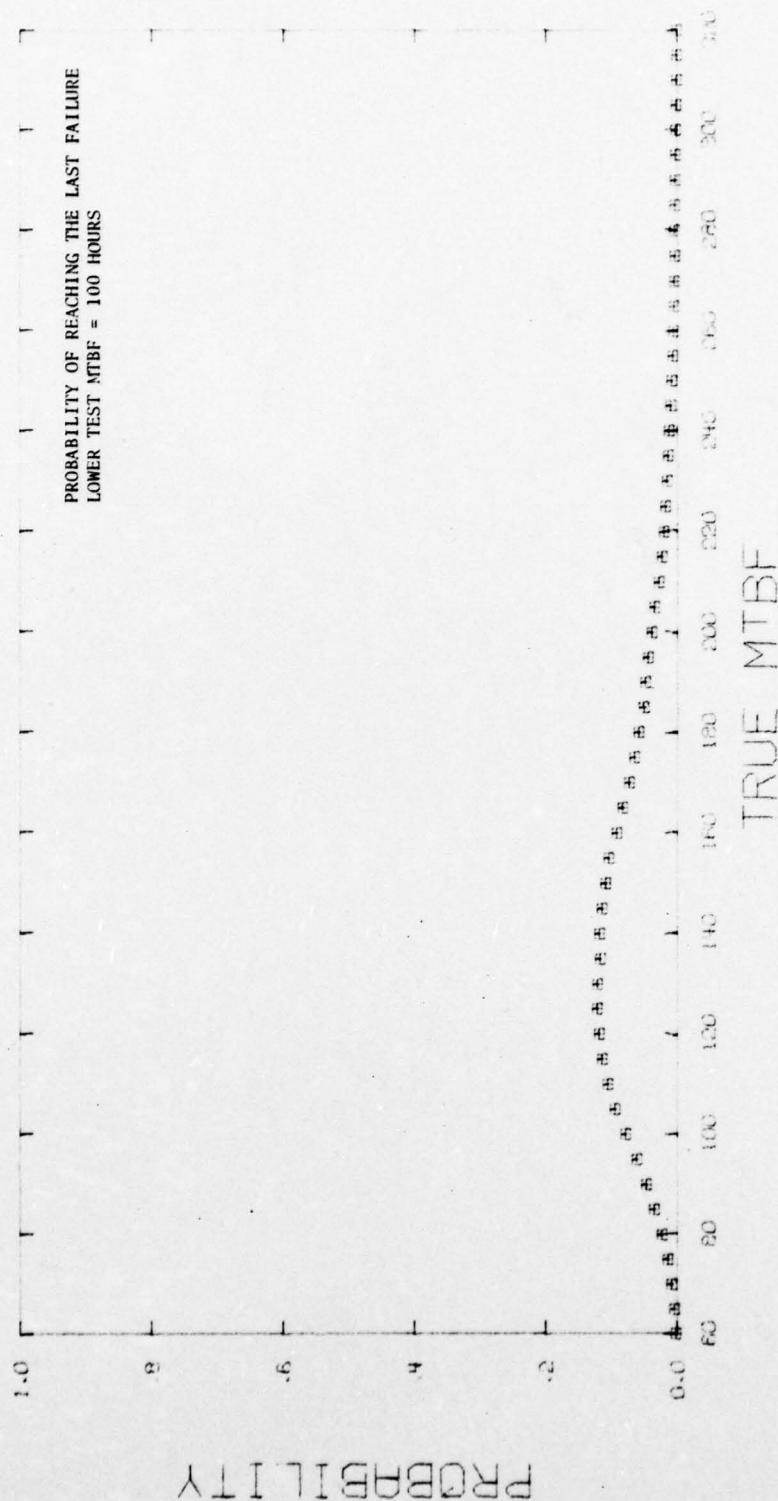
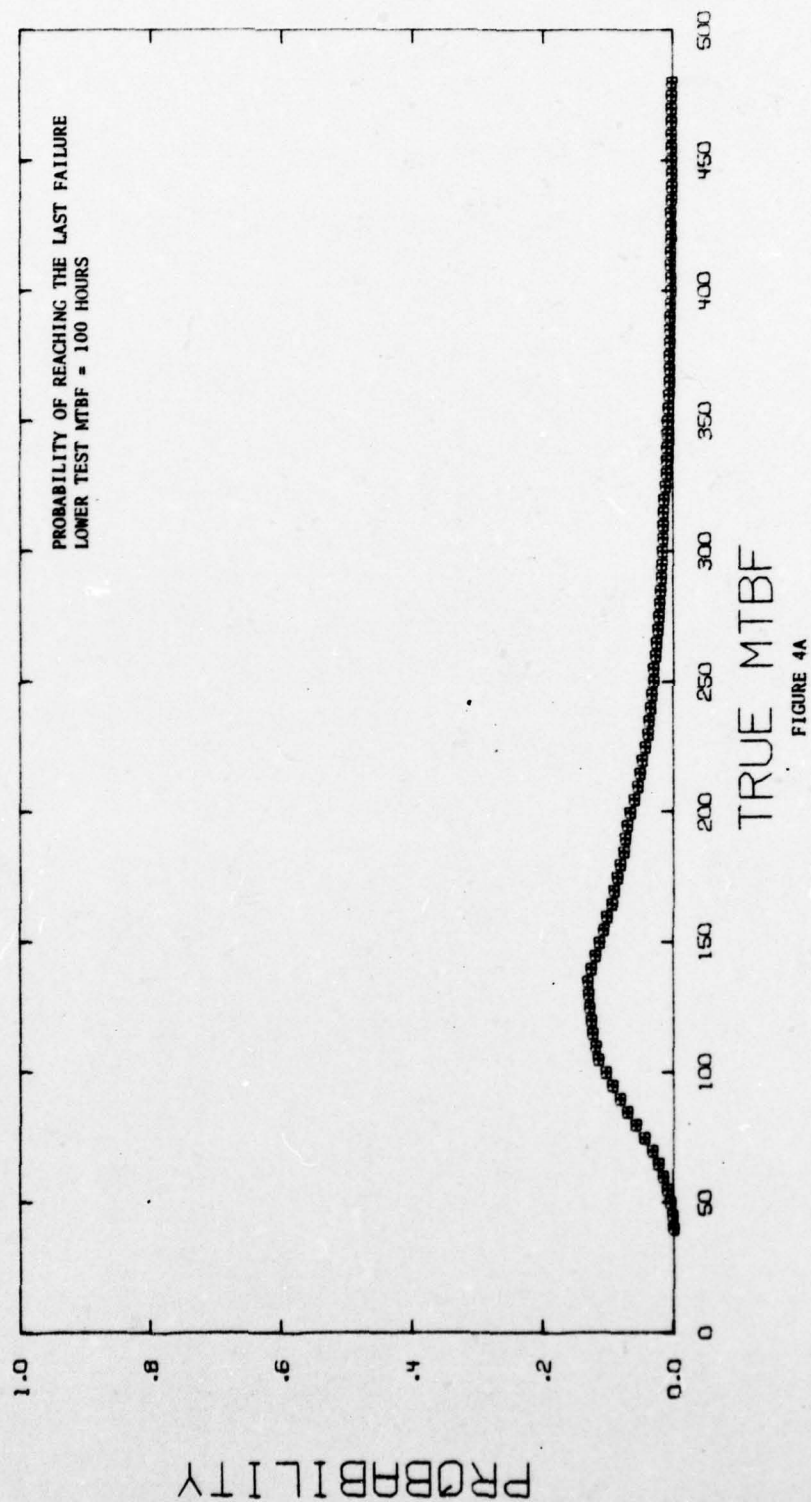
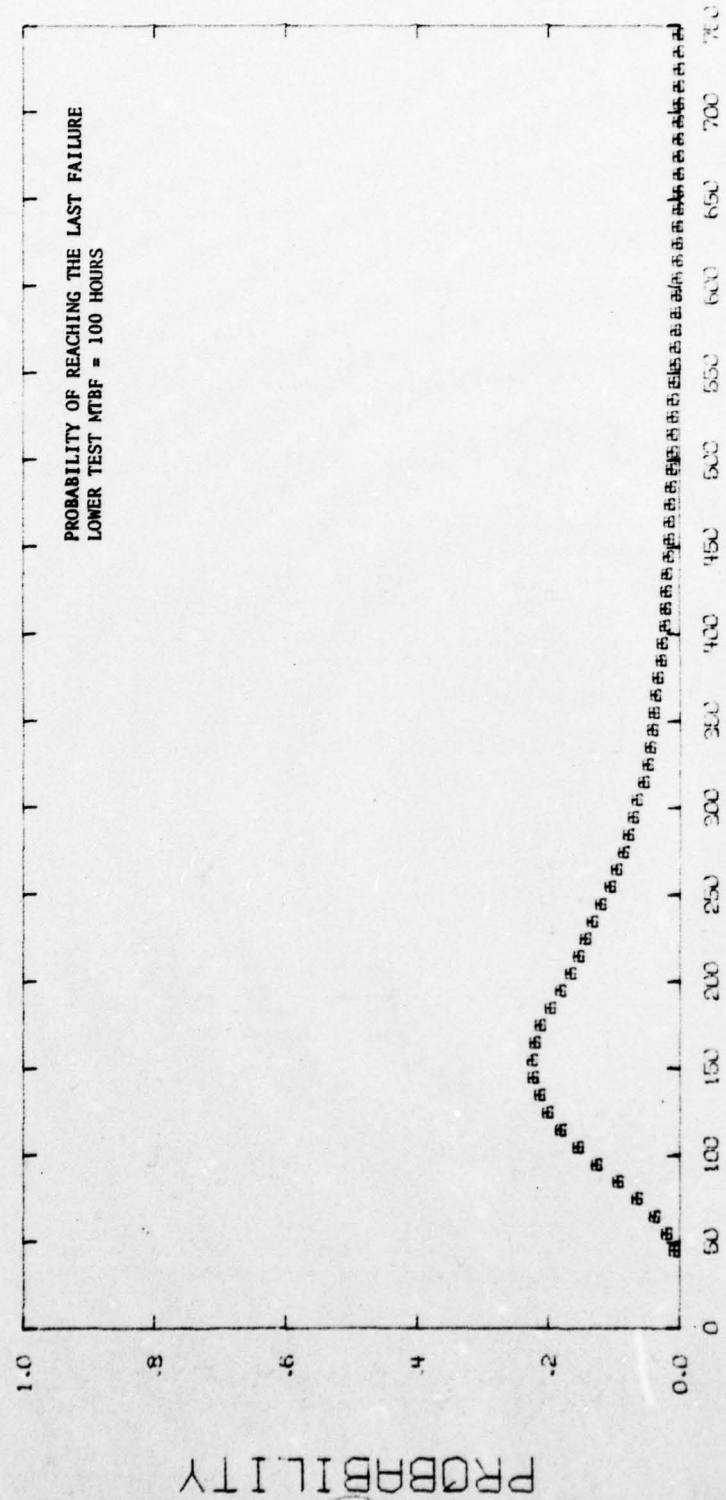


FIGURE 3A

MIL-STD 781 C
TEST PLAN 4 C

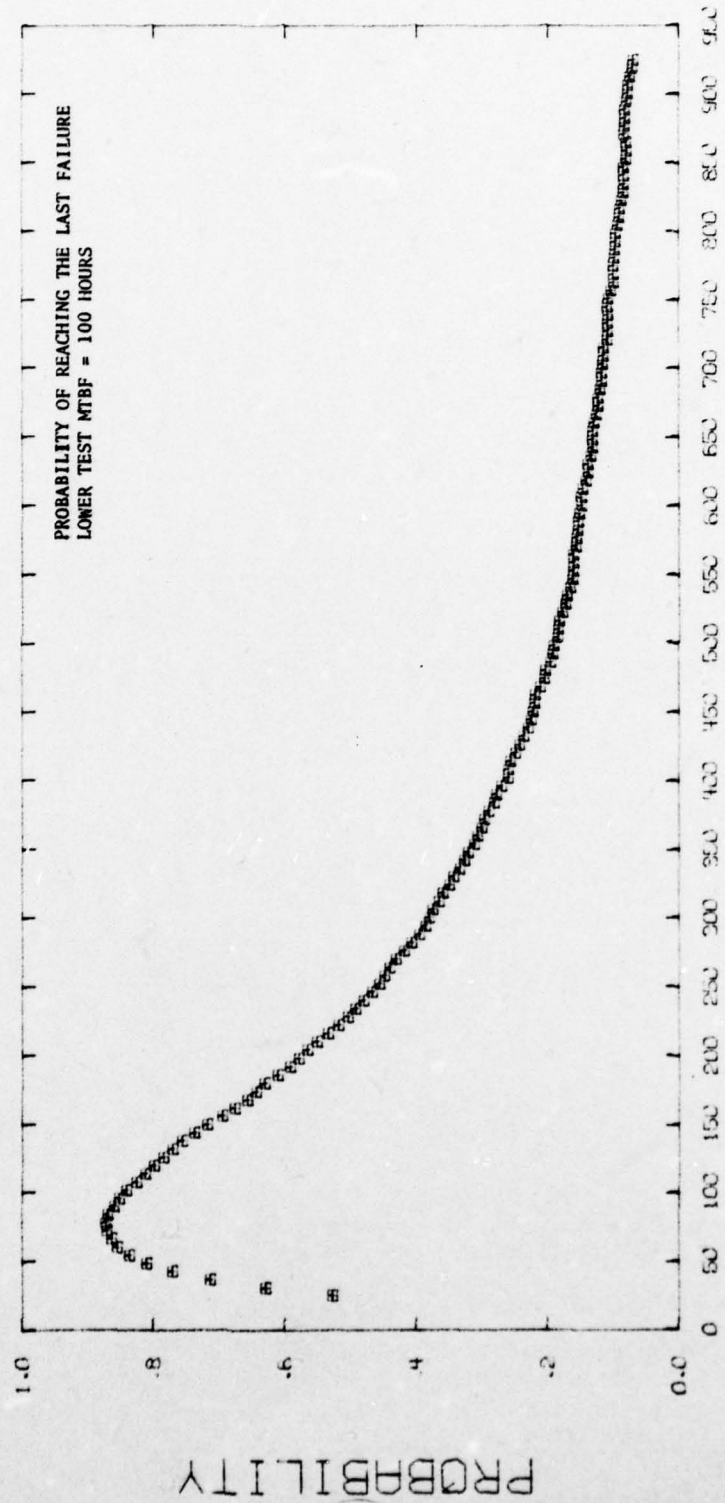


MIL-STD 781 C TEST PLAN 5 C



TRUE MTBF
FIGURE 5A

MIL-STD 781 C TEST PLAN 6 C



TRUE MTBF

FIGURE 6A

MIL-STD 781 C
TEST PLAN 7 C

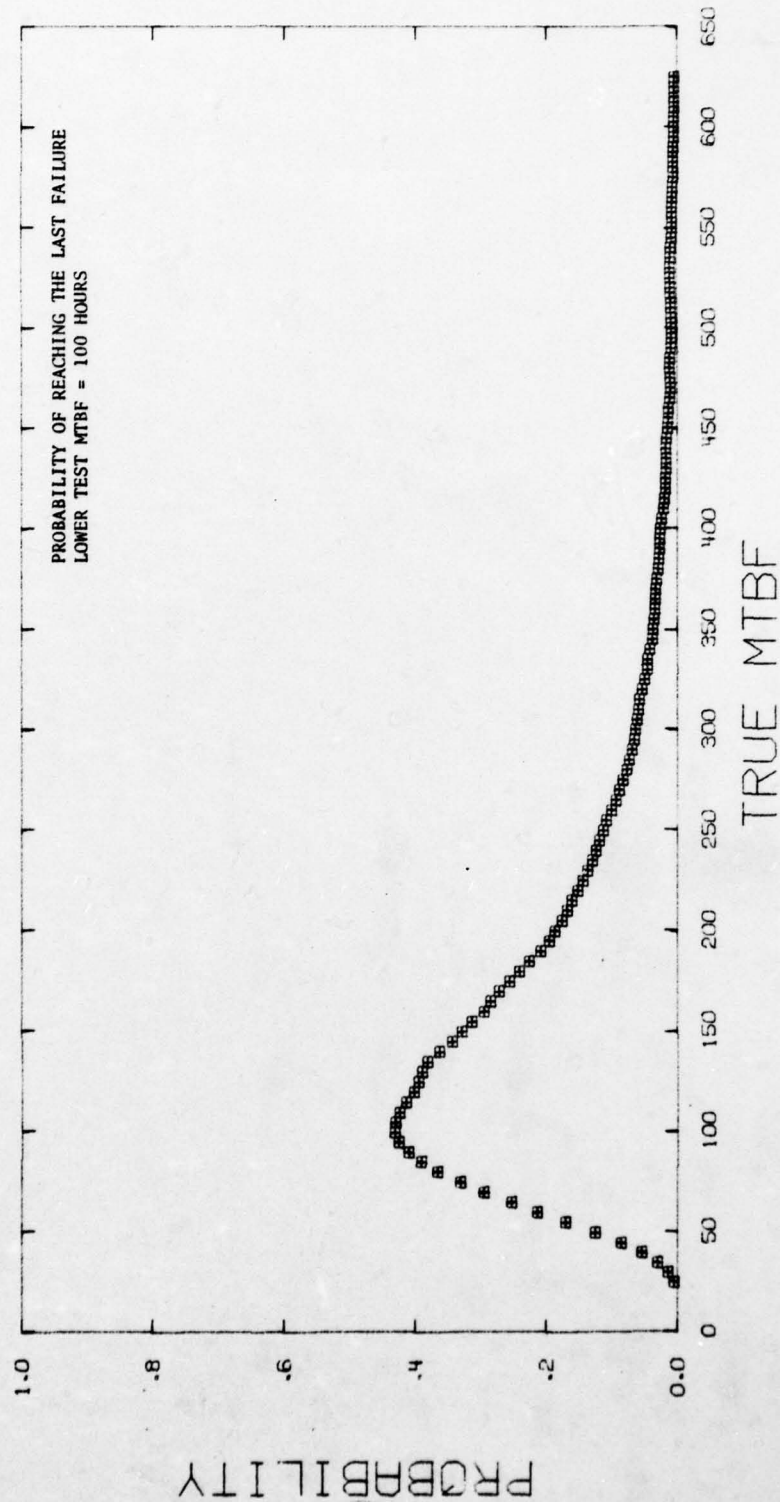
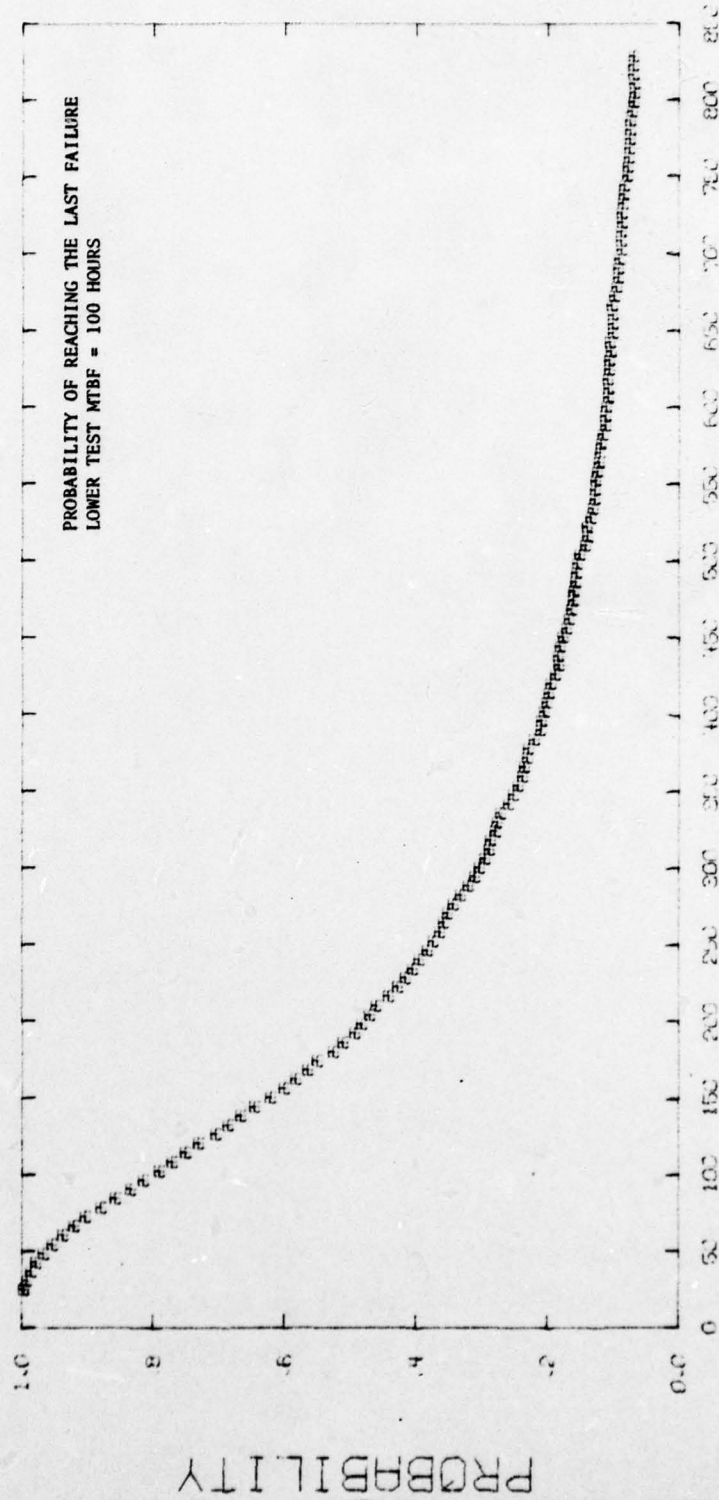


FIGURE 7A

MIL-STD 781 C TEST PLAN 8 C



TRUE MTBF

FIGURE 8A

MIL-STD 781 C TEST PLAN 1 C

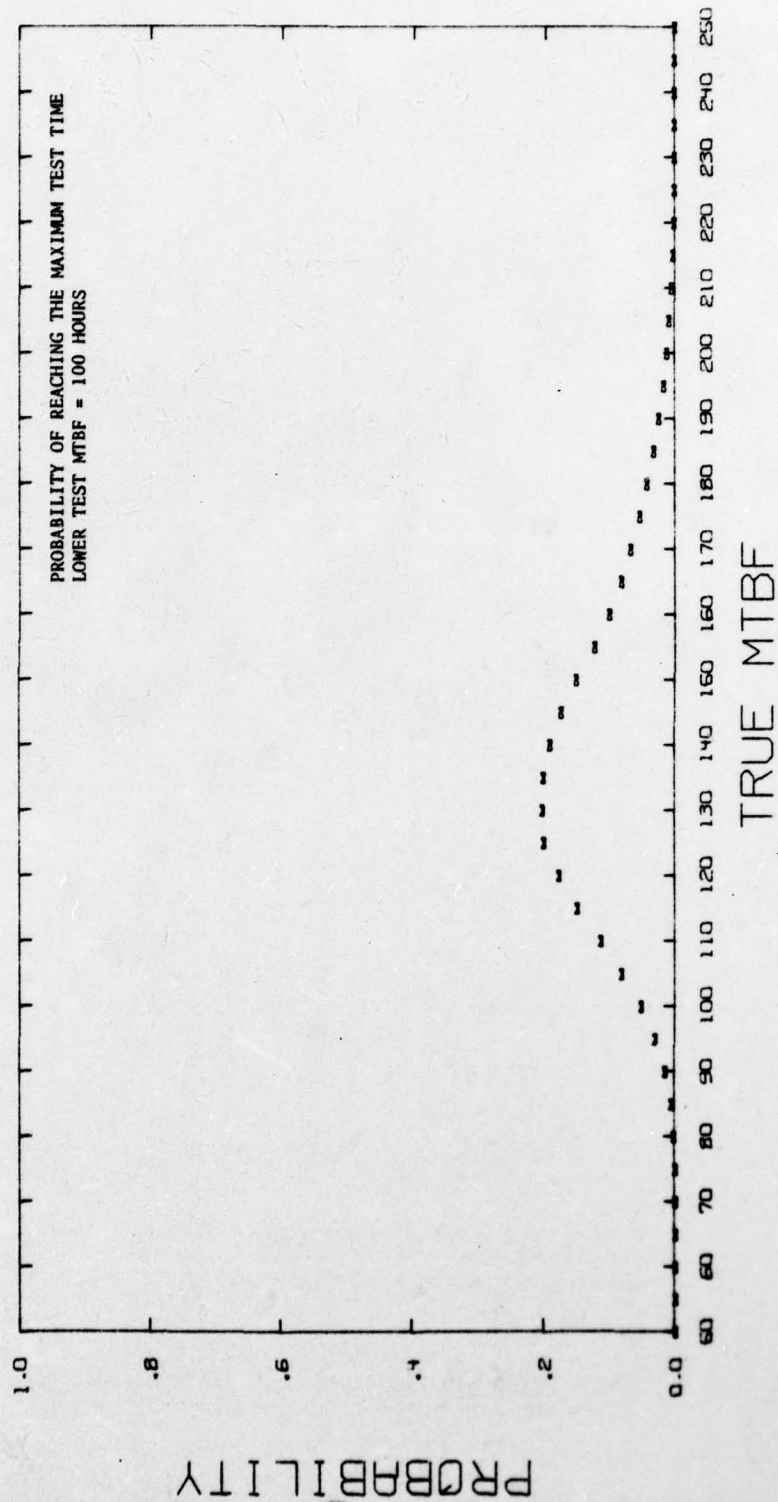


FIGURE 1B

MIL-STD 781 C TEST PLAN 2 C

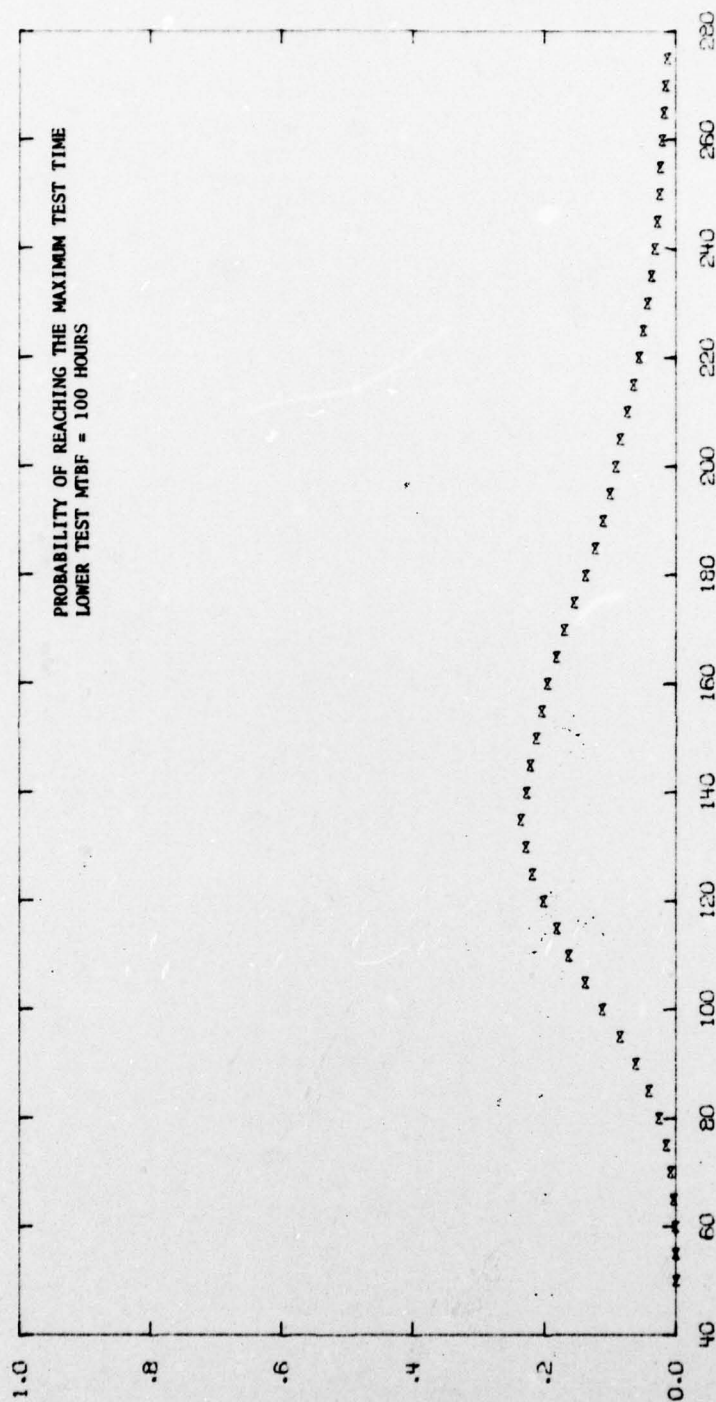


FIGURE 2B

PROBABILITY

MIL-STD 781 C TEST PLAN 3 C

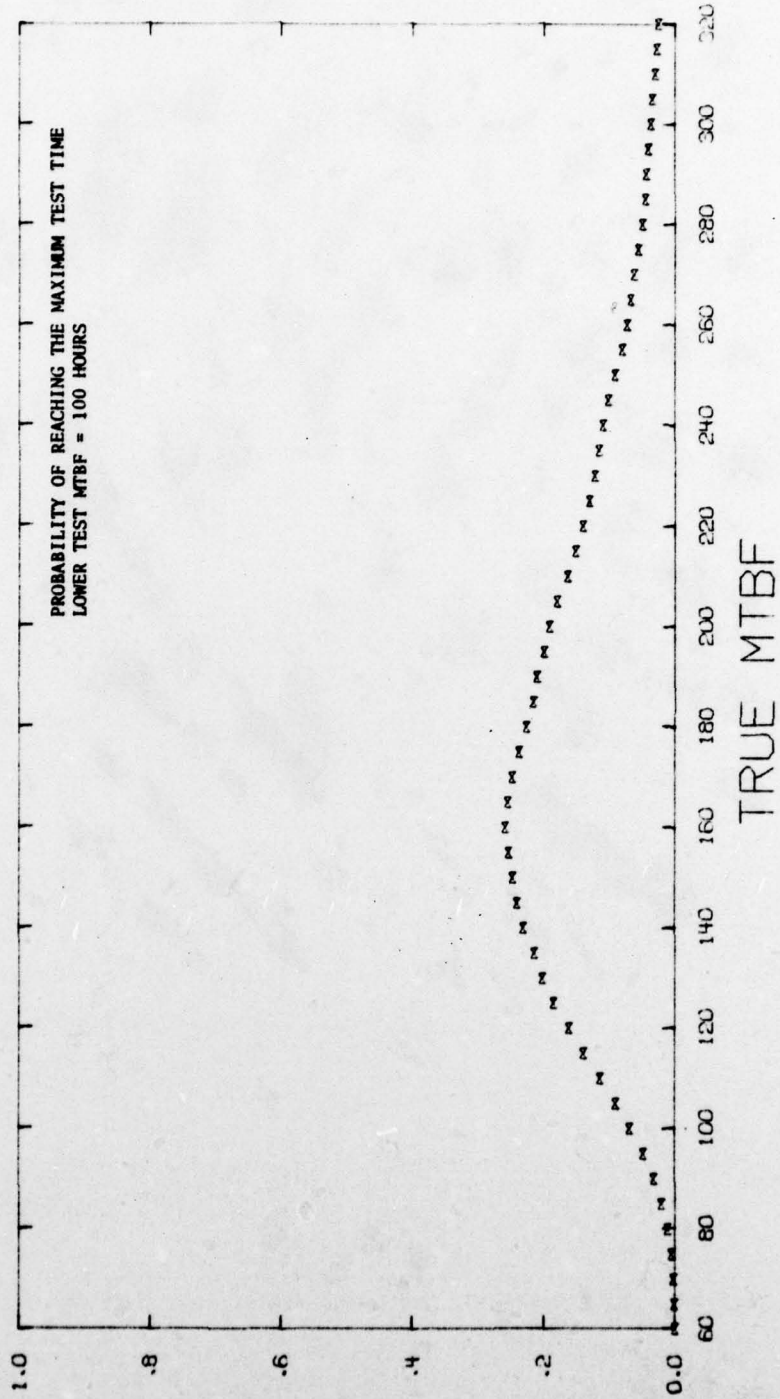


FIGURE 3B

PROBABILITY

MIL-STD 781 C
TEST PLAN 4 C

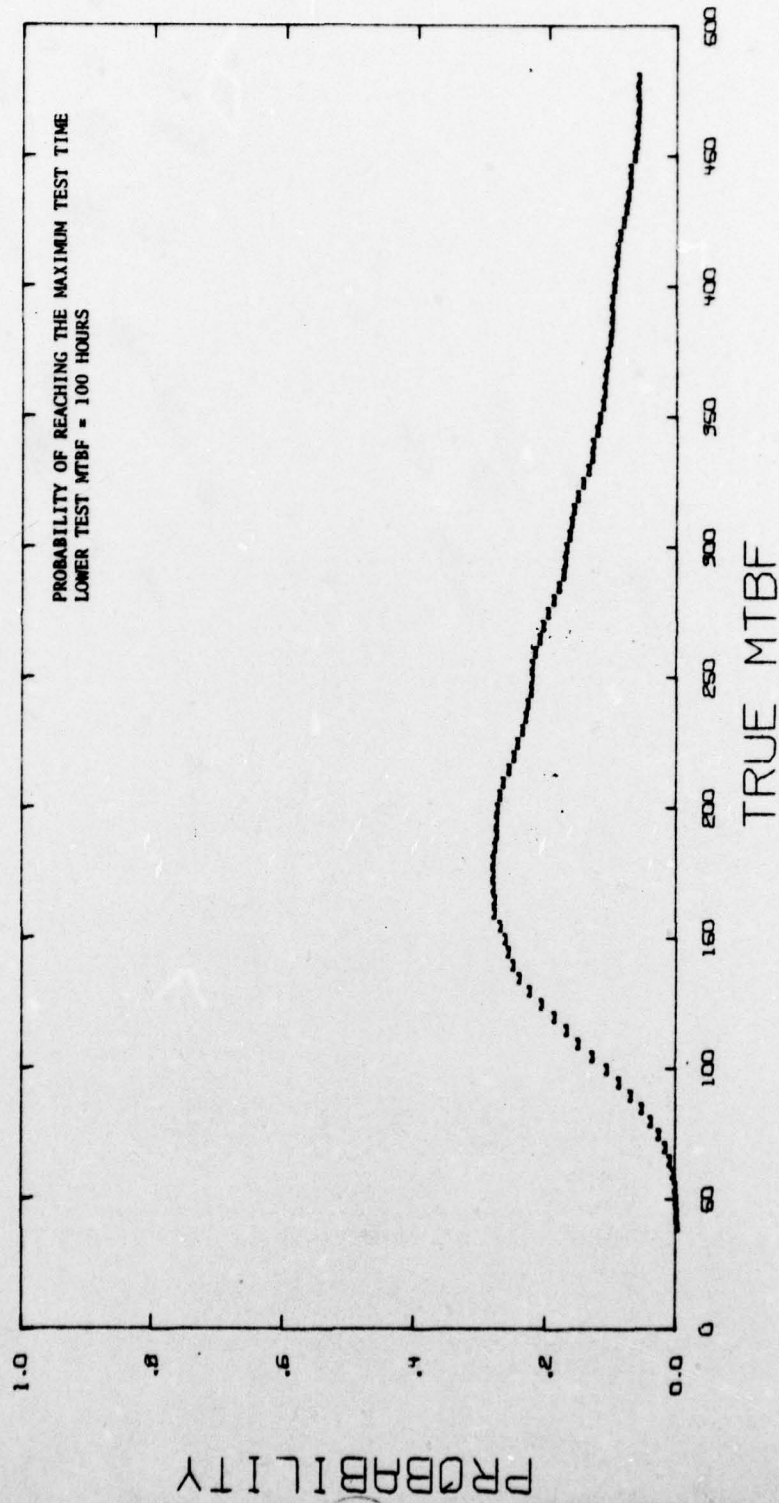
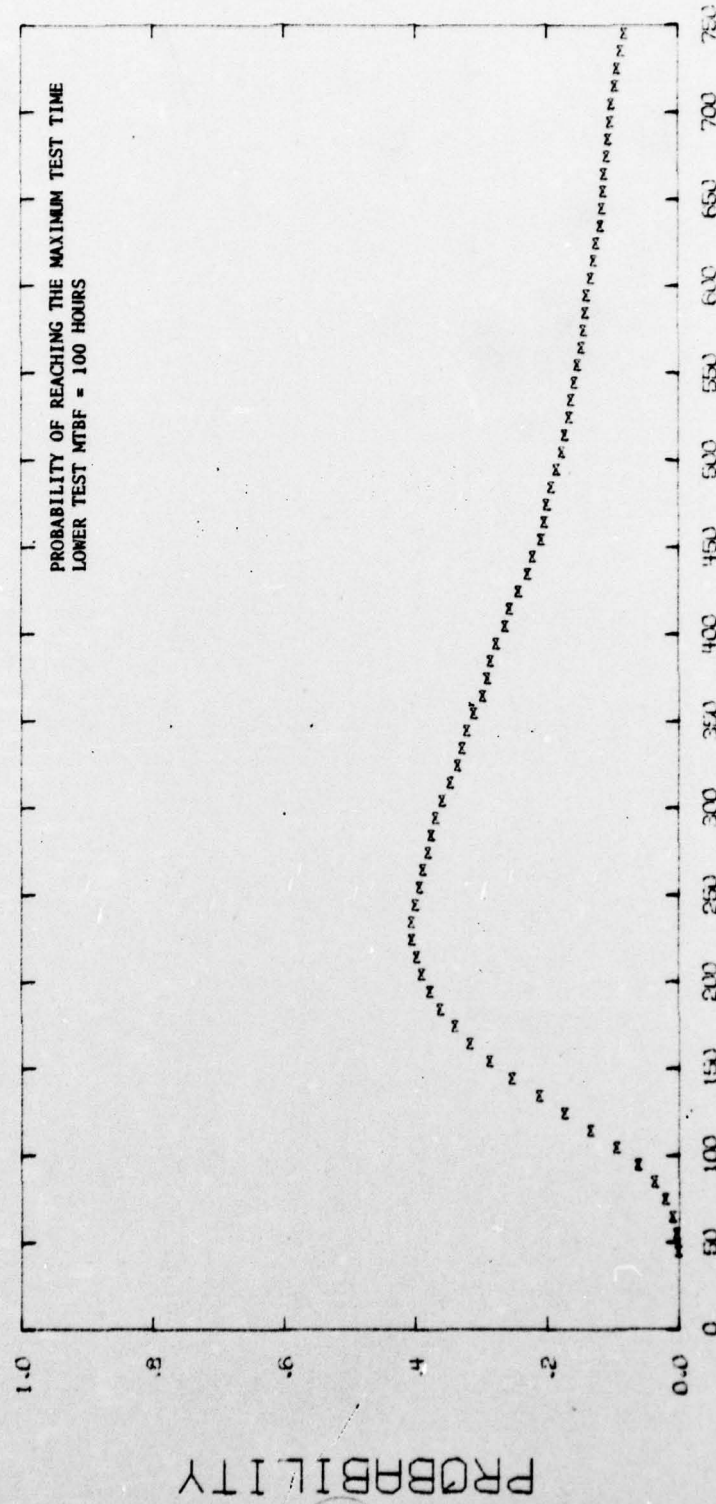


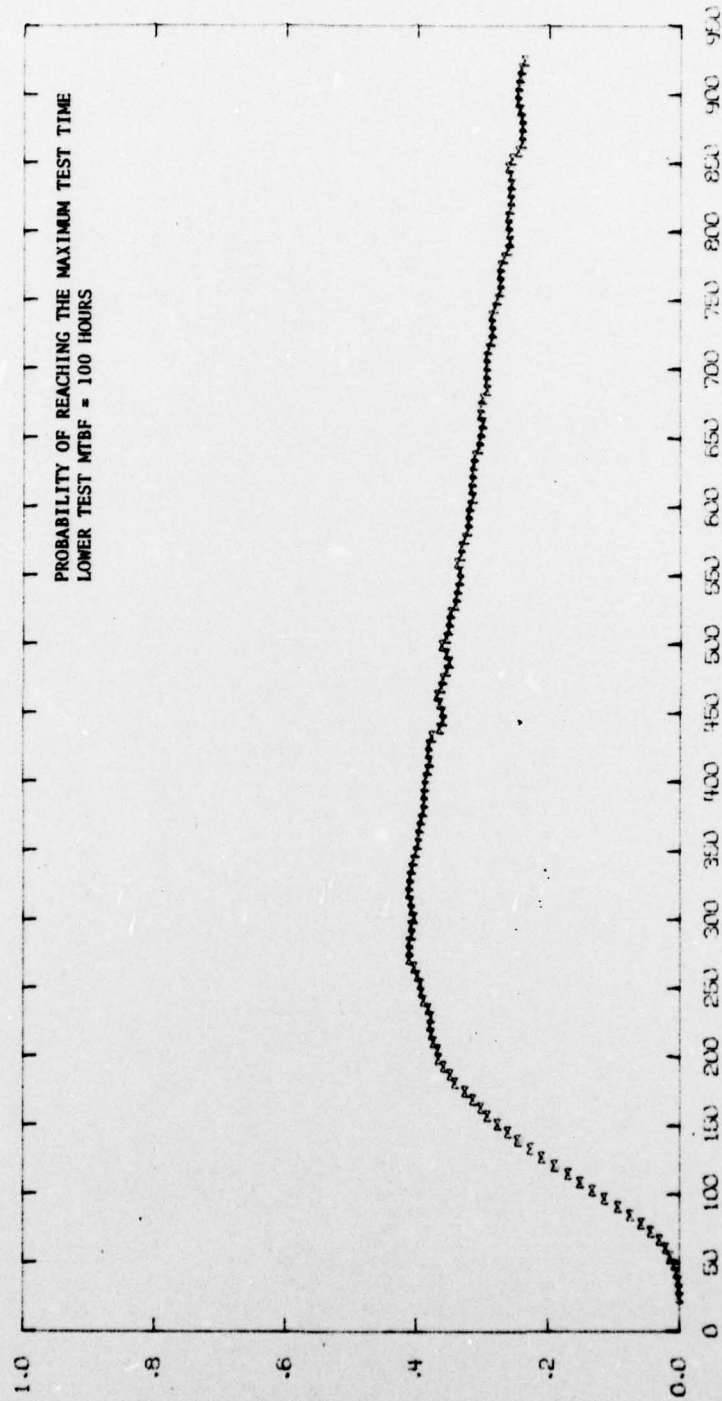
FIGURE 4B

MIL-STD 781 C TEST PLAN 5 C



TRUE MTBF
FIGURE 5B

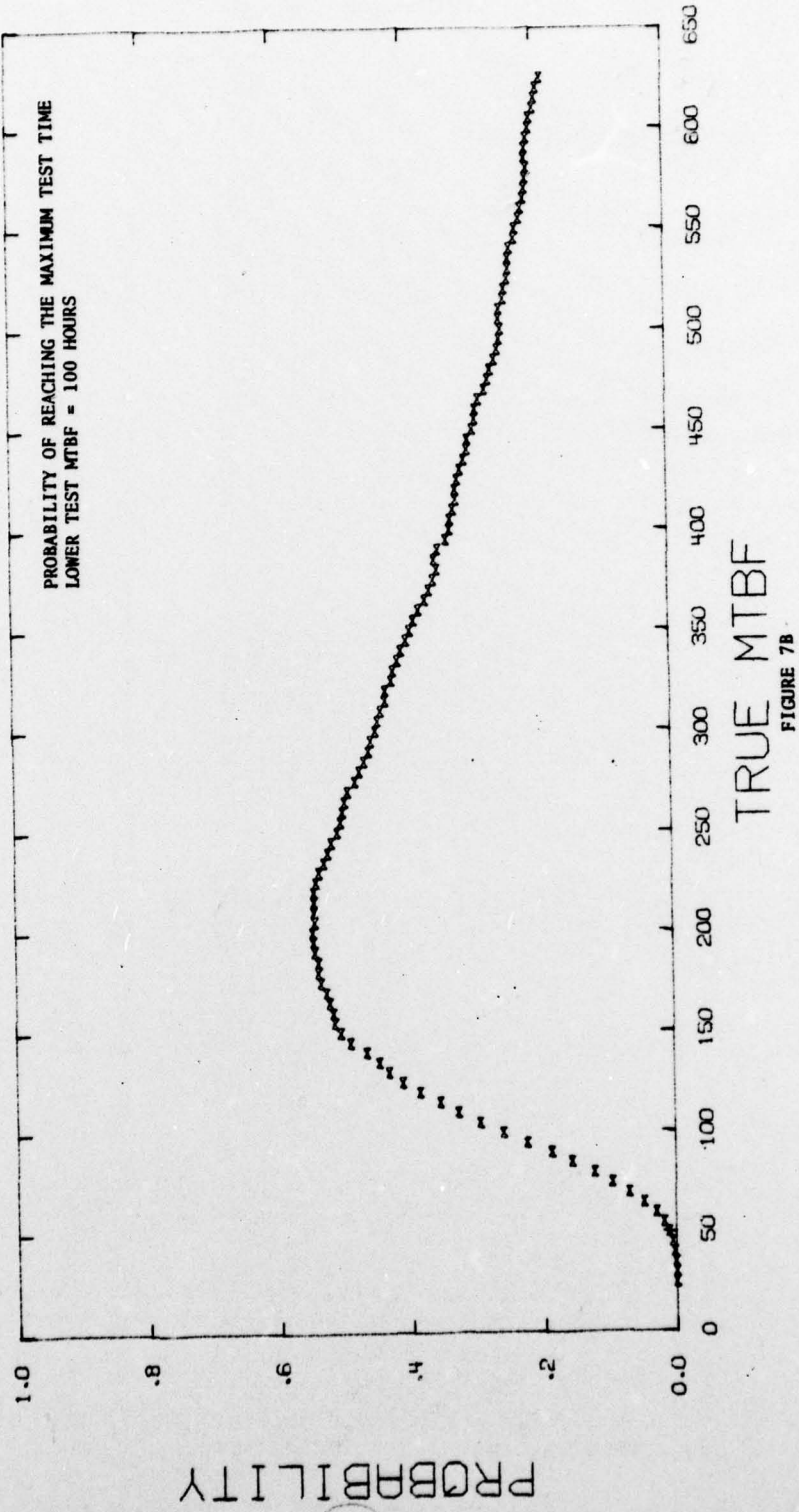
MIL-STD 781 C TEST PLAN 6 C



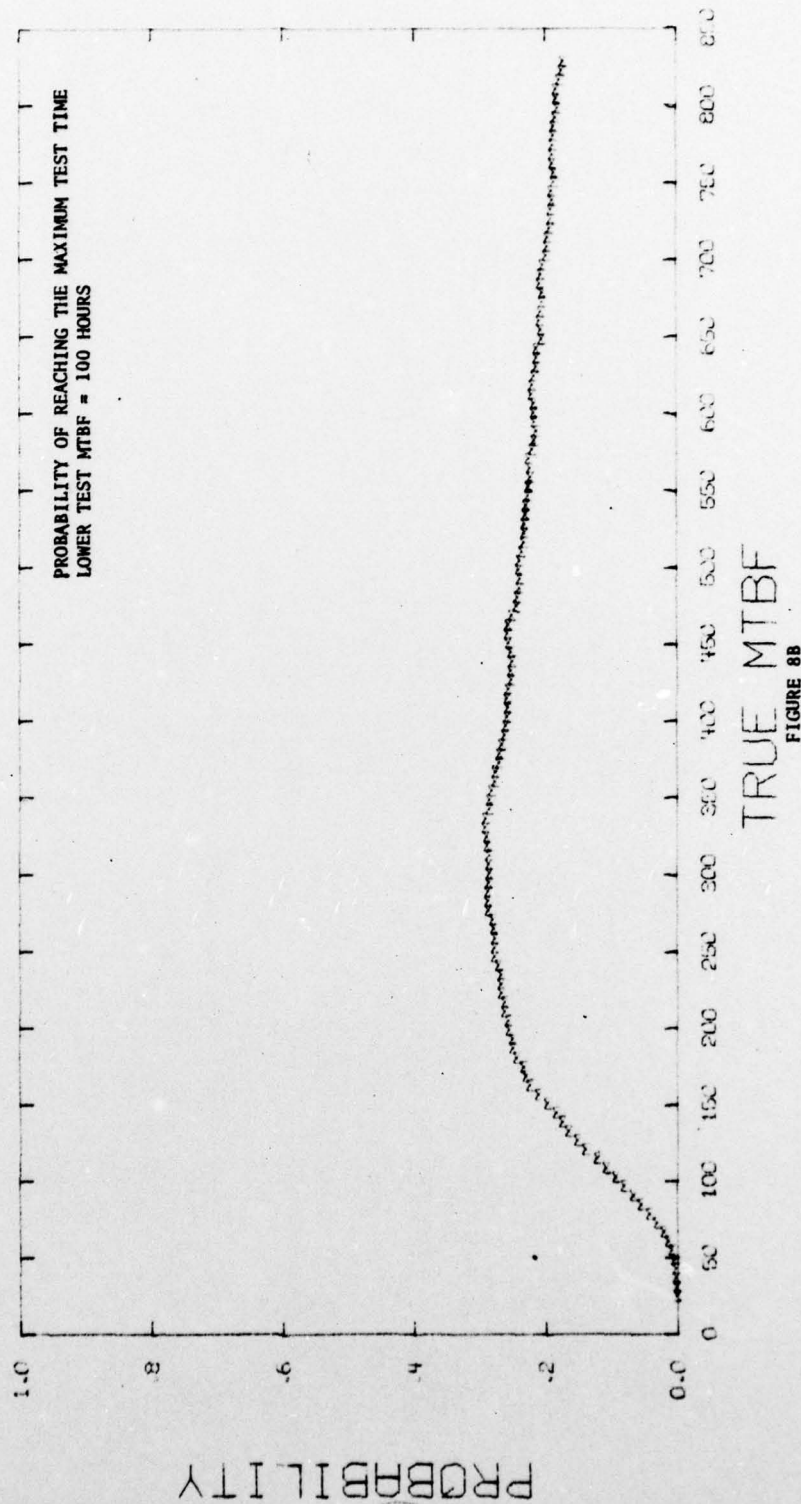
TRUE MTBF

FIGURE 68

MIL-STD 781 C
TEST PLAN 7 C



MIL-STD 781 C TEST PLAN 8 C



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RILLY.T90.STMFZ.F2.
ACCOUNT(SAIMEL)
BEGIN.ATTACH.PLUTLH.
REQUEST.TAPE13.0FF.
FTN(60.SL.AL.H)
MAP(PART)
BEGIN.PLOT.CALCOMP.TAPE13.
EXIT.
BEGIN.PLOT.CALCOMP.TAPE13.
EXIT.
?

```

PROGRAM MSTRIC(INPUT,OUTPUT,TAPES=INPUT,TAPES=OUTPUT,TAPE13)
C      THIS PROGRAM IS A MONTE CARLO SIMULATION OF A PROBABILITY
C      RATIO SEQUENTIAL TEST (PST) PLAN FROM MILITARY
C      STANDARD 7HIC. THIS SIMULATION DETERMINES, FOR A
C      RANGE OF TRUE MTHFS, (1) THE PROBABILITY OF REACHING
C      MAXIMUM (TOTAL) TEST TIME BEFORE MAKING A DECISION
C      (EITHER ACCEPT OR REJECT) AND (2) THE PROBABILITY
C      OF REACHING THE LAST FAILURE. FOUR SUBROUTINES ARE
C      INTRODUCED INTO THE PROGRAM FOR THE EXPRESS PURPOSE
C      OF PERFORMING CURVE SMOOTHING. THIS PROCEDURE IS
C      ACCOMPLISHED WITH THE AID OF FOUR DIFFERENT WEIGHTING
C      SCHEMES, UTILIZING (1) A NEIGHBORHOOD OF THREE POINTS,
C      (2) A NEIGHBORHOOD OF FIVE POINTS, (3) A NEIGHBORHOOD
C      OF SEVEN POINTS, AND (4) A NEIGHBORHOOD OF NINE POINTS.

INTEGER      NOF(200)
REAL         MLINE(200),ALINE(200)
REAL         TMTBF(500),MTBF(500)
REAL         MATRIX(25,3),D(2)
REAL         TITLE1(1),TITLE2(2)
REAL         TITLE3(2),TITLE4(2)
REAL         TITLE5(5),TITLE6(6)
DIMENSION    TITLE7(4),LABEL(4)
COMMON       AKOUNT(500),BKOUNT(500)
COMMON       CKOUNT(500),DKOUNT(500)
DATA         LABEL/'HNOEMM','SAIMEL','B367','X3588'/
DATA         NUPLT/0/
HEAD(5,10)MAXNRF,NHITER,NMTP,NMPLNS,BASE,VALUE,DELTA,THETA1
10  FORMAT(4I10,4F10,2)
   INTVLS=MAXNRF+1
   HEAD(5,20)(MLINE(I),I=1,INTVLS)
20  FORMAT(4F10,2)
   HEAD(5,20)(ALINE(I),I=1,INTVLS)
   DO 30 K=1,INTVLS
     NOF(K)=K-1
30  CONTINUE
   DO 50 K=1,NMPLNS
     HEAD(5,40)MATRIX(K,1),MATRIX(K,2),MATRIX(K,3)
40  FORMAT(3F10,2)
50  CONTINUE
   WRITE(6,40)
60  FORMAT(11,T36,'MILITARY STANDARD 7H1 C'//T78,
$THE MINIMUM NUMBER//T79,'OF FAILURES FROM//T4,
$TEST PLAN//T24,'MAXIMUM NUMBER//T49,
$MAXIMUM TEST TIME//T40,'WHICH TO REACH//T6,
$NUMBER//T25,'OF FAILURES//T44,'(THETA ONE //T59,
$MULTIPLE//T74,'MAXIMUM TEST TIME//T4,
$10(1-),T24,14(1-),T43,20(1-),T78,18(1-))
   WRITE(6,70)(L,MATRIX(L,1),MATRIX(L,2),MATRIX(L,3),L=1,NMPLNS)
70  FORMAT(11,T7,13,T29,F5,0,T53,F10,2,T85,F5,0)
   RNMTHF=(VALUE-BASE)/DELTA+1.
   IF(RNMTHF.GT.AINT(RNMTHF))GOTO 80
   RNMTHF=RNMTHF
   GOTO 40

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80 NMMTHF=MMTHF+1.0
90 WRITE(6.100)
100 FORMAT(11,T4,MILITARY STANDARD 761 C)
    WRITE(6.110)NMTF
110 FORMAT(10,T4,TEST PLAN 1,13)
    WRITE(6.120)MAXNMF
120 FORMAT(10,T4,THE MAXIMUM NUMBER OF FAILURES 1,
    $FOM THIS PLAN IS 1,I4///)
    WRITE(6.130)
130 FORMAT(1,T22,ACCEPT-REJECT CRITERIA/T22,
    $22(1-1))
    WRITE(6.140)
140 FORMAT(10,T34,TOTAL TEST TIME)
    WRITE(6.150)
150 FORMAT(1,T31,(THETA ONE MULTIPLE))
    WRITE(6.160)
160 FORMAT(10,T8,NUMBER OF/T8,FAILURES,T26,
    $REJECT LINE,T46,ACCEPT LINE/T8,
    $10(1-1),T26,12(1-1),T46,12(1-1))
    DO 190 K=1,INTVLS
        IF(MOD(K,20).EQ.0)WRITE(6.170)
        WRITE(6.180)NOF(K),RLINE(K),ALINE(K)
170 FORMAT(11,T8,NUMBER OF/T8,FAILURES,T26,
    $REJECT LINE,T46,ACCEPT LINE/T8,
    $10(1-1),T26,12(1-1),T46,12(1-1))
180 FORMAT(10,T11,I4,T27,F10.2,T47,F10.2)
190 CONTINUE
    DO 200 K=1,INTVLS
        RLINE(K)=RLINE(K)*THETA1
        ALINE(K)=ALINE(K)*THETA1
200 CONTINUE
    DO 210 L=1,NRPLNS
        MATRIX(L,2)=MATRIX(L,2)*THETA1
210 CONTINUE
    DO 220 K=1,NRPLNS
        IF(MAXNMF.EQ.1)UPPER=MATRIX(K,2)
        IF(MAXNMF.EQ.2)LIMIT=MATRIX(K,3)
220 CONTINUE
    WRITE(6.100)
    WRITE(6.110)NMTF
    WRITE(6.230)THETA1
230 FORMAT(10,T4,THETA ONE FOR THIS PLAN IS 1,
    $T32,F10.2,T44,HOURS)
    WRITE(6.240)UPPER
240 FORMAT(10,T4,THE MAXIMUM TEST TIME FOR THIS 1,
    $PLAN IS 1,F10.2,T56,HOURS)
    WRITE(6.250)BASE.VALUE
250 FORMAT(10,T4,THE RANGE OF TRUE MTRFS CONSIDERED 1,
    $IS 1,F10.2,1-F10.2,T64,HOURS)
    WRITE(6.260)NMTF
260 FORMAT(10,T4,THE NUMBER OF ITERATIONS FOR THIS 1,
    $SIMULATION IS 1,I10)
    WRITE(6.120)MAXNMF
    WRITE(6.130)
    WRITE(6.140)
    WRITE(6.160)
    DO 270 K=1,INTVLS
        IF(MOD(K,10).EQ.0)WRITE(6.170)
        WRITE(6.180)NOF(K),RLINE(K),ALINE(K)
270 CONTINUE
        BASE=BASE-DELTA
        IF(BASE.LE.0)GOTO 540
        NUM=NMTF+1
        DO 280 K=1,NUM
            TMTF(K)=BASE
        BASE=BASE-DELTA

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240 CONTINUE
K=0
290 K=K+1
NCASE=0
ARG=1./TMTBF(K)
KOUNT=0
KNT=0
300 NCASE=NCASE+1
IF(NCASE.GT.NWRITE)GOTO 340
ACCU=0.
DO 340 NFAIL=1,INTVLS
NFAIL=NFAIL-1
IF(NFAIL.EQ.1)GOTO 320
310 ACCU=ACCU+EXP(-ARG)
IF(ACCU.EQ.0.)GOTO 310
IF(NFAIL.EQ.0.AND.ACCU.GE.ALIN(NFAIL))GOTO 350
IF(NFAIL.EQ.0.AND.(ACCU.GT.FLIN(NFAIL).AND.
*ACCU.LT.ALIN(NFAIL)))GOTO 340
320 DO 330 J=LIMIT,MAXNRF
IF(NFAIL.EQ.J.AND.ACCU.GE.UPPER)KOUNT=KOUNT+1
330 CONTINUE
IF(NFAIL.EQ.MAXNRF)KNT=KNT+1
IF(ACCU.LE.FLIN(NFAIL).OR.ACCU.GE.ALIN(NFAIL))GOTO 350
340 CONTINUE
350 GOTO 300
360 AKOUNT(K)=KOUNT
RKOUNT(K)=KNT
IF(K.NE.NUMH)GOTO 290
TITLE1(1)=THUE MTOF>
TITLE2(1)=PROBABILIT
TITLE2(2)=Y>
TITLE4(1)=MIL-STD 78
TITLE4(2)=1 C>
CALL SUM(NWRITE,NRMTBF)
MODE=0
LEVELS=NRMTBF/15
IF(MOD(NRMTBF,15).GT.0)LEVELS=LEVELS+1
IF(LEVELS.LE.0)LEVELS=1
ENCODE(16,370,TITLE3)NRTP
370 FORMAT(10HTEST PLAN ,I3.3H C>)
ENCODE(48,380,TITLE5)MAXNRF
380 FORMAT(42HPROBABILITY OF REACHING THE LAST FAILURE (,I4.2H)>)
ENCODE(50,390,TITLE6)UPPER
390 FORMAT(43HPROBABILITY OF REACHING MAXIMUM TEST TIME (,F10.2.
54H HNS)>)
ENCODE(35,400,TITLE7)THETA1
400 FORMAT(14HLOWEN TEST MTOF = ,F10.2,7H HOURS>)
U(1)=TMTBF(5)*1.0001
D(2)=TMTBF(NRMTBF+4)*.99999
DO 410 N=1,NRMTBF
MTHF(N)=TMTBF(N+4)
410 CONTINUE
XA=3.
420 JUMP=1
INTU=15
DO 470 M=1,LEVELS
WRITE(6,430)NRTP,THETA1
430 FORMAT(11,T55,MIL-STD 781 C:/T54.
51TEST PLAN ,I3,C/T47,THETA ONE = ,
5F10.2,HOURS:///)
WRITE(6,440)UPPER,MAXNRF
440 FORMAT(1,T48,PROBABILITY OF REACHING,T77.
41PROBABILITY OF REACHING,T30,THUE MTOF,T51.
51MAXIMUM TEST TIME,T80,THE LAST FAILURE,T32.
51(HOURS),T50,(,F10.2,T43,HOURS),T74.
51(FAILURE NW, ,I4,)/T30,11(,),T48,23(,),T77.

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523(1-1)
DO 440 N=JUMP,INTO
IF(N.GT.NHMTBF)GOTO 470
JMTBF=N+4
WRITE(6,450)JMTBF(JMTBF),CROUNT(N),DROUNT(N)
450 FORMAT('0',T31,F10.2,T57,F6.4,T66,F6.4)
460 CONTINUE
JUMP=JUMP+15
INTO=INTO+15
470 CONTINUE
IF(NOPLOT.EQ.1)GOTO 490
IF(MODE.GT.0)GOTO 480
CALL PLTBEG(72..25..1.0.13.LABEL)
CALL FIASCA(0(1).2.10..05.DMIN.DMAX.DELD)
480 CALL PLTSCA(XX.2..0MIN.0..05..2)
CALL PLTDTS(3.10.MTBF,CROUNT,NHMTBF.0)
CALL PLTAXS(DEL0..2.DMIN.DMAX.0.0.1.0.4)
CALL LABELA(DEL0..2.DMIN.DMAX.0..1.1.1.1)
CALL PLTSCA(XX.2..0..0..05..2)
CALL PLTDTS(3.10.2.05*05.1.45.1.0)
CALL PLTDTS(3.14.2.05*05.1.55.1.0)
CALL PLTSYM(.25.TITLE1.0..3.875*05..-15)
CALL PLTSYM(.25.TITLE2.90..-05..225)
CALL PLTSYM(.25.TITLE3.0..3.125*05.1.05)
CALL PLTSYM(.25.TITLE4.0..3.375*05.1.15)
CALL PLTSYM(.10.TITLE7.0..2.05*05.1.35)
CALL PLTSYM(.10.TITLE6.0..2.25*05.1.45)
CALL PLTSYM(.10.TITLE5.0..2.25*05.1.55)
CALL PLTSCA(XX.11.75.DMIN.0..05..2)
CALL PLTDTS(3.14.MTBF,CROUNT,NHMTBF.0)
CALL PLTAXS(DEL0..2.DMIN.DMAX.0..1.0.4)
CALL LABELA(DEL0..2.DMIN.DMAX.0..1.1.1.1)
CALL PLTSCA(XX.11.75.0..0..05..2)
CALL PLTSYM(.25.TITLE1.0..3.875*05..-15)
CALL PLTSYM(.25.TITLE2.90..-05..225)
CALL PLTSYM(.25.TITLE3.0..3.125*05.1.05)
CALL PLTSYM(.25.TITLE4.0..3.375*05.1.15)
490 MODE=MODE+1
GOTO(500,510,520,530,540).MODE
500 CALL SUB3(NHITER,NHMTBF,NUMB)
XX=17.
GOTO 420
510 CALL SUB5(NHMTBF)
XX=31.
GOTO 420
520 CALL SUB7(NHMTBF)
XX=45.
GOTO 420
530 CALL SUB9(NHMTBF)
XX=59.
GOTO 420
540 WRITE(4,550)DELTAX
550 FORMAT('1',T4,'THE INCREMENT VALUE CHOSEN ('F10.2,
$') FOR THE RANGE OF TRUE MTHFS CONSIDERED WAS TOO LARGE.1//T4,
$'CHOOSE A SMALLER INCREMENT VALUE SUCH THAT THE INCREMENT ',
$'VALUE MULTIPLIED BY FOUR (4) AND THEN SUBTRACTED 1/17,
$'FROM YOUR BASE MTHF WILL RESULT IN A NUMBER THAT IS ',
$'GREATER THAN ZERO.1)
560 CALL PLTBGE
STOP
END
SUBROUTINE SUB1(NHITER,NHMTBF)
COMMON AKOUNT(500),BKOUNT(500)
COMMON CROUNT(500),DROUNT(500)
NHITER=NHITER
DO 5 N=1,NHMTBF

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CKOUNT(N)=AKOUNT(N+4)/ARITER
DKOUNT(N)=BKOUNT(N+4)/ARITER
5 CONTINUE
RETURN
END
SUBROUTINE SUB3(NRITER,NRMTBF,NUMB)
COMMON AKOUNT(500),BKOUNT(500)
COMMON CKOUNT(500),DKOUNT(500)
ARITER=NRITER
DO 5 K=1,NUMB
AKOUNT(K)=AKOUNT(K)/ARITER
BKOUNT(K)=BKOUNT(K)/ARITER
5 CONTINUE
DO 10 I=1,NRMTBF
CKOUNT(I)=(AKOUNT(I+3)+AKOUNT(I+5))/4.+(AKOUNT(I+4))/2.
DKOUNT(I)=(BKOUNT(I+3)+BKOUNT(I+5))/4.+(BKOUNT(I+4))/2.
10 CONTINUE
RETURN
END
SUBROUTINE SUB5(NRMTBF)
COMMON AKOUNT(500),BKOUNT(500)
COMMON CKOUNT(500),DKOUNT(500)
DO 5 I=1,NRMTBF
CKOUNT(I)=(AKOUNT(I+2)+AKOUNT(I+6))/10.
+ (AKOUNT(I+3)+AKOUNT(I+5))/5.
+ (AKOUNT(I+4))*2./5.
DKOUNT(I)=(BKOUNT(I+2)+BKOUNT(I+6))/10.
+ (BKOUNT(I+3)+BKOUNT(I+5))/5.
+ (BKOUNT(I+4))*2./5.
5 CONTINUE
RETURN
END
SUBROUTINE SUB7(NRMTBF)
COMMON AKOUNT(500),BKOUNT(500)
COMMON CKOUNT(500),DKOUNT(500)
DO 5 K=1,NRMTBF
CKOUNT(K)=(AKOUNT(K+1)+AKOUNT(K+7))/22.
+ (AKOUNT(K+2)+AKOUNT(K+6))/11.
+ (AKOUNT(K+3)+AKOUNT(K+5))*2./11.
+ (AKOUNT(K+4))*4./11.
DKOUNT(K)=(BKOUNT(K+1)+BKOUNT(K+7))/22.
+ (BKOUNT(K+2)+BKOUNT(K+6))/11.
+ (BKOUNT(K+3)+BKOUNT(K+5))*2./11.
+ (BKOUNT(K+4))*4./11.
5 CONTINUE
RETURN
END
SUBROUTINE SUB9(NRMTBF)
COMMON AKOUNT(500),BKOUNT(500)
COMMON CKOUNT(500),DKOUNT(500)
DO 5 I=1,NRMTBF
CKOUNT(I)=(AKOUNT(I)+AKOUNT(I+8))/46.
+ (AKOUNT(I+1)+AKOUNT(I+7))/23.
+ (AKOUNT(I+2)+AKOUNT(I+6))*2./23.
+ (AKOUNT(I+3)+AKOUNT(I+5))*4./23.
+ AKOUNT(I+4)*8./23.
DKOUNT(I)=(BKOUNT(I)+BKOUNT(I+8))/46.
+ (BKOUNT(I+1)+BKOUNT(I+7))/23.
+ (BKOUNT(I+2)+BKOUNT(I+6))*2./23.
+ (BKOUNT(I+3)+BKOUNT(I+5))*4./23. + BKOUNT(I+4)*8./23.
5 CONTINUE
RETURN
END

```

7	2000	5	8	45.00	745.00	10.00	100.00
0.00	0.00	.57	2.22	3.87	5.52	7.17	10.35

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3.75	5.40	7.05	4.70	10.35	10.35	10.35	10.35
41.	49.50	34.					
19.	21.90	15.					
16.	20.60	12.					
8.	9.74	5.					
7.	10.35	4.					
3.	4.50	2.					
6.	4.80	3.					
3.	4.50	2.					

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