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TECHNICAL REPORT 4293

A COMPUTER PROGRAM THAT COMPUTES AND DRAWS AN EXACT OPERATING CHARACTERISTIC CURVE USING THE HYPERGEOMETRIC PROBABILITY DISTRIBUTION

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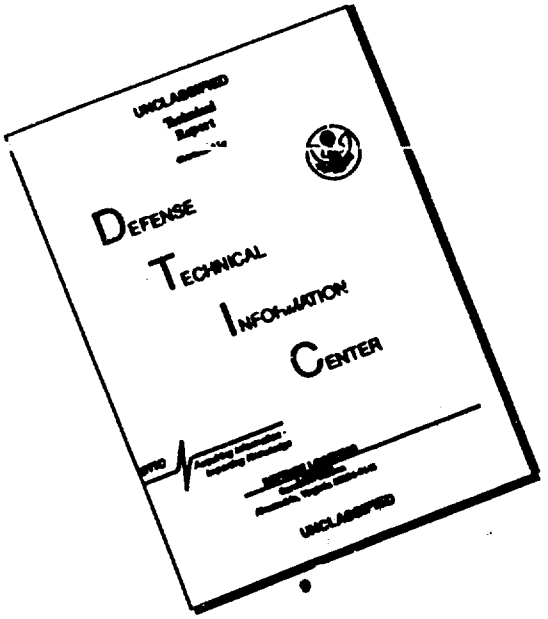

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A computer program was developed which uses the Hypergeometric Probability Distribution in computing and plotting percent defective vs. 10 important probability of acceptance points (.99, .975, .95, .90, .75, .50, .25, .10, .05 and .01).

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SUMMARY

A computer program was developed which uses the Hypergeometric Probability Distribution in computing and plotting percent defective vs. 10 important probability of acceptance points (.99, .975, .95, .90, .75, .50, .25, .10, .05 and .01).

DISCUSSION

An operating characteristic curve is a tool used in quality control for the purpose of buying or selling manufactured goods.

Using the formulae and solution as discussed in Reference 1 and altering the FORTRAN computer program described in that Reference, a new program was generated which computes and plots percent defective for 10 important probability of acceptance levels. Additional related information printed out is: defectives in original population, reliability, and confidence level.

Note: Since it is quite unusual that a sample will exceed 50% of the population, this condition has not been programmed. If it is desired to compute this, use the equalities as shown and discussed on page 4 of Reference 2.

FORTRAN PROGRAM

```
PROGRAM     ANNERO     TRACE                                CDC 6600 FTN V3.0-P261 OPT=1  11/09/71  13.37.26.
            PROGRAM ANNERO(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT    )
            DIMENSION G(60),BOPD (60),PAC(60),PACL(60),BOPL(60),PACCT(10),
           1PD(20),PA(20)
            DATA PACCT/.99,.975,.95,.90,.75,.5,.25,.10,.05,.01/
 5          WRITE (6,871)
            CALL PLOT (3.,3.,-3)
      400   READ (5,200) POP,SAMPLE,       DEF
      200   FORMAT(3F10.0)
            IF (POP) 399,399,243
 10   243   IF (SAMPLE - DEF)560,560,563
      560   WRITE (6,561) DEF,SAMPLE
      561   FORMAT (1H1,20(/),20X,*THE PROBABILITY OF OBTAINING *,F10.0,* DEFE
           1CTS OR LESS IN A SAMPLE OF*,F10.0,*  IS*/20X,*ALWAYS 1 REGARDLESS
           2OF THE NUMBER OF INTERESTING ONES IN THE POPULATION.*)
 15         GO TO 400
      563    IF (SAMPLE - POP/2.)565,565,564
      564   WRITE (6,566) SAMPLE,POP
      566   FORMAT (1H1,20(/),20X,*NOW YOU HAVE DONE IT.  I TOLD YOU NOT TO EN
           1TER A SAMPLE SIZE GREATER*/20X,*THAN 1/2 OF THE POPULATION.  YOU E
 20        2NTERED A SAMPLE SIZE OF*,F10.0,* AND*/20X,* A POPULATION SIZE OF*,
           3F10.0,//20X,*IF YOU LIKE THIS PROGRAM, FAN MAIL WILL BE ACCEPTED.*
           4)
      565   WRITE (6,201)POP,SAMPLE,       DEF
      201   FORMAT (1H1,//50X,30HOPERATING CHARACTERISTIC CURVE,
 25        1  //25X,15HPOPULATION SIZE,                F10.0,5X,6HSAMPLE,
           2F9.0,5X,18HACCEPTABLE DEFECTS,F6.0///26X13HIF DEFECTIVES,7X,7HPERC
           3ENT,5X,14HPROBABILITY OF,4X,14HRELIABILITY,5X,
           410HCONFIDENCE/27X,11HIN ORIGINAL,7X,9HDEFECTIVE,6X,10HACCEPTANCE,
           510X,2HIS,14X,2HIS/25X,14HPOPULATION ARE,
 30        610X,2HIS,13X,2HIS//)
            ICON = 1
      475    CONF =  PACCT(ICON)
            AREA =    CONF - .5
            IF (AREA - .499 ) 477,476,476
 35   476    GUESS=((DEF + 4. )/  SAMPLE )  * POP
            IF (GUESS - POP - SAMPLE) 260,261,261
      261   GUESS = POP - 2. + DEF -  SAMPLE
      260    CALL BACK (POP,SAMPLE,GUESS,DEF,REL,OTHERS,A,SUM,BAC,POPD)
            PAC(1) = BAC
 40         BOPD(1) = POPD
             GUESS =((DEF+2.)/SAMPLE) * POP
             CALL BACK (POP,SAMPLE,GUESS,DEF,REL,OTHERS,A,SUM,BAC,POPD)
            PAC(2) = BAC
            BOPD(2) = POPD
 45         IF ( BOPD(1) - BOPD(2)) 778,779,778
      779    GUESS = POPD - 4.
            CALL BACK (POP,SAMPLE,GUESS,DEF,REL,OTHERS,A,SUM,BAC,POPD)
            PAC(1) = BAC
            BOPD(1) = POPD
 50   778   DO 787  I = 3,20
            N = I +1
            G(I) =  BOPD (I-2) - (.5 - PAC(I-2) - AREA)/ ( PAC(I-1) - PAC(I-2)
           1) * (BOPD(I-2) - BOPD(I-1))
             IF (G(I) - DEF) 401,402,402
 55   401   GUESS = DEF +  2.
```

```
      GO TO 403
402   GUESS = G(I)
403   CALL BACK (POP,SAMPLE,GUESS,DEF,REL,OTHERS,A,SUM,BAC,POPD)
      BOPD(I) = POPD
      PAC (I) = BAC
      IF (ABS(BOPD(I) - BOPD(I-1)) - 3.)782,782,787
787   CONTINUE
782   IF (AREA - .5*PAC(N-1))207,206,206
207   DO 208 I = N,30
      JEST = I
      IF (AREA - .5 * BAC) 211,491,491
211   G(I) = G(I-1) - 1.
      GUESS = G(I)
      CALL BACK (POP,SAMPLE,GUESS ,DEF,REL,OTHERS,A,SUM,BAC,POPD)
      BOPD (I) = POPD
      PAC  (I) = BAC
208   CONTINUE
      GO TO 491
206   DO 209 I = N,30
      IF (G(I-1)+1. - POP) 210,491,491
210   G(I)= G(I-1)+ 1.
      JEST = I
      IF (AREA -.5 * BAC)491,247,247
247   GUESS = G(I)
      CALL BACK (POP,SAMPLE,GUESS ,DEF,REL,OTHERS,A,SUM,BAC,POPD)
      BOPD (I) = POPD
      PAC  (I) = BAC
209   CONTINUE
      GO TO 491
240   WRITE (6,241) POP
      PO (2*ICON)      = 100.
      PA (2*ICON)      =  0.0
241   FORMAT (27X,F10.0,9X,6H100.00,9X,6H1.000000,9X,6H   .00,9X,6H1.000
     1000)
      GO TO 800
477    GUESS = (( DEF - 4.) /SAMPLE ) * POP
       IF  (GUESS - DEF - 1. ) 360,360,361
360    GUESS = DEF + 1.
361    CALL BACK (POP,SAMPLE,GUESS,DEF,REL,OTHERS,A,SUM,BAC,POPD)
      BOPL(1) = POPD
      PACL(1)= BAC
       GUESS = ((DEF - .1) /SAMPLE ) * POP
      IF (GUESS - BOPL(1) -4.5)362,362,363
362     GUESS =(DEF/SAMPLE ) * POP  + 5.
363   CALL BACK (POP,SAMPLE,GUESS,DEF,REL,OTHERS,A,SUM,BAC,POPD)
      BOPL(2) = POPD
      PACL(2)= BAC
      IF (   (BOPL(1) - BOPL(2))      )  378,379,378
379    GUESS = POPD + 4.
      CALL BACK (POP,SAMPLE,GUESS,DEF,REL,OTHERS,A,SUM,BAC,POPD)
      PACL(2)  = BAC
      BOPL(2) =POPD
370   DO 387 I = 3,20
      N = I +1
      G(I) = BOPL(I-2) + (PACL(I-2)- .5  *AREA)/(PACL(I - 2) - PACL(I-1)
```

```
      I) = (BOPL(I-1) - BOPL(I-2))
        IF (G(I))791,791,792
  791   G(I) = 2.
  792   GUESS = G(I)
        CALL BACK (POP,SAMPLE,GUESS,DEF,REL,OTHERS,A,SUM,BAC,POPD)
        BOPL(I) = POPD
        PACL(I) = BAC
        IF (ABS(BOPL(I) - BOPL(I-1)) - 3.)382,382,387
  387   CONTINUE
  382   IF (PACL(N-1)-.5 - AREA)307,307,306
  307   DO 305 I = N,50
        JEST =I
        IF (BAC - .5 - AREA)320,320,494
  320   G(I) = G(I-1) - 1.
        GUESS = G(I)
        IF (GUESS) 82,84,84
  82    GUESS = -1.5
  84    CALL BACK (POP,SAMPLE,GUESS,DEF,REL,OTHERS,A,SUM,BAC,POPD)
        PACL (I) = BAC
        BOPL (I) = POPD
  305       CONTINUE
        GO TO 494
  306   DO 309 I = N,50
        JEST =I
        IF (BAC -.5 - AREA)494,310,310
  310   G(I) = G(I-1) + 1.
        GUESS = G(I)
        CALL BACK (POP,SAMPLE,GUESS,DEF,REL,OTHERS,A,SUM,BAC,POPD)
        PACL (I) = BAC
        BOPL (I) = POPD
  309    CONTINUE
        GO TO 494
  491   POPDA = BOPD(JEST - 1)
        POPDB = BOPD(JEST - 2)
        PACA  = PAC(JEST- 1)
        PACB  = PAC(JEST - 2)
  495   IF (POPDA - POPDB)492,492,493
  494   POPDA = BOPL(JEST-1)
        POPDB = BOPL(JEST - 2)
        PACA  = PACL (JEST-1)
        PACB  = PACL (JEST - 2)
        GO TO 495
  493   PCTD = POPDB/POP  * 100.
        REL  = 100. - PCTD
        SUM  = 1. - PACB
        PA (2* ICON - 1 )= PACB
        PD (2* ICON - 1 )= PCTD
        WRITE (6,559)POPDB,PCTD,PACB,REL,SUM
        IF (POPDA - POP)431,240,240
  431   PCTD = POPDA/POP * 100.
        REL  = 100. - PCTD
        SUM  = 1. - PACA
        PD (2*ICON)       = PCTD
        PA (2*ICON)       = PACA
        WRITE (6,559)POPDA,PCTD,PACA,REL,SUM
```

```
      GO TO 479
492   POPDC = POPDA
      PACC
      POPC
      PACA
      POPDB = POPDC
      PACB = PACC
      GO TO 493
479   WRITE (6,400)
480   FORMAT (/)
      ICON = 1 + ICON
      IF (ICON - 11) 475,800,800
800   ICON = ICON-2 - 2
      CALL SCALE    (PD,ICON,1,10,0,0,0,10,,1)
      CALL SCALE    (PA,ICON,1,10,0,0,0,0,1,1)
      CALL AXIS  (0.0,0.0,17HPERCENT DEFECTIVE,17,10,0,0,0,0,0,10,)
      CALL AXIS  (0.0,0.0,25HPROBABILITY OF ACCEPTANCE,25,10,0,90.,0.0,
     10,1)
      CALL LINE (PD,PA,ICON,1,20,,10,0)
      CALL SYMBOL (5.0,10.0,27HO, C, CURVE  HYPERGEOMETRIC,27,,14,0,0)
      CALL SYMBOL (5.0, 9.5,10HPOPOLATION,10,,14,0,0)
      CALL NUMBER (7.0,9.50,POP,0,,14,0,0)
      CALL SYMBOL (5.0, 9.0, 8HSAMPLE,8,,14,0,0)
      CALL NUMBER (7.0, 9.0,SAMPLE,0,,14,0,0)
      CALL SYMBOL (5.0, 8.5,10HDEFECTIVES,10,,14,0,0)
      CALL NUMBER (7.0, 8.5,DEF,0,,14,0,0)
      CALL PLOT   (15.0,0.0,-3)
      GO TO 400
871   FORMAT (1H1,20(/),30X,*THE AUTHOR, MR. D RAPPAPORT, IS ONLY RESPON
     1SIBLE FOR ALL MISTAKES.*)
899   FORMAT (27X,F10.0,9X,F8.2,9X,F8.0, 9X,F8.2,9X,F8.0)
999   STOP
      END
```

```
      SUBROUTINE BACK (POP,SAMPLE,GUESS,DEF,REL,OTHERS,A,SUM,BAC,POPD)
102   IGLOO = GUESS
      POPD  = IGLOO + 1
103   IF (POP - POPD)116,116,117
116   IGLOO = .9999 * POP
      POPD  = IGLOO
      IF (POP - POPD - SAMPLE)130,117,117
130   IGLOO = POP - SAMPLE + DEF + .1
      POPD = IGLOO
117   CONTINUE
      W = DEF
      IF (POPD -POP/2.)119,119,111
119   X= POPD
      Y = SAMPLE
      Z = POP
118   BAC  = ANNE (Z,Y,X,W)
      REL  = (1. -(POPD/POP)) * 100.
      OTHERS =  POP - POPD
      A = 100. - REL
      SUM = 1. -  BAC
      RETURN
111   W = SAMPLE -    W - 1.
      X = POP  - POPD
      Y = SAMPLE
      Z = POP
      SUM =  ANNE (Z,Y,X,W)
      REL  = (1. - (POPD/POP)) * 100.
      A    =  100. - REL
      BAC  =  1. - SUM
      OTHERS = POP - POPD
      RETURN
      END
```

```
      FUNCTION ANNE (HILARY,RAY,DIANE,DEF)
      II = DEF  + .1
   17 IF (RAY - DIANE) 10,10,11
   10 MOE = RAY + 1.1
      GO TO 15
   11 MOE = DIANE + 1.1
      GO TO 15
   15 FLO = 0.0
      JOYCE = 1
      LENNY = 0
      CLARA=1.
      SYDELL = HILARY - DIANE
      XLAURA = HILARY - RAY
      XMARC = SYDELL - RAY
      IF (XLAURA - SYDELL) 1,1,2
    2 BEN = XLAURA
      TOBY = SYDELL
      GO TO 3
    1 BEN = SYDELL
      TOBY = XLAURA
    3 JOSH= HILARY - BEN + .1
      HERB = 0.0
   25 IF ( JOYCE - JOSH) 22,22,4
   22 CONTINUE
      HERB = ALOG10 ( TOBY/HILARY ) + HERB
      TOBY = TOBY - 1.
      HILARY = HILARY - 1.
        JOYCE = JOYCE + 1
      GO TO 25
    4 CONTINUE
      DO 16 ISIDOR = 1,MOE
      IF (HERB + 90.) 8,8,20
   20 FLO = FLO + ( 10. ** HERB)
   21 TRUDY =  1. - FLO
    9 SAM = 10. ** HERB
      IF (II - LENNY) 23,23,8
    8 LENNY = LENNY + 1
      HERB = HERB + ALOG10 ((RAY*DIANE)/((XMARC + 1.)* CLARA))
      CLARA = CLARA + 1.
      XMARC = XMARC + 1.
      DIANE = DIANE  - 1.
      RAY = RAY -1.
   16 CONTINUE
   23 ANNE = FLO
      RETURN
      END
```

REFERENCES

1. Donald C. Rappaport, A Computer Program for Exact Reliability and Confidence Using the Hypergeometric Probability Distribution, Picatinny Arsenal Technical Report 4181, January 1971.

2. G. J. Lieberman and D. B. Owen, Tables of the Hypergeometric Probability Distribution, Stanford University Press, Stanford, California, 1961.

APPENDIX A

Input

INPUT

F - format

Column Numbers	Input	Format
1-10	Population	F 10.0
11-20	Sample	F 10.0
21-30	Defectives	F 10.0

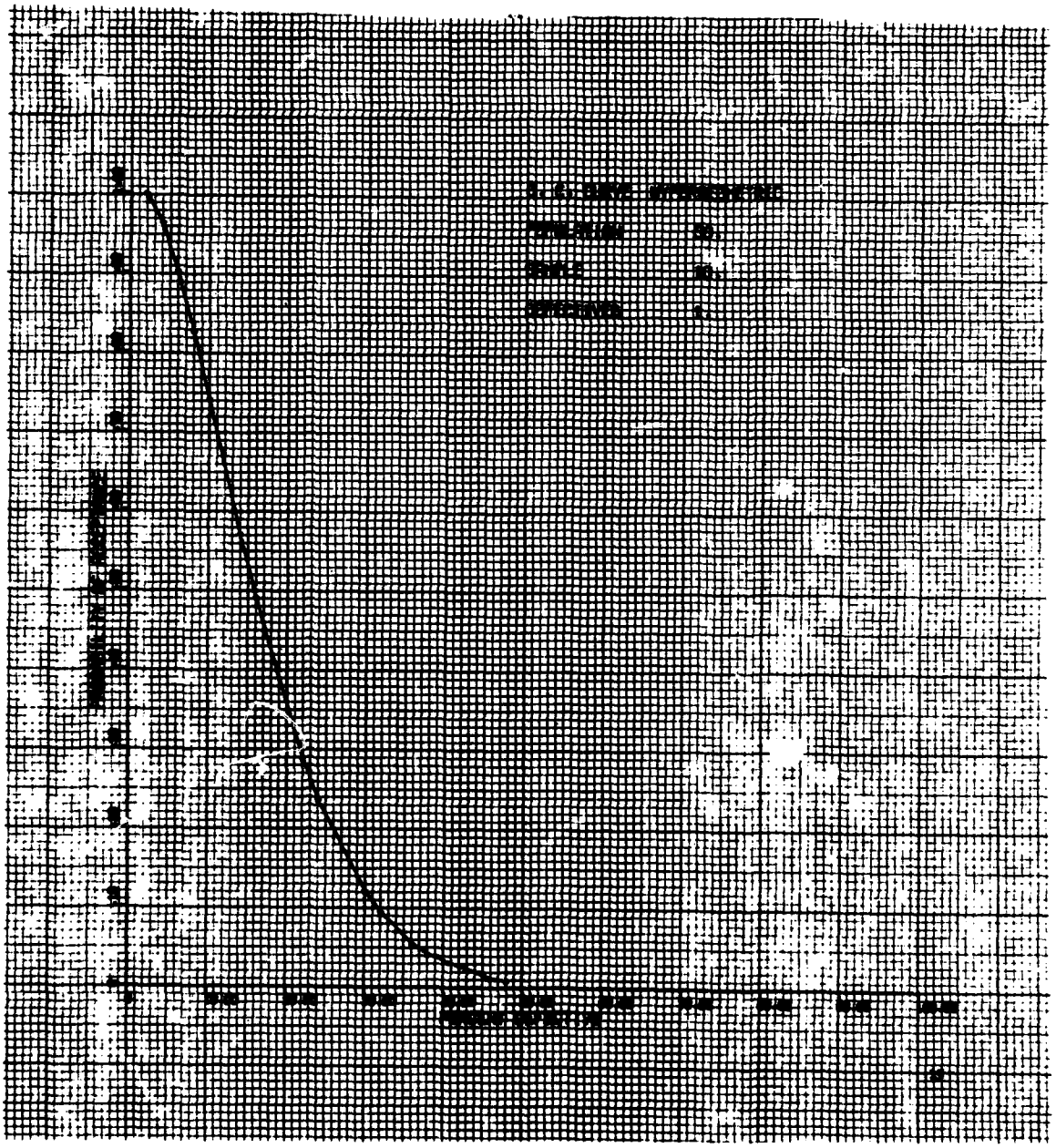
APPENDIX B

Sample Output

OPERATING CHARACTERISTIC CURVE

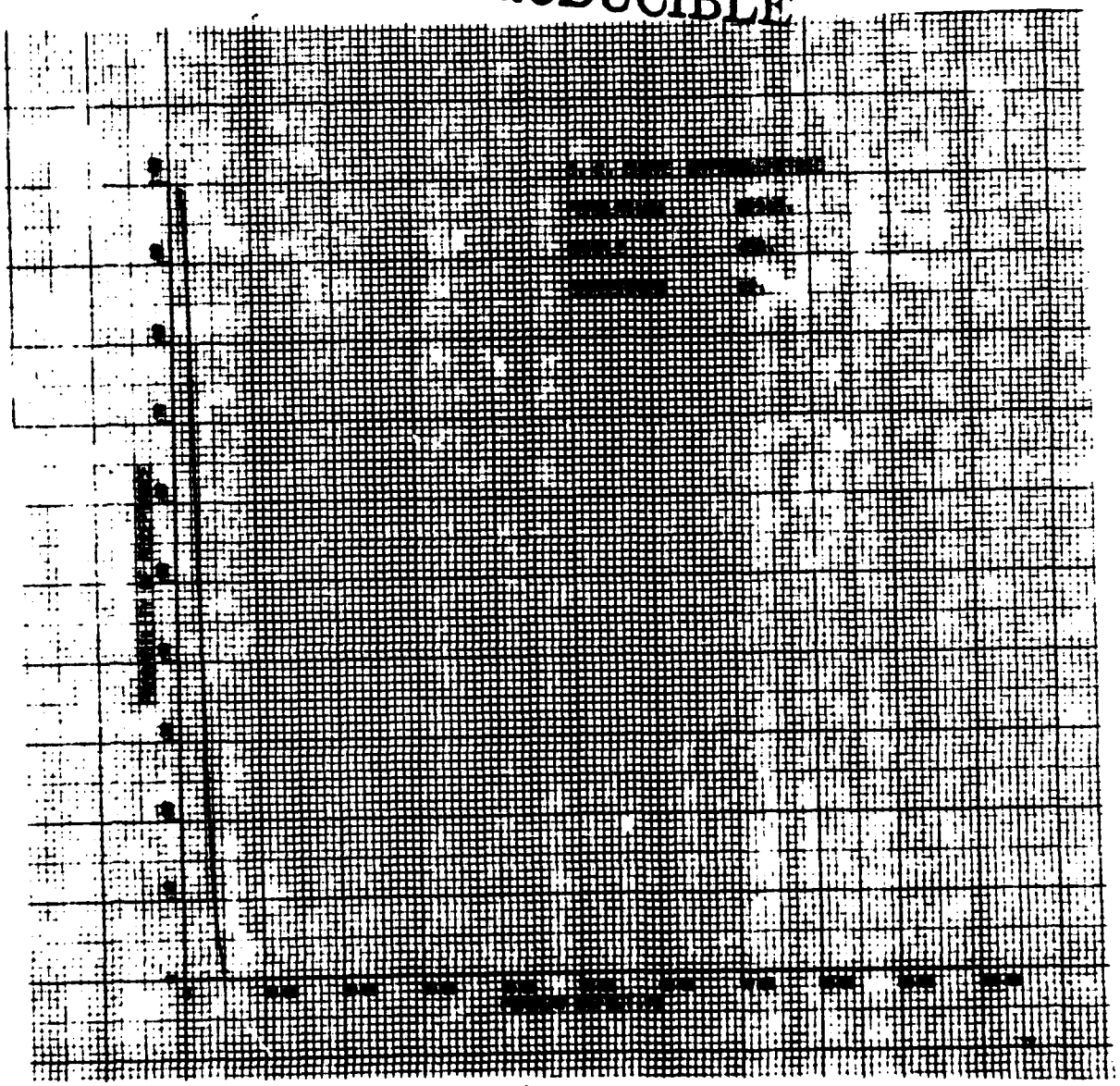
POPULATION SIZE 50. SAMPLE 10. ACCEPTABLE DEFECTS 1.

IF DEFECTIVES IN ORIGINAL POPULATION ARE	PERCENT DEFECTIVE IS	PROBABILITY OF ACCEPTANCE IS	RELIABILITY IS	CONFIDENCE IS
1.	2.00	1.000000	98.00	.000000
2.	4.00	.963265	96.00	.036735
1.	2.00	1.000000	98.00	.000000
2.	4.00	.963265	96.00	.036735
2.	4.00	.963265	96.00	.036735
3.	6.00	.902041	94.00	.097959
3.	6.00	.902041	94.00	.097959
4.	8.00	.825836	92.00	.174164
4.	8.00	.825836	92.00	.174164
5.	10.00	.741900	90.00	.258100
7.	14.00	.570934	86.00	.429066
8.	16.00	.490502	84.00	.509498
11.	22.00	.288817	78.00	.711183
12.	24.00	.236449	76.00	.763551
15.	30.00	.120975	70.00	.879025
16.	32.00	.094463	68.00	.905537
18.	36.00	.055430	64.00	.944570
19.	38.00	.041607	62.00	.958393
23.	46.00	.011315	54.00	.988685
24.	48.00	.007817	52.00	.992183



OPERATING CHARACTERISTIC CURVE

POPULATION SIZE 12345. SAMPLE 456. ACCEPTABLE DEFECTS 12.

IF DEFECTIVES IN ORIGINAL POPULATION ARE	PERCENT DEFECTIVE IS	PROBABILITY OF ACCEPTANCE IS	RELIABILITY IS	CONFIDENCE IS
169.	1.37	.990082	98.63	.009918
170.	1.38	.989609	98.62	.010391
191.	1.55	.975010	98.45	.024990
192.	1.56	.974058	98.44	.025942
211.	1.71	.950528	98.29	.049472
212.	1.72	.948980	98.28	.051020
236.	1.91	.901517	98.09	.098483
237.	1.92	.899096	98.08	.100904
283.	2.29	.751692	97.71	.248308
284.	2.30	.747811	97.70	.252189
342.	2.77	.501683	97.23	.498317
343.	2.78	.497393	97.22	.502607
408.	3.30	.252853	96.70	.747147
409.	3.31	.249799	96.69	.750201
475.	3.85	.100760	96.15	.899240
476.	3.86	.099233	96.14	.900767
518.	4.20	.050349	95.80	.949651
519.	4.20	.049500	95.80	.950500
605.	4.90	.010041	95.10	.989959
606.	4.91	.009842	95.09	.990158

NOT REPRODUCIBLE