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COMPUTER AIDED PARAMETRIC SONAR DESIGN.(U)
MAY 73 E C GANNON, R P PINGREE
UNCLASSIFIED NUSC-TM-TDIX-33-73 NL

1 OF 1
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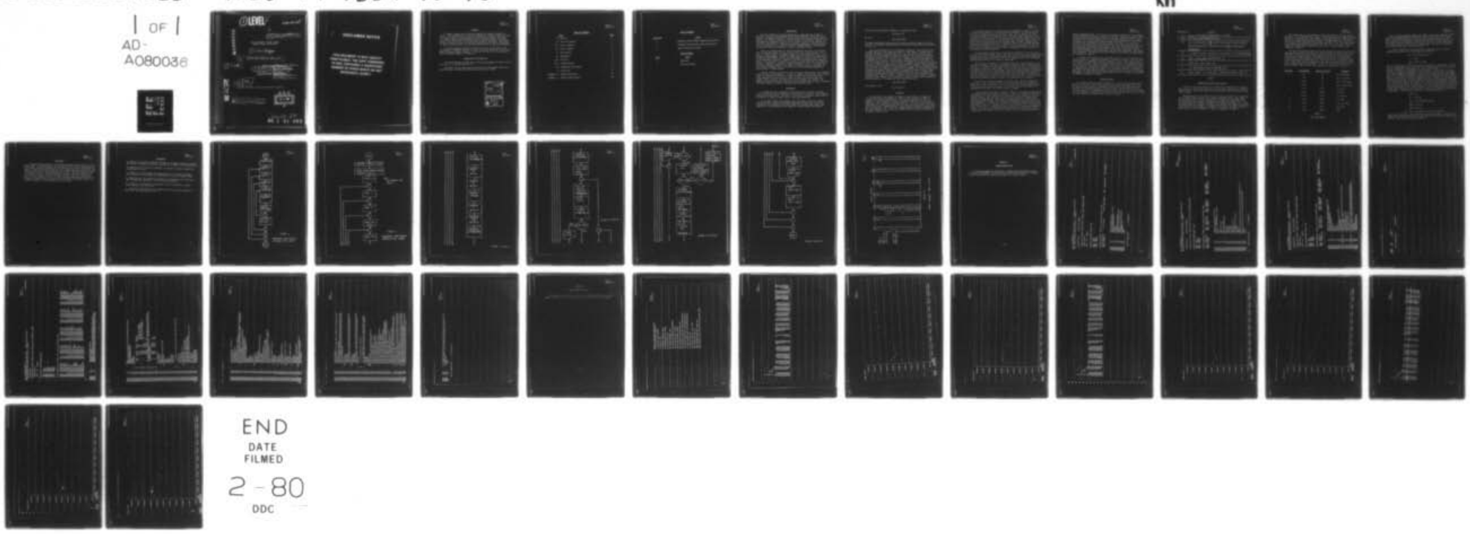

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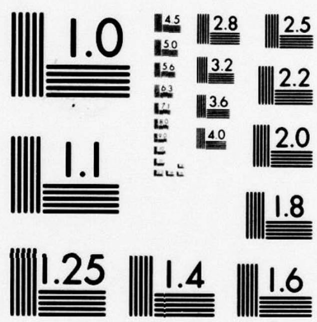

MICROCOPY RESOLUTION TEST CHART
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(6) COMPUTER AIDED PARAMETRIC SONAR DESIGN.

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ABSTRACT

A computer program was written that enables the design of parametric sonars. This program accepts as inputs temperature, salinity, depth, estimates of projector area, desired secondary source level and secondary frequency. The program computes various parametric sonar quantities among them primary source level, directivity index and primary operating frequency. The program actually generates a matrix of possible design values that permit the designer to choose those which best suit his needs based on other system considerations.

The design program is written in Fortran V for use on the Univac 1108. The program is completely general and any of the input parameters can be varied while holding the others constant. A discussion on how to use the program as well as a sample example is included.

ADMINISTRATIVE INFORMATION

This memorandum was prepared under Project No. A-614-19, Principal Investigator, Dr. A. J. Van Woerkum, Code TC.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

From the viewpoint of the individual who is faced with the design of a parametric sonar, the calculations involved seem repetitive and in some cases endless. The Mellen and Moffett[1] curves together with the appropriate equations given in the reference contain all of the necessary information. However, the information is presented in such a way as to make it easy to work through the curves and calculations to analyze the parametric operation of existing projectors and systems but it is difficult and not straightforward to work backward through the curves and equations to design a projector system.

There is a solution which is offered by Moffett[2] that uses a "load line" type of technique similar to that used in vacuum tube circuit design. This is good for a small number of possible designs of a given parametric sonar. The method requires, however, repetitive computations to arrive at the dimensionless parameters 1/(2)(AL)(RO) for each possible parametric stepdown ratio (the ratio of the parametric difference frequency to the mean projector driving frequency FO/F). The term (AL) is absorption in nepers per meter while RO is the Rayleigh distance. Appendix B contains a complete glossary of terms. The "load line" method is presently limited by the number of families of curves available for the different stepdown ratios and the accuracy of interpolating between the given curves of a given family.

A means, therefore, was devised where the whole design process was automated using the Univac 1108 computer. In essence, computer aided design. The solution allows the designer to work from a known secondary source level (LSS) and a known secondary frequency (F) for a range of values of projector size (A), primary source level per tone (LSP) and a given stepdown ratio (FO/F). The computer program will build a matrix of possible designs that can then be compared with other factors to achieve a workable and realistic design.

BACKGROUND

In parametric sonar calculations, two distinct and different problems arise. One is that of the analysis of existing sonar to predict their parametric operating characteristics. The other is the design of parametric sonars having a given set or range of output source levels and frequencies.

In the first problem, one usually knows the primary operating frequency (FO), the primary source level (LSP), and the projector area (A). From these one obtains the secondary source level (LSS) and secondary directivity index (NDIS) for a given downshift ratio (FO/F) by using the Mellen and Moffett curves and the appropriate formulae. In summary, we know

FO, LSP and A.

We find

LSS, FO/F, NDIS.

The Mellen and Moffett curves and the associate equations readily lend themselves to solving this problem because of the way the equations and the curves are set up.

The second problem is one of designing a parametric sonar starting from "scratch" where one only knows the desired, or the range of desired, LSS, F, and NDIS and wants to find FO, LSP and A. At first glance one would say, "Why not just work backwards through the equations with the aid of the Mellen and Moffett curves?" Alas, life is not so simple. The equations depend on a knowledge of FO, and A. In other words, something must be known about the projector before starting. Unfortunately, determining FO, A, and LSP is the goal of the design process. This is just the opposite of the analysis previously discussed. There is a method that has been proposed by Moffett that utilizes the "load line" technique previously mentioned. This method is excellent when an exact FO and A are sought for a given LSS, F, and NDIS. The method becomes time consuming and requires tedious repetitive calculations when a range of values is sought and when one needs numerous possibilities in order to examine and choose an optimum solution based on factors other than just parametric sonar considerations. What is needed is a method of constructing a matrix of possible parametric sonar designs for the designer to weigh in consort with associated system parameters. In summary for this situation we know

LSS, FO/F, NDIS

and we want to find

FO, LSP and A.

SOLUTION

The solution to the problem is computer aided design. A program was written that allows the designer to vary F, A, LSS, and FO/F in order to construct the desired design matrix. The program compilation is given in Appendix A. This program is versatile enough so that three other parameters temperature (T), salinity (S) and depth (D) can be varied in coarse steps and their effects on the design studied. The results are tabulated and two on-line plots are possible. The results of a sample example are shown in Appendix B. The on-line plots can be of any two variables and each plot can be altered by changing a computer card.

At present, one plot is acoustic power in dB (PADB) vs. FO/F for a given LSS with the parameters T, S, D, F and A held constant. Then either LSS, F, or A can be changed and another plot made. Thus, one can examine the range of possible designs that are within the desired power budget and select a reasonable one. The second plot is secondary directivity index (NDIS) vs FO/F for the same given conditions as in the previous plot. From this the designer can select the necessary quantities for a desired range of NDIS. Normally, many plots will be produced resulting in families of LSS curves with NDIS and PADB plotted against FO/F with T, S, D, constant for many combinations of F and A. Once a set of parameters is decided upon, the appropriate exact constants can be obtained from the tabulation.

One thing that has been done to aid in plot comparisons is to force the plots to a convenient common scale. This was done by the use of two dummy points on each plot. This was necessary because the routine as originally compiled by Gordon[3] automatically scaled the axis for the plotting range. For the desired comparisons of plots, such scaling is undesirable.

The program is outlined in a simplified flow chart shown in Figure 1. It operates as follows: The inner loop computes parametric sonar design constants for each of a sequence of FO/F values. This is done for each of a sequence of LSS values in the input data (LSS1). Next, the two inner loops are repeated for a sequence of values for A and finally these three innermost loops are repeated for each value of F in the input data. These four loops generate a matrix of possible designs for the ranges of FO/F, LSS, A, and F chosen. Each matrix is built up for constant values of T, S, and D. The values for T, S, and D can be altered by changing them when the data is programmed into the computer.

The plots as presently compiled plot after each sequence of FO/F for a given LSS. Thus, a family of curves of different LSS values is generated. These are for each combination of T, S, D, F, and A and are plotted with FO/F as the horizontal axis on each plot. The vertical axis on plot number 1 is PADB while the vertical axis on plot number 2 is NDIS.

A more detailed flow chart is shown in Figure 2. It shows an expansion of the computational block diagram of Figure 1. Thus, the location of the various calculations are shown along with the appropriate tests required to keep the program bounded. Once the data is entered, the calculations leading to the quantity 1/(2)(AL)(RO) are made where the attenuation loss is (AL) and the Rayleigh distance is (RO). This quantity 1/(2)(AL)(RO) together with the FO/F and a quantity X is entered into a numerical integration subroutine devised by Goldstein[4]. The X is a parameter that ties the integration to a scaled source level (L*) which is a normalized parametric quantity in the Mellen and Moffett theory. The output of the numerical integration enters into several simple computations, the results of which are tested to see if they fall within the proper programmed bounds. If the tests are failed, a new value of X is chosen and the integration routine is redone and retested. Depending on how the tests are passed, the program either proceeds to calculate further parametric sonar quantities for the given solution of the numerical integration or the program recognizes that the numerical integration has searched as far as it can. In any event, the program will proceed to readout the results in a table then recycle to the next FO/F in the innermost loop. Once the desired LSS values has been completely investigated, the computer constructs the two on-line plots previously mentioned. The program then recycles until all possible values of F, A, LSS and FO/F have been investigated and all plots completed. The program then terminates. The detailed flow chart (Figure 2) references equations which are tabulated in Table I.

In essence, the program takes some known values for a given condition and hunts, by means of a numerical integration routine and specific tests, for other needed values to completely describe a parametric sonar. Since usually there is a range of desired values, the program builds a matrix of possible solutions. The accuracy of these solutions depends on the accuracy of the parameter X used in the numerical integration. Presently, the solution calculates an LSS which is compared with the input LSS (LSS1). The calculated value has a tolerance of ± 0.82 dB. The resultant LSP, parametric gain (G), acoustic power (PA and PADB), and primary frequency directivity index (NDIP) all have a tolerance of ± 0.41 dB. The NDIS has a ± 0.82 dB tolerance.

PROGRAM OPTIONS

The design program has certain options as a result of the general form in which it is written. The program contains four nested loops any of which can be varied or held constant by appropriate input data on the input data cards. The plots can be varied, however, this may involve repositioning the plot in the program as well as changing two program cards. The user may have to redimension the storage associated with the loops preceding the plot in order to be sure the data computed is retained until the plot is called.

Equation No.	Equation
1.	$X_{(I+1)} = 1.1X_I$ FOR 86 VALUES FROM $X = 0.090909$
2[5].	$FT = 21.9 \times 10^{6-(1520/(T+273))}$ kHz
3[5].	$AL = (1/8.68)(1/914.4)\left\{\left[(1.86 \times 10^{-2})(S)(FT)(FO)^2/\left[(FT)^2+(FO)^2\right]\right] + \left[2.68 \times 10^{-2}(FO)^2/FT\right] + \left[0.1(FO)^2/(1+(FO)^2)\right]\right\}(1-6.33233 \times 10^{5}D)$ NEPERS/METER
4[5].	$C = 1449.2 + 4.623T - 0.0546(T^2) + 1.391\ (S-35) + 0.017D$ METERS/SECOND
5[6].	$NDIP = 10\ LOG_{10}(4\pi A\ (FO)^2(10^3)^2/C^2)$ DB
6.	$PADB = LSP - 70.8 - NDIP$ DB
7.	$PA = ANTILOG\left[(1/10)(LSP-70.8-NDIP)\right]$ WATTS
8[1].	$NDIS = (NDIP) + 3 - 10\ LOG_{10}\left[1 + ((FO)/F)(2\pi(AL)(RO) + X)\right]$ DB

TABLE I

PROGRAM USAGE AND SAMPLE EXAMPLE

In order to use the program, the user must stack appropriately formatted data cards in a fixed order at the end of the program. There are six different types of cards. These cards will now be discussed in order from front to back of the stack.

The first type of card contains only one card and comes first in the data. It is formatted into 4 fields of one integer number per field. Each number must be right justified in a field width of five (Fortran V statement (I5)). The first field uses columns 1 through 5 and contains the number of F values. The second field uses columns 6 through 10 and contains the number of A values. The third field uses columns 11 through 15 and contains the number of LSS values. The fourth field uses columns 16 through 20 and contains the number of FO/F values plus 1. This arrangement of fields is summarized in Table 2.

The second type of card contains only one card and it is the 2nd card in the data. It is formatted into 3 fields. Each field contains a number that is written in a floating point format which is right justified in a field width of 10 with a 4 decimal place accuracy (Fortran V statement (F10.4)). The first field uses columns 1 through 10 and contains the value for T. The second field uses columns 11 through 20 and contains the value for 5. The third field uses columns 21 through 30 and contains the value for D. These fields are also summarized in Table 2.

The third through sixth type of cards may contain more than 1 card for each type but only one value for each card. Thus, one must use as many cards for each type as there are values associated with that type and the cards for each type must be grouped together. Each number is written in a floating point format which is right justified in a field width of 10 with a 5 decimal place accuracy (Fortran V statement (F10.5)). Each third type of card gives a value for F. Each fourth type of card gives a value for A. Each fifth type of card gives an input value for LSS (LSS1). Lastly, each sixth type of card gives a value for FO/F. Each of these field layouts are summarized in Table 2.

Card Type	Card Columns	Fortran IV Format	Agreement
1	1-5	I5	No. of F values
	6-10	I5	No. of A values
	11-15	I5	No. of LSS values
	16-20	I5	No. of FO/F values
2	1-10	F10.4	T in deg C
	11-20	F10.4	S in PPT
	21-30	F10.4	D in meters
3	1-10	F10.5	F in kHz
4	1-10	F10.5	A in sq. meters
5	1-10	F10.5	LSS in dB
6	1-10	F10.5	FO/F

TABLE 2

DATA CARD FORMATS

The use of this program requires the input of data from a program stored on tape in the NUSC New London Laboratory Univac 1108 files. This is tape U183. Different parameter plots may be made by simply changing the call to plot (Call Plot A) statements. There are two such plots in the program. The plot routine can be eliminated by removing the two call to plot cards which are located adjacent to each other in the program. The rest of the program should run and the table of results printed.

A sample example will now be discussed. Suppose we want to design a parametric sonar that has the following specifications:

$$LSS = 90 \text{ dB}//1\mu\text{bar-meter}$$

$$F = 3 \text{ kHz}$$

$$N_{DI} = 30 \text{ dB to } 35 \text{ dB}$$

and the power budget is such that we wish to minimize its consumption. Assume that the system will work in the ocean (S = 35 ppt) and that the system must be capable of operating in the winter ($T = 7^{o}C$) on the surface (D = 0). The data is programmed as shown in Figure 3. The tables of results are shown in Appendix B along with 3 sets of plots. Examination of the results shows several design possibilities all within the region of a dip in the PADB plots. If it were not possible to examine so large a quantity of points, the dip quite possibly would go unnoticed because there is a tendency for the unwitting designer to assumethat increased stepdown ratio means increased power consumption. Apparently, this is not always true. When the desired points are isolated on the plots, the designer then can go to the tables and from them he can determine the design that gives the desired source level within the NDIS restrictions. The desired design for the sample example is the one underlined in the appropriate table of Appendix B and encircled on each of the associated PADB and NDIS vs FO/F plots. The selected design has the following parameters:

$$FO/F = 10$$

$$FO = 30 \text{ kHz}$$

$$LSP = 131.2 \text{ dB}//1\mu\text{bar-meter}$$

$$NDIP = 36.1 \text{ dB}$$

$$NDIS = 34.4 \text{ dB}$$

and $PA = 267.1$ watts/each primary frequency.

Other related quantities can be obtained from the data tables. For different applications these quantities may assume importance and thus are readily available if design tradeoffs become necessary.

CONCLUSION

A computer aided parametric sonar design program has been written for the UNIVAC 1108. This program allows the designer to take a given secondary source level (LSS), secondary frequency (F) and secondary directivity index (NDIS) and compute a range of possible parametric sonar designs that will satisfy his needs. Thus, the selection of sonar parameters is no longer limited by the difficulty of examining a range of possible parametric designs. The sonar designer can now construct a matrix of possible designs then base the final selection on which of these designs best fits the other systems parameters being considered. By means of computer aided design, literally hundreds of possible designs for a given situation can be investigated in a short time.

REFERENCES

1. Mellen, R. H. and M. B. Moffett, "A Model for Parametric Radiator Design," USN Journal of Underwater Acoustics, Vol. 22, No. 2, April 1972 (Unclassified).

2. Moffett, M. B., "Load Line Technique for Parametric Design," unpublished communication in 1972.

3. Gordon, R. L., "A Fortran V Plotting Routine for the Univac 1108 High Speed Printers," USL Tech Memo No. 2242-291-68, 25 July 1968 (Unclassified).

4. Goldstein, M., "On A numerical Integration in Parametric Sonar Research," NUSC Tech Memo No. PA4-268-71, 21 Oct 1971, (Unclassified).

5. Urick, R. J., "Principles of Underwater Sound for Engineers," McGraw Hill, Copyright 167, pages 88-96.

6. "The Design and Construction of Magnetostriction Transducers," NDRC Div 6 Report Vol. 13, dated 1946, p. 128.

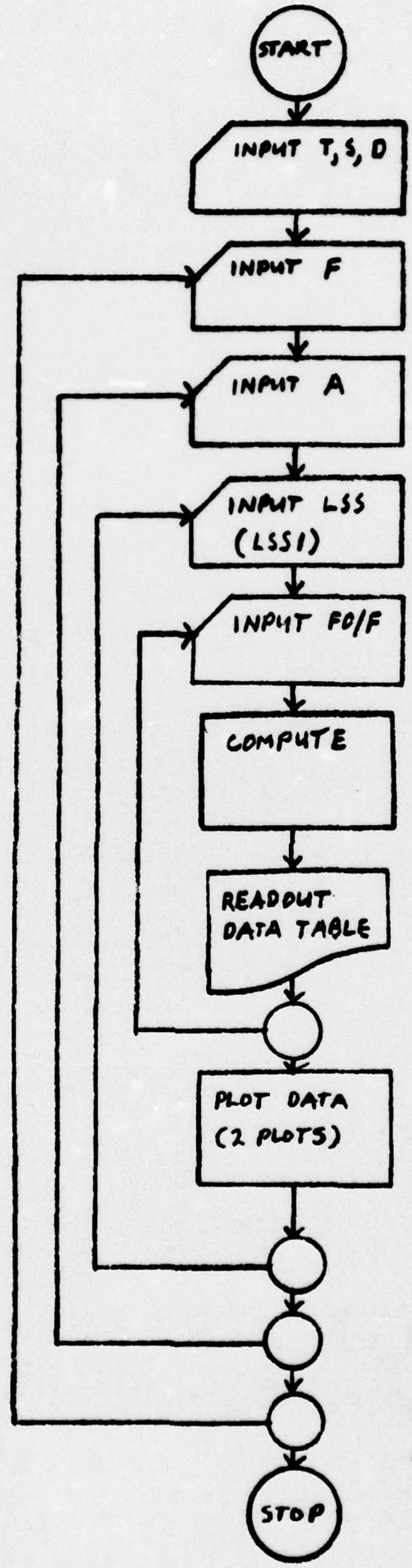
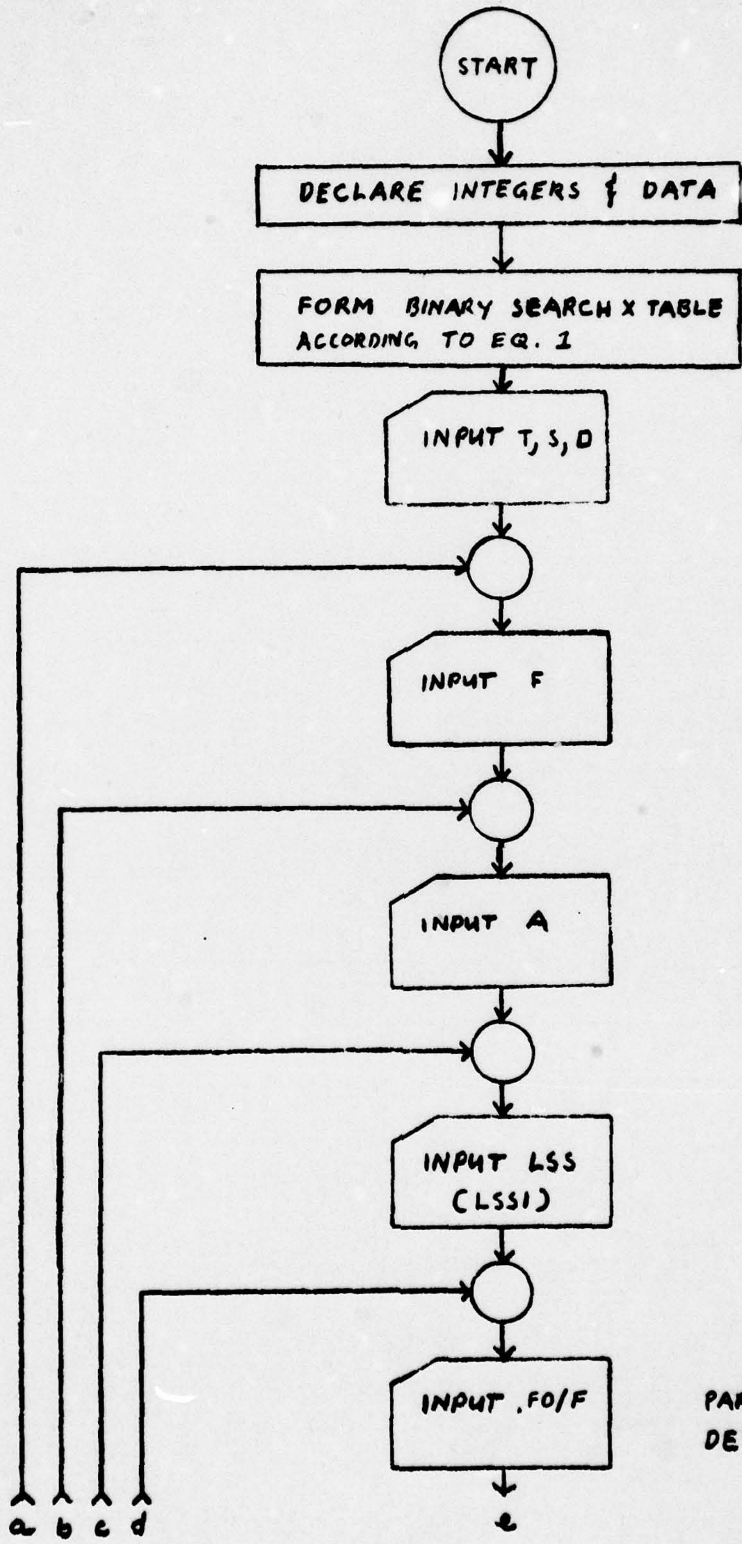


FIGURE 1

PARAMETRIC SONAR DESIGN, SIMPLIFIED FLOW CHART



NOTE:
FOR EQUATIONS SEE TABLE 1

FIGURE 2

PARAMETRIC SONAR DESIGN, DETAILED FLOW CHART

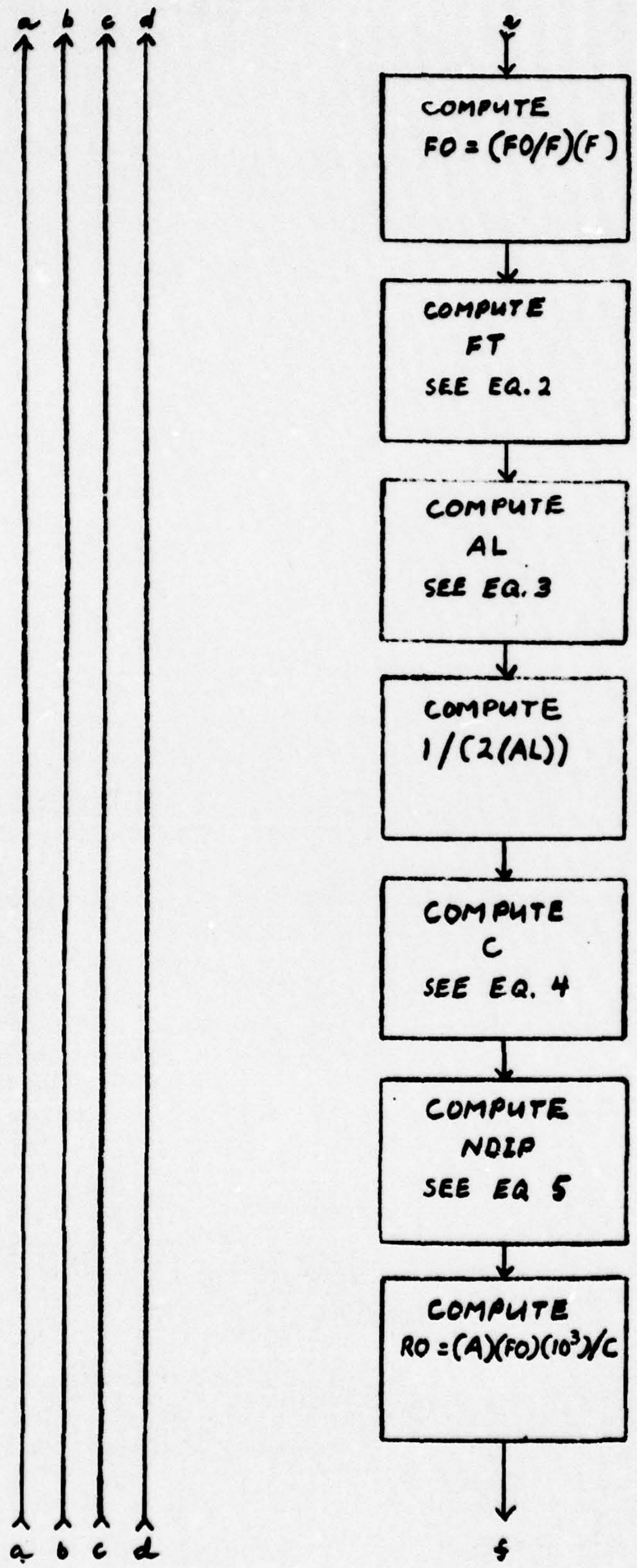


FIGURE 2 (CONT. 1)

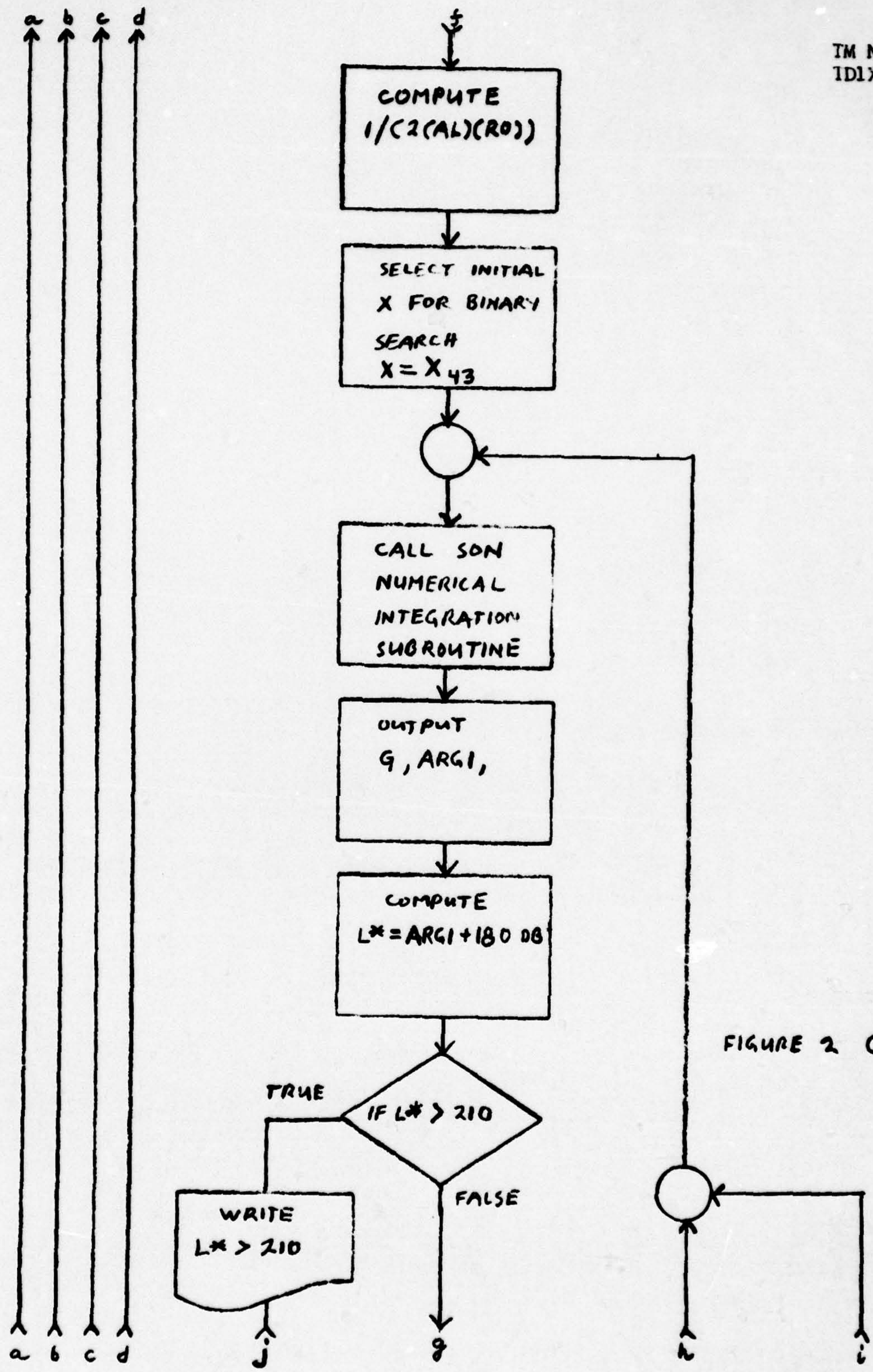


FIGURE 2 (CON'T 2)

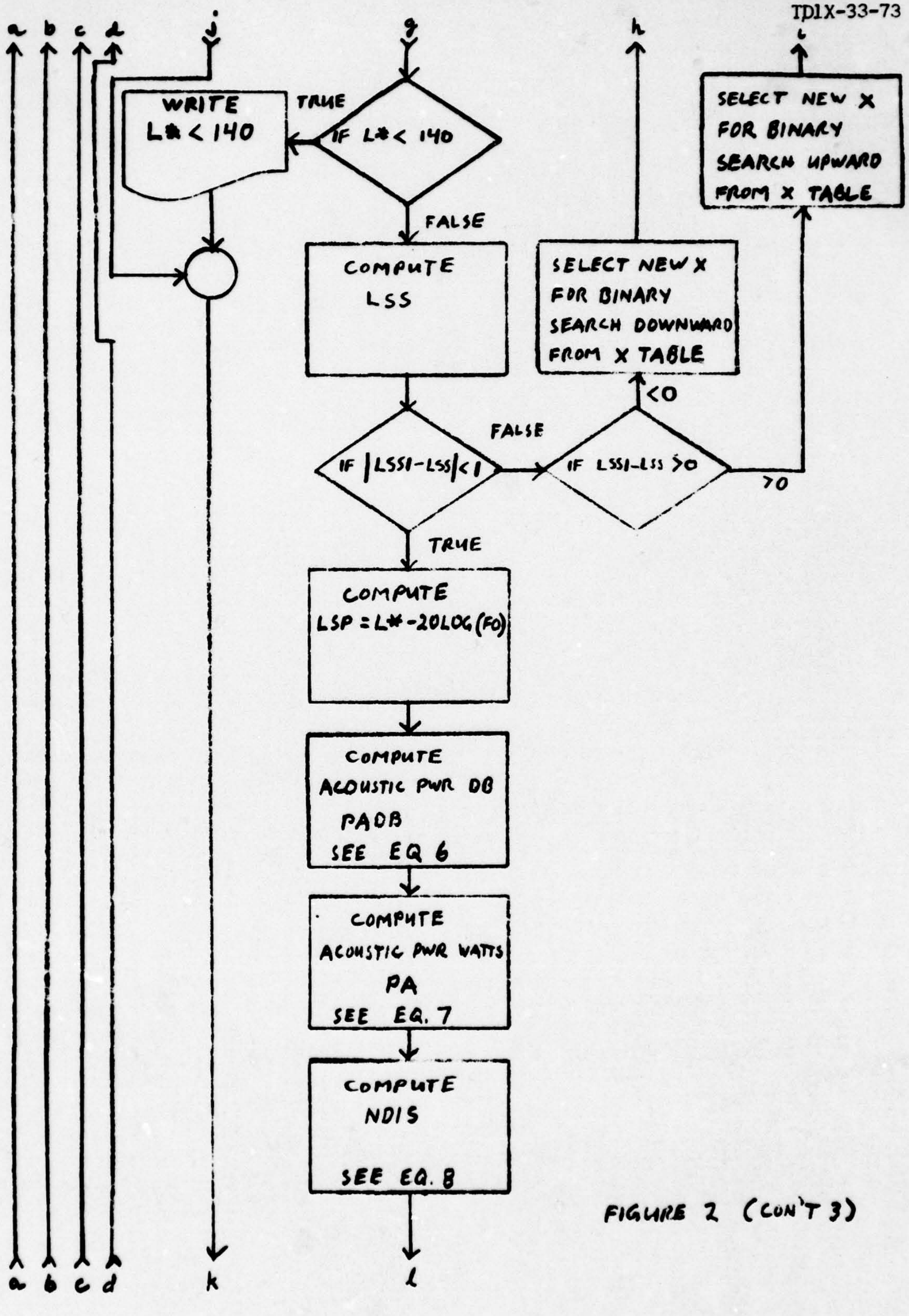


FIGURE 2 (CON'T 3)

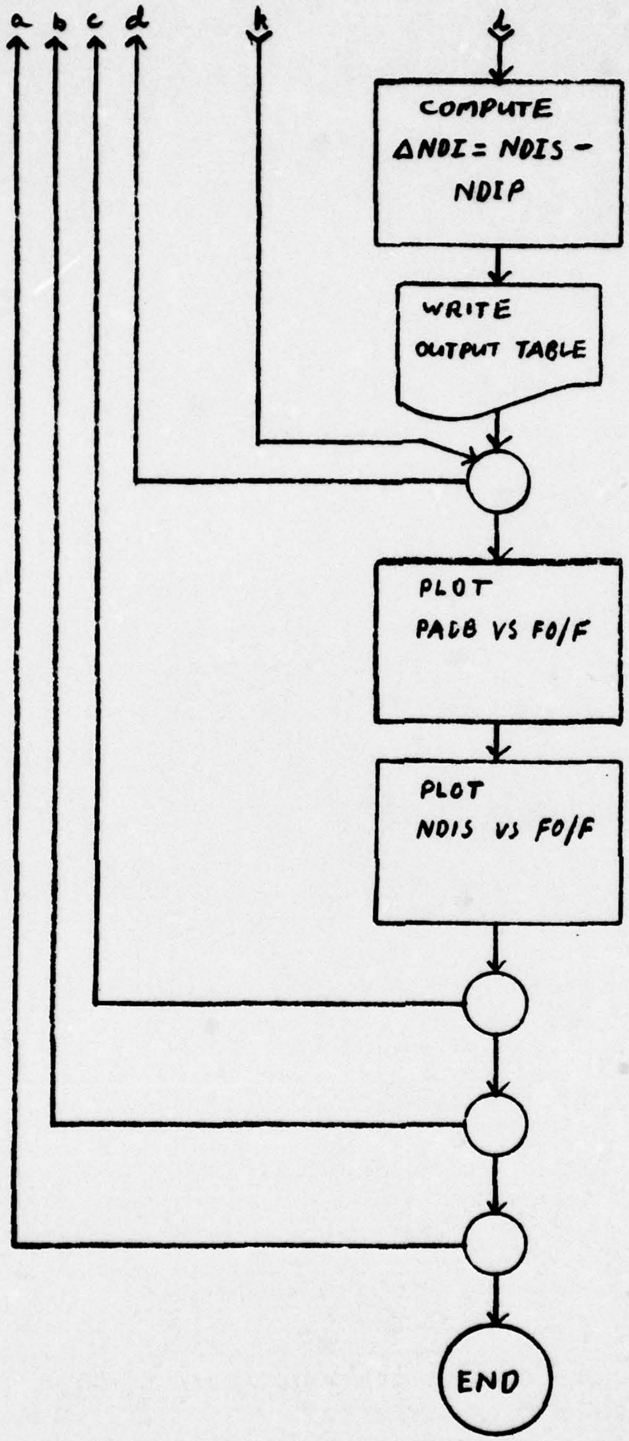


FIGURE 2 (CON'T. 4)

COLUMN NUMBER

	1–5	6–10	11–15	16–20	21–25	26–30
CARD 1	1	3	1	12		
CARD 2		7.		35.		0.
TYPE 3 CARDS		3.				
TYPE 4 CARDS		.1964				
		.3927				
		.7854				
TYPE 5 CARDS		90.				
TYPE 6 CARDS		5.				
		7.5				
		10.				
		12.5				
		15.				
		20.				
		30.				
		40.				
		50.				
		70.				
		100.				

FIGURE 3

SAMPLE EXAMPLE DATA FORMAT

APPENDIX A

PROGRAM COMPILATION

The program compilation shown here is complete with subroutines except for the plot subroutine. That particular one was on tape and was not compiled as was the material that was put in by means of a deck of cards.

```
@     FOR SUB,SUB                                                                                   21:34:46. 50
UNIVAC 1108 FORTRAN V LEVEL 2206 0026      (EXEC8 LEVEL E1201-0011)
THIS COMPILATION WAS DONE ON 14 JUN 73 AT 21:34:46

    SUBROUTINE SUB        ENTRY POINT 000067

    STORAGE USED: CODE(1) 000103; DATA(0) 000020; BLANK COMMON(2) 000000

     COMMON BLOCKS:

     0003   BLK    000010

    EXTERNAL REFERENCES (BLOCK, NAME)

     0004   DSINH
     0005   DEXP
     0006   DSQRT
     0007   NERR3$

    STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

     0003 D 000000 ARO       0003 D 000006 E          0003 D 000002 GKDKO      0000    000012 INJP$      0000 D 000000 T
     0003 D 000004 X


00101        1*            SUBROUTINE SUB(A,J,H,F)
00103        2*            IMPLICIT DOUBLE PRECISION (A-H,O-Z)
00104        3*            COMMON/BLK/ARO,GKDKO,X,E
00105        4*            T=A+J*H
00106        5*            F=DSINH(T)
00107        6*            T=1.0D0+((X*T)**2)/4.0D0
00110        7*            IF(ARO.GT.0.0D0) E=DEXP(-F*ARO)
00112        8*            F=F**2
00113        9*            F=(1.0D0+F)/(1.0D0+F*GKDKO**2)
00114       10*            F=E*(DSQRT(F)/T)
00115       11*            RETURN
00116       12*            END

      END OF COMPILATION:        NO  DIAGNOSTICS.
```

```
      FOR ROM,ROM                                                                                   21:34:47. 40
UNIVAC 1108 FORTRAN V LEVEL 2206 0026      (EXEC8 LEVEL E1201-0011)
THIS COMPILATION WAS DONE ON 14 JUN 73 AT 21:34:47

   SUBROUTINE ROM        ENTRY POINT 000246

   STORAGE USED: CODE(1) 000275; DATA(0) 000060; BLANK COMMON(2) 000000

   EXTERNAL REFERENCES (BLOCK, NAME)

    0003    SUB
    0004    NEXP1$
    0005    NEXP6$
    0006    NERR3$

   STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

    0001   000071 120G      0001   000120 130G      0001   000033 4L       0000 D 000003 F       0000 D 000005 FN
    0000 D 000000 H         0000   000031 INJP$     0000 I 000015 IU       0000 I 000012 J       0000 I 000013 J1
    0000 I 000002 K         0000 I 000014 L         0000 I 000011 M        0000 D 000007 SIG


00101       1*            SUBROUTINE ROM(A,B,W,EPS,IV,NMX)
00103       2*            DIMENSION W(NMX,NMX)
00104       3*            IMPLICIT DOUBLE PRECISION (A-H,O-Z)
00105       4*            H=B-A
00106       5*            K=0
00107       6*            CALL SUB(A,0,H,F)
00110       7*            FN=F
00111       8*            CALL SUB(A,1,H,F)
00112       9*            W(1,1)=((F+FN)*H)/2.0D0
00113      10*          4 K=K+1
00114      11*            H=H/2.0D0
00115      12*            SIG=0.0D0
00116      13*            M=2**(K-1)
00117      14*            DO 1 J=1,M
00122      15*            J1=2*J-1
00123      16*            CALL SUB(A,J1,H,F)
00124      17*          1 SIG=SIG+F
00126      18*            W(K+1,1)=W(K,1)/2.0D0+H*SIG
00127      19*            DO 2 L=1,K
00132      20*            IU=K+1-L
00133      21*            IV=L+1
00134      22*          2 W(IU,IV)=(4.0D0**(IV-1)*W(IU+1,IV-1)-W(IU,IV-1))/(4.0D0**(IV-1)-1.
00134      23*           1D0)
00136      24*            IF(ABS(W(IU,IV)-W(IU,IV-1)).LT.ABS(W(IU,IV))*EPS) RETURN
00140      25*            GO TO 4
00141      26*            END

      END OF COMPILATION:        NO  DIAGNOSTICS.
```

```
@ FOR SON,SON                                                                                    21:34:48.364
UNIVAC 1108 FORTRAN V LEVEL 2206 0026      (EXEC8 LEVEL E1201-0011)
THIS COMPILATION WAS DONE ON 14 JUN 73 AT 21:34:48

   SUBROUTINE SON        ENTRY POINT 000134

   STORAGE USED: CODE(1) 000160; DATA(0) 011664; BLANK COMMON(2) 000000

    COMMON BLOCKS:

    0003   BLK    000010

   EXTERNAL REFERENCES (BLOCK, NAME)

    0004   ROM
    0005   DLOG
    0006   DATAN
    0007   DLOG10
    0010   NERR3S

   STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

    0001     000045 1L       0000 D 011612 A       0000 D 011620 ALN1    0003 D 000000 ARO     0000 D 011614 B
    0003 D 000006 E          0000 D 011610 EPS     0000 D 011622 FAC     0003 D 000002 GKDKO   0000 D 011616 GKDKOS
    0000     011650 INJPS    0000 I 011624 IV      0000 D 000000 W       0003 D 000004 X

 00101       1*             SUBROUTINE SON (RARO,RKDKO,ARG,ANS,AIN,NMX)
 00103       2*             IMPLICIT DOUBLE PRECISION (A-H,O-Z)
 00104       3*             COMMON/BLK/ARO,GKDKO,X,E
 00105       4*             DIMENSION W(50,50)
 00106       5*             EPS=.5D-05
 00107       6*             A=0.0
 00110       7*             B=20.0
 00111       8*             E=1.CD0
 00112       9*             ARO=0.0D0
 00113      10*             IF(RARO.GT.ARO) ARO=1.0D0/RARO
 00115      11*             GKDKO=1.0D0/RKDKO
 00116      12*             GKDKOS=GKDKO**2
 00117  *DIAGNOSTIC*  THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL.
 00117      13*             IF(RARO.EQ.0.0D0) GO TO 1
 00121      14*             ALN1=DLOG(RKDKO)
 00122      15*             B=DLOG((84.0D0+ALN1)*RARO)
 00123      16*           1 FAC=GKDKOS*(X/2.0D0)
 00124      17*             CALL ROM(A,B,W,EPS,IV,50)
 00125      18*             AIN=W(1,IV)
 00126  *DIAGNOSTIC*  THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL.
 00126      19*             IF(RARO.EQ.0.0D0) AIN=AIN+2.0D0*RKDKO*(1.5707963267948900-DATAN(10
 00126      20*            1.0D0*X))/X
 00130      21*             AIN=FAC*AIN
 00131      22*             ARG=20.0D0*DLOG10(X)
 00132      23*             ANS=20.0D0*DLOG10(AIN)
```

```
00133      24*          RETURN
00134      25*          END

      END OF COMPILATION:        2 DIAGNOSTICS.
```

```
@      FOR SONAR,SONAR                                                                                  21:34:49.464
UNIVAC 1108 FORTRAN V LEVEL 2206 0026      (EXEC8 LEVEL E1201-0011)
THIS COMPILATION WAS DONE ON 14 JUN 73 AT 21:34:49

     MAIN PROGRAM

     STORAGE USED: CODE(1) 001012; DATA(0) 004536; BLANK COMMON(2) 000000

      COMMON BLOCKS:

      0003    BLK     000010

     EXTERNAL REFERENCES (BLOCK, NAME)

      0004    SON
      0005    PLOTA
      0006    NRDU$
      0007    NIO2$
      0010    NEXPO$
      0011    NIO1$
      0012    NWDU$
      0013    ALOG10
      0014    DLOG10
      0015    NSTOP$

     STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

      0000    004023 100F     0000    004002 101F     0000    004003 102F     0000    004025 103F     0000    004242 104F
      0000    004262 105F     0000    004321 106F     0000    004346 107F     0000    004356 112F     0000    004402 113F
      0000    004426 114F     0001    000016 117G     0001    000523 13L      0001    000531 14L      0001    000541 15L
      0001    000140 156G     0001    000160 164G     0001    000557 17L      0001    000172 172G     0001    000204 200G
      0001    000573 200L     0001    000234 206G     0001    000671 210L     0001    000237 211G     0001    000247 214G
      0001    000717 220L     0001    000312 236G     0001    000430 257G     0001    000744 4L       0001    000571 5L
      0000 R  001130 A        0000 R  002424 ADUM     0000 D  003410 AIN      0000 R  001750 ALPHA    0000 D  003416 ANS
      0000 R  003244 ANS1     0000 D  003414 ARG      0000 R  003100 ARG1     0003 D  000000 ARO      0000 R  003760 C
      0000 R  003753 D        0000 R  001274 DELNDI   0000 R  004000 DUM      0003 D  000006 E        0000 R  000764 F
      0000 R  001440 FO       0000 R  003764 FT       0003 D  000002 GKDKO    0000 I  003737 I        0000 I  003754 IA
      0000 I  003755 IB       0000 I  003756 IC       0000 I  003734 ICARD    0000 I  003774 ICONST   0000 I  003757 ID
      0000 I  003776 IDUM1    0000 I  003775 IDUM2    0000 I  003761 II       0000 I  003773 IIX      0000 I  003767 IMAX
      0000 I  003770 IMID     0000 I  003766 IMIN     0000 I  003771 IND      0000 I  003772 IOPT     0000 I  003735 IPRINT
      0000 I  003777 ISAVE    0000 I  003762 J        0000 I  003763 JJ       0000 I  003740 KN       0000 I  003741 KN1
      0000 I  003742 KN2      0000 I  003743 KN3      0000 R  000620 LSP      0000 R  000000 LSS      0000 R  000144 LSS1
      0000 I  003744 N        0000 R  000454 NDIP     0000 R  000310 NDIS     0000 I  003765 NLX      0000 I  003745 N1
      0000 I  003746 N2       0000 I  003747 N3       0000 I  003750 N4       0000 R  002114 PA       0000 R  002260 PADB
      0000 R  003736 PI       0000 R  004001 PY       0000 R  002570 RARO     0000 D  003420 RARO1    0000 R  002734 RFDFO
      0000 D  003422 RFDFO1   0000 R  001604 RO       0000 R  003752 S        0000 R  003751 T        0003 D  000004 X
      0000 D  003412 XO       0000 D  003424 XX

00101        1*          REAL LSS,LSS1,NDIS,NDIP,LSP
00103        2*          PARAMETER LMX=100
00104        3*          DIMENSION LSS(LMX),LSP(LMX),LSS1(LMX),NDIS(LMX),F(LMX),A(LMX)
00105        4*          DIMENSION DELNDI(LMX),FO(LMX),RO(LMX),ALPHA(LMX),NDIP(LMX),PA(LMX)
00106.       5*          DIMENSION PADB(LMX),ADUM(LMX),RARO(LMX),RFDFO(LMX),ARG1(LMX),ANS1(
```

```
00106          1LMX)
00107          DOUBLE PRECISION ARO,GKDKO,X,E,AIN,XO,ARG,ANS,RARO1,RFDFO1
00110          DOUBLE PRECISION XX(LMX)
00111          COMMON/BLK/ARO,GKDKO,X,E
00112          ICARD=3
00113          IPRINT=4
00114          PI=3.14159
00114    C
00114    C         CARD   COLUMNS   FORMAT   ARGUMENT
00114    C         ----   -------   ------   --------
00114    C          1      1-5       I5        KN- NO. OF F VALUES
00114    C                 6-10      I5        KN1- NO. OF A VALUES
00114    C                 11-15     I5        KN2- NO. OF LSS VALUES
00114    C                 16-20     I5        KN3- NO. OF FO/F VALUES +1
00114    C          2      1-10      F10.4     T
00114    C                 11-20     F10.4     S
00114    C                 21-30     F10.4     D
00114    C         IN THE FOLLOWING CARDS,IF MORE THAN ONE VALUE OF THE VARIABLES
00114    C         IS DESIRED (BASED ON CARD NO.1) THEN RELATED CARDS (ALL F'S) MUST
00114    C         BE GROUPED TOGETHER
00114    C          3      1-10      F10.5     F
00114    C          4      1-10      F10.5     A
00114    C          5      1-10      F10.5     LSS
00114    C          6      1-10      F10.5     FO/F
00114    C
00115          XO=.90909091D-2
00116          DO 8 I=1,86
00121          XX(I)=1.1*XO
00122        8 XO=XX(I)
00124          READ(ICARD,101) KN,KN1,KN2,KN3
00132      101 FORMAT(4I5)
00133          N=KN
00134          N1=KN1
00135          N2=KN2
00136          N3=KN3
00137          N4=N3+1
00140          RFDFO(1)=0.0
00141          PADB(1)=0.0
00142          NDIS(1)=0.0
00142    C
00142    C         IF POWER IS IN EXCESS OF 100KW CHANGE SCALE OF PADB PLOT
00142    C
00143          PADB(N4)=50.
00144          NDIS(N4)=50.
00145          RFDFO(N4)=0.0
00146          READ(ICARD,102) T,S,D
00153      102 FORMAT(3F10.4)
00154          READ(ICARD,100) (F(IA),IA=1,N)
00162          READ(ICARD,100) (A(IB),IB=1,N1)
00170          READ(ICARD,100) (LSS1(IC),IC=1,N2)
00176          READ(ICARD,100) (RFDFO(ID),ID=2,N3)
00204          C=1449.2+4.623*T-.0546*(T**2)+1.391*(S-35.)+.017 *D
00205          DO 1 I=1,KN
00210          DO 2 II=1,KN1
00213          DO 3 J=1,KN2
00216          WRITE(IPRINT,107)
00220          WRITE(IPRINT,103)
00222          WRITE(IPRINT,114)
```

```
00224          WRITE(IPRINT,104) T,D,S,C,A(II)
00233          WRITE(IPRINT,105)
00235          DO 4 JJ=2,KN3
00240          FO(JJ)=RFDFO(JJ)*F(I)
00241          E=(10.**3)*FO(JJ)
00242          FT=21.9*10.**(6.-(1520./(T+273.)))
00243          ALPHA(JJ)=(1./8.68)*(1.-(.00006332*D))*(1./914.4)*(.0186*((S*FT*(F
00243         1O(JJ)**2))/(FT**2+FO(JJ)**2))+(.0268*FO(JJ)**2/FT    )+((.1*FO(JJ)*
00243         2*2)/(1.+FO(JJ)**2)))
00244          NDIP(JJ)=10.*ALOG10((4.*PI*A(II)*E**2)/C**2)
00245          RO(JJ)=(A(II)*FO(JJ)*(10.**3))/C
00246          RAHO(JJ)=1.0/(2.*ALPHA(JJ)*RO(JJ))
00247          ADUM(JJ)=1.0/(2.*ALPHA(JJ))
00250          NLX=86
00251          IMIN=1
00252          IMAX=NLX
00253          IMID=NLX/2
00254          IND=NLX/2
00255          IOPT=0
00256       20 DO 5 IIX=1,91
00261          X=AX(IND)
00262          RAHO1=RAHO(JJ)
00263          RFDFO1=RFDFO(JJ)
00264          CALL SUN(RAHO1,RFDFO1,ARG,ANS,AIN,50)
00265          ARG1(JJ)=ARG
00266          ANS1(JJ)=ANS
00267          ARG1(JJ)=ARG1(JJ)+180.
00270          IF(ARG1(JJ).GT.210.) GO TO 210
00272          IF(ARG1(JJ).LT.140.) GO TO 220
00274          LSS(JJ)=ARG1(JJ)-20.*ALOG10(FO(JJ))+ANS1(JJ)
00275          IF(ABS(LSS1(J)-LSS(JJ)).LT.1.) GO TO 200
00277          IF(IOPT.NE.0) GO TO 15
00301          IOPT=1
00302          IF(LSS1(J)-LSS(JJ)) 12,12,13
00305       12 ICONST=-1
00306          IDUM2=IMIN
00307          IDUM1=IMID
00310          GO TO 14
00311       13 ICONST=1
00312          IDUM1=IMAX
00313          IDUM2=IMID
00314       14 IND=(IDUM1+IDUM2+ICONST)/2
00315          ISAVE=IDUM2
00316          GO TO 5
00317       15 IF(LSS1(J)-LSS(JJ)) 17,17,16
00322       16 ICONST=1
00323          ISAVE=IND
00324          IDUM2=IND
00325          IND=(IDUM1+IDUM2+ICONST)/2
00326          GO TO 5
00327       17 ICONST=-1
00330          IDUM2=ISAVE
00331          IDUM1=IND
00332          IND=(IDUM1+IDUM2+ICONST)/2
00333        5 CONTINUE
00335      200 LSP(JJ)=ARG1(JJ)-20.*ALOG10(FO(JJ))
00336          PADB(JJ)=LSP(JJ)-70.8-NDIP(JJ)
00337          DUM=.1*PADB(JJ)
```

```
c0340          PA(JJ)=10.**DUM
00341          NDIS(JJ)=(NDIP(JJ)+3.)-10.*ALOG10(1.+(RFDFO(JJ)*(2.*PI*ALPHA(JJ)*R
00341         1O(JJ)+X)))
00342          DELNDI(JJ)=NDIS(JJ)-NDIP(JJ)
c0343          WRITE(IPRINT,106)  F(I),PADB(JJ),RFDFO(JJ),FO(JJ),ALPHA(JJ),ADUM(J
00343         1J),RO(JJ),RARO(JJ),NDIP(JJ),LSS(JJ),LSP(JJ),ARG1(JJ),ANS1(JJ),PA(J
00343         2J),NDIS(JJ),DELNDI(JJ)
00365          GO TO 4
00366      210 LSP(JJ)=0.0
c0367          PADB(JJ)=0.0
00370          NDIS(JJ)=0.0
00371          WRITE(IPRINT,112)  F(I),PADB(JJ),RFDFO(JJ),FO(JJ),ALPHA(JJ),ADUM(J
00371         1J),RO(JJ),RARO(JJ),NDIP(JJ),LSS(JJ),LSP(JJ),ARG1(JJ),ANS1(JJ)
00410          GO TO 4
c0411      220 LSP(JJ)=0.0
00412          PADB(JJ)=0.0
00413          NDIS(JJ)=0.0
00414          WRITE(IPRINT,113)  F(I),PADB(JJ),RFDFO(JJ),FO(JJ),ALPHA(JJ),ADUM(J
00414         1J),RO(JJ),RARO(JJ),NDIP(JJ),LSS(JJ),LSP(JJ),ARG1(JJ),ANS1(JJ)
00433        4 CONTINUE
c0433    C
00433    C     THE PLOT ROUTINES ARE ON TAPE U183
c0433    C
00435          CALL PLOTA(RFDFO,PADB,PY,N4,1H*,1H+,1,'PADB VS FO/F',2,IPRINT)
00436          CALL PLOTA(RFDFO,NDIS,PY,N4,1H*,1H+,1,'NDIS VS FO/F',2,IPRINT)
00437        3 CONTINUE
00441        2 CONTINUE
00443        1 CONTINUE
00445      100 FORMAT(F10.5)
00446      103 FORMAT(50X,'T= WATER TEMPERATURE (DEGREES C)'
c0446         1,//50X,'D= PROJECTOR DEPTH (METERS)',
c0446         3//50X,'S= SALINITY (PPT)',
00446         4//50X,'F= SECONDARY FREQUENCY (KHZ)',
00446         5//50X,'A= PROJECTOR AREA (SQ. METERS)',
c0446         6//50X,'FO/F= DOWNSHIFT RATIO',
c0446         7//50X,'FO= PRIMARY FREQUENCY (KHZ)',
00446         8//50X,'AL= ABSORPTION CONSTANT (NEPERS/METER)',
c0446         9//50X,'1/2AL= REACTION LIMIT (METERS)',
00446         1//50X,'RO= RAYLIEGH DISTANCE (METERS)',
c0446         2//50X,'NDIP= DIRECTIVITY INDEX-PRIMARY (DB)',
00446         3//50X,'LSS= SECONDARY SOURCE LEVEL (DB//MICROBAR-METER)',
n0446         4//50X,'LSP= PRIMARY SOURCE LEVEL (DB//MICROBAR-METER)',
00446         5//50X,'L*= SCALED SOURCE LEVEL (DB//MICROBAR-METER-KHZ)',
c0446         6//50X,'G= PARAMETER GAIN (DB)',
c0446         7//50X,'PA= ACOUSTIC POWER PER TONE (WATTS)',
00446         8//50X,'ANDI= DIRECTIVITY GAIN (DB)',
00446         9//50X,'NDIS= SECONDARY DIRECTIVITY INDEX (DB)',
00446         1//50X,'PADB= ACOUSTIC POWER (DB//WATT) PER EACH PRIMARY TONE')
00447      104 FORMAT(//5X,'T= ',F5.0,//5X,'D= ',F8.1,//5X,'S= ',F4.0,//5X,'C= ',
00447         1F6.0,//5X,'A= ',F9.4)
00450      105 FORMAT(5X,'F',8X,'PADB',3X,'FO/F',5X,'FO',8X,'AL',5X,'1/2AL',5X,'R
00450         1O',4X,'1/2ALRO',1X,'NDIP',5X,'LSS',4X,'LSP',4X,'L*',5X,'G',5X,'PA(
00450         2WATTS)',1X,'NDIS',3X,'ANDI')
00451      106 FORMAT(F9.3,3X,F5.1,1X,F7.2,1X,F8.3,1X,F9.6,1X,F7.0,1X,F7.0,1X,F8.
n0451         11,1X,F5.1,1X,F6.1,1X,F6.1,1X,F6.1,1X,F5.1,1X,F9.1,1X,F5.1,2X,F5.1)
00452      107 FORMAT(49X,'PARAMETRIC SONAR DESIGN AND ANALYSIS')
00453      112 FORMAT(F9.3,3X,F5.1,1X,F7.2,1X,F8.3,1X,F9.6,1X,F7.0,1X,F7.0,1X,F8.
a0453         11,1X,F5.1,1X,F6.1,1X,F6.1,1X,F6.1,1X,F5.1,10X,'L* > 210.')
```

```
00434    180*        113 FORMAT(F9.3,3X,F5.1,1X,F7.2,1X,F8.3,1X,F9.6,1X,F7.0,1X,F7.0,1X,F8.
00454    181*           1,1X,F5.1,1X,F6.1,1X,F6.1,1X,F6.1,1X,F5.1,10X,'L* < 140.')
00455    182*        114 FORMAT(1H1)
00456    183*            STOP
00457    184*            END

         END OF COMPILATION:        NO DIAGNOSTICS.
```

APPENDIX B

SAMPLE EXAMPLE READOUT

The sample example tables and plots are shown here. These are as they appear on line out of the high speed printer associated with the computer.

PARAMETRIC SONAR DESIGN AND ANALYSIS

```
T= WATER TEMPERATURE (DEGREES C)
D= PROJECTOR DEPTH (METERS)
S= SALINITY (PPT)
F= SECONDARY FREQUENCY (KHZ)
A= PROJECTOR AREA (SQ. METERS)
FO/F= DOWNSHIFT RATIO
FO= PRIMARY FREQUENCY (KHZ)
AL= ABSORPTION CONSTANT (NEPERS/METER)
1/2AL= REACTION LIMIT (METERS)
RO= RAYLIEGH DISTANCE (METERS)
NDIP= DIRECTIVITY INDEX-PRIMARY (DB)
LSS= SECONDARY SOURCE LEVEL (DB//MICROBAR-METER)
LSP= PRIMARY SOURCE LEVEL (DB//MICROBAR-METER)
L*= SCALED SOURCE LEVEL (DB//MICROBAR-METER-KHZ)
G= PARAMETER GAIN (DB)
PA= ACOUSTIC POWER PER TONE (WATTS)
ΔNDI= DIRECTIVITY GAIN (DB)
NDIS= SECONDARY DIRECTIVITY INDEX (DB)
PADB= ACOUSTIC POWER (DB//WATT) PER EACH PRIMARY TONE
```

T= 7.

D= .0

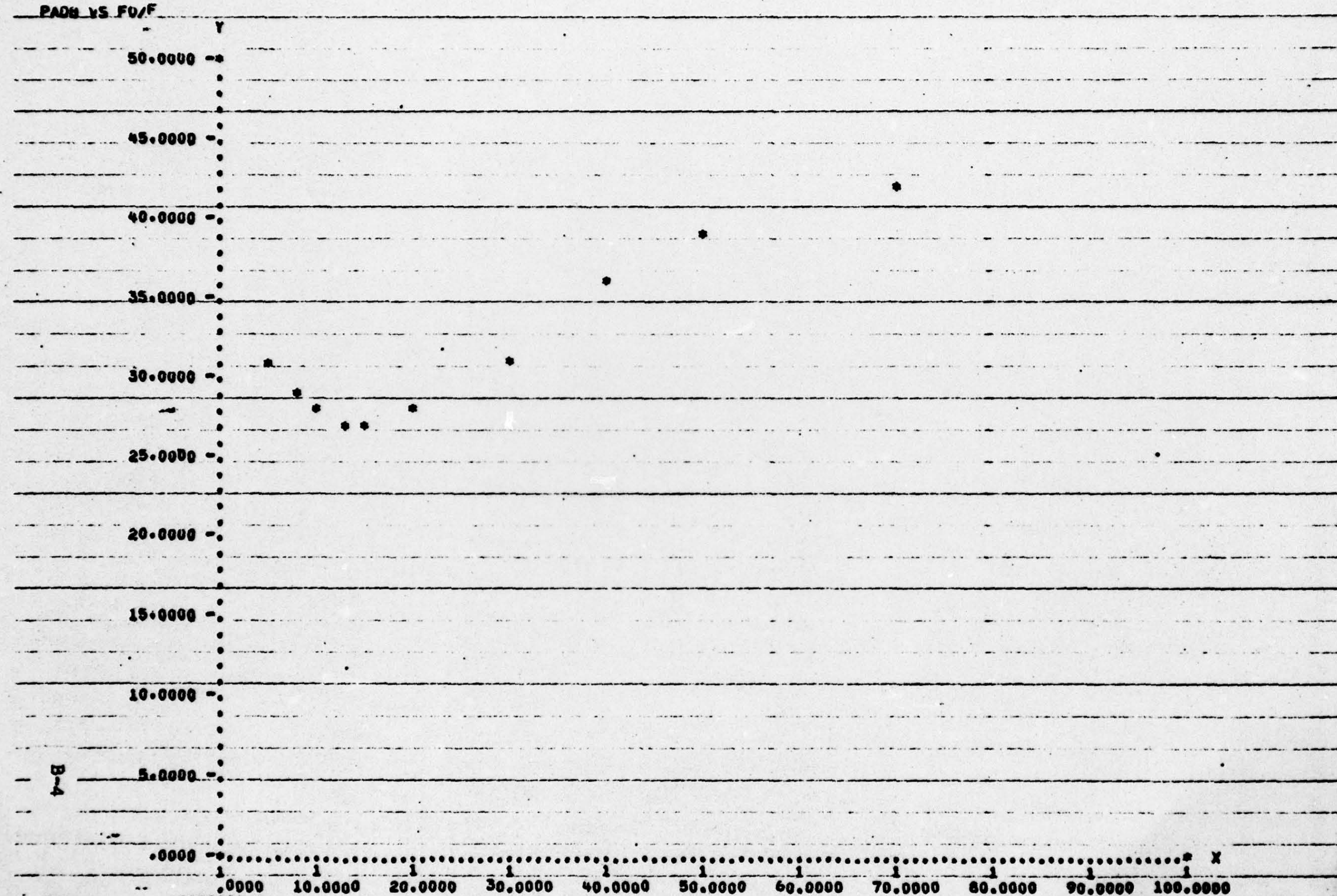
S= 35.

C= 1479.

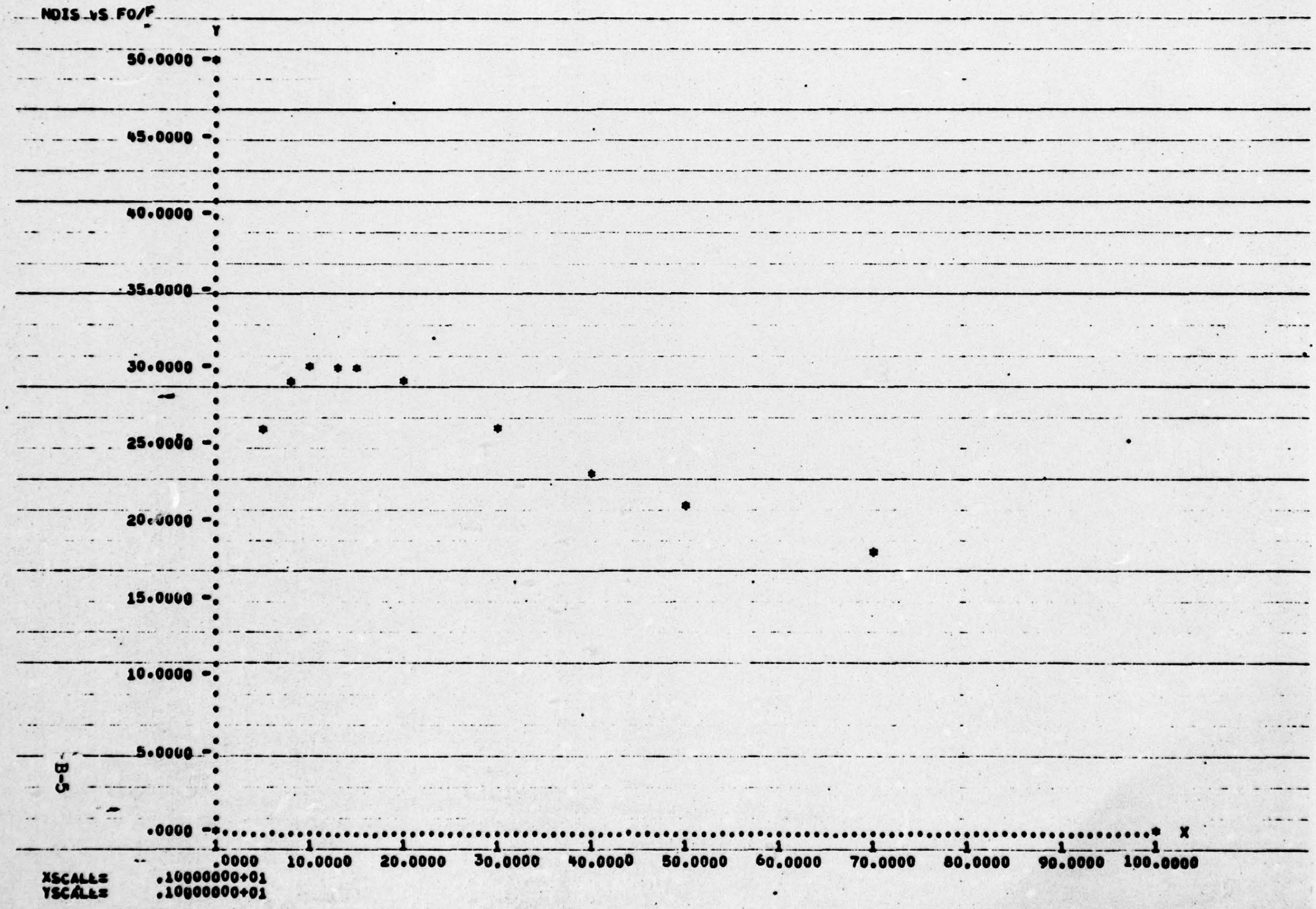
A= .1960

F	PADB	FO/F	FO	AL	1/2AL	RO	1/2ALRO	NDIP	LSS	LSP	L*	-Q	PA(WATTS)	NDIS	ΔNDI
3.000	30.7	5.00	15.000	.000241	2079.	2.	1043.5	24.0	89.4	125.6	149.1	-36.2	1185.2	26.4	2.4
3.000	29.5	7.50	22.500	.000506	988.	3.	330.5	27.6	91.0	127.9	154.9	-36.9	889.0	28.8	1.3
3.000	27.8	10.00	30.000	.000846	591.	4.	148.3	30.1	89.8	128.7	158.2	-38.9	603.0	30.0	-.1
3.000	27.2	12.50	37.500	.001237	404.	5.	81.1	32.0	89.7	130.0	161.5	-40.3	529.4	30.3	-1.7
3.000	27.4	15.00	45.000	.001657	302.	6.	50.5	33.6	90.2	131.8	164.8	-41.5	547.3	30.0	-3.6
3.000	28.2	20.00	60.000	.002510	199.	8.	25.0	36.1	90.5	135.1	170.6	-44.6	657.6	29.0	-7.1
3.000	31.1	30.00	90.000	.004021	124.	12.	10.4	39.6	89.2	141.5	180.6	-52.3	1279.5	26.4	-13.2
3.000	36.0	40.00	120.000	.005186	96.	16.	6.1	42.1	89.5	148.9	190.5	-59.4	3987.5	23.2	-18.9
3.000	38.8	50.00	150.000	.006109	82.	20.	4.1	44.0	89.4	153.6	197.1	-64.2	7504.9	21.0	-23.0
3.000	42.0	70.00	210.000	.007653	65.	28.	2.3	47.0	89.3	159.8	206.2	-70.5	15902.7	18.1	-28.8
3.000	.0	100.00	300.000	.009969	50.	40.	1.3	50.1	83.0	.0	210.4	-76.9	L* > 210.		

PADH VS FO/F



XSCALE= .10000000+01
YSCALE= .10000000+01


NDIS VS FO/F
Y
50.0000
45.0000
40.0000
35.0000
30.0000
25.0000
20.0000
15.0000
10.0000
5.0000
.0000
X
.0000
10.0000
20.0000
30.0000
40.0000
50.0000
60.0000
70.0000
80.0000
90.0000
100.0000
XSCALE= .10000000+01
YSCALE= .10000000+01

T= 7.

D= .0

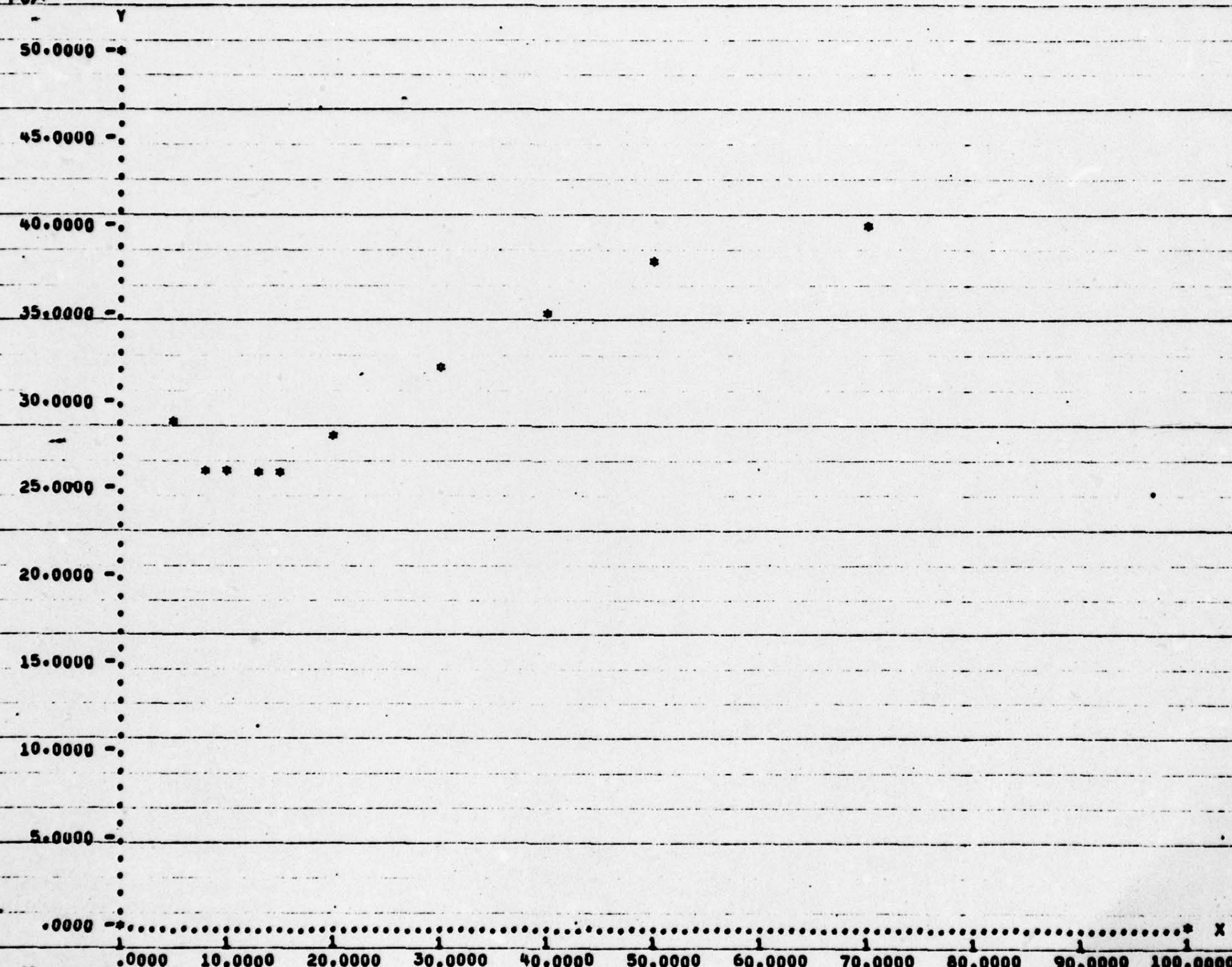
S= 35.

C= 1479.

A= .3947

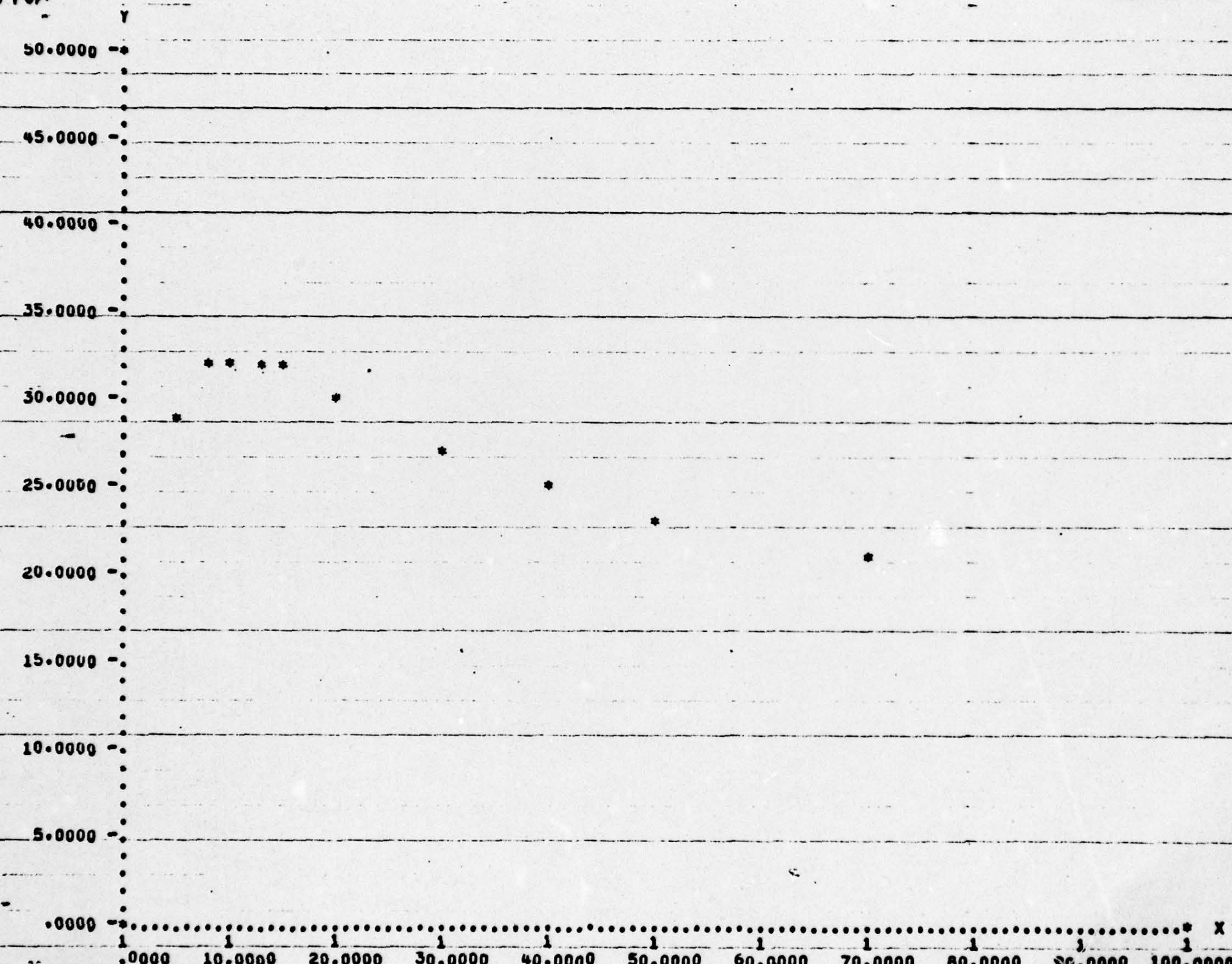
F	PAWO	FU/F	FO	AL	1/2AL	RO	1/2ALRO	NDIP	LSS	LSP	L*	6	PA(WATTS)	NDIS	ΔNDI
3.000	26.6	5.00	15.000	.000241	2079.	4.	521.9	27.1	89.9	126.4	149.9	-36.5	717.2	29.3	2.3
3.000	26.5	7.50	22.500	.000506	988.	6.	165.3	30.6	89.4	127.9	154.9	-38.5	444.6	31.6	1.1
3.000	26.4	10.00	30.000	.000846	591.	8.	74.1	33.1	90.9	130.3	159.9	-39.4	441.5	32.3	-.8
3.000	25.9	12.50	37.500	.001237	404.	10.	40.6	35.0	90.2	131.7	163.2	-41.5	387.7	32.3	-2.8
3.000	26.0	15.00	45.000	.001657	302.	12.	25.3	36.6	90.1	133.4	166.5	-43.3	400.8	31.8	-4.8
3.000	27.7	20.00	60.000	.002510	199.	16.	12.5	39.1	90.6	137.6	173.1	-47.0	582.7	30.3	-8.8
3.000	32.2	30.00	90.000	.004021	124.	24.	5.2	42.6	90.6	145.6	184.7	-55.1	1659.7	27.1	-15.5
3.000	35.8	40.00	120.000	.005106	98.	32.	3.0	45.1	90.3	151.4	193.0	-61.1	3532.9	24.7	-20.4
3.000	36.2	50.00	150.000	.006109	82.	40.	2.1	47.1	90.8	156.1	199.6	-65.2	6649.4	22.6	-24.4
3.000	39.8	70.00	210.000	.007653	65.	56.	1.2	50.0	89.5	160.6	207.1	-71.1	9623.6	20.5	-29.5
3.000	.0	100.00	300.000	.009969	50.	80.	.6	53.1	82.2	.0	210.4	-77.7	L* > 210.		

PADB VS FO/F



XSCALE= .10000000+01
YSCALE= .10000000+01

NOIS VS FO/F



XSCALE= .10000000+01
YSCALE= .10000000+01

T= 7.

U= .0

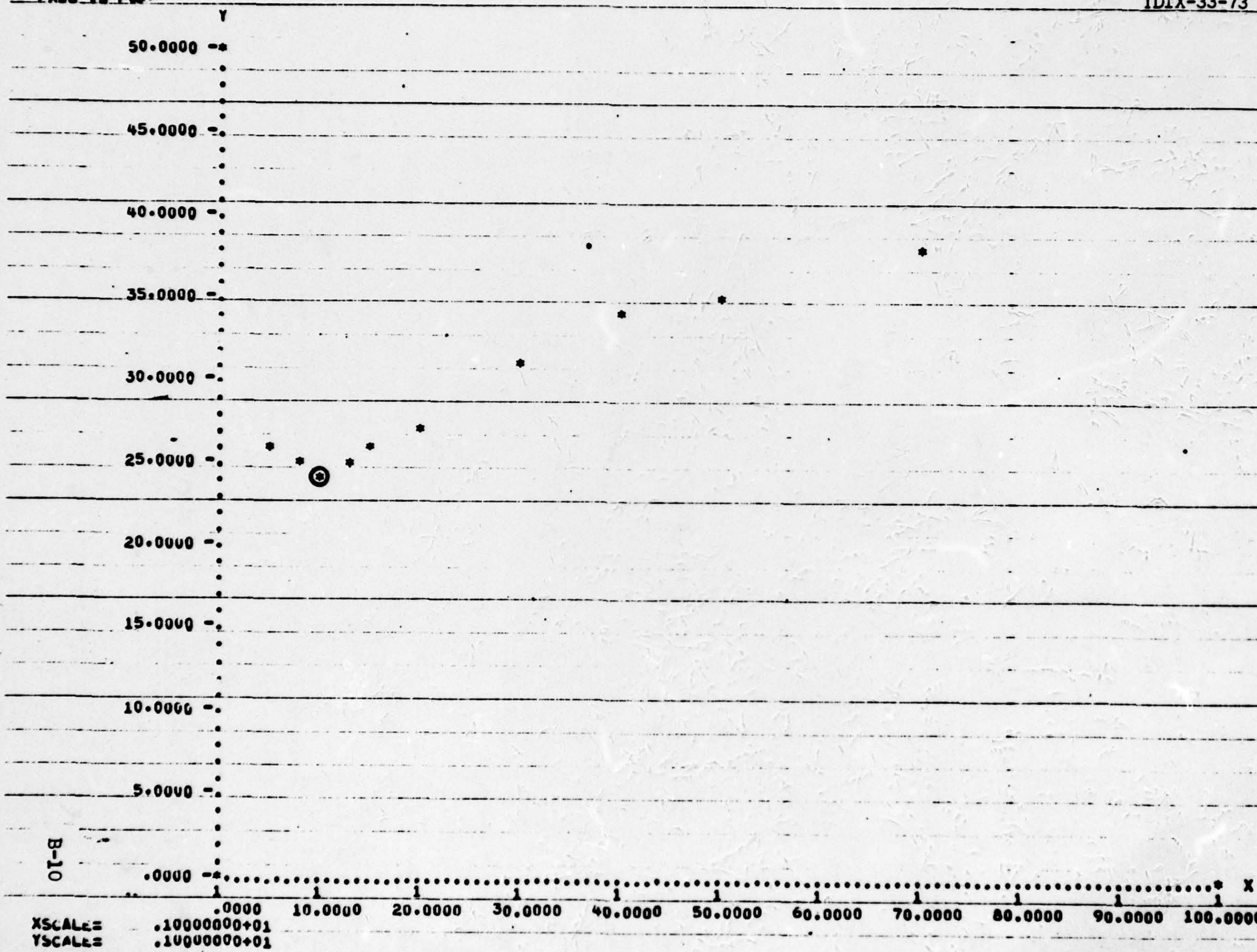
S= 35.

C= 1479.

A= .7854

F	PAUB	F0/F	F0	AL	1/2AL	R0	1/2ALR0	NDIP	LSS	LSP	L*	G	PA(WATTS)	NDIS	ANDI
3.000	26.6	5.00	15.000	.000241	2079.	8.	260.9	30.1	90.2	127.2	150.8	-37.0	433.9	32.2	2.1
3.000	25.1	7.50	22.500	.000506	988.	12.	82.7	33.6	90.7	129.5	156.6	-38.8	325.5	34.1	.5
3.000	24.3	10.00	30.000	.000846	591.	16.	37.1	36.1	89.9	131.2	160.7	-41.2	267.1	34.4	-1.7
3.000	24.6	12.50	37.500	.001237	404.	20.	20.3	38.0	90.1	133.4	164.8	-43.3	283.8	33.9	-4.1
3.000	25.5	15.00	45.000	.001657	302.	24.	12.6	39.6	90.7	135.9	169.0	-45.2	355.0	33.1	-6.5
3.000	27.1	20.00	60.000	.002510	199.	32.	6.3	42.1	90.2	140.0	175.6	-49.9	516.1	31.5	-10.6
3.000	30.6	30.00	90.000	.004021	124.	48.	2.6	45.6	89.6	147.3	186.4	-57.7	1215.0	28.6	-17.0
3.000	34.1	40.00	120.000	.005186	96.	64.	1.5	48.1	90.3	153.1	194.6	-62.8	2586.3	26.4	-21.8
3.000	35.2	50.00	150.000	.006109	82.	80.	1.0	50.1	89.5	156.1	199.6	-66.6	3324.7	[illegible]5.1	-25.0
3.000	38.5	70.00	210.000	.007653	65.	112.	.6	53.0	90.4	162.3	208.7	-71.8	7044.9	22.4	-30.6
3.000	.0	100.00	300.000	.009969	50.	159.	.3	56.1	81.0	.0	210.4	-78.8	L* > 210.		

PADB VS FO/F


Y
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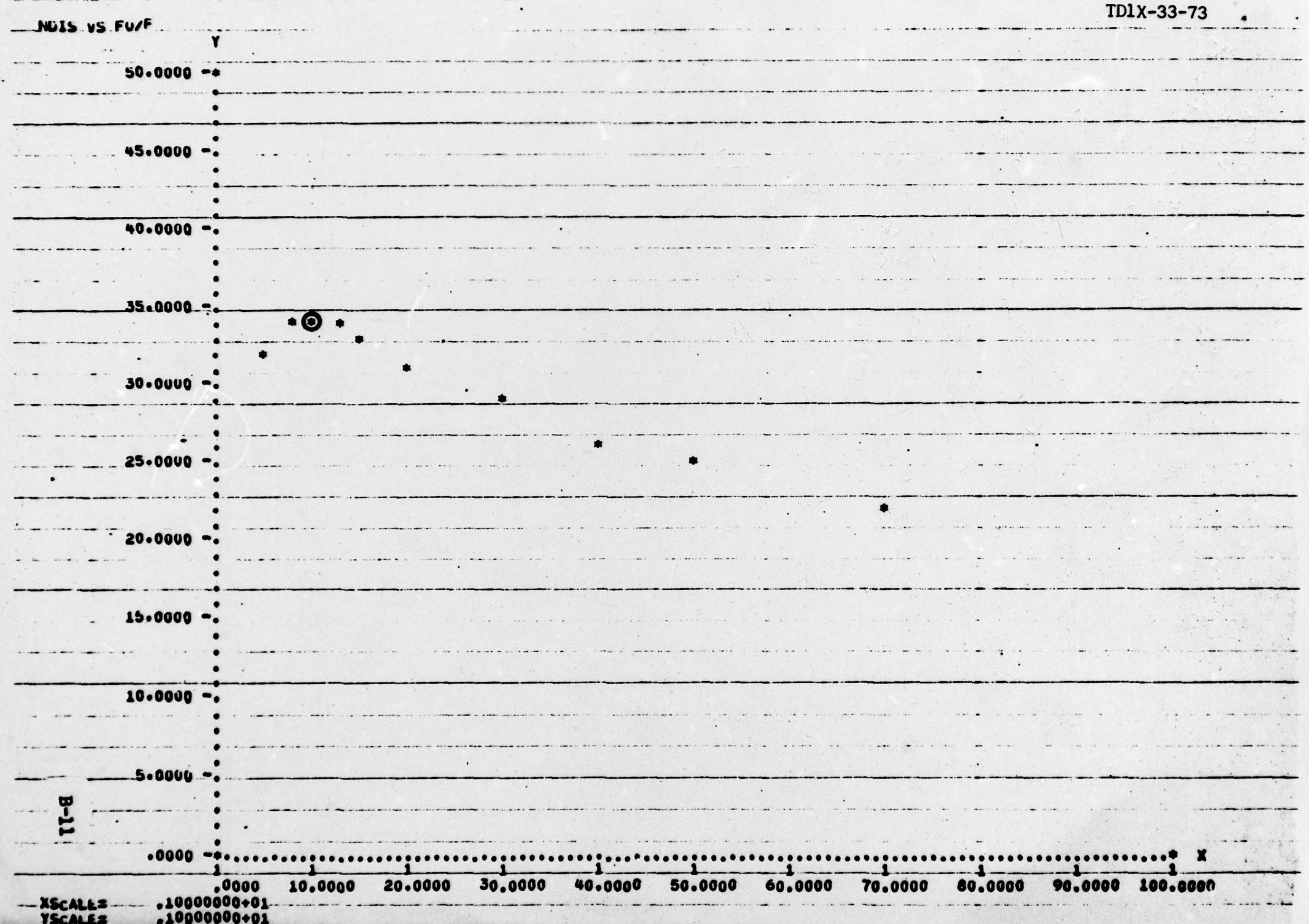
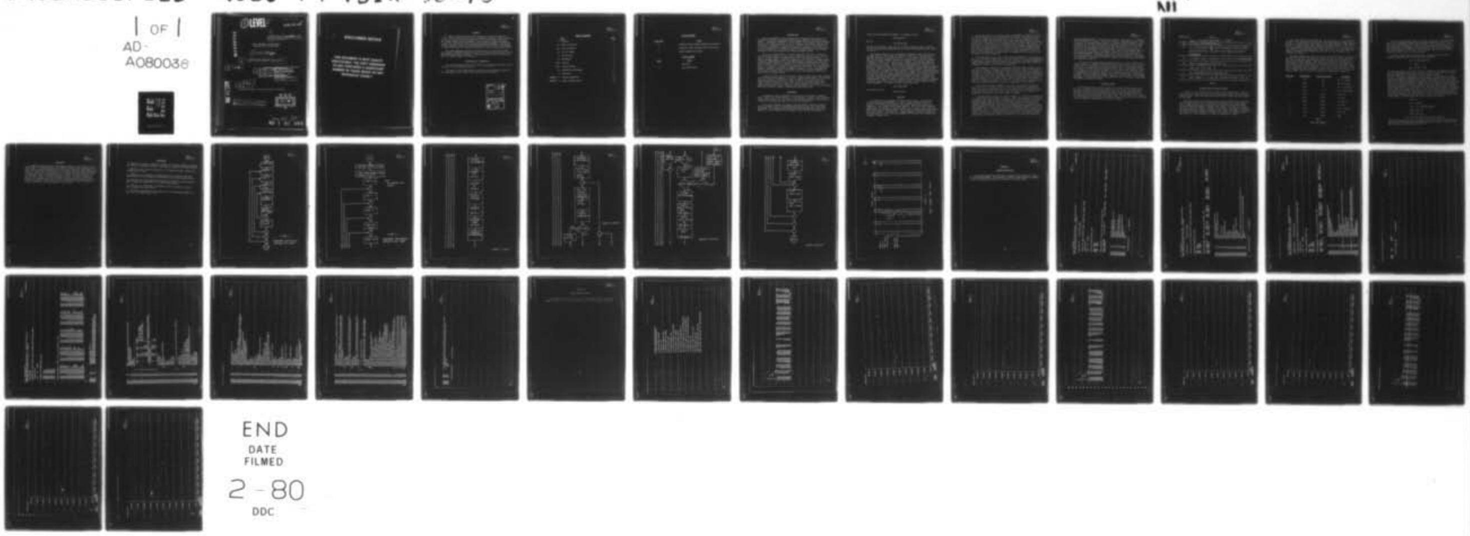
45.0000
40.0000
35.0000
30.0000
25.0000
20.0000
15.0000
10.0000
5.0000
.0000
X
.0000
10.0000
20.0000
30.0000
40.0000
50.0000
60.0000
70.0000
80.0000
90.0000
100.0000
XSCALE= .10000000+01
YSCALE= .10000000+01

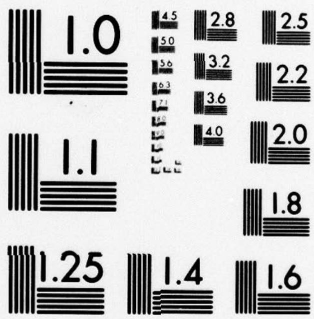

NDIS VS FU/F
Y
50.0000
45.0000
40.0000
35.0000
30.0000
25.0000
20.0000
15.0000
10.0000
5.0000
.0000
X
.0000
10.0000
20.0000
30.0000
40.0000
50.0000
60.0000
70.0000
80.0000
90.0000
100.0000
XSCALE= .10000000+01
YSCALE= .10000000+01

AD-A080 036 NAVAL UNDERWATER SYSTEMS CENTER NEWPORT RI F/G 17/1
COMPUTER AIDED PARAMETRIC SONAR DESIGN.(U)
MAY 73 E C GANNON, R P PINGREE
UNCLASSIFIED NUSC-TM-TD1X-33-73 NL

1 OF 1
AD-
A080036



END
DATE
FILMED
2-80
DDC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

TM No. NUSC-TM-TD1X-33-73

NAVAL UNDERWATER SYSTEMS CENTER
Newport, Rhode Island 02840

Technical Memorandum

COMPUTER AIDED PARAMETRIC SONAR DESIGN

23 May 1973

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42

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ABSTRACT

A computer program was written that enables the design of parametric sonars. This program accepts as inputs temperature, salinity, depth, estimates of projector area, desired secondary source level and secondary frequency. The program computes various parametric sonar quantities among them primary source level, directivity index and primary operating frequency. The program actually generates a matrix of possible design values that permit the designer to choose those which best suit his needs based on other system considerations.

The design program is written in Fortran V for use on the Univac 1108. The program is completely general and any of the input parameters can be varied while holding the others constant. A discussion on how to use the program as well as a sample example is included.

ADMINISTRATIVE INFORMATION

This memorandum was prepared under Project No. A-614-19, Principal Investigator, Dr. A. J. Van Woerkum, Code TC.

The authors of this memorandum are located at the New London Laboratory, Naval Underwater Systems Center, New London, Connecticut 06320.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

From the viewpoint of the individual who is faced with the design of a parametric sonar, the calculations involved seem repetitive and in some cases endless. The Mellen and Moffett[1] curves together with the appropriate equations given in the reference contain all of the necessary information. However, the information is presented in such a way as to make it easy to work through the curves and calculations to analyze the parametric operation of existing projectors and systems but it is difficult and not straightforward to work backward through the curves and equations to design a projector system.

There is a solution which is offered by Moffett[2] that uses a "load line" type of technique similar to that used in vacuum tube circuit design. This is good for a small number of possible designs of a given parametric sonar. The method requires, however, repetitive computations to arrive at the dimensionless parameters 1/(2)(AL)(RO) for each possible parametric stepdown ratio (the ratio of the parametric difference frequency to the mean projector driving frequency FO/F). The term (AL) is absorption in nepers per meter while RO is the Rayleigh distance. Appendix B contains a complete glossary of terms. The "load line" method is presently limited by the number of families of curves available for the different stepdown ratios and the accuracy of interpolating between the given curves of a given family.

A means, therefore, was devised where the whole design process was automated using the Univac 1108 computer. In essence, computer aided design. The solution allows the designer to work from a known secondary source level (LSS) and a known secondary frequency (F) for a range of values of projector size (A), primary source level per tone (LSP) and a given stepdown ratio (FO/F). The computer program will build a matrix of possible designs that can then be compared with other factors to achieve a workable and realistic design.

BACKGROUND

In parametric sonar calculations, two distinct and different problems arise. One is that of the analysis of existing sonar to predict their parametric operating characteristics. The other is the design of parametric sonars having a given set or range of output source levels and frequencies.

In the first problem, one usually knows the primary operating frequency (FO), the primary source level (LSP), and the projector area (A). From these one obtains the secondary source level (LSS) and secondary directivity index (NDIS) for a given downshift ratio (FO/F) by using the Mellen and Moffett curves and the appropriate formulae. In summary, we know

FO, LSP and A.

We find

LSS, FO/F, NDIS.

The Mellen and Moffett curves and the associate equations readily lend themselves to solving this problem because of the way the equations and the curves are set up.

The second problem is one of designing a parametric sonar starting from "scratch" where one only knows the desired, or the range of desired, LSS, F, and NDIS and wants to find FO, LSP and A. At first glance one would say, "Why not just work backwards through the equations with the aid of the Mellen and Moffett curves?" Alas, life is not so simple. The equations depend on a knowledge of FO, and A. In other words, something must be known about the projector before starting. Unfortunately, determining FO, A, and LSP is the goal of the design process. This is just the opposite of the analysis previously discussed. There is a method that has been proposed by Moffett that utilizes the "load line" technique previously mentioned. This method is excellent when an exact FO and A are sought for a given LSS, F, and NDIS. The method becomes time consuming and requires tedious repetitive calculations when a range of values is sought and when one needs numerous possibilities in order to examine and choose an optimum solution based on factors other than just parametric sonar considerations. What is needed is a method of constructing a matrix of possible parametric sonar designs for the designer to weigh in consort with associated system parameters. In summary for this situation we know

LSS, FO/F, NDIS

and we want to find

FO, LSP and A.

SOLUTION

The solution to the problem is computer aided design. A program was written that allows the designer to vary F, A, LSS, and FO/F in order to construct the desired design matrix. The program compilation is given in Appendix A. This program is versatile enough so that three other parameters temperature (T), salinity (S) and depth (D) can be varied in coarse steps and their effects on the design studied. The results are tabulated and two on-line plots are possible. The results of a sample example are shown in Appendix B. The on-line plots can be of any two variables and each plot can be altered by changing a computer card.

At present, one plot is acoustic power in dB (PADB) vs. FO/F for a given LSS with the parameters T, S, D, F and A held constant. Then either LSS, F, or A can be changed and another plot made. Thus, one can examine the range of possible designs that are within the desired power budget and select a reasonable one. The second plot is secondary directivity index (NDIS) vs FO/F for the same given conditions as in the previous plot. From this the designer can select the necessary quantities for a desired range of NDIS. Normally, many plots will be produced resulting in families of LSS curves with NDIS and PADB plotted against FO/F with T, S, D, constant for many combinations of F and A. Once a set of parameters is decided upon, the appropriate exact constants can be obtained from the tabulation.

One thing that has been done to aid in plot comparisons is to force the plots to a convenient common scale. This was done by the use of two dummy points on each plot. This was necessary because the routine as originally compiled by Gordon[3] automatically scaled the axis for the plotting range. For the desired comparisons of plots, such scaling is undesirable.

The program is outlined in a simplified flow chart shown in Figure 1. It operates as follows: The inner loop computes parametric sonar design constants for each of a sequence of FO/F values. This is done for each of a sequence of LSS values in the input data (LSS1). Next, the two inner loops are repeated for a sequence of values for A and finally these three innermost loops are repeated for each value of F in the input data. These four loops generate a matrix of possible designs for the ranges of FO/F, LSS, A, and F chosen. Each matrix is built up for constant values of T, S, and D. The values for T, S, and D can be altered by changing them when the data is programmed into the computer.

The plots as presently compiled plot after each sequence of FO/F for a given LSS. Thus, a family of curves of different LSS values is generated. These are for each combination of T, S, D, F, and A and are plotted with FO/F as the horizontal axis on each plot. The vertical axis on plot number 1 is PADB while the vertical axis on plot number 2 is NDIS.

A more detailed flow chart is shown in Figure 2. It shows an expansion of the computational block diagram of Figure 1. Thus, the location of the various calculations are shown along with the appropriate tests required to keep the program bounded. Once the data is entered, the calculations leading to the quantity 1/(2)(AL)(RO) are made where the attenuation loss is (AL) and the Rayleigh distance is (RO). This quantity 1/(2)(AL)(RO) together with the FO/F and a quantity X is entered into a numerical integration subroutine devised by Goldstein[4]. The X is a parameter that ties the integration to a scaled source level (L*) which is a normalized parametric quantity in the Mellen and Moffett theory. The output of the numerical integration enters into several simple computations, the results of which are tested to see if they fall within the proper programmed bounds. If the tests are failed, a new value of X is chosen and the integration routine is redone and retested. Depending on how the tests are passed, the program either proceeds to calculate further parametric sonar quantities for the given solution of the numerical integration or the program recognizes that the numerical integration has searched as far as it can. In any event, the program will proceed to readout the results in a table then recycle to the next FO/F in the innermost loop. Once the desired LSS values has been completely investigated, the computer constructs the two on-line plots previously mentioned. The program then recycles until all possible values of F, A, LSS and FO/F have been investigated and all plots completed. The program then terminates. The detailed flow chart (Figure 2) references equations which are tabulated in Table I.

In essence, the program takes some known values for a given condition and hunts, by means of a numerical integration routine and specific tests, for other needed values to completely describe a parametric sonar. Since usually there is a range of desired values, the program builds a matrix of possible solutions. The accuracy of these solutions depends on the accuracy of the parameter X used in the numerical integration. Presently, the solution calculates an LSS which is compared with the input LSS (LSS1). The calculated value has a tolerance of $\pm$0.82 dB. The resultant LSP, parametric gain (G), acoustic power (PA and PADB), and primary frequency directivity index (NDIP) all have a tolerance of $\pm$0.41 dB. The NDIS has a $\pm$0.82 dB tolerance.

PROGRAM OPTIONS

The design program has certain options as a result of the general form in which it is written. The program contains four nested loops any of which can be varied or held constant by appropriate input data on the input data cards. The plots can be varied, however, this may involve repositioning the plot in the program as well as changing two program cards. The user may have to redimension the storage associated with the loops preceding the plot in order to be sure the data computed is retained until the plot is called.

Equation No.	Equation
1.	$X_{(I+1)} = 1.1X_I$ FOR 86 VALUES FROM $X = 0.090909$
2[5].	$FT = 21.9 \times 10^{6-(1520/(T+273))}$ kHz
3[5].	$AL = (1/8.68)(1/914.4)\left\{\left[(1.86\times10^{-2})(S)(FT)(FO)^2/\left[(FT)^2+(FO)^2\right]\right] + \left[2.68\times10^{-2}(FO)^2/FT\right] + \left[0.1(FO)^2/(1+(FO)^2)\right]\right\}(1-6.33233\times10^{5}D)$ NEPERS/METER
4[5].	$C = 1449.2 + 4.623T - 0.0546(T^2) + 1.391\,(S-35) + 0.017D$ METERS/SECOND
5[6].	$NDIP = 10\,LOG_{10}(4\pi A\,(FO)^2(10^3)^2/C^2)$ DB
6.	$PADB = LSP - 70.8 - NDIP$ DB
7.	$PA = ANTILOG\left[(1/10)(LSP-70.8-NDIP)\right]$ WATTS
8[1].	$NDIS = (NDIP) + 3 - 10\,LOG_{10}\left[1 + ((FO)/F)(2\pi(AL)(RO) + X)\right]$ DB

TABLE I

PROGRAM USAGE AND SAMPLE EXAMPLE

In order to use the program, the user must stack appropriately formatted data cards in a fixed order at the end of the program. There are six different types of cards. These cards will now be discussed in order from front to back of the stack.

The first type of card contains only one card and comes first in the data. It is formatted into 4 fields of one integer number per field. Each number must be right justified in a field width of five (Fortran V statement (I5)). The first field uses columns 1 through 5 and contains the number of F values. The second field uses columns 6 through 10 and contains the number of A values. The third field uses columns 11 through 15 and contains the number of LSS values. The fourth field uses columns 16 through 20 and contains the number of FO/F values plus 1. This arrangement of fields is summarized in Table 2.

The second type of card contains only one card and it is the 2nd card in the data. It is formatted into 3 fields. Each field contains a number that is written in a floating point format which is right justified in a field width of 10 with a 4 decimal place accuracy (Fortran V statement (F10.4)). The first field uses columns 1 through 10 and contains the value for T. The second field uses columns 11 through 20 and contains the value for 5. The third field uses columns 21 through 30 and contains the value for D. These fields are also summarized in Table 2.

The third through sixth type of cards may contain more than 1 card for each type but only one value for each card. Thus, one must use as many cards for each type as there are values associated with that type and the cards for each type must be grouped together. Each number is written in a floating point format which is right justified in a field width of 10 with a 5 decimal place accuracy (Fortran V statement (F10.5)). Each third type of card gives a value for F. Each fourth type of card gives a value for A. Each fifth type of card gives an input value for LSS (LSS1). Lastly, each sixth type of card gives a value for FO/F. Each of these field layouts are summarized in Table 2.

Card Type	Card Columns	Fortran IV Format	Agreement
1	1-5	I5	No. of F values
	6-10	I5	No. of A values
	11-15	I5	No. of LSS values
	16-20	I5	No. of FO/F values
2	1-10	F10.4	T in deg C
	11-20	F10.4	S in PPT
	21-30	F10.4	D in meters
3	1-10	F10.5	F in kHz
4	1-10	F10.5	A in sq. meters
5	1-10	F10.5	LSS in dB
6	1-10	F10.5	FO/F

TABLE 2

DATA CARD FORMATS

The use of this program requires the input of data from a program stored on tape in the NUSC New London Laboratory Univac 1108 files. This is tape U183. Different parameter plots may be made by simply changing the call to plot (Call Plot A) statements. There are two such plots in the program. The plot routine can be eliminated by removing the two call to plot cards which are located adjacent to each other in the program. The rest of the program should run and the table of results printed.

A sample example will now be discussed. Suppose we want to design a parametric sonar that has the following specifications:

LSS = 90 dB//1μbar-meter

F = 3 kHz

N_{DI} = 30 dB to 35 dB

and the power budget is such that we wish to minimize its consumption. Assume that the system will work in the ocean (S = 35 ppt) and that the system must be capable of operating in the winter (T = 7°C) on the surface (D = 0). The data is programmed as shown in Figure 3. The tables of results are shown in Appendix B along with 3 sets of plots. Examination of the results shows several design possibilities all within the region of a dip in the PADB plots. If it were not possible to examine so large a quantity of points, the dip quite possibly would go unnoticed because there is a tendency for the unwitting designer to assumethat increased stepdown ratio means increased power consumption. Apparently, this is not always true. When the desired points are isolated on the plots, the designer then can go to the tables and from them he can determine the design that gives the desired source level within the NDIS restrictions. The desired design for the sample example is the one underlined in the appropriate table of Appendix B and encircled on each of the associated PADB and NDIS vs FO/F plots. The selected design has the following parameters:

FO/F = 10

FO = 30 kHz

LSP = 131.2 dB//1μbar-meter

NDIP = 36.1 dB

NDIS = 34.4 dB

and PA = 267.1 watts/each primary frequency.

Other related quantities can be obtained from the data tables. For different applications these quantities may assume importance and thus are readily available if design tradeoffs become necessary.

CONCLUSION

A computer aided parametric sonar design program has been written for the UNIVAC 1108. This program allows the designer to take a given secondary source level (LSS), secondary frequency (F) and secondary directivity index (NDIS) and compute a range of possible parametric sonar designs that will satisfy his needs. Thus, the selection of sonar parameters is no longer limited by the difficulty of examining a range of possible parametric designs. The sonar designer can now construct a matrix of possible designs then base the final selection on which of these designs best fits the other systems parameters being considered. By means of computer aided design, literally hundreds of possible designs for a given situation can be investigated in a short time.

REFERENCES

1. Mellen, R. H. and M. B. Moffett, "A Model for Parametric Radiator Design," USN Journal of Underwater Acoustics, Vol. 22, No. 2, April 1972 (Unclassified).

2. Moffett, M. B., "Load Line Technique for Parametric Design," unpublished communication in 1972.

3. Gordon, R. L., "A Fortran V Plotting Routine for the Univac 1108 High Speed Printers," USL Tech Memo No. 2242-291-68, 25 July 1968 (Unclassified).

4. Goldstein, M., "On A numerical Integration in Parametric Sonar Research," NUSC Tech Memo No. PA4-268-71, 21 Oct 1971, (Unclassified).

5. Urick, R. J., "Principles of Underwater Sound for Engineers," McGraw Hill, Copyright 167, pages 88-96.

6. "The Design and Construction of Magnetostriction Transducers," NDRC Div 6 Report Vol. 13, dated 1946, p. 128.

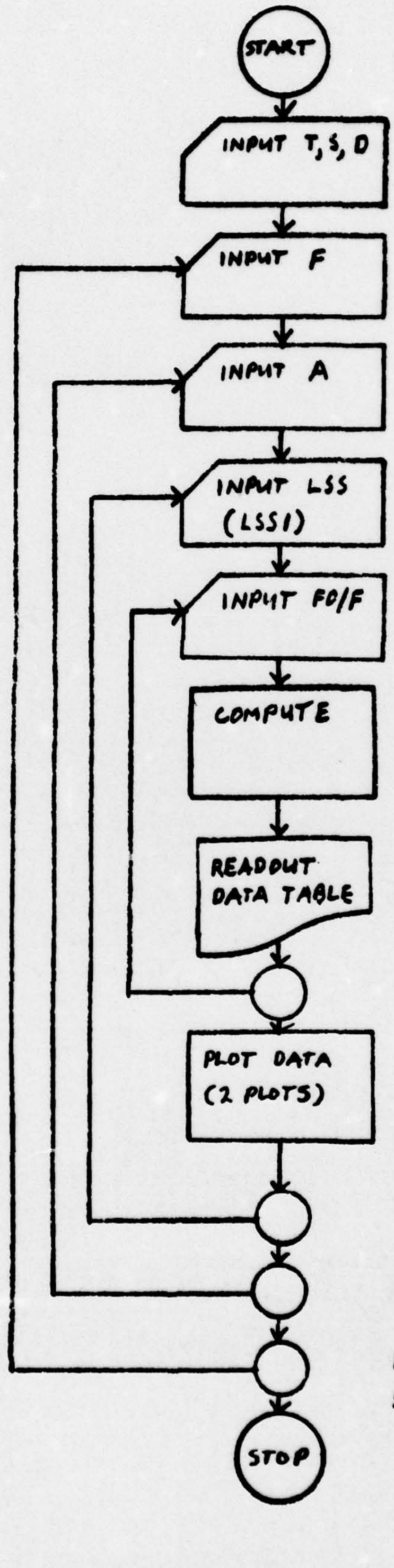
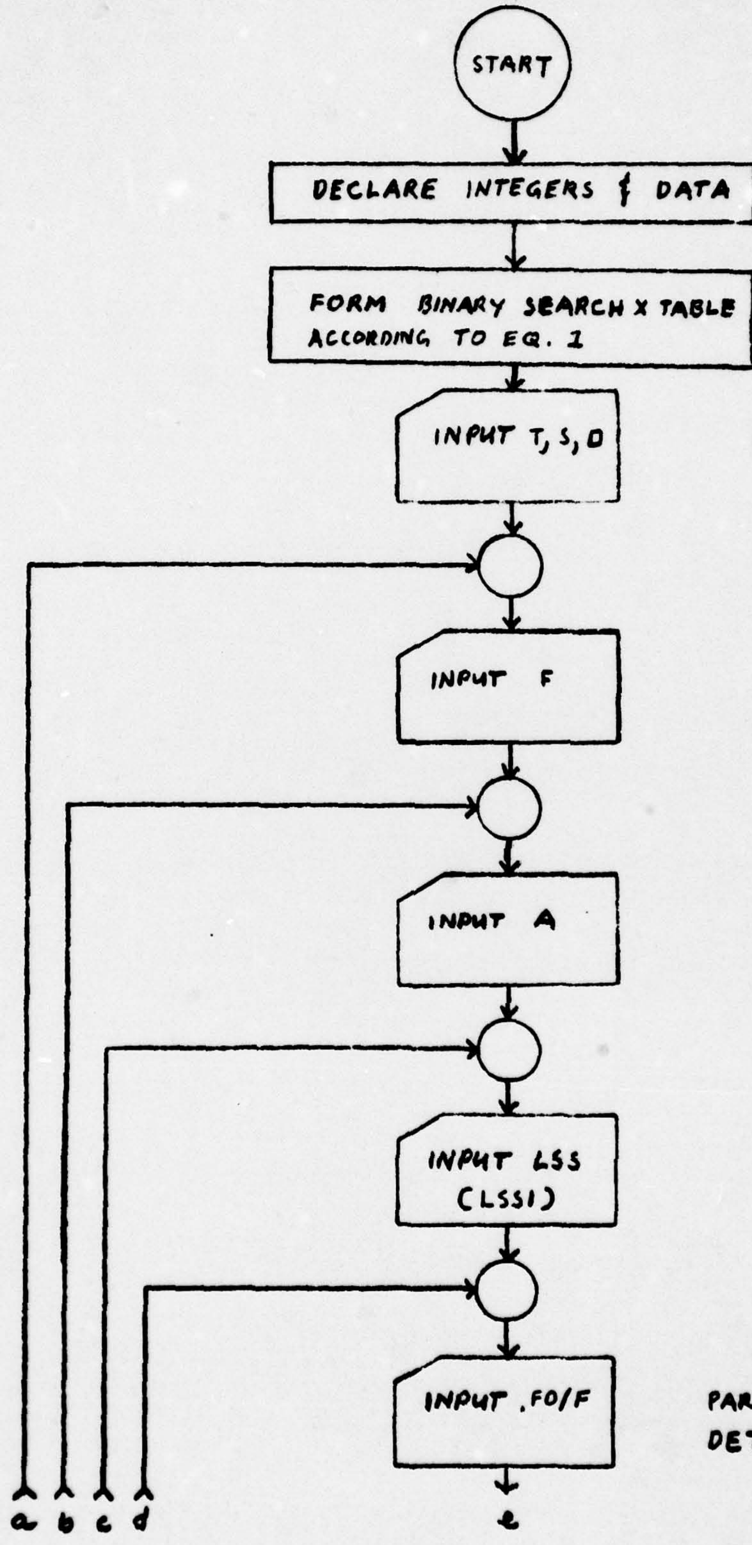


FIGURE 1

PARAMETRIC SONAR DESIGN,
SIMPLIFIED FLOW CHART



NOTE:
FOR EQUATIONS SEE TABLE 1

FIGURE 2

PARAMETRIC SONAR DESIGN, DETAILED FLOW CHART

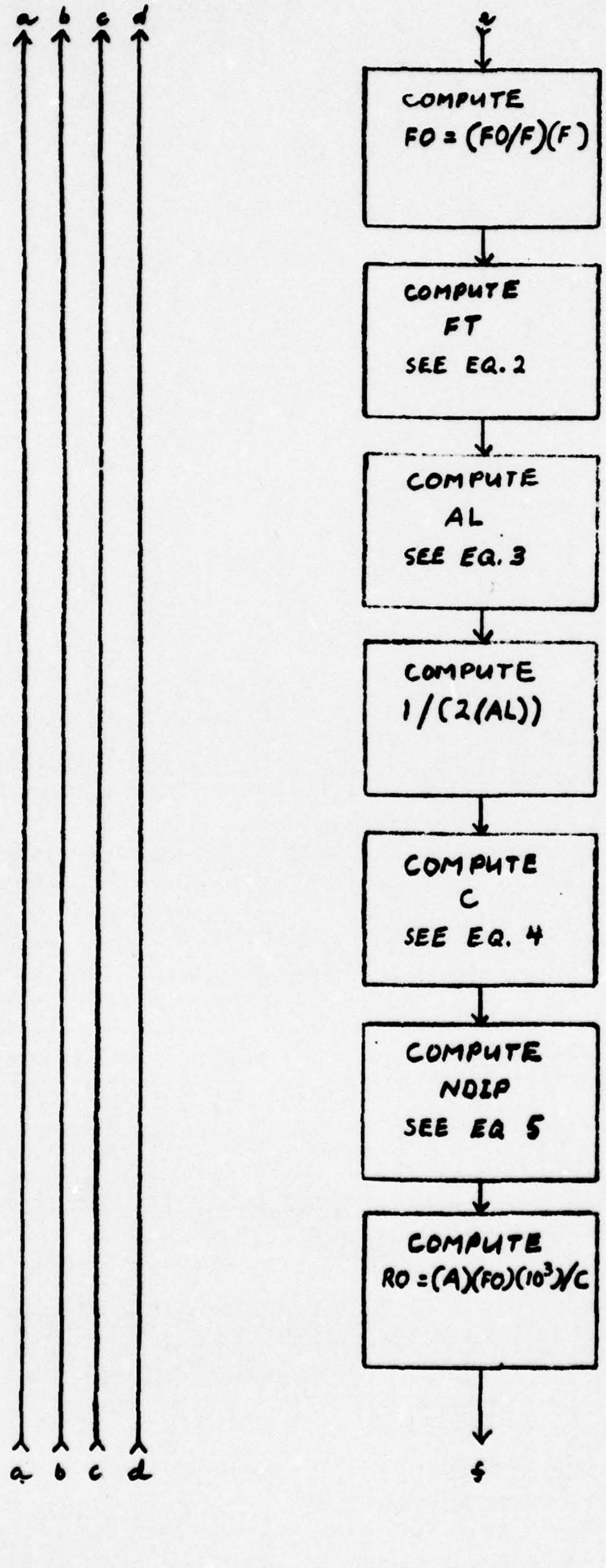


FIGURE 2 (CONT. 1)

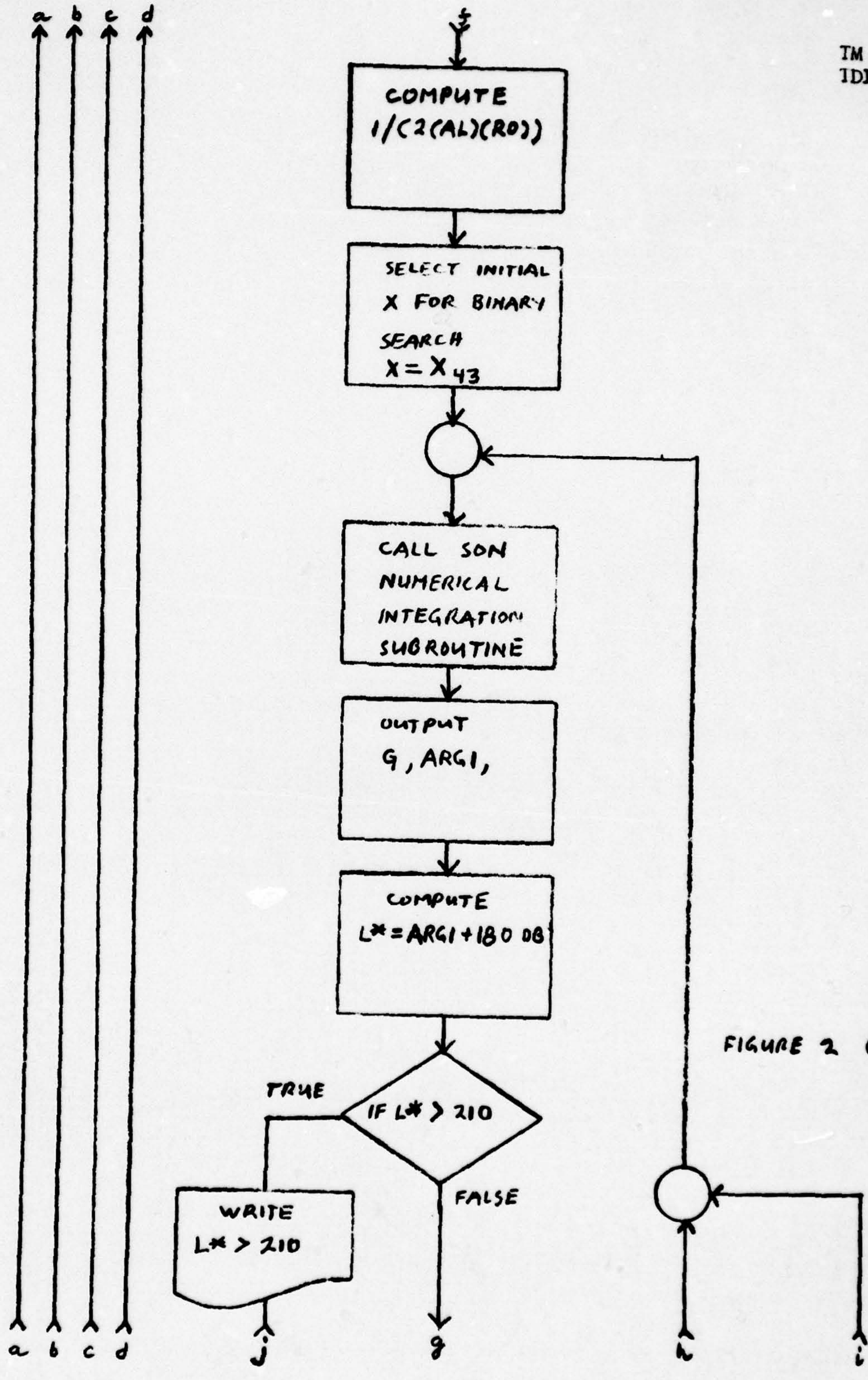


FIGURE 2 (CON'T 2)

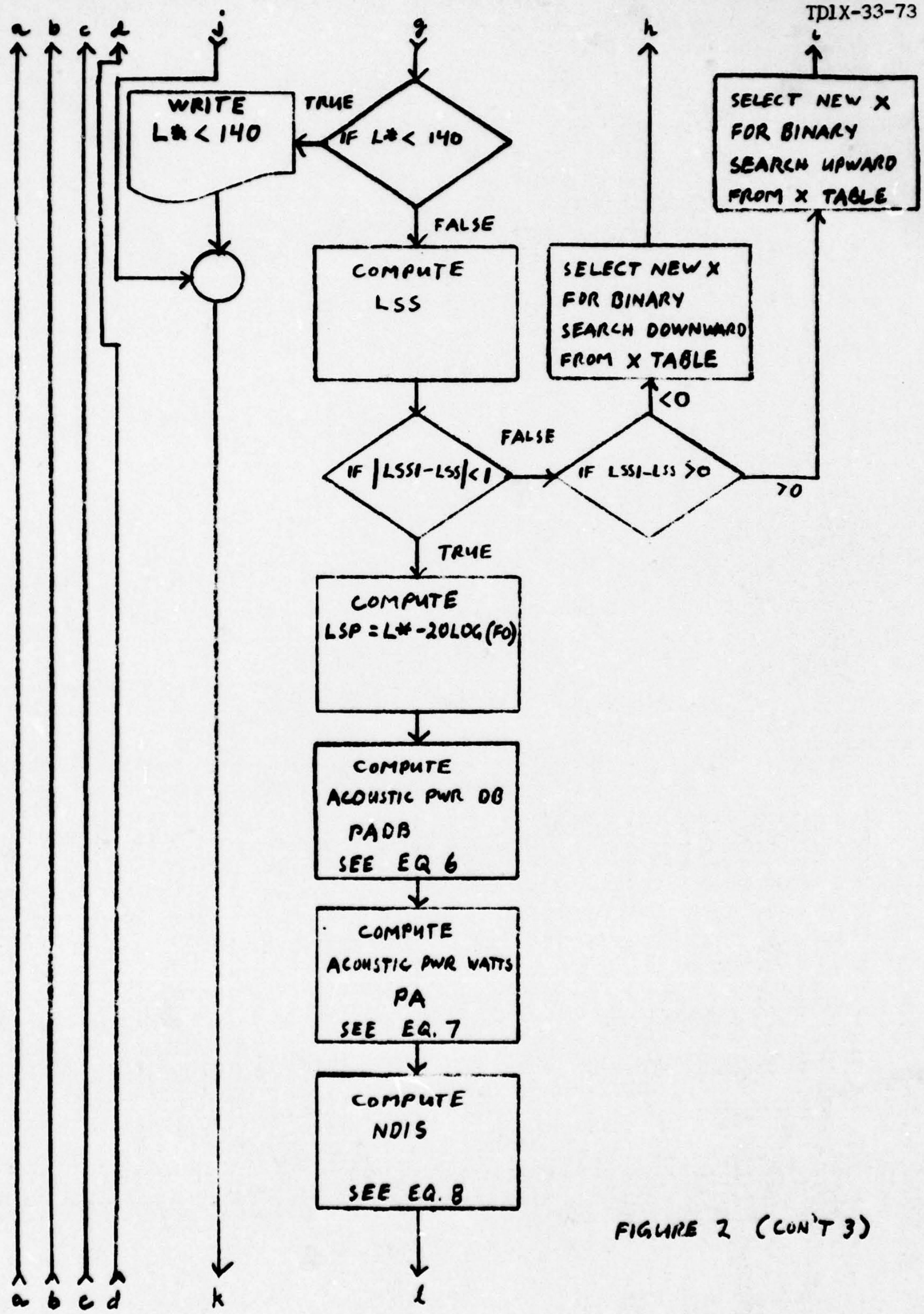


FIGURE 2 (CON'T 3)

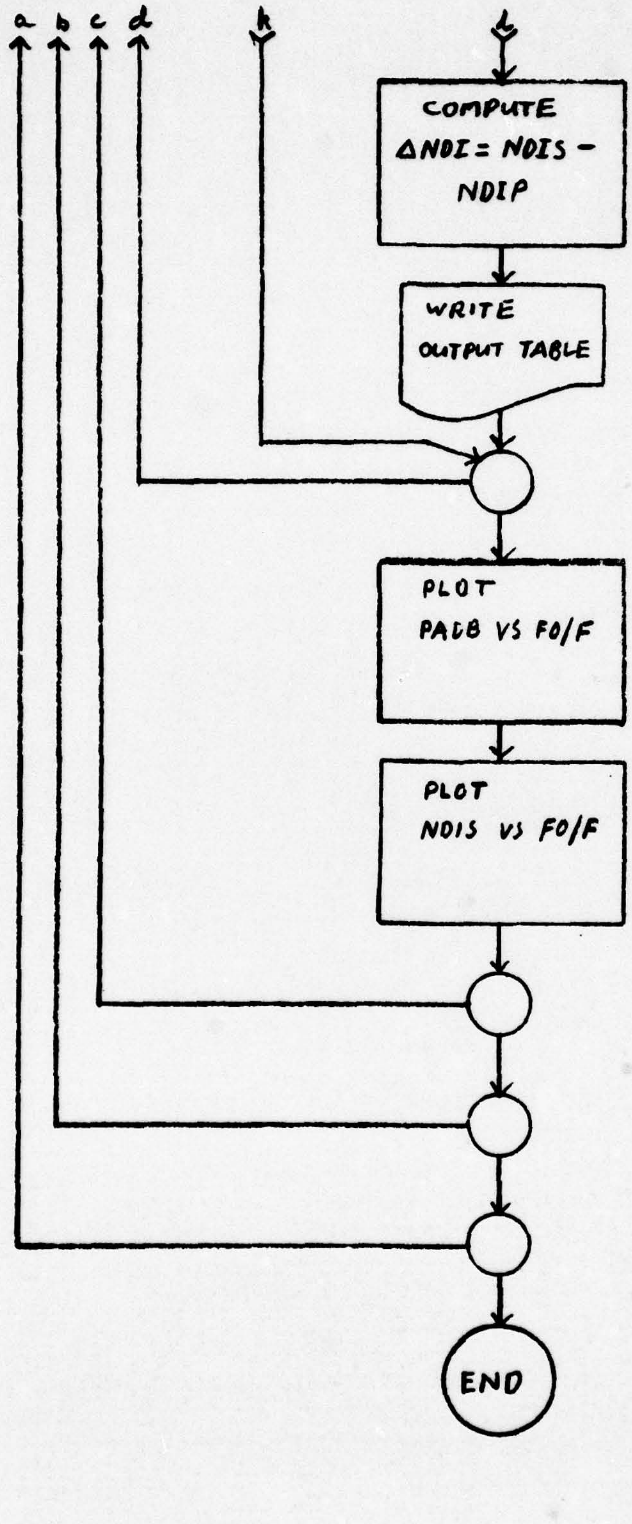


FIGURE 2 (CON'T. 4)

COLUMN NUMBER

	1–5	6–10	11–15	16–20	21–25	26–30
CARD 1	1	3	1	12		
CARD 2		7.		35.		0.
TYPE 3 CARDS		3.				
TYPE 4 CARDS		.1964				
		.3927				
		.7854				
TYPE 5 CARDS		90.				
TYPE 6 CARDS		5.				
		7.5				
		10.				
		12.5				
		15.				
		20.				
		30.				
		40.				
		50.				
		70.				
		100.				

FIGURE 3

SAMPLE EXAMPLE DATA FORMAT

APPENDIX A

PROGRAM COMPILATION

The program compilation shown here is complete with subroutines except for the plot subroutine. That particular one was on tape and was not compiled as was the material that was put in by means of a deck of cards.

```
    FOR SUB,SUB                                                                                21:34:46.50
UNIVAC 1108 FORTRAN V LEVEL 2206 0026      (EXEC8 LEVEL E1201-0011)
THIS COMPILATION WAS DONE ON 14 JUN 73 AT 21:34:46

   SUBROUTINE SUB      ENTRY POINT 000067

   STORAGE USED: CODE(1) 000103; DATA(0) 000020; BLANK COMMON(2) 000000

    COMMON BLOCKS:

    0003   BLK     000010

   EXTERNAL REFERENCES (BLOCK, NAME)

    0004   DSINH
    0005   DEXP
    0006   DSQRT
    0007   NERR3$

   STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

    0003 D 000000 ARO      0003 D 000006 E       0003 D 000002 GKDKO     0000    000012 INJP$     0000 D 000000 T
    0003 D 000004 X


00101       1*          SUBROUTINE SUB(A,J,H,F)
00103       2*          IMPLICIT DOUBLE PRECISION (A-H,O-Z)
00104       3*          COMMON/BLK/ARO,GKDKO,X,E
00105       4*          T=A+J*H
00106       5*          F=DSINH(T)
00107       6*          T=1.0D0+((X*T)**2)/4.0D0
00110       7*          IF(ARO.GT.0.0D0) E=DEXP(-F*ARO)
00112       8*          F=F**2
00113       9*          F=(1.0D0+F)/(1.0D0+F*GKDKO**2)
00114      10*          F=E*(DSQRT(F)/T)
00115      11*          RETURN
00116      12*          END

     END OF COMPILATION:        NO  DIAGNOSTICS.
```

```
   FOR ROM,ROM                                                                                21:34:47. 40
UNIVAC 1108 FORTRAN V LEVEL 2206 0026     (EXEC8 LEVEL E1201-0011)
THIS COMPILATION WAS DONE ON 14 JUN 73 AT 21:34:47

    SUBROUTINE ROM        ENTRY POINT 000246

    STORAGE USED: CODE(1) 000275; DATA(0) 000060; BLANK COMMON(2) 000000

    EXTERNAL REFERENCES (BLOCK, NAME)

     0003   SUB
     0004   NEXP1$
     0005   NEXP9$
     0006   NERR3$

    STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

     0001    000071 120G      0001    000120 130G      0001    000033 4L        0000 D 000003 F        0000 D 000005 FN
     0000 D  000000 H         0000    000031 INJP$     0000 I 000015 IU         0000 I 000012 J        0000 I 000013 J1
     0000 I  000002 K         0000 I  000014 L         0000 I 000011 M          0000 D 000007 SIG


00101              SUBROUTINE ROM(A,B,W,EPS,IV,NMX)
00103              DIMENSION W(NMX,NMX)
00104              IMPLICIT DOUBLE PRECISION (A-H,O-Z)
00105              H=B-A
00106              K=0
00107              CALL SUB(A,0,H,F)
00110              FN=F
00111              CALL SUB(A,1,H,F)
00112              W(1,1)=((F+FN)*H)/2.0D0
00113            4 K=K+1
00114              H=H/2.0D0
00115              SIG=0.0D0
00116              M=2**(K-1)
00117              DO 1 J=1,M
00122              J1=2*J-1
00123              CALL SUB(A,J1,H,F)
00124            1 SIG=SIG+F
00126              W(K+1,1)=W(K,1)/2.0D0+H*SIG
00127              DO 2 L=1,K
00132              IU=K+1-L
00133              IV=L+1
00134            2 W(IU,IV)=(4.0D0**(IV-1)*W(IU+1,IV-1)-W(IU,IV-1))/(4.0D0**(IV-1)-1.
00134             1D0)
00136              IF(ABS(W(IU,IV)-W(IU,IV-1)).LT.ABS(W(IU,IV))*EPS) RETURN
00140              GO TO 4
00141              END

    END OF COMPILATION:        NO  DIAGNOSTICS.
```

```
@     FOR SON,SON                                                          21:34:48.364
UNIVAC 1108 FORTRAN V LEVEL 2206 0026      (EXEC8 LEVEL E1201-0011)
THIS COMPILATION WAS DONE ON 14 JUN 73 AT 21:34:48

   SUBROUTINE SON        ENTRY POINT 000134

   STORAGE USED: CODE(1) 000160; DATA(0) 011664; BLANK COMMON(2) 000000

    COMMON BLOCKS:

    0003   BLK    000010

   EXTERNAL REFERENCES (BLOCK, NAME)

    0004   ROM
    0005   DLOG
    0006   DATAN
    0007   DLOG10
    0010   NERR3$

   STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

    0001     000045 1L      0000 D 011612 A      0000 D 011620 ALN1    0003 D 000000 ARO      0000 D 011614 B
    0003 D 000006 E         0000 D 011610 EPS    0000 D 011622 FAC     0003 D 000002 GKDKO    0000 D 011616 GKDKOS
    0000     011650 INJP$   0000 I 011624 IV     0000 D 000000 W       0003 D 000004 X


 00101      1*          SUBROUTINE SON (RARO,RKDKO,ARG,ANS,AIN,NMX)
 00103      2*          IMPLICIT DOUBLE PRECISION (A-H,O-Z)
 00104      3*          COMMON/BLK/ARO,GKDKO,X,E
 00105      4*          DIMENSION W(50,50)
 00106      5*          EPS=.5D-05
 00107      6*          A=0.0
 00110      7*          B=20.0
 00111      8*          E=1.0D0
 00112      9*          ARO=0.0D0
 00113     10*          IF(RARO.GT.ARO) ARO=1.0D0/RARO
 00115     11*          GKDKO=1.0D0/RKDKO
 00116     12*          GKDKOS=GKDKO**2
 00117  *DIAGNOSTIC*  THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL.
 00117     13*          IF(RARO.EQ.0.0D0) GO TO 1
 00121     14*          ALN1=DLOG(RKDKO)
 00122     15*          B=DLOG((84.0D0+ALN1)*RARO)
 00123     16*        1 FAC=GKDKOS*(X/2.0D0)
 00124     17*          CALL ROM(A,B,W,EPS,IV,50)
 00125     18*          AIN=W(1,IV)
 00126  *DIAGNOSTIC*  THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL.
 00126     19*          IF(RARO.EQ.0.0D0) AIN=AIN+2.0D0*RKDKO*(1.5707963267948900-DATAN(10
 00126     20*         1.0D0*X))/X
 00130     21*          AIN=FAC*AIN
 00131     22*          ARG=20.0D0*DLOG10(X)
 00132     23*          ANS=20.0D0*DLOG10(AIN)
```

```
00133     24*        RETURN
00134     25*        END

          END OF COMPILATION:          2 DIAGNOSTICS.
```

```
@    FOR SONAR,SONAR                                                                        21:34:49.464
UNIVAC 1108 FORTRAN V LEVEL 2206 0026      (EXEC8 LEVEL E1201-0011)
THIS COMPILATION WAS DONE ON 14 JUN 73 AT 21:34:49

   MAIN PROGRAM

   STORAGE USED: CODE(1) 001012; DATA(0) 004536; BLANK COMMON(2) 000000

    COMMON BLOCKS:

    0003   BLK     000010

   EXTERNAL REFERENCES (BLOCK, NAME)

    0004   SON
    0005   PLOTA
    0006   NRDU$
    0007   NI02$
    0010   NEXP6$
    0011   NI01$
    0012   NWDU$
    0013   ALOG10
    0014   DLOG10
    0015   NSTOP$

   STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

    0000   004023 100F     0000   004002 101F     0000   004003 102F     0000   004025 103F     0000   004242 104F
    0000   004262 105F     0000   004321 106F     0000   004346 107F     0000   004356 112F     0000   004402 113F
    0000   004426 114F     0001   000016 117G     0001   000523 13L      0001   000531 14L      0001   000541 15L
    0001   000146 156G     0001   000160 164G     0001   000557 17L      0001   000172 172G     0001   000204 200G
    0001   000575 200L     0001   000234 206G     0001   000671 210L     0001   000237 211G     0001   000247 214G
    0001   000717 220L     0001   000312 236G     0001   000430 257G     0001   000744 4L       0001   000571 5L
    0000 R 001130 A        0000 R 002424 ADUM     0000 D 003410 AIN      0000 R 001750 ALPHA    0000 D 003416 ANS
    0000 R 003244 ANS1     0000 D 003414 ARG      0000 R 003100 ARG1     0003 D 000000 ARO      0000 R 003760 C
    0000 R 003753 D        0000 R 001274 DELNDI   0000 R 004000 DUM      0003 D 000006 E        0000 R 000764 F
    0000 R 001440 FO       0000 R 003764 FT       0003 D 000002 GKDKO    0000 I 003737 I        0000 I 003754 IA
    0000 I 003755 IB       0000 I 003756 IC       0000 I 003734 ICARD    0000 I 003774 ICONST   0000 I 003757 ID
    0000 I 003776 IDUM1    0000 I 003775 IDUM2    0000 I 003761 II       0000 I 003773 IIX      0000 I 003767 IMAX
    0000 I 003770 IMID     0000 I 003766 IMIN     0000 I 003771 IND      0000 I 003772 IOPT     0000 I 003735 IPRINT
    0000 I 003777 ISAVE    0000 I 003762 J        0000 I 003763 JJ       0000 I 003740 KN       0000 I 003741 KN1
    0000 I 003742 KN2      0000 I 003743 KN3      0000 R 000620 LSP      0000 R 000000 LSS      0000 R 000144 LSS1
    0000 I 003744 N        0000 R 000454 NDIP     0000 R 000310 NDIS     0000 I 003765 NLX      0000 I 003745 N1
    0000 I 003746 N2       0000 I 003747 N3       0000 I 003750 N4       0000 R 002114 PA       0000 R 002260 PADB
    0000 R 003736 PI       0000 R 004001 PY       0000 R 002570 RARO     0000 D 003420 RARO1    0000 R 002734 RFDFO
    0000 D 003422 RFDFO1   0000 R 001604 RO       0000 R 003752 S        0000 R 003751 T        0003 D 000004 X
    0000 D 003412 XO       0000 D 003424 XX

00101      1*         REAL LSS,LSS1,NDIS,NDIP,LSP
00103      2*         PARAMETER LMX=100
00104      3*         DIMENSION LSS(LMX),LSP(LMX),LSS1(LMX),NDIS(LMX),F(LMX),A(LMX)
00105      4*         DIMENSION DELNDI(LMX),FO(LMX),RO(LMX),ALPHA(LMX),NDIP(LMX),PA(LMX)
00106.     5*         DIMENSION PADB(LMX),ADUM(LMX),RARO(LMX),RFDFO(LMX),ARG1(LMX),ANS1(
```

```
00106          1LMX)
00107          DOUBLE PRECISION ARO,GKDKO,X,E,AIN,XO,ARG,ANS,RARO1,RFDFO1
00110          DOUBLE PRECISION XX(LMX)
00111          COMMON/BLK/ARO,GKDKO,X,E
00112          ICARD=3
00113          IPRINT=4
00114          PI=3.14159
00114    C
00114    C         CARD   COLUMNS   FORMAT   ARGUMENT
00114    C         ----   -------   ------   --------
00114    C          1       1-5       I5       KN- NO. OF F VALUES
00114    C                  6-10      I5       KN1- NO. OF A VALUES
00114    C                  11-15     I5       KN2- NO. OF LSS VALUES
00114    C                  16-20     I5       KN3- NO. OF FO/F VALUES +1
00114    C          2       1-10      F10.4    T
00114    C                  11-20     F10.4    S
00114    C                  21-30     F10.4    D
00114    C         IN THE FOLLOWING CARDS,IF MORE THAN ONE VALUE OF THE VARIABLES
00114    C         IS DESIRED (BASED ON CARD NO.1) THEN RELATED CARDS (ALL F'S) MUST
00114    C         BE GROUPED TOGETHER
00114    C          3       1-10      F10.5    F
00114    C          4       1-10      F10.5    A
00114    C          5       1-10      F10.5    LSS
00114    C          6       1-10      F10.5    FO/F
00114    C
00115          XO=.909090910-2
00116          DO 8 I=1,86
00121          XX(I)=1.1*XO
00122        8 XO=XX(I)
00124          READ(ICARD,101) KN,KN1,KN2,KN3
00132      101 FORMAT(4I5)
00133          N=KN
00134          N1=KN1
00135          N2=KN2
00136          N3=KN3
00137          N4=N3+1
00140          RFDFO(1)=0.0
00141          PADB(1)=0.0
00142          NDIS(1)=0.0
00142    C
00142    C         IF POWER IS IN EXCESS OF 100KW CHANGE SCALE OF PADB PLOT
00142    C
00143          PADB(N4)=50.
00144          NDIS(N4)=50.
00145          RFDFO(N4)=0.0
00146          READ(ICARD,102) T,S,D
00153      102 FORMAT(3F10.4)
00154          READ(ICARD,100) (F(IA),IA=1,N)
00162          READ(ICARD,100) (A(IB),IB=1,N1)
00170          READ(ICARD,100) (LSS1(IC),IC=1,N2)
00176          READ(ICARD,100) (RFDFO(ID),ID=2,N3)
00204          C=1449.2+4.623*T-.0546*(T**2)+1.391*(S-35.)+.017 *D
00205          DO 1 I=1,KN
00210          DO 2 II=1,KN1
00213          DO 3 J=1,KN2
00216          WRITE(IPRINT,107)
00220          WRITE(IPRINT,103)
00222          WRITE(IPRINT,114)
```

```
00224         WRITE(IPRINT,104) T,D,S,C,A(II)
00233         WRITE(IPRINT,105)
00235         DO 4 JJ=2,KN3
00240         FO(JJ)=RFDFO(JJ)*F(I)
00241         E=(10.**3)*FO(JJ)
00242         FT=21.9*10.**(6.-(1520./(T+273.)))
00243         ALPHA(JJ)=(1./8.68)*(1.-(.00006332*D))*(1./914.4)*(.0186*((S*FT*(F
00243        1O(JJ)**2))/(FT**2+FO(JJ)**2))+(.0268*FO(JJ)**2/FT    )+((.1*FO(JJ)*
00243        2*2)/(1.+FO(JJ)**2)))
00244         NDIP(JJ)=10.*ALOG10((4.*PI*A(II)*E**2)/C**2)
00245         RO(JJ)=(A(II)*FO(JJ)*(10.**3))/C
00246         RARO(JJ)=1.0/(2.*ALPHA(JJ)*RO(JJ))
00247         ADUM(JJ)=1.0/(2.*ALPHA(JJ))
00250         NLX=86
00251         IMIN=1
00252         IMAX=NLX
00253         IMID=NLX/2
00254         IND=NLX/2
00255         IOPT=0
00256      20 DO 5 IIX=1,91
00261         X=XX(IND)
00262         RARO1=RARO(JJ)
00263         RFDFO1=RFDFO(JJ)
00264         CALL SUN(RARO1,RFDFO1,ARG,ANS,AIN,50)
00265         ARG1(JJ)=ARG
00266         ANS1(JJ)=ANS
00267         ARG1(JJ)=ARG1(JJ)+180.
00270         IF(ARG1(JJ).GT.210.) GO TO 210
00272         IF(ARG1(JJ).LT.140.) GO TO 220
00274         LSS(JJ)=ARG1(JJ)-20.*ALOG10(FO(JJ))+ANS1(JJ)
00275         IF(ABS(LSS1(J)-LSS(JJ)).LT.1.) GO TO 200
00277         IF(IOPT.NE.0) GO TO 15
00301         IOPT=1
00302         IF(LSS1(J)-LSS(JJ)) 12,12,13
00305      12 ICONST=-1
00306         IDUM2=IMIN
00307         IDUM1=IMID
00310         GO TO 14
00311      13 ICONST=1
00312         IDUM1=IMAX
00313         IDUM2=IMID
00314      14 IND=(IDUM1+IDUM2+ICONST)/2
00315         ISAVE=IDUM2
00316         GO TO 5
00317      15 IF(LSS1(J)-LSS(JJ)) 17,17,16
00322      16 ICONST=1
00323         ISAVE=IND
00324         IDUM2=IND
00325         IND=(IDUM1+IDUM2+ICONST)/2
00326         GO TO 5
00327      17 ICONST=-1
00330         IDUM2=ISAVE
00331         IDUM1=IND
00332         IND=(IDUM1+IDUM2+ICONST)/2
00333       5 CONTINUE
00335     200 LSP(JJ)=ARG1(JJ)-20.*ALOG10(FO(JJ))
00336         PADB(JJ)=LSP(JJ)-70.8-NDIP(JJ)
00337         DUM=.1*PADB(JJ)
```

```
00340            PA(JJ)=10.**DUM
00341            NDIS(JJ)=(NDIP(JJ)+3.)-10.*ALOG10(1.+(RFDFO(JJ)*(2.*PI*ALPHA(JJ)*R
00341           1O(JJ)+X)))
00342            DELNDI(JJ)=NDIS(JJ)-NDIP(JJ)
00343            WRITE(IPRINT,106)  F(I),PADB(JJ),RFDFO(JJ),FO(JJ),ALPHA(JJ),ADUM(J
00343           1J),RO(JJ),RARO(JJ),NDIP(JJ),LSS(JJ),LSP(JJ),ARG1(JJ),ANS1(JJ),PA(J
00343           2J),NDIS(JJ),DELNDI(JJ)
00365            GO TO 4
00366        210 LSP(JJ)=0.0
00367            PADB(JJ)=0.0
00370            NDIS(JJ)=0.0
00371            WRITE(IPRINT,112)  F(I),PADB(JJ),RFDFO(JJ),FO(JJ),ALPHA(JJ),ADUM(J
00371           1J),RO(JJ),RARO(JJ),NDIP(JJ),LSS(JJ),LSP(JJ),ARG1(JJ),ANS1(JJ)
00410            GO TO 4
00411        220 LSP(JJ)=0.0
00412            PADB(JJ)=0.0
00413            NDIS(JJ)=0.0
00414            WRITE(IPRINT,113)  F(I),PADB(JJ),RFDFO(JJ),FO(JJ),ALPHA(JJ),ADUM(J
00414           1J),RO(JJ),RARO(JJ),NDIP(JJ),LSS(JJ),LSP(JJ),ARG1(JJ),ANS1(JJ)
00433          4 CONTINUE
00433      C
00433      C     THE PLOT ROUTINES ARE ON TAPE U183
00433      C
00435            CALL PLOTA(RFDFO,PADB,PY,N4,1H*,1H+,1,'PADB VS FO/F',2,IPRINT)
00436            CALL PLOTA(RFDFO,NDIS,PY,N4,1H*,1H+,1,'NDIS VS FO/F',2,IPRINT)
00437          3 CONTINUE
00441          2 CONTINUE
00443          1 CONTINUE
00445        100 FORMAT(F10.5)
00446        103 FORMAT(50X,'T= WATER TEMPERATURE (DEGREES C)'
00446           1,//50X,'D= PROJECTOR DEPTH (METERS)',
00446           3//50X,'S= SALINITY (PPT)',
00446           4//50X,'F= SECONDARY FREQUENCY (KHZ)',
00446           5//50X,'A= PROJECTOR AREA (SQ. METERS)',
00446           6//50X,'FO/F= DOWNSHIFT RATIO',
00446           7//50X,'FO= PRIMARY FREQUENCY (KHZ)',
00446           8//50X,'AL= ABSORPTION CONSTANT (NEPERS/METER)',
00446           9//50X,'1/2AL= REACTION LIMIT (METERS)',
00446           1//50X,'RO= RAYLIEGH DISTANCE (METERS)',
00446           2//50X,'NDIP= DIRECTIVITY INDEX-PRIMARY (DB)',
00446           3//50X,'LSS= SECONDARY SOURCE LEVEL (DB//MICROBAR-METER)',
00446           4//50X,'LSP= PRIMARY SOURCE LEVEL (DB//MICROBAR-METER)',
00446           5//50X,'L*= SCALED SOURCE LEVEL (DB//MICROBAR-METER-KHZ)',
00446           6//50X,'G= PARAMETER GAIN (DB)',
00446           7//50X,'PA= ACOUSTIC POWER PER TONE (WATTS)',
00446           8//50X,'ANDI= DIRECTIVITY GAIN (DB)',
00446           9//50X,'NDIS= SECONDARY DIRECTIVITY INDEX (DB)',
00446           1//50X,'PADB= ACOUSTIC POWER (DB//WATT) PER EACH PRIMARY TONE')
00447        104 FORMAT(//5X,'T= ',F5.0,//5X,'D= ',F8.1,//5X,'S= ',F4.0,//5X,'C= ',
00447           1F8.0,//5X,'A= ',F9.4)
00450        105 FORMAT(5X,'F',8X,'PADB',3X,'FO/F',5X,'FO',8X,'AL',5X,'1/2AL',5X,'R
00450           1O',4X,'1/2ALRO',1X,'NDIP',3X,'LSS',4X,'LSP',4X,'L*',5X,'G',5X,'PA(
00450           2WATTS)',1X,'NDIS',3X,'ANDI')
00451        106 FORMAT(F9.3,3X,F5.1,1X,F7.2,1X,F8.3,1X,F9.6,1X,F7.0,1X,F7.0,1X,F8.
00451           1,1X,F5.1,1X,F6.1,1X,F6.1,1X,F6.1,1X,F5.1,1X,F9.1,1X,F5.1,2X,F5.1)
00452        107 FORMAT(49X,'PARAMETRIC SONAR DESIGN AND ANALYSIS')
00453        112 FORMAT(F9.3,3X,F5.1,1X,F7.2,1X,F8.3,1X,F9.6,1X,F7.0,1X,F7.0,1X,F8.
00453           1,1X,F5.1,1X,F6.1,1X,F6.1,1X,F6.1,1X,F5.1,10X,'L* > 210.')
```

```
00434    180*        113 FORMAT(F9.3,3X,F5.1,1X,F7.2,1X,F8.3,1X,F9.6,1X,F7.0,1X,F7.0,1X,F8.
00454    181*           1,1X,F5.1,1X,F6.1,1X,F6.1,1X,F6.1,1X,F5.1,10X,'L* < 140.')
00455    182*        114 FORMAT(1H1)
00456    183*            STOP
00457    184*            END

      END OF COMPILATION:        NO  DIAGNOSTICS.
```

APPENDIX B

SAMPLE EXAMPLE READOUT

The sample example tables and plots are shown here. These are as they appear on line out of the high speed printer associated with the computer.

PARAMETRIC SONAR DESIGN AND ANALYSIS

T= WATER TEMPERATURE (DEGREES C)

D= PROJECTOR DEPTH (METERS)

S= SALINITY (PPT)

F= SECONDARY FREQUENCY (KHZ)

A= PROJECTOR AREA (SQ. METERS)

FO/F= DOWNSHIFT RATIO

FO= PRIMARY FREQUENCY (KHZ)

AL= ABSORPTION CONSTANT (NEPERS/METER)

1/2AL= REACTION LIMIT (METERS)

RO= RAYLIEGH DISTANCE (METERS)

NDIP= DIRECTIVITY INDEX-PRIMARY (DB)

LSS= SECONDARY SOURCE LEVEL (DB//MICROBAR-METER)

LSP= PRIMARY SOURCE LEVEL (DB//MICROBAR-METER)

L*= SCALED SOURCE LEVEL (DB//MICROBAR-METER-KHZ)

G= PARAMETER GAIN (DB)

PA= ACOUSTIC POWER PER TONE (WATTS)

ΔNDI= DIRECTIVITY GAIN (DB)

NDIS= SECONDARY DIRECTIVITY INDEX (DB)

PADB= ACOUSTIC POWER (DB//WATT) PER EACH PRIMARY TONE

T= 7.

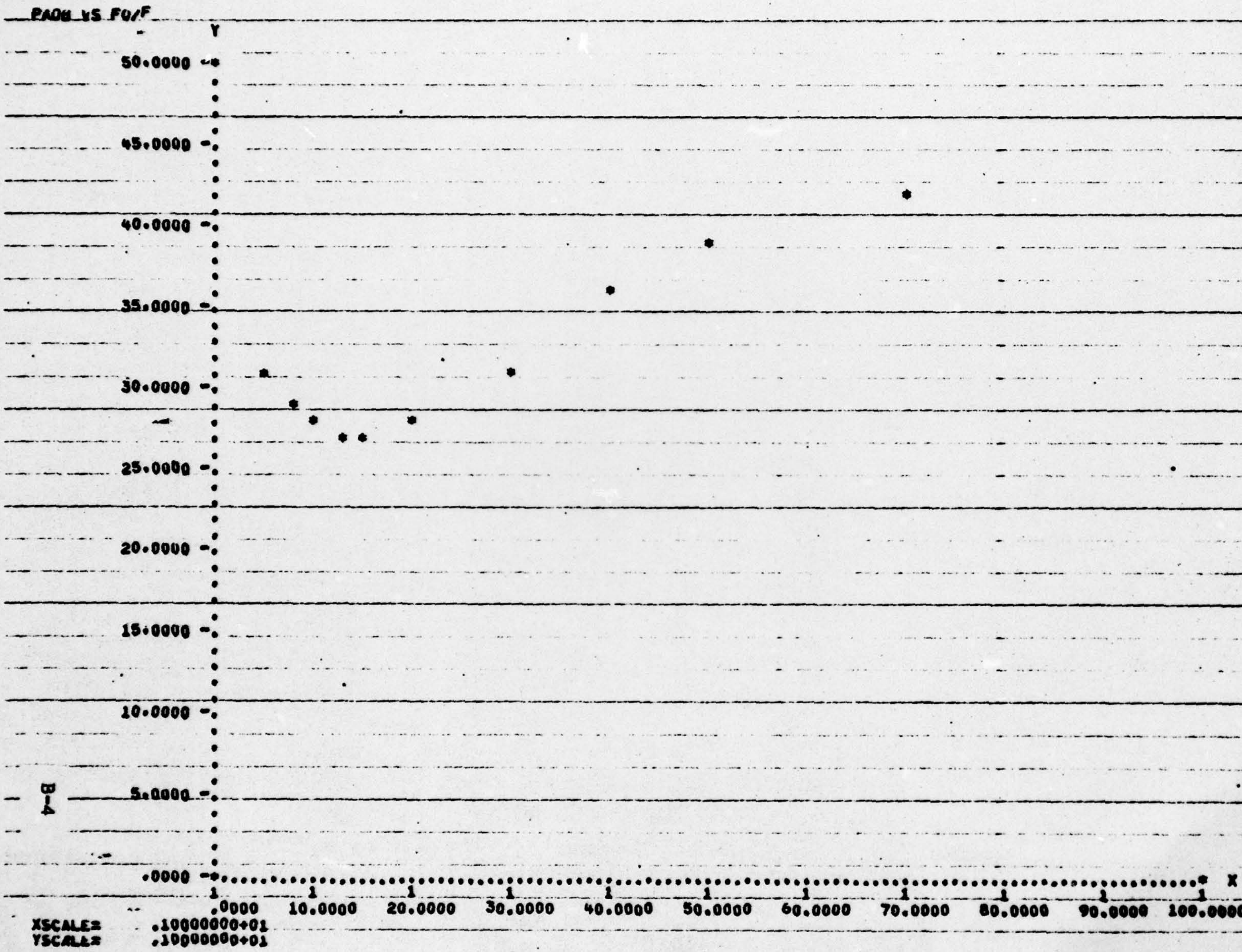
D= .0

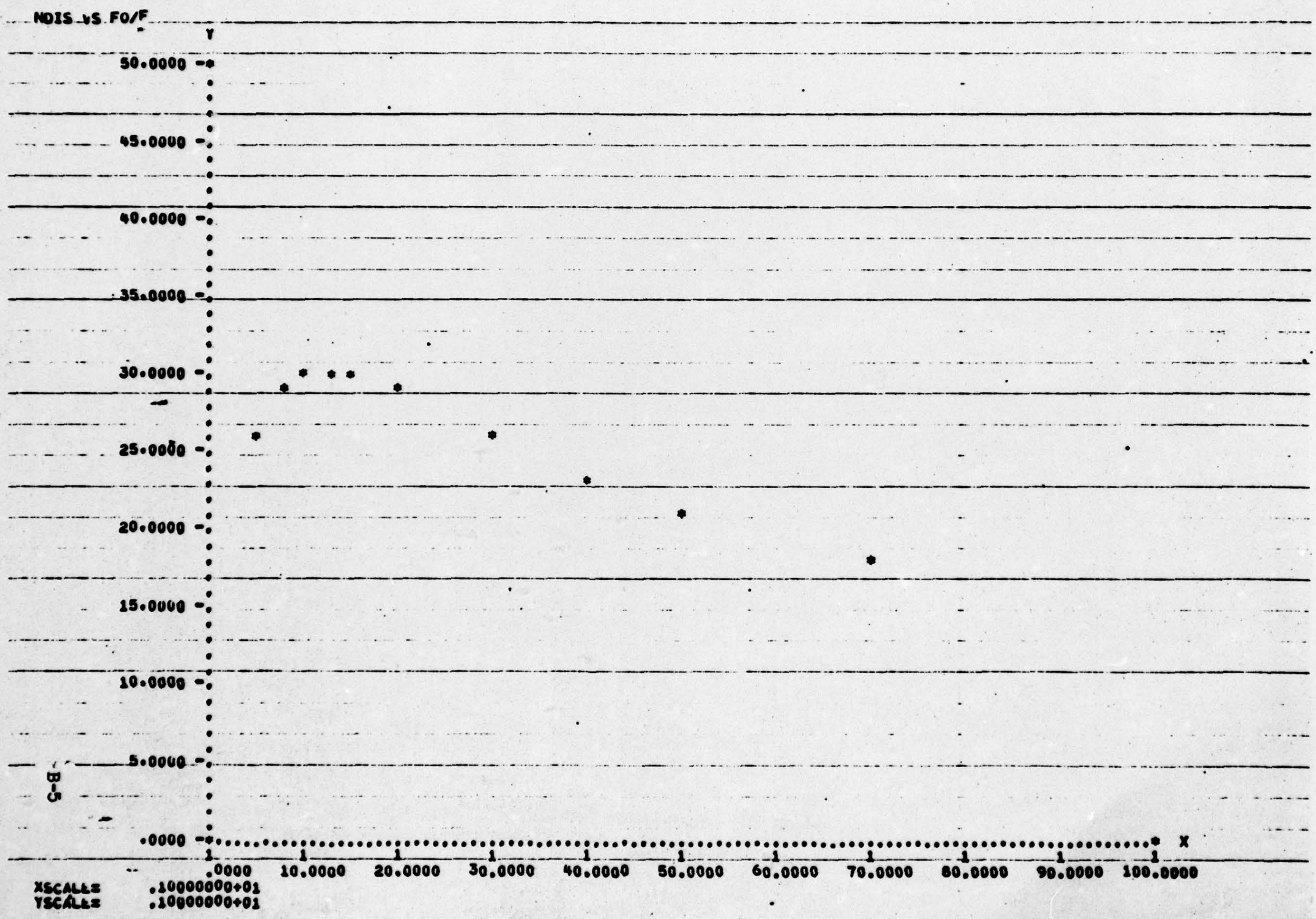
S= 35.

C= 1479.

A= .1964

F	PADB	FU/F	FO	AL	1/2AL	RO	1/2ALRO	NDIP	LSS	LSP	L*	G	PA(WATTS)	NDIS	ΔNDI
3.000	30.7	5.00	15.000	.000241	2079.	2.	1043.5	24.0	89.4	125.6	149.1	-36.2	1185.2	26.4	2.4
3.000	29.5	7.50	22.500	.000506	988.	3.	330.5	27.6	91.0	127.9	154.9	-36.9	889.0	28.8	1.3
3.000	27.8	10.00	30.000	.000846	591.	4.	148.3	30.1	89.8	128.7	158.2	-38.9	603.0	30.0	-.1
3.000	27.2	12.50	37.500	.001257	404.	5.	81.1	32.0	89.7	130.0	161.5	-40.3	529.4	30.3	-1.7
3.000	27.4	15.00	45.000	.001657	302.	6.	50.5	33.6	90.2	131.8	164.8	-41.5	547.3	30.0	-3.6
3.000	28.2	20.00	60.000	.002510	199.	8.	25.0	36.1	90.5	135.1	170.6	-44.6	657.6	29.0	-7.1
3.000	31.1	30.00	90.000	.004021	124.	12.	10.4	39.6	89.2	141.5	180.6	-52.3	1279.5	26.4	-13.2
3.000	36.0	40.00	120.000	.005186	96.	16.	6.1	42.1	89.5	148.9	190.5	-59.4	3987.5	23.2	-18.9
3.000	38.8	50.00	150.000	.006109	82.	20.	4.1	44.0	89.4	153.6	197.1	-64.2	7504.9	21.0	-23.0
3.000	42.0	70.00	210.000	.007653	65.	28.	2.3	47.0	89.3	159.8	206.2	-70.5	15902.7	18.1	-28.8
3.000	.0	100.00	300.000	.009969	50.	40.	1.3	50.1	83.0	.0	210.4	-76.9	L* > 210.		


PAOH VS FO/F
Y
50.0000
45.0000
40.0000
35.0000
30.0000
25.0000
20.0000
15.0000
10.0000
5.0000
.0000
X
.0000
10.0000
20.0000
30.0000
40.0000
50.0000
60.0000
70.0000
80.0000
90.0000
100.0000
XSCALE= .10000000+01
YSCALE= .10000000+01


NDIS vS FO/F
Y
50.0000
45.0000
40.0000
35.0000
30.0000
25.0000
20.0000
15.0000
10.0000
5.0000
.0000
X
.0000
10.0000
20.0000
30.0000
40.0000
50.0000
60.0000
70.0000
80.0000
90.0000
100.0000
XSCALE= .10000000+01
YSCALE= .10000000+01

T= 7.

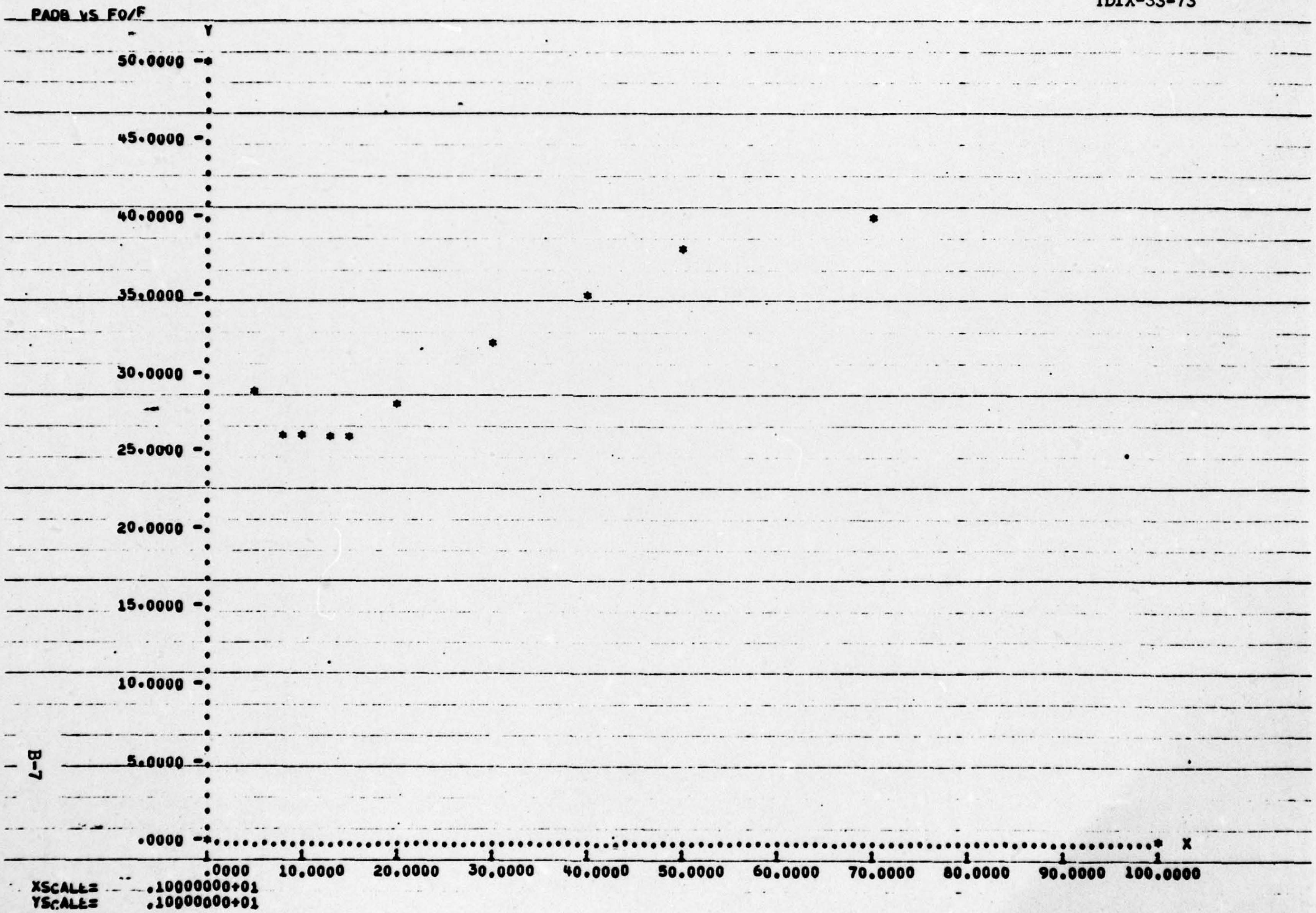
D= .0

S= 35.

C= 1479.

A= .3927

F	PAUO	FU/F	FO	AL	1/2AL	RO	1/2ALRO	NDIP	LSS	LSP	L*	G	PA(WATTS)	NDIS	ΔNDI
3.000	26.6	5.00	15.000	.000241	2079.	4.	521.9	27.1	89.9	126.4	149.9	-36.5	717.2	29.3	2.3
3.000	26.5	7.50	22.500	.000506	988.	6.	165.3	30.6	89.4	127.9	154.9	-38.5	444.6	31.6	1.1
3.000	26.4	10.00	30.000	.000846	591.	8.	74.1	33.1	90.9	130.3	159.9	-39.4	441.5	32.3	-.8
3.000	25.9	12.50	37.500	.001257	404.	10.	40.6	35.0	90.2	131.7	163.2	-41.5	387.7	32.3	-2.8
3.000	26.0	15.00	45.000	.001657	302.	12.	25.3	36.6	90.1	133.4	166.5	-43.3	400.8	31.8	-4.8
3.000	27.7	20.00	60.000	.002510	199.	16.	12.5	39.1	90.6	137.6	173.1	-47.0	582.7	30.3	-8.8
3.000	32.2	30.00	90.000	.004021	124.	24.	5.2	42.6	90.6	145.6	184.7	-55.1	1659.7	27.1	-15.5
3.000	35.5	40.00	120.000	.005106	98.	32.	3.0	45.1	90.3	151.4	193.0	-61.1	3532.9	24.7	-20.4
3.000	38.2	50.00	150.000	.006109	82.	40.	2.1	47.1	90.8	156.1	199.6	-65.2	6649.4	22.6	-24.4
3.000	39.8	70.00	210.000	.007053	65.	56.	1.2	50.0	89.5	160.6	207.1	-71.1	9623.6	20.5	-29.5
3.000	.0	100.00	300.000	.007969	50.	80.	.6	53.1	82.2	.0	210.4	-77.7	L* > 210.		


PADB VS FO/F
Y
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40.0000
35.0000
30.0000
25.0000
20.0000
15.0000
10.0000
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.0000
10.0000
20.0000
30.0000
40.0000
50.0000
60.0000
70.0000
80.0000
90.0000
100.0000
X
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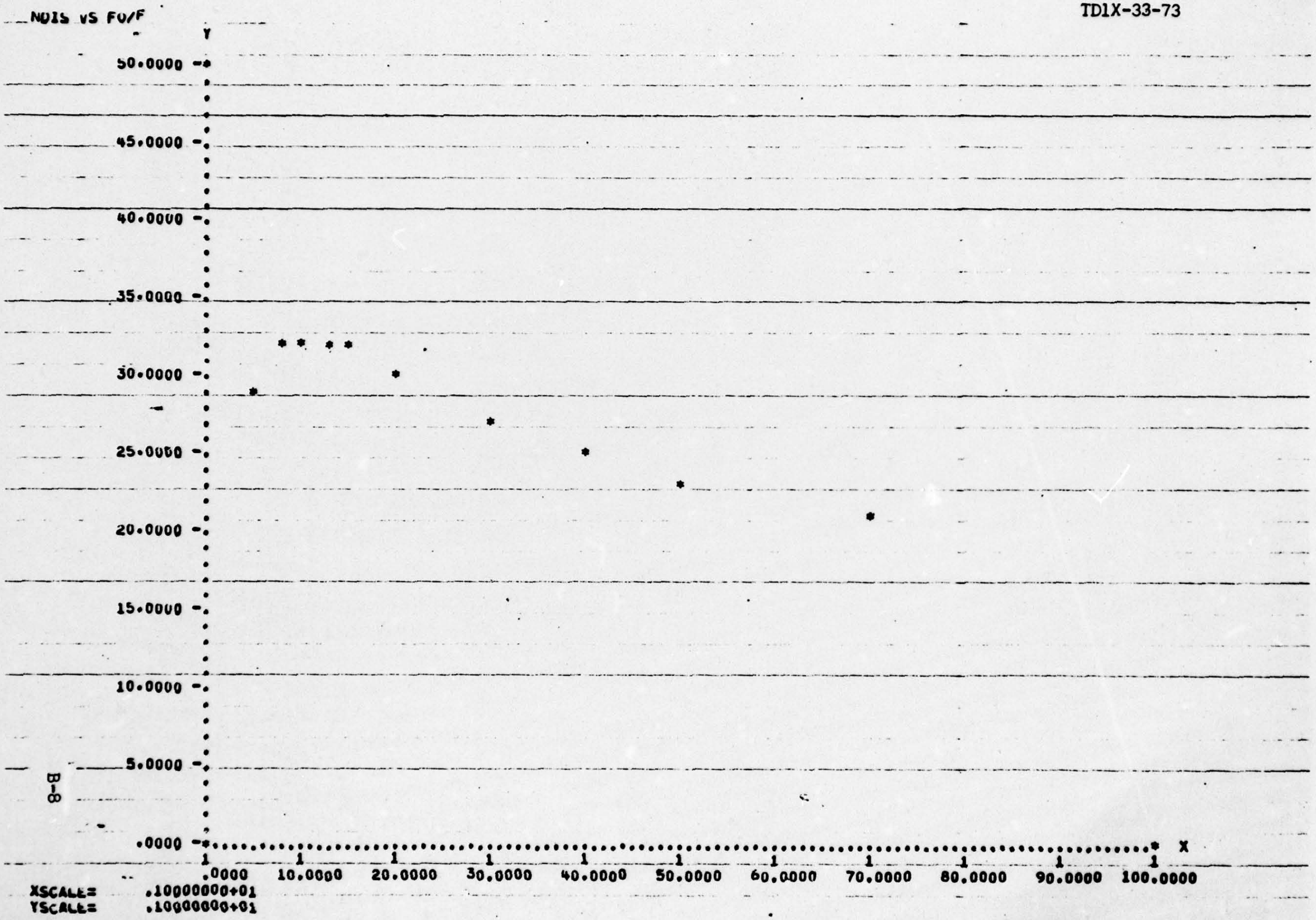
YSCALE= .10000000+01


NDIS VS FO/F
Y
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45.0000
40.0000
35.0000
30.0000
25.0000
20.0000
15.0000
10.0000
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10.0000
20.0000
30.0000
40.0000
50.0000
60.0000
70.0000
80.0000
90.0000
100.0000
X
XSCALE= .10000000+01
YSCALE= .10000000+01

T= 7.

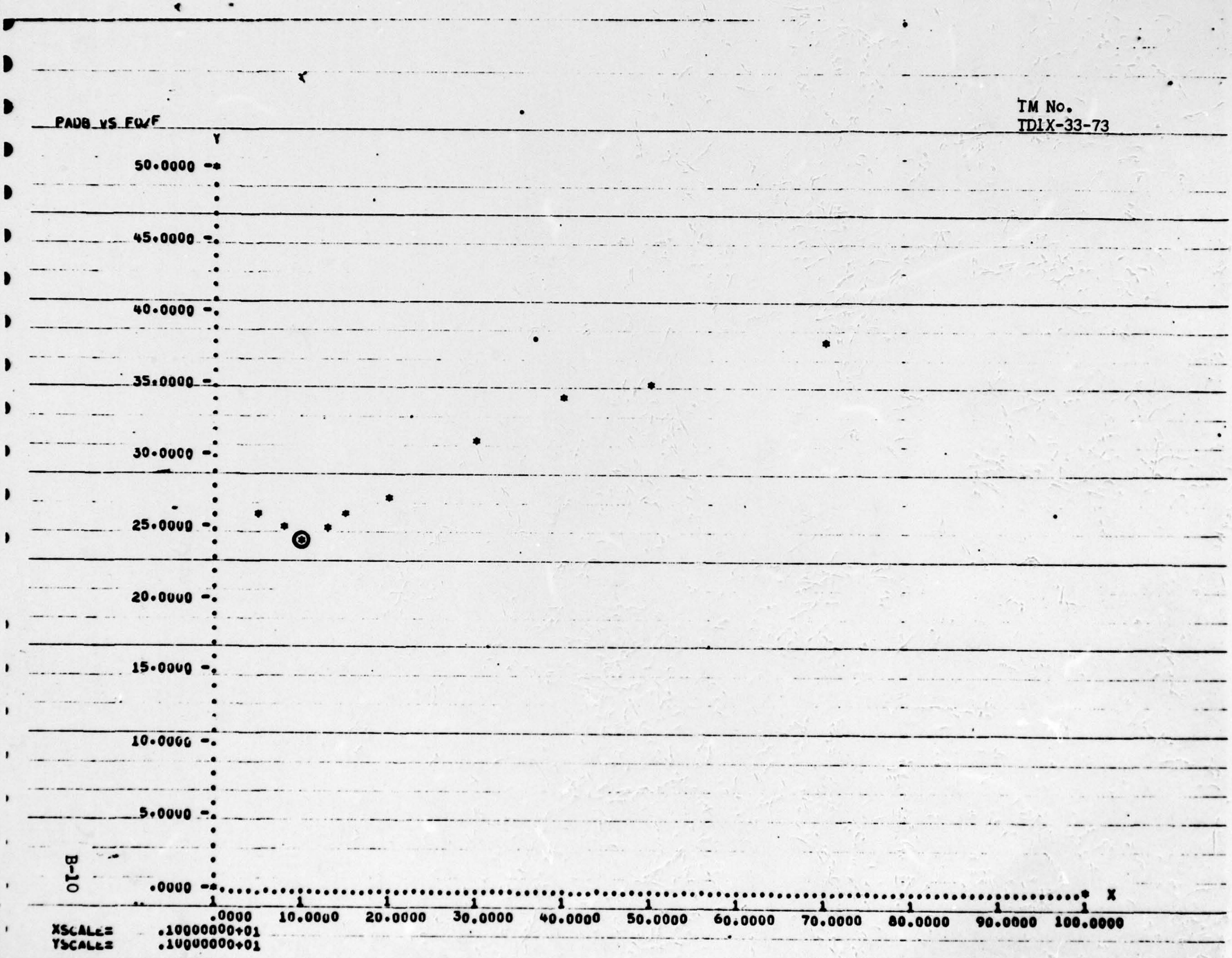
D= .0

S= 35.

C= 1479.

A= .7854

F	PAdB	FO/F	FO	AL	1/2AL	RO	1/2ALRO	NDIP	LSS	LSP	L*	G	PA(WATTS)	NDIS	ΔNDI
3.000	26.6	5.00	15.000	.000241	2079.	8.	260.9	30.1	90.2	127.2	150.8	-37.0	433.9	32.2	2.1
3.000	25.1	7.50	22.500	.000506	988.	12.	82.7	33.6	90.7	129.5	156.6	-38.8	325.5	34.1	.5
3.000	24.3	10.00	30.000	.000846	591.	16.	37.1	36.1	89.9	131.2	160.7	-41.2	267.1	34.4	-1.7
3.000	24.6	12.50	37.500	.001237	404.	20.	20.3	38.0	90.1	133.4	164.8	-43.3	283.8	33.9	-4.1
3.000	25.5	15.00	45.000	.001657	302.	24.	12.6	39.6	90.7	135.9	169.0	-45.2	355.0	33.1	-6.5
3.000	27.1	20.00	60.000	.002510	199.	32.	6.3	42.1	90.2	140.0	175.6	-49.9	516.1	31.5	-10.6
3.000	30.6	30.00	90.000	.004021	124.	48.	2.6	45.6	89.6	147.3	186.4	-57.7	1215.0	28.6	-17.0
3.000	34.1	40.00	120.000	.005186	96.	64.	1.5	48.1	90.3	153.1	194.6	-62.8	2586.3	26.4	-21.8
3.000	35.2	50.00	150.000	.006109	82.	80.	1.0	50.1	89.5	156.1	199.6	-66.6	3324.7	25.1	-25.0
3.000	38.5	70.00	210.000	.007653	65.	112.	.6	53.0	90.4	162.3	208.7	-71.8	7044.9	22.4	-30.6
3.000	.0	100.00	300.000	.009969	50.	159.	.3	56.1	81.0	.0	210.4	-78.8	L* > 210.		


PADB VS FO/F
Y
50.0000
45.0000
40.0000
35.0000
30.0000
25.0000
20.0000
15.0000
10.0000
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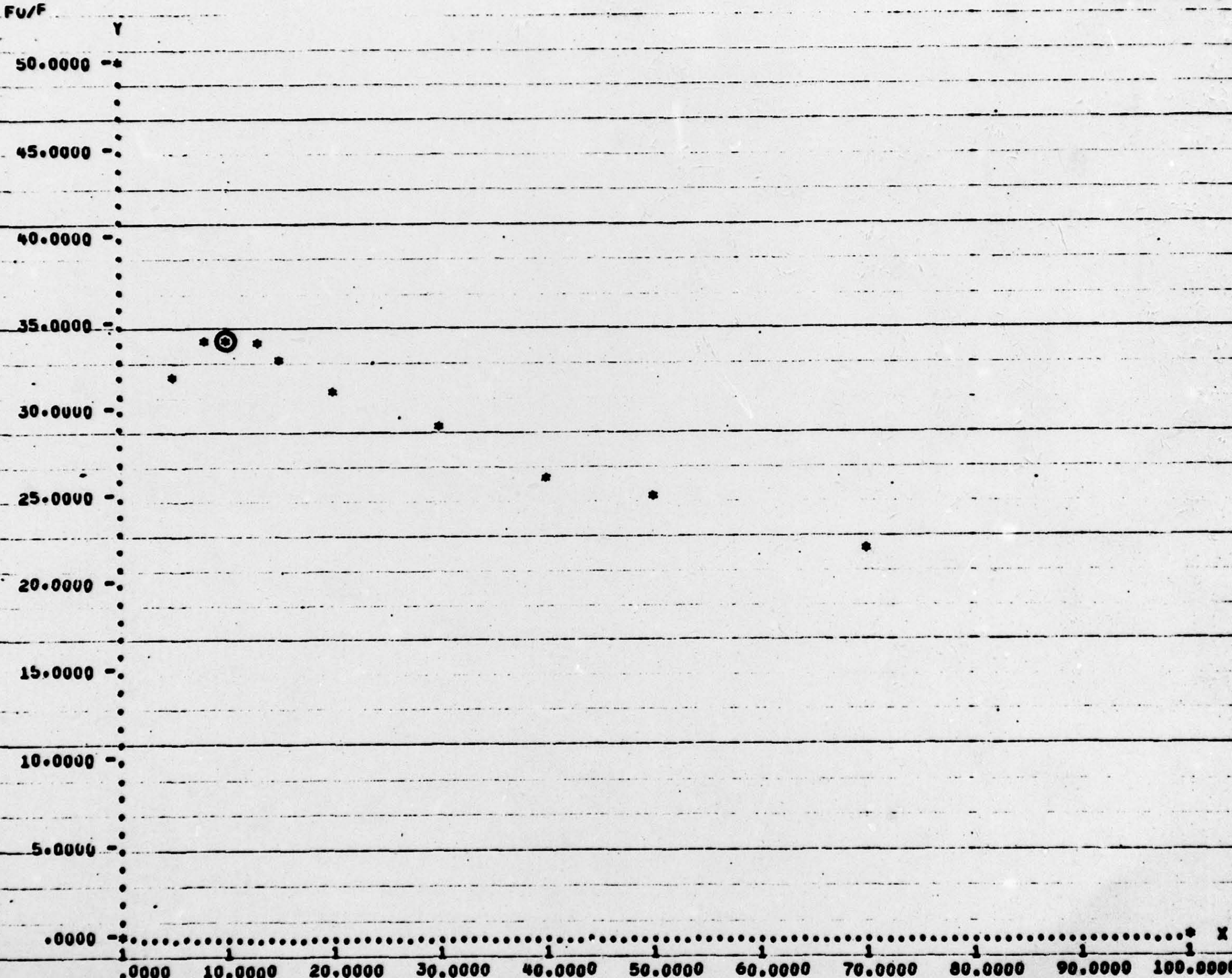
.0000
X
.0000
10.0000
20.0000
30.0000
40.0000
50.0000
60.0000
70.0000
80.0000
90.0000
100.0000
XSCALE= .10000000+01
YSCALE= .10000000+01

NDIS VS FU/F



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YSCALE= .10000000+01