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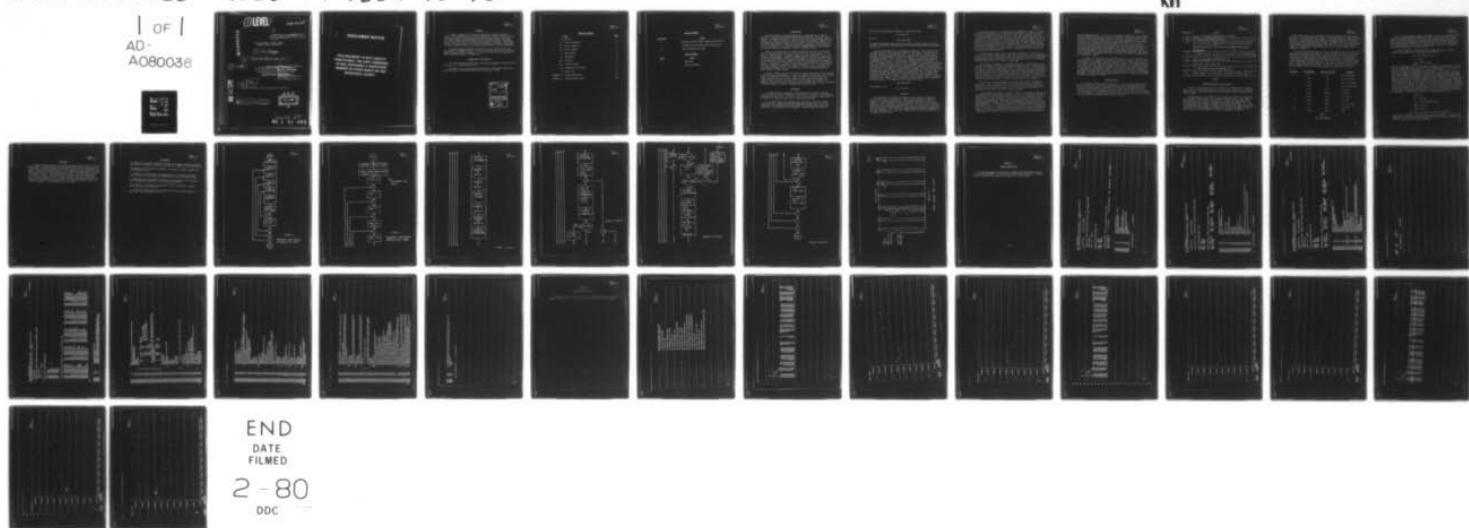
NAVAL UNDERWATER SYSTEMS CENTER NEWPORT RI  
COMPUTER AIDED PARAMETRIC SONAR DESIGN.(U)

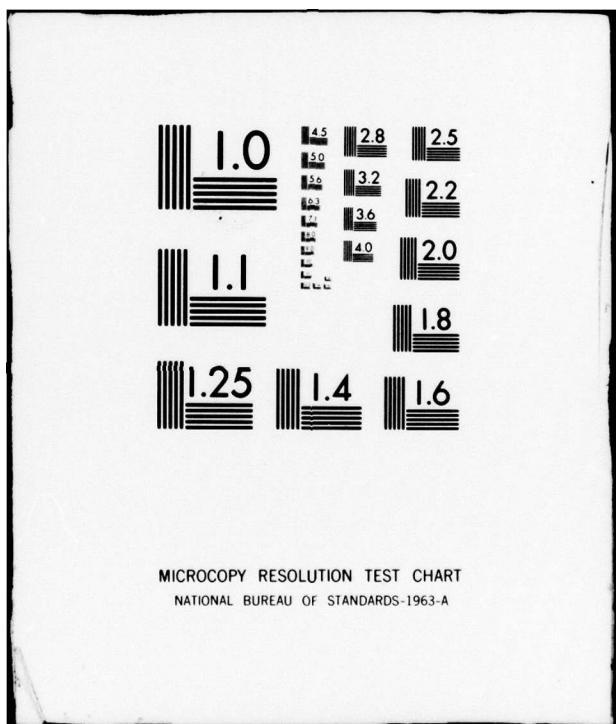
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MAY 73 E C GANNON, R P PINGREE  
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NAVAL UNDERWATER SYSTEMS CENTER  
Newport, Rhode Island 02840

⑨ Technical Memorandum

⑥ COMPUTER AIDED PARAMETRIC SONAR DESIGN

⑪ 23 May 73

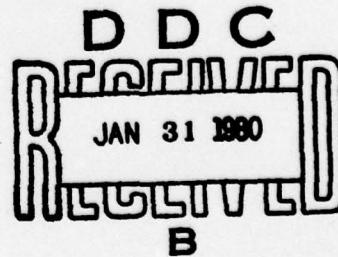
Prepared by Edmund C. Passon  
Edmund C. Gannon,  
Parametric Sonar Group  
Robert P. Pingree  
A. J. Van Wervkum  
Robert P. Pingree  
R. P. Pingree  
Digital Computing Division

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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.

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## 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<sup>1</sup> 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<sup>2</sup> 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<sup>3</sup> 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<sup>4</sup>. 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

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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 <sup>5</sup> . | $FT = 21.9 \times 10^6 - (1520/(T+273))$ kHz                                                                                                                                                                                                          |
| 3 <sup>5</sup> . | $AL = (1/8.68)(1/914.4) \left\{ \left[ (1.86 \times 10^{-2})(S)(FT)(FO)^2 / [(FT)^2 + (FO)^2] \right] + \left[ 2.68 \times 10^{-2}(FO)^2 / FT \right] + \left[ 0.1(FO)^2 / (1 + (FO)^2) \right] \right\} (1 - 6.33233 \times 10^5 D)$<br>NEPERS/METER |
| 4 <sup>5</sup> . | $C = 1449.2 + 4.623T - 0.0546(T^2) + 1.391 (S-35) + 0.017D$ METERS/SECOND                                                                                                                                                                             |
| 5 <sup>6</sup> . | $NDIP = 10 \log_{10} (4\pi A (FO)^2 (10^3)^2 / C^2)$ DB                                                                                                                                                                                               |
| 6.               | $PADB = LSP - 70.8 - NDIP$ DB                                                                                                                                                                                                                         |
| 7.               | $PA = \text{ANTILOG} \left[ (1/10)(LSP-70.8-NDIP) \right]$ WATTS                                                                                                                                                                                      |
| 8 <sup>1</sup> . | $NDIS = (NDIP) + 3 - 10 \log_{10} \left[ 1 + ((FO)/F)(2\pi (AL)(RO) + X) \right]$ 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.

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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 S. 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.

| <u>Card Type</u> | <u>Card Columns</u> | <u>Fortran IV Format</u> | <u>Agreement</u>   |
|------------------|---------------------|--------------------------|--------------------|
| 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

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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 ( $S = 35 \text{ ppt}$ ) and that the system must be capable of operating in the winter ( $T = 7^\circ\text{C}$ ) 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 assume that 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  $PA = 267.1 \text{ watts/each primary frequency.}$

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.

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#### 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 1971, pages 88-96.
6. "The Design and Construction of Magnetostriction Transducers," NDRC Div 6 Report Vol. 13, dated 1946, p. 128.

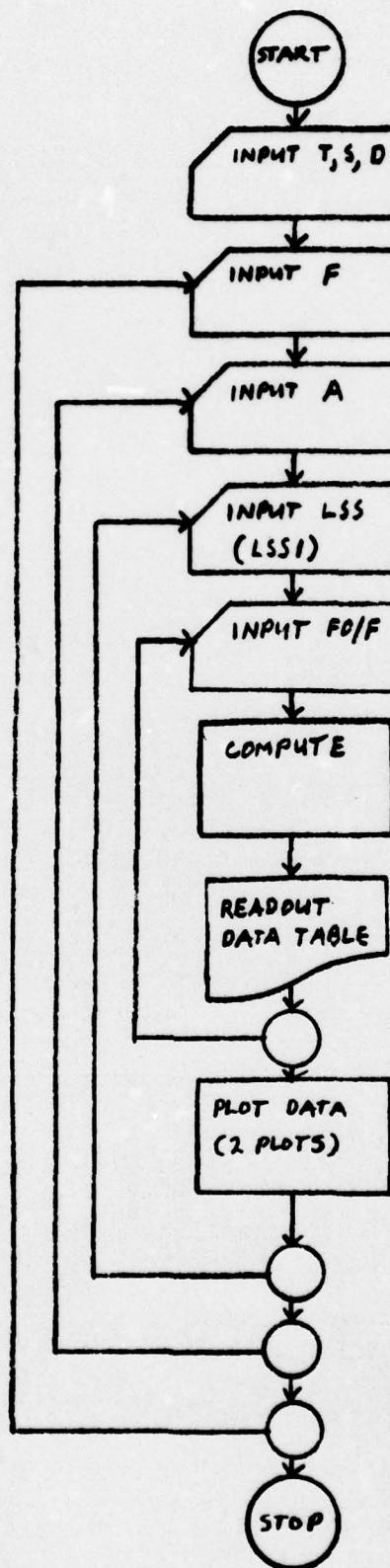


FIGURE 1

PARAMETRIC SONAR DESIGN,  
SIMPLIFIED FLOW CHART

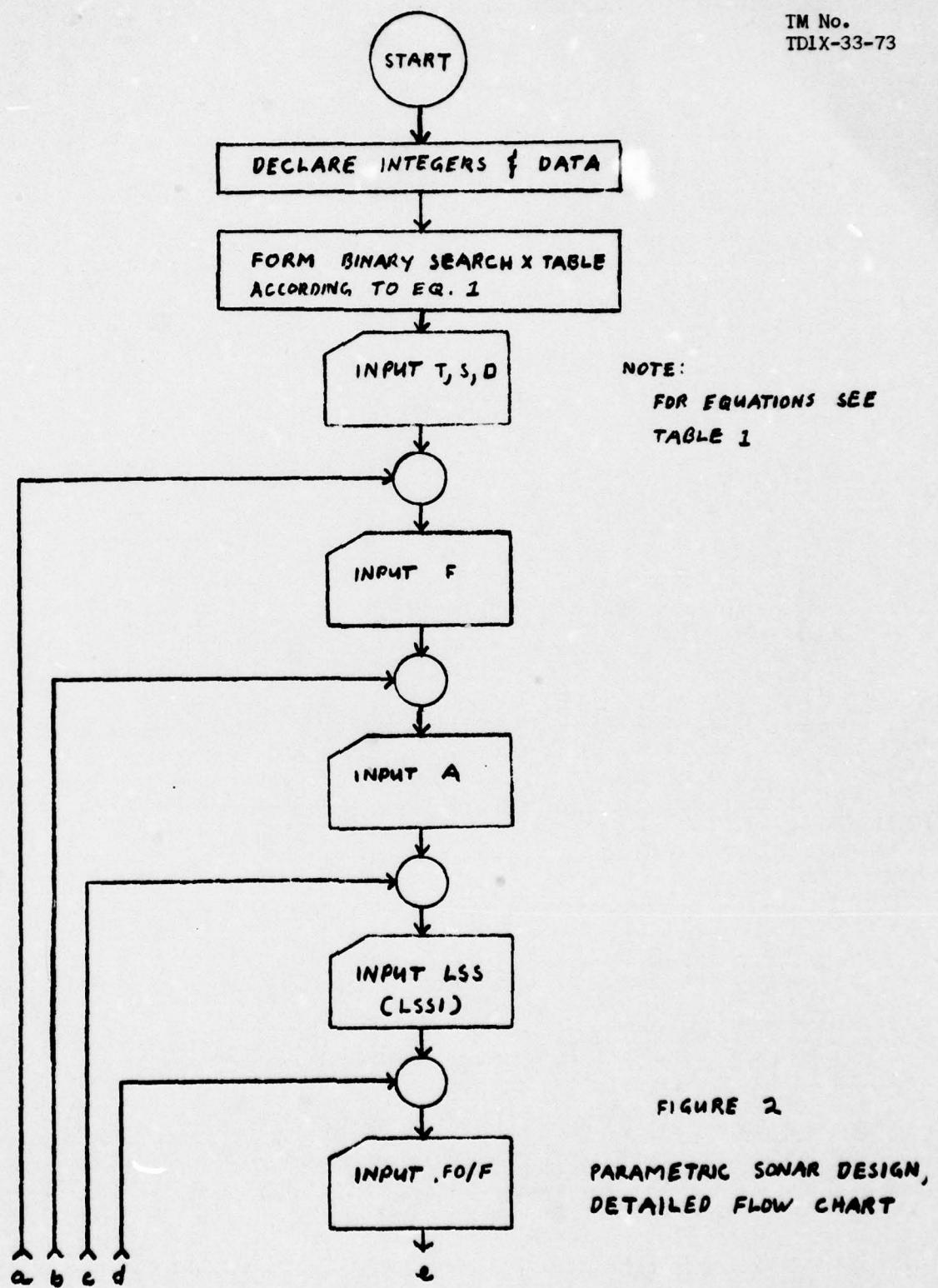


FIGURE 2

PARAMETRIC SONAR DESIGN,  
DETAILED FLOW CHART

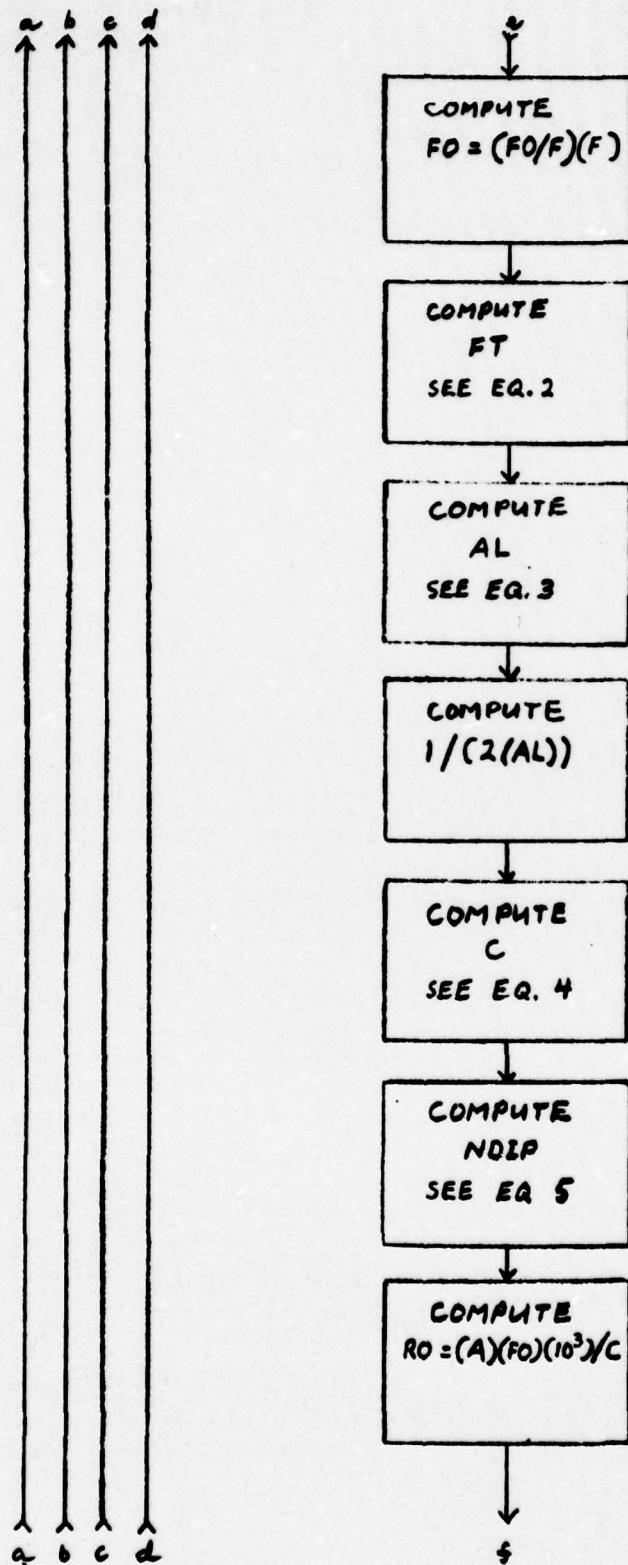


FIGURE 2 (CONT. 1)

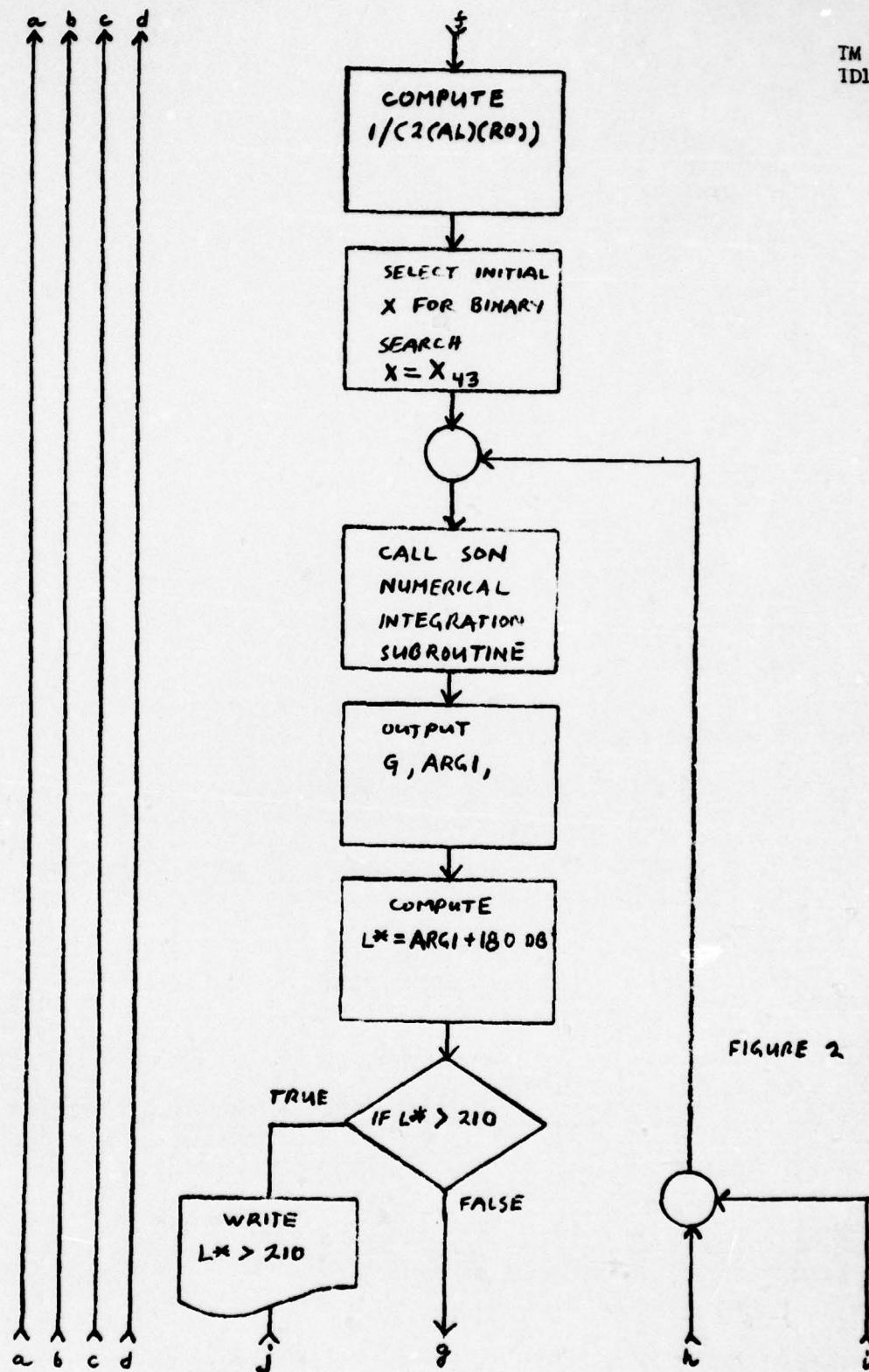


FIGURE 2 (CON'T 2)

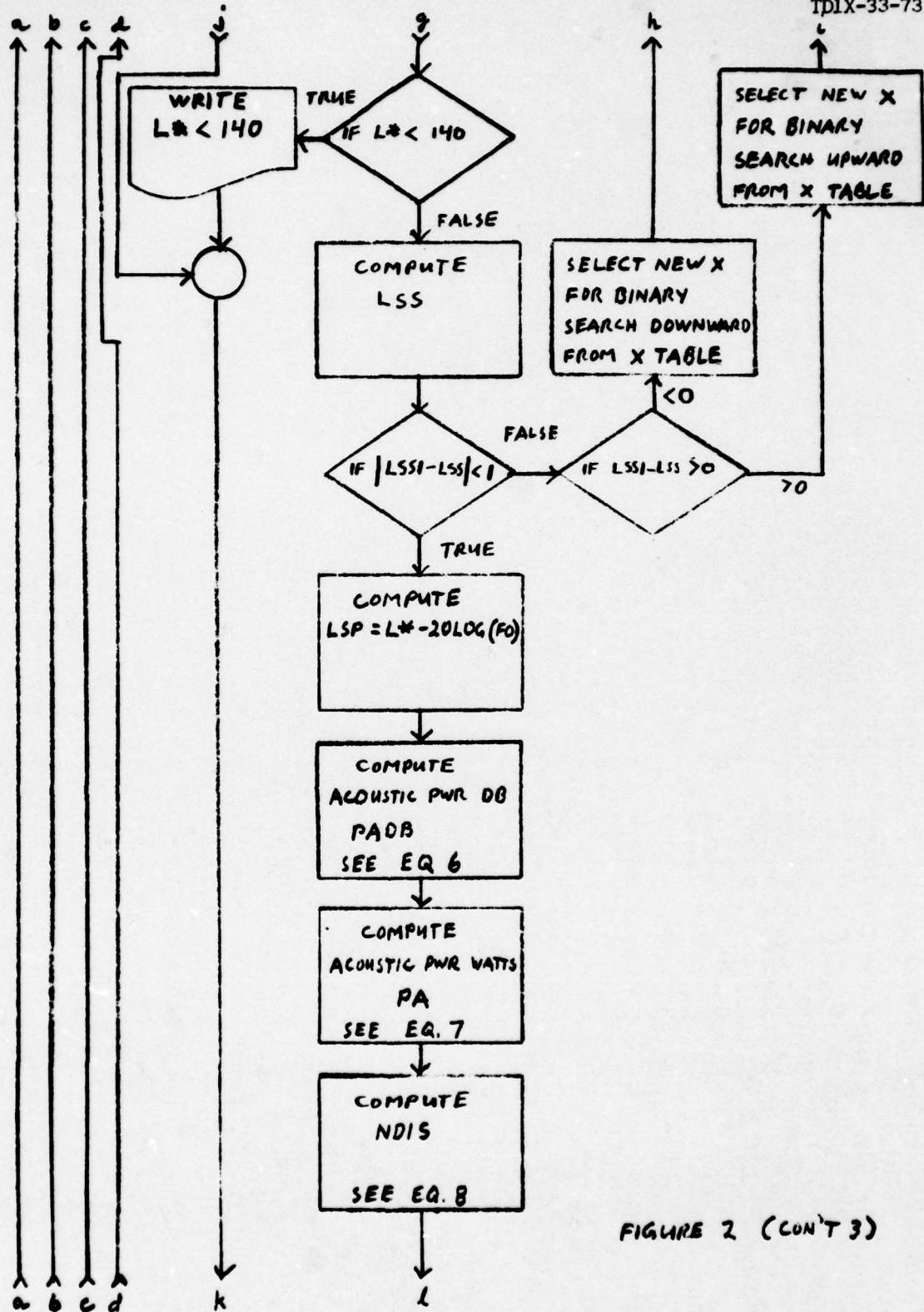


FIGURE 2 (CON'T 3)

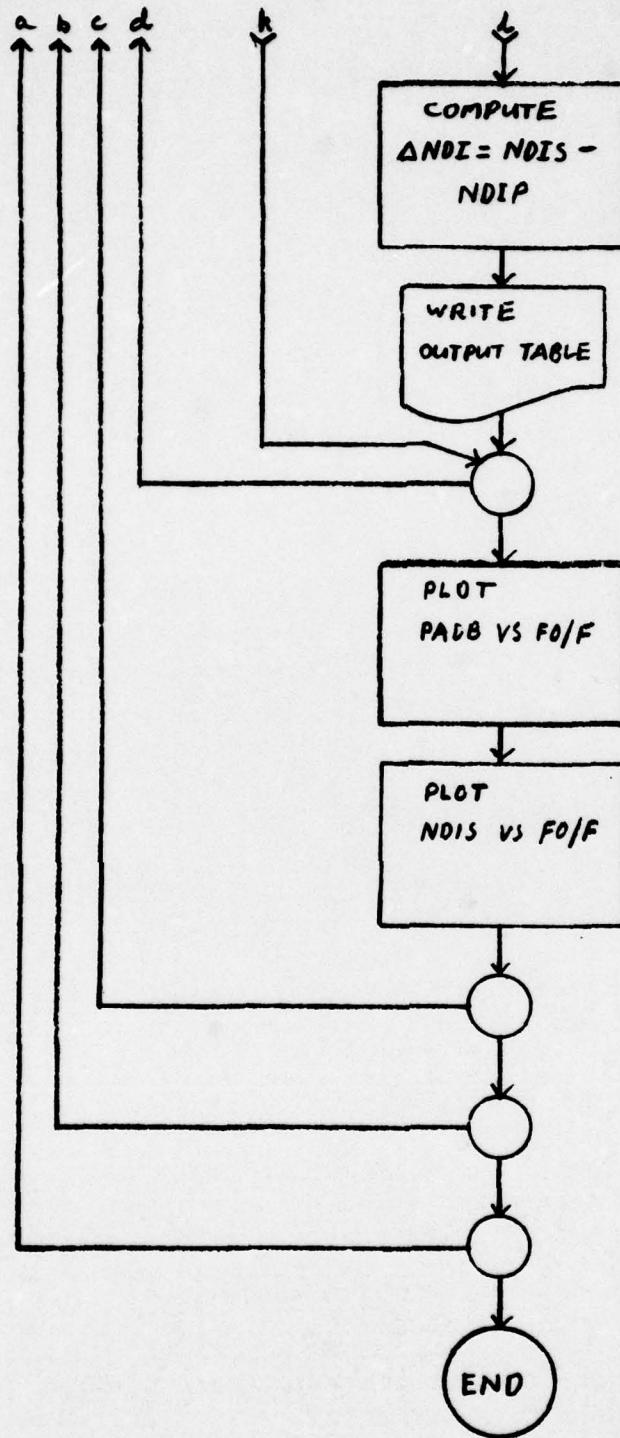


FIGURE 2 (CON'T. 4)

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FIGURE 3  
SAMPLE EXAMPLE DATA FORMAT

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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.

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FOR SUD, JUN  
UNIVAC 1108 FORTRESS V LEVEL 2206 0026 (EXEC8 LEVEL E1201-0011)  
THIS COMPILED WAS DONE ON 14 JUN 73 AT 21:34:46

21139146..50

SUBROUTINE SUB ENTRY POINT 000067

STORAGE USED: CODE(1) 0001031 DATA(0) 0000201 BLANK COMMON(2) 0000000

COMMON BLOCKS:

0003 BLK 000010

EXTERNAL REFERENCES (BLOCK, NAME)

|             |  |
|-------------|--|
| 0004 USINH  |  |
| 0005 DEXP   |  |
| 0006 USQRT  |  |
| 0007 NERK3S |  |

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

|                   |                 |                    |                  |               |
|-------------------|-----------------|--------------------|------------------|---------------|
| 0003 D 000000 ANO | 0003 D 000006 E | 0003 D 000002 GKD0 | 0000 000012 INPS | 0000 000000 T |
| 0003 D 000008 X   |                 |                    |                  |               |

```
00101 1*      SUBROUTINE SUB(A,J,H,F)
C0102 2*      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
C0103 3*      COMMON/BLK/AR0,GKD0,X,E
C0104 4*      TEAT+J*H
C0105 4*      F=USINH(T)
C0106 5*      TE1=0.00+((A*T1)**2)/4.000
C0107 6*      IF (AR0.GT.0.000) E=DEXP(-F*AR0)
C0108 7*      F=F**2
C0112 8*      F=(1.000+F)/(1.000+F*GKD0**2)
C0113 9*      FEE=DSQRT(F1/T)
C0114 10*     RETURN
C0115 11*     END
C0116 12*     END
```

END OF COMPILATION: NO DIAGNOSTICS.

FOR NOM-NOM  
UNIVAC 1108 FORTRAN V LEVEL 2206 0026 (EXEC8 LEVEL E1201-0011)  
THIS COMPILED IN GAS DUNE UN 14 JUN 73 AT 21:34:47

TM No.  
TDIX-33-73  
211394167. 40

SUBROUTINE RUM ENTRY POINT 000246

STORAGE USED: C0E(1) 0002751 DATA(0) 0000601 BLANK COMMON(2) 0000000

EXTERNAL REFERENCES (BLOCK, NAME)

|      |        |
|------|--------|
| 0003 | SUB    |
| 0004 | NEXP1S |
| 0005 | NEXPYS |
| 0006 | NEPR3S |

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

|      |        |        |      |        |        |          |        |    |                  |
|------|--------|--------|------|--------|--------|----------|--------|----|------------------|
| 0001 | 000071 | 1206   | 0001 | 000120 | 1306   | 0001     | 000033 | 4L | 0000 D 000005 FN |
| 0000 | D      | 000009 | H    | 0000   | 000031 | INJPS    | 0000   | I  | 000015 TU        |
| 0000 | I      | 000002 | K    | 0000   | 1      | 000014 L | 0000   | I  | 000011 H         |
|      |        |        |      |        |        |          |        | D  | 000007 SIG       |

```

C0101    1*      SUBROUTINE ROM(A,B,W,EPS,IV,NMX)
C0102    2*      DIMENSION A(NMX,NMX)
C0103    3*      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
C0104    4*      H=U-A
C0105    5*      K=0
C0106    6*      CALL SUB(A,0,H,F)
C0107    7*      FN=F
C0110    8*      CALL SUB(A,1,H,F)
C0111    9*      K(1,1)=(F+FN)*H1/2.0D0
C0112   10*      K=K+1
C0113   11*      H1=H/2.000
C0114   12*      SIG=0.000
C0115   13*      K=K*(K-1)
C0116   14*      UU 1  J=1,M
C0117   15*      J1=2+J-1
C0122   16*      CALL SUB(A,J1,H,F)
C0123   17*      SIG=SIG+F
C0124   18*      K(K+1,1)=M(K,1)/2.0D0+H*SIG
C0126   19*      UU 2  L=L,K
C0127   20*      UU K+1-L
C0132   21*      IV=L+1
C0133   22*      2  ((IU,IV)=(4.0D0**((IV-1)*W(IU+1,IV-1)-W(IU,IV-1))/(4.0D0**((IV-1)-1.
C0134   23*      1D0))
C0135   24*      IF (ABS(W(IU,IV))-W(IU,IV-1)).LT.ABS(W(IU,IV)) .EPS) RETURN
C0136   25*      GO TO 4
C0140   26*      ENQ

```

A-3      END OF COMPILATION!      NO DIAGNOSTICS.

TM No.  
TDIX-33-73

FOR SON, SUN  
UNIVAC 1108 FORTKAN V LEVEL 2206 0026 (EXEC0 LEVEL E1201-0011)  
THIS COMPILED AS DONE ON 14 JUN 73 AT 21:34:48

21134100.366

SUBROUTINE SUN ENTRY POINT 000134

STORAGE USED: CODE(1) 0001601 DATA(0) 0116641 BLANK COMMON(2) 0000000

COMMON BLOCKS:

0003 BLK 000010

EXTERNAL REFERENCES (BLOCK, NAME)

|      |        |
|------|--------|
| 0001 | ROM    |
| 0003 | DLOG   |
| 0006 | DATAN  |
| 0007 | DLOG10 |
| 0010 | NRH35  |

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

|      |        |      |                   |                     |                      |
|------|--------|------|-------------------|---------------------|----------------------|
| 0001 | 000045 | IL   | 0000 D 011612 A   | 0000 D 000000 ARO   | 0000 D 011664 B      |
| 0003 | 0      | EPS  | 0000 D 011622 FAC | 0003 D 000002 GRDKO | 0000 D 011616 GRDKOS |
| 0000 | 011650 | INPS | 0000 D 011624 IV  | 0003 D 000004 X     |                      |

00101 1\* SUBROUTINE SON (RARKO,RKUKO,ARG,ANS,AIN,NMX)  
00102 2\* IMPLICIT DOUBLE PRECISION (A-H,O-Z)  
00103 COMMON/BLK/ARG,RKUKO,X,E  
00104 3\* DIMENSION X(150,50),  
00105 4\* EPS=5E-05  
00106 5\* AE=0.0  
00107 6\* BE=0.0  
00108 7\* E=1.CD  
00111 8\* AKU=0.000  
00112 9\* IF (RARKO.GT.ARO) ARO=1.000/RARKO  
00113 10\* GKKO=1.000/RKUKO  
00115 11\* GKKO=GRKUKO\*\*2  
00116 12\* \*DIAGNOSTIC\* THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL.  
00117 13\* 00117 IF (RARKO.EQ.0.000) GO TO 1  
00118 14\* AL1=DLOG (RKUKO)  
00121 15\* BEULOG ((R4.000+ALN1)\*RARKO)  
00122 16\* 1 FAC=GRKUKO\*(X/2.000)  
00123 17\* CALL HUM(A,B,N,EPs,IV,50)  
00125 18\* AIN=1.IV  
00126 19\* \*DIAGNOSTIC\* THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL.  
00126 20\* 1.F (RARKO.EQ.0.000) AIN=AIN+2.000\*GRKUKO/(1.5707963267948900-DATAN(10

1.000\*X))/X  
AIN=FAC\*AIN  
AIN=20.000\*DLOG610(X)  
AIN=20.000\*DLOG610(AIN)

TM No.  
TDIX-33-73

00133 24\* RETURN  
00134 25\* ENQ

END OF COMPLAINTS 2 DIAGNOSTICS.

21134199.464

FOR SONAKI/SUNAR  
UNIVAC 1108 FORTRESS V LEVEL 2206 0026 (EJECT LEVEL E1201-0011)  
THIS COMPILED WAS DONE ON 14 JUN 73 AT 21134149

MAIN PROGRAM

STORAGE USED: CODE(11) 0010121 DATA(0) 0045361 BLANK COMMON(12) 0000000

COMMON BLOCKS:

0003 BLK 000000

EXTERNAL REFERENCES (BLOCK, NAME)

|      |        |
|------|--------|
| 0004 | SON    |
| 0005 | PLOTA  |
| 0006 | NHDUS  |
| 0007 | N1023  |
| 0010 | HEXPoS |
| 0011 | N1013  |
| 0012 | Nhdus  |
| 0013 | AL010  |
| 0014 | DLQ10  |
| 0015 | NSTOP3 |

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

|      |          |       |      |          |        |      |          |       |      |          |        |
|------|----------|-------|------|----------|--------|------|----------|-------|------|----------|--------|
| 0000 | 004023   | 100F  | 0000 | 004003   | 102F   | 0000 | 004025   | 103F  | 0000 | 004242   | 104F   |
| 0000 | 004262   | 105F  | 0000 | 004321   | 106F   | 0000 | 004346   | 112F  | 0000 | 004402   | 113F   |
| 0000 | 004426   | 114F  | 0001 | 000016   | 1176   | 0001 | 000023   | 13L   | 0001 | 000531   | 14L    |
| 0001 | 000149   | 1566  | 0001 | 000160   | 1646   | 0001 | 000557   | 17L   | 0001 | 000172   | 1726   |
| 0001 | 000573   | 200L  | 0001 | 000234   | 2066   | 0001 | 000671   | 210L  | 0001 | 000237   | 2116   |
| 0001 | 000717   | 220L  | 0001 | 000312   | 2366   | 0001 | 000430   | 2576  | 0001 | 000744   | 4L     |
| 0000 | R 001130 | A     | 0000 | R 002474 | ADM    | 0000 | D 003410 | AIN   | 0000 | R 001750 | ALPHA  |
| 0000 | R 03244  | AN51  | 0000 | D 003414 | ARG    | 0000 | R 003100 | ARG1  | 0003 | D 000000 | ARO    |
| 0000 | R 003753 | D     | 0000 | R 001274 | VELN01 | 0000 | R 004000 | DUM   | 0003 | D 000006 | E      |
| 0000 | R 01449  | FU    | 0000 | R 003764 | FT     | 0003 | D 000002 | GDKO  | 0000 | I 003737 | I      |
| 0000 | I 003755 | I8    | 0000 | I 003756 | IC     | 0000 | I 003734 | ICARD | 0000 | I 003774 | ICONST |
| 0000 | I 003776 | IUM1  | 0000 | I 003775 | IOUR1  | 0000 | I 003761 | II    | 0000 | I 003773 | IIX    |
| 0000 | I 003770 | IM1D  | 0000 | I 003766 | IMIN   | 0000 | I 003771 | IND   | 0000 | I 003772 | IOPT   |
| 0000 | I 003777 | ISAV1 | 0000 | I 003762 | J      | 0000 | I 003763 | JJ    | 0000 | I 003740 | KN1    |
| 0000 | I 003742 | KM2   | 0000 | I 003743 | KN3    | 0000 | R 000620 | LSP   | 0000 | R 000000 | LSS1   |
| 0000 | I 003744 | N     | 0000 | R 000454 | NQIP   | 0000 | R 000310 | NQIS  | 0000 | I 003765 | NLX    |
| 0000 | I 003746 | N2    | 0000 | I 003747 | N3     | 0000 | I 003750 | N4    | 0000 | R 002114 | PA     |
| 0000 | R 003748 | P1    | 0000 | R 004001 | PT     | 0000 | R 002570 | RARO  | 0000 | D 003420 | RARO1  |
| 0000 | D 003422 | KDFU1 | 0000 | R 001604 | RO     | 0000 | R 003752 | S     | 0000 | R 003751 | T      |
| 0000 | D 003412 | X0    | 0000 | D 003424 | XX     | 0003 | D 000004 | X     |      |          |        |

A-6

00101 10  
00103 20  
00108 30  
00109 40  
00105 50  
00106 50

HEAL LSS,LSS1,NQIS,NQIP,LSP  
PARAMETER LMX=100  
DIMENSION LSS(LMX),LSP(LMX),LSS1(LMX),NQIS(LMX),NQIP(LMX),AL(MX),  
DIMENSION VELND1(LMX),FO(LMX),RO(LMX),ALPHA(LMX),NOIP(LMX),PA(LMX),  
DIMENSION PAB(LMX),ADUM(LMX),RARO(LMX),RDFD(LMX),ARG1(LMX),ANS1(LMX)

```

62
63      DOUBLE PRECISION A00, G00K0, X, E, AIN, X0, ARG, ANS, RAR01, RFDF01
64
65      DOUBLE PRECISION XX(LMX)
66
67      COMMON/BLK/ A00, G00K0, X, E
68
69      ICARD=3
70      IPRINT=4
71      PI=3.14159
72
73      C   CAR0   COLUMNS   FORMAT   ARGUMENT
74      C   C       C       C       C
75      C   1       1-5      15      KN- NO. OF F VALUES
76      C   1       6-10     15      KN1- NO. OF A VALUES
77      C   1       11-15    15      KN2- NO. OF LSS. VALUES
78      C   1       16-20    15      KN3- NO. OF FO/F VALUES +1
79
80      C   2       1-10     F0.4    T
81      C   2       11-20    F0.4
82      C   2       21-20    F0.4
83      C   2       21-30    F0.4
84      C   2       0
85
86      C   3       1-10     F10.5
87      C   3       1-10     F10.5
88      C   3       1-10     F10.5
89      C   3       1-10     F10.5
90
91      C   4       1-10     F10.5
92      C   4       1-10     F10.5
93      C   4       1-10     F10.5
94      C   4       1-10     F10.5
95
96      C   5       1-10     F10.5
97      C   5       1-10     F10.5
98      C   5       1-10     F10.5
99      C   5       1-10     F10.5
100
101      C   6       1-10     F10.5
102
103      C   7       1-10     F10.5
104
105      C   8       1-10     F10.5
106
107      C   9       1-10     F10.5
108
109      C   10      1-10     F10.5
110
111      C   11      1-10     F10.5
112
113      C   12      1-10     F10.5
114
115      C   13      1-10     F10.5
116
117      C   14      1-10     F10.5
118
119      C   15      1-10     F10.5
120
121      C   16      1-10     F10.5
122
123      C   17      1-10     F10.5
124
125      C   18      1-10     F10.5
126
127      C   19      1-10     F10.5
128
129      C   20      1-10     F10.5
130
131      C   21      1-10     F10.5
132
133      C   22      1-10     F10.5
134
135      C   23      1-10     F10.5
136
137      C   24      1-10     F10.5
138
139      C   25      1-10     F10.5
140
141      C   26      1-10     F10.5
142
143      C   27      1-10     F10.5
144
145      C   28      1-10     F10.5
146
147      C   29      1-10     F10.5
148
149      C   30      1-10     F10.5
150
151      C   31      1-10     F10.5
152
153      C   32      1-10     F10.5
154
155      C   33      1-10     F10.5
156
157      C   34      1-10     F10.5
158
159      C   35      1-10     F10.5
160
161      C   36      1-10     F10.5
162
163      C   37      1-10     F10.5
164
165      C   38      1-10     F10.5
166
167      C   39      1-10     F10.5
168
169      C   40      1-10     F10.5
170
171      C   41      1-10     F10.5
172
173      C   42      1-10     F10.5
174
175      C   43      1-10     F10.5
176
177      C   44      1-10     F10.5
178
179      C   45      1-10     F10.5
180
181      C   46      1-10     F10.5
182
183      C   47      1-10     F10.5
184
185      C   48      1-10     F10.5
186
187      C   49      1-10     F10.5
188
189      C   50      1-10     F10.5
190
191      C   51      1-10     F10.5
192
193      C   52      1-10     F10.5
194
195      C   53      1-10     F10.5
196
197      C   54      1-10     F10.5
198
199      C   55      1-10     F10.5
199
200      C   56      1-10     F10.5
201
202      C   57      1-10     F10.5
203
204      C   58      1-10     F10.5
205
206      C   59      1-10     F10.5
207
208      C   60      1-10     F10.5
209
210      C   61      1-10     F10.5
211
212      C   62      1-10     F10.5
213
214      C   63      1-10     F10.5
215
216      C   64      1-10     F10.5
217
218      C   65      1-10     F10.5
219
220      C   66      1-10     F10.5
221
222      C   67      1-10     F10.5
223
224      C   68      1-10     F10.5
225
226      C   69      1-10     F10.5
227
228      C   70      1-10     F10.5
229
230      C   71      1-10     F10.5
231
232      C   72      1-10     F10.5
233
234      C   73      1-10     F10.5
235
236      C   74      1-10     F10.5
237
238      C   75      1-10     F10.5
239
240      C   76      1-10     F10.5
241
242      C   77      1-10     F10.5
243
244      C   78      1-10     F10.5
245
246      C   79      1-10     F10.5
247
248      C   80      1-10     F10.5
249
250      C   81      1-10     F10.5
251
252      C   82      1-10     F10.5
253
254      C   83      1-10     F10.5
255
256      C   84      1-10     F10.5
257
258      C   85      1-10     F10.5
259
260      C   86      1-10     F10.5
261
262      C   87      1-10     F10.5
263
264      C   88      1-10     F10.5
265
266      C   89      1-10     F10.5
267
268      C   90      1-10     F10.5
269
270      C   91      1-10     F10.5
271
272      C   92      1-10     F10.5
273
274      C   93      1-10     F10.5
275
276      C   94      1-10     F10.5
277
278      C   95      1-10     F10.5
279
280      C   96      1-10     F10.5
281
282      C   97      1-10     F10.5
283
284      C   98      1-10     F10.5
285
286      C   99      1-10     F10.5
287
288      C   100     1-10     F10.5
289
290      C   101     1-10     F10.5
291
292      C   102     1-10     F10.5
293
294      C   103     1-10     F10.5
295
296      C   104     1-10     F10.5
297
298      C   105     1-10     F10.5
299
300      C   106     1-10     F10.5
301
302      C   107     1-10     F10.5
303
304      C   108     1-10     F10.5
305
306      C   109     1-10     F10.5
307
308      C   110     1-10     F10.5
309
310      C   111     1-10     F10.5
311
312      C   112     1-10     F10.5
313
314      C   113     1-10     F10.5
315
316      C   114     1-10     F10.5
317
318      C   115     1-10     F10.5
319
320      C   116     1-10     F10.5
321
322      C   117     1-10     F10.5
323
324      C   118     1-10     F10.5
325
326      C   119     1-10     F10.5
327
328      C   120     1-10     F10.5
329
330      C   121     1-10     F10.5
331
332      C   122     1-10     F10.5
333
334      C   123     1-10     F10.5
335
336      C   124     1-10     F10.5
337
338      C   125     1-10     F10.5
339
340      C   126     1-10     F10.5
341
342      C   127     1-10     F10.5
343
344      C   128     1-10     F10.5
345
346      C   129     1-10     F10.5
347
348      C   130     1-10     F10.5
349
350      C   131     1-10     F10.5
351
352      C   132     1-10     F10.5
353
354      C   133     1-10     F10.5
355
356      C   134     1-10     F10.5
357
358      C   135     1-10     F10.5
359
360      C   136     1-10     F10.5
361
362      C   137     1-10     F10.5
363
364      C   138     1-10     F10.5
365
366      C   139     1-10     F10.5
367
368      C   140     1-10     F10.5
369
370      C   141     1-10     F10.5
371
372      C   142     1-10     F10.5
373
374      C   143     1-10     F10.5
375
376      C   144     1-10     F10.5
377
378      C   145     1-10     F10.5
379
380      C   146     1-10     F10.5
381
382      C   147     1-10     F10.5
383
384      C   148     1-10     F10.5
385
386      C   149     1-10     F10.5
387
388      C   150     1-10     F10.5
389
390      C   151     1-10     F10.5
391
392      C   152     1-10     F10.5
393
394      C   153     1-10     F10.5
395
396      C   154     1-10     F10.5
397
398      C   155     1-10     F10.5
399
400      C   156     1-10     F10.5
401
402      C   157     1-10     F10.5
403
404      C   158     1-10     F10.5
405
406      C   159     1-10     F10.5
407
408      C   160     1-10     F10.5
409
410      C   161     1-10     F10.5
411
412      C   162     1-10     F10.5
413
414      C   163     1-10     F10.5
415
416      C   164     1-10     F10.5
417
418      C   165     1-10     F10.5
419
420      C   166     1-10     F10.5
421
422      C   167     1-10     F10.5
423
424      C   168     1-10     F10.5
425
426      C   169     1-10     F10.5
427
428      C   170     1-10     F10.5
429
430      C   171     1-10     F10.5
431
432      C   172     1-10     F10.5
433
434      C   173     1-10     F10.5
435
436      C   174     1-10     F10.5
437
438      C   175     1-10     F10.5
439
440      C   176     1-10     F10.5
441
442      C   177     1-10     F10.5
443
444      C   178     1-10     F10.5
445
446      C   179     1-10     F10.5
447
448      C   180     1-10     F10.5
449
450      C   181     1-10     F10.5
451
452      C   182     1-10     F10.5
453
454      C   183     1-10     F10.5
455
456      C   184     1-10     F10.5
457
458      C   185     1-10     F10.5
459
460      C   186     1-10     F10.5
461
462      C   187     1-10     F10.5
463
464      C   188     1-10     F10.5
465
466      C   189     1-10     F10.5
467
468      C   190     1-10     F10.5
469
470      C   191     1-10     F10.5
471
472      C   192     1-10     F10.5
473
474      C   193     1-10     F10.5
475
476      C   194     1-10     F10.5
477
478      C   195     1-10     F10.5
479
480      C   196     1-10     F10.5
481
482      C   197     1-10     F10.5
483
484      C   198     1-10     F10.5
485
486      C   199     1-10     F10.5
487
488      C   200     1-10     F10.5
489
490      C   201     1-10     F10.5
491
492      C   202     1-10     F10.5
493
494      C   203     1-10     F10.5
495
496      C   204     1-10     F10.5
497
498      C   205     1-10     F10.5
499
500      C   206     1-10     F10.5
501
502      C   207     1-10     F10.5
503
504      C   208     1-10     F10.5
505
506      C   209     1-10     F10.5
507
508      C   210     1-10     F10.5
509
510      C   211     1-10     F10.5
511
512      C   213     1-10     F10.5
513
514      C   214     1-10     F10.5
515
516      C   215     1-10     F10.5
517
518      C   216     1-10     F10.5
519
520      C   217     1-10     F10.5
521
522      C   218     1-10     F10.5
523
524      C   219     1-10     F10.5
525
526      C   220     1-10     F10.5
527
528      C   221     1-10     F10.5
529
530      C   222     1-10     F10.5
531
532      C   223     1-10     F10.5
533
534      C   224     1-10     F10.5
535
536      C   225     1-10     F10.5
537
538      C   226     1-10     F10.5
539
540      C   227     1-10     F10.5
541
542      C   228     1-10     F10.5
543
544      C   229     1-10     F10.5
545
546      C   230     1-10     F10.5
547
548      C   231     1-10     F10.5
549
550      C   232     1-10     F10.5
551
552      C   233     1-10     F10.5
553
554      C   234     1-10     F10.5
555
556      C   235     1-10     F10.5
557
558      C   236     1-10     F10.5
559
560      C   237     1-10     F10.5
561
562      C   238     1-10     F10.5
563
564      C   239     1-10     F10.5
565
566      C   240     1-10     F10.5
567
568      C   241     1-10     F10.5
569
570      C   242     1-10     F10.5
571
572      C   243     1-10     F10.5
573
574      C   244     1-10     F10.5
575
576      C   245     1-10     F10.5
577
578      C   246     1-10     F10.5
579
580      C   247     1-10     F10.5
581
582      C   248     1-10     F10.5
583
584      C   249     1-10     F10.5
585
586      C   250     1-10     F10.5
587
588      C   251     1-10     F10.5
589
590      C   252     1-10     F10.5
591
592      C   253     1-10     F10.5
593
594      C   255     1-10     F10.5
595
596      C   257     1-10     F10.5
597
598      C   259     1-10     F10.5
599
600      C   261     1-10     F10.5
601
602      C   263     1-10     F10.5
603
604      C   265     1-10     F10.5
605
606      C   267     1-10     F10.5
607
608      C   269     1-10     F10.5
609
610      C   271     1-10     F10.5
611
612      C   273     1-10     F10.5
613
614      C   275     1-10     F10.5
615
616      C   277     1-10     F10.5
617
618      C   279     1-10     F10.5
619
620      C   281     1-10     F10.5
621
622      C   283     1-10     F10.5
623
624      C   285     1-10     F10.5
625
626      C   287     1-10     F10.5
627
628      C   289     1-10     F10.5
629
630      C   291     1-10     F10.5
631
632      C   293     1-10     F10.5
633
634      C   295     1-10     F10.5
635
636      C   297     1-10     F10.5
637
638      C   299     1-10     F10.5
639
640      C   301     1-10     F10.5
641
642      C   303     1-10     F10.5
643
644      C   305     1-10     F10.5
645
646      C   307     1-10     F10.5
647
648      C   309     1-10     F10.5
649
650      C   311     1-10     F10.5
651
652      C   313     1-10     F10.5
653
654      C   315     1-10     F10.5
655
656      C   317     1-10     F10.5
657
658      C   319     1-10     F10.5
659
660      C   321     1-10     F10.5
661
662      C   323     1-10     F10.5
663
664      C   325     1-10     F10.5
665
666      C   327     1-10     F10.5
667
668      C   329     1-10     F10.5
669
670      C   331     1-10     F10.5
671
672      C   333     1-10     F10.5
673
674      C   335     1-10     F10.5
675
676      C   337     1-10     F10.5
677
678      C   339     1-10     F10.5
679
680      C   341     1-10     F10.5
681
682      C   343     1-10     F10.5
683
684      C   345     1-10     F10.5
685
686      C   347     1-10     F10.5
687
688      C   349     1-10     F10.5
689
690      C   351     1-10     F10.5
691
692      C   353     1-10     F10.5
693
694      C   355     1-10     F10.5
695
696      C   357     1-10     F10.5
697
698      C   359     1-10     F10.5
699
700      C   361     1-10     F10.5
701
702      C   363     1-10     F10.5
703
704      C   365     1-10     F10.5
705
706      C   367     1-10     F10.5
707
708      C   369     1-10     F10.5
709
710      C   371     1-10     F10.5
711
712      C   373     1-10     F10.5
713
714      C   375     1-10     F10.5
715
716      C   377     1-10     F10.5
717
718      C   379     1-10     F10.5
719
720      C   381     1-10     F10.5
721
722      C   383     1-10     F10.5
723
724      C   385     1-10     F10.5
725
726      C   387     1-10     F10.5
727
728      C   389     1-10     F10.5
729
730      C   391     1-10     F10.5
731
732      C   393     1-10     F10.5
733
734      C   395     1-10     F10.5
735
736      C   397     1-10     F10.5
737
738      C   399     1-10     F10.5
739
740      C   401     1-10     F10.5
741
742      C   403     1-10     F10.5
743
744      C   405     1-10     F10.5
745
746      C   407     1-10     F10.5
747
748      C   409     1-10     F10.5
749
750      C   411     1-10     F10.5
751
752      C   413     1-10     F10.5
753
754      C   415     1-10     F10.5
755
756      C   417     1-10     F10.5
757
758      C   419     1-10     F10.5
759
760      C   421     1-10     F10.5
761
762      C   423     1-10     F10.5
763
764      C   425     1-10     F10.5
765
766      C   427     1-10     F10.5
767
768      C   429     1-10     F10.5
769
770      C   431     1-10     F10.5
771
772      C   433     1-10     F10.5
773
774      C   435     1-10     F10.5
775
776      C   437     1-10     F10.5
777
778      C   439     1-10     F10.5
779
780      C   441     1-10     F10.5
781
782      C   443     1-10     F10.5
783
784      C   445     1-10     F10.5
785
786      C   447     1-10     F10.5
787
788      C   449     1-10     F10.5
789
790      C   451     1-10     F10.5
791
792      C   453     1-10     F10.5
793
794      C   455     1-10     F10.5
795
796      C   457     1-10     F10.5
797
798      C   459     1-10     F10.5
799
800      C   461     1-10     F10.5
801
802      C   463     1-10     F10.5
803
804      C   465     1-10     F10.5
805
806      C   467     1-10     F10.5
807
808      C   469     1-10     F10.5
809
810      C   471     1-10     F10.5
811
812      C   473     1-10     F10.5
813
814      C   475     1-10     F10.5
815
816      C   477     1-10     F10.5
817
818      C   479     1-10     F10.5
819
820      C   481     1-10     F10.5
821
822      C   483     1-10     F10.5
823
824      C   485     1-10     F10.5
825
826      C   487     1-10     F10.5
827
828      C   489     1-10     F10.5
829
830      C   491     1-10     F10.5
831
832      C   493     1-10     F10.5
833
834      C   495     1-10     F10.5
835
836      C   497     1-10     F10.5
837
838      C   499     1-10     F10.5
839
840      C   501     1-10     F10.5
841
842      C   503     1-10     F10.5
843
844      C   505     1-10     F10.5
845
846      C   507     1-10     F10.5
847
848      C   509     1-10     F10.5
849
850      C   511     1-10     F10.5
851
852      C   513     1-10     F10.5
853
854      C   515     1-10     F10.5
855
856      C   517     1-10     F10.5
857
858      C   519     1-10     F10.5
859
860      C   521     1-10     F10.5
861
862      C   523     1-10     F10.5
863
864      C   525     1-10     F10.5
865
866      C   527     1-10     F10.5
867
868      C   529     1-10     F10.5
869
870      C   531     1-10     F10.5
871
872      C   533     1-10     F10.5
873
874      C   535     1-10     F10.5
875
876      C   537     1-10     F10.5
877
878      C   539     1-10     F10.5
879
880      C   541     1-10     F10.5
881
882      C   543     1-10     F10.5
883
884      C   545     1-10     F10.5
885
886      C   547     1-10     F10.5
887
888      C   549     1-10     F10.5
889
890      C   551     1-10     F10.5
891
892      C   553     1-10     F10.5
893
894      C   555     1-10     F10.5
895
896      C   557     1-10     F10.5
897
898      C   559     1-10     F10.5
899
900      C   561     1-10     F10.5
901
902      C   563     1-10     F10.5
903
904      C   565     1-10     F10.5
905
906      C   567     1-10     F10.5
907
908      C   569     1-10     F10.5
909
910      C   571     1-10     F10.5
911
912      C   573     1-10     F10.5
913
914      C   575     1-10     F10.5
915
916      C   577     1-10     F10.5
917
918      C   579     1-10     F10.5
919
920      C   581     1-10     F10.5
921
922      C   583     1-10     F10.5
923
924      C   585     1-10     F10.5
925
926      C   587     1-10     F10.5
927
928      C   589     1-10     F10.5
929
930      C   591     1-10     F10.5
931
932      C   593     1-10     F10.5
933
934      C   595     1-10     F10.5
935
936      C   597     1-10     F10.5
937
938      C   599     1-10     F10.5
939
940      C   601     1-10     F10.5
941
942      C   603     1-10     F10.5
943
944      C   605     1-10     F10.5
945
946      C   607     1-10     F10.5
947
948      C   609     1-10     F10.5
949
950      C   611     1-10     F10.5
951
952      C   613     1-10     F10.5
953
954      C   615     1-10     F10.5
955
956      C   617     1-10     F10.5
957
958      C   619     1-10     F10.5
959
960      C   621     1-10     F10.5
961
962      C   623     1-10     F10.5
963
964      C   625     1-10     F10.5
965
966      C   627     1-10     F10.5
967
968      C   629     1-10     F10.5
969
970      C   631     1-10     F10.5
971
972      C   633     1-10     F10.5
973
974      C   635     1-10     F10.5
975
976      C   637     1-10     F10.
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TM No. TD1X-33-73

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644 WRITE(IPRINT,T,104) T,D,S,C,A(11)
655 WRITE(IPRINT,T,105)
660 DO 4 JU=2,IJN3
665   FO(JU)=RFU0(JU)+F(1)
670   E=(10.*J)*FO(JU)
675   F1=21.*9*10.^-6.*1520.^/(T+273.
680   ALPHAI(JU)=(1./B,1.)*(1.,-,(0.0006
685   101.*J)*E*2)+(FT1*2+F0(JU)*2)/(2*21./
690   (1.+FO(JU)**2))
695   MU(JU)=10.*AL0610((4.*SPI(A(11
700   R0(JU))=(A(11)*FO(JU)*(10.*N**3))
705   HAO(JU)=1.0/(2.*ALPHA(JU)*R0(JU))
710   ALM(JU)=1.0/(2.*ALPHA(JU)))
715   ALX=6.
720   IMIN=N,LX
725   IMID=NLX/2
730   ILM=NLX/2
735   10*T=0
740   20 UO 5 LIX=1.91
745   X=AX(LID)
750   RAMOL=RAMOL(JU)
755   RFU01=RFU0(JU),
760   CALL SUN(RAR01,RFDF01,ARG,ANS,A
765   AM61(JU)=A1G
770   AM51(JU)=A1S
775   AH01(JU)=AH01(JU)+160.
780   AH01(JU)=AH01(JU).61.210.) GO TO 210
785   IF (AH01(JU).LT.140.) GO TO 220
790   LS1(JU)=AK01(JU)-20.*AL0610(F0(JU)
795   IF (ABS(LSS1(JU))-LSS1(JU)).LT.1.) GO
800   IF (IUP1.NE.0) GO TU 15
805   10*T=1
810   IF (LSS1(JU)-LSS(JU)) 12,12,13
815   ICONST=-1
820   IDUM1=IMIN
825   IDUM2=IMID
830   GO TO 14
835   13 ICONS1=1
840   IDUM1=IMAX
845   IDUM2=IJH1D
850   14 IMu=(IDUM1+IDUM2+ICONST)/2
855   ISAVE=IDUM2
860   15 IF (LSS1(JU)-LSS(JU)) 17,17,16
865   16 ISAVE=IJH1D
870   IDUM2=IJH1D
875   IMu=(IDUM1+IDUM2+ICONST)/2
880   17 ICONST=-1
885   IDUM2=ISAVE
890   18 IMU=(IDUM1+IDUM2+ICONST)/2
895   CONTINUE
900   200 LSp(JU)=ARu(JU)-20.*AL0610(F0(JU)
905   PAu(JU)=ZSp(JU)-70.*CDP1P(JU)
910   DSp(JU)=ZDP1P(JU)

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122* PA(JJJ)=0.* DUM
123* NDIS(JJJ)=(NDIP(JJJ)+3.)-10.*ALOG10(11.* (NFDFO(JJJ)+1.))
124* IJ(JJJ+X1))=NDIS(JJJ)-NDIP(JJJ)
125* UELIJ(JJJ)=NDIS(JJJ)-NDIP(JJJ)
126* WHIT(LP1,LT,106) F(I,J),PAUB(JJJ),RFDFO(JJJ),FO(JJJ),ALPHA(JJJ),ADUM(J
127* IJJ),RO(JJJ),MARIO(JJJ),NDIP(JJJ),LSS(JJJ),LSP(JJJ),ANS1(JJJ),PA(I
128* 2JJ),NULIS(JJJ),DELNDI(JJJ)
129* 60 TU 4
130* 210 LS*(JJJ)=0.0
131* PAUB(JJJ)=0.0
132* NDIS(JJJ)=2.0
133* WHITE(I,PAINT,112) F(I,J),PAUB(JJJ),NFDFO(JJJ),FO(JJJ),ALPHA(JJJ),ADUM(J
134* IJJ),RO(JJJ),MARIO(JJJ),NDIP(JJJ),LSS(JJJ),LSP(JJJ),ANS1(JJJ),ANS1(JJJ)
00371 134* 60 TO 4
00410 135* 220 LS*(JJJ)=0.0
00411 136* HALD(JJJ)=0.0
00412 137* NDIS(JJJ)=0.0
00413 138* WRITE(I,PAINT,113) F(I,J),PAUB(JJJ),NFDFO(JJJ),FO(JJJ),ALPHA(JJJ),ADUM(J
00414 139* IJJ),RO(JJJ),MARIO(JJJ),NDIP(JJJ),LSS(JJJ),LSP(JJJ),ANS1(JJJ),ANS1(JJJ)
00415 140* 4 CONTINUE
00433 141* 4 CONTINUE
00434 142* C
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00034 181\* 114 F0MMAT(1MH)  
00035 182\* 114 F0MMAT(1MH)  
00036 183\* STOP  
00037 184\* ENQ

END OF COMPILETION: 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.

TM No.  
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PARAMETRIC SONAR DESIGN AND ANALYSIS  
T= WATER TEMPERATURE (DEGREES C)

U= PROJECTOR DEPTH (METERS)

S= SALINITY (PPT)

F<sub>2</sub>= SECONDARY FREQUENCY (KHZ)

A= PROJECTOR AREA (SQ. METERS)

F<sub>0</sub>/F<sub>2</sub>= DOWNSHIFT RATIO

F<sub>0</sub>= PRIMARY FREQUENCY (KHZ)

AL= ABSORPTION CONSTANT (NEPERS/METER)

L/2AL= REACTION LIMIT (METERS)

R<sub>0</sub>= RAYLEIGH DISTANCE (METERS)

NDP= DIRECTIVITY INDEX-PRIMARY (DB)

L<sub>SS</sub>= SECONDARY SOURCE LEVEL (DB/MICROBAR-METER)

L<sub>SP</sub>= PRIMARY SOURCE LEVEL (DB/MICROBAR-METER)

L<sub>0</sub>= SCALED SOURCE LEVEL (DB/MICROBAR-METER-KHZ)

G= PARAMETER GAIN (DB)

P<sub>A</sub>= ACOUSTIC POWER PER TONE (WATTS)

AND= DIRECTIVITY GAIN (DB)

NDIS= SECONDARY DIRECTIVITY INDEX (DB)

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

T3 7.

D3 .0

S2 35.

C2 1479.

| AS    | .1969 | F <sub>0</sub> | F <sub>0</sub> /F | R <sub>0</sub> | AL    | 1/2AL | R <sub>0</sub> | 1/2ALRU | NDIP | LSS   | LSP   | L <sub>p</sub> | PA (WATTS) | NOTS.                 | AND?  |
|-------|-------|----------------|-------------------|----------------|-------|-------|----------------|---------|------|-------|-------|----------------|------------|-----------------------|-------|
| 3.000 | 30.7  | 5.00           | 15.000            | .000241        | 2079. | 20    | 1043.5         | 24.0    | 69.4 | 125.6 | 149.1 | 136.2          | 1185.2     | 26.4                  |       |
| 3.000 | 29.5  | 7.50           | 22.500            | .000506        | 989.  | 30    | 330.5          | 27.6    | 91.0 | 127.7 | 159.9 | 136.9          | 689.0      | 26.4                  | 1.3   |
| 3.000 | 27.8  | 10.00          | 30.000            | .000696        | 591.  | 40    | 149.3          | 30.1    | 89.9 | 126.7 | 158.2 | 136.9          | 603.0      | 26.4                  |       |
| 3.000 | 27.4  | 12.50          | 37.500            | .001237        | 404.  | 50    | 61.1           | 32.0    | 89.7 | 130.0 | 161.5 | 140.3          | 522.4      | 30.3                  | -1.7  |
| 3.000 | 26.2  | 15.00          | 45.000            | .001657        | 302.  | 60    | 50.5           | 33.6    | 90.2 | 131.0 | 164.8 | 141.5          | 547.3      | 30.0                  | -3.6  |
| 3.000 | 31.4  | 20.00          | 60.000            | .002510        | 199.  | 60    | 25.0           | 36.1    | 90.5 | 139.4 | 170.6 | 144.6          | 657.6      | 27.0                  | -7.1  |
| 3.000 | 36.0  | 40.00          | 120.000           | .005156        | 90.   | 120   | 10.4           | 39.6    | 89.6 | 141.5 | 180.6 | 152.3          | 1279.5     | 26.4                  | -13.2 |
| 3.000 | 36.0  | 50.00          | 150.000           | .006209        | 82.   | 20    | 4.1            | 44.0    | 89.4 | 153.0 | 197.1 | 144.2          | 3987.5     | 23.2                  | -16.9 |
| 3.000 | 42.0  | 70.00          | 210.000           | .007653        | 69.   | 20    | 2.3            | 47.0    | 89.3 | 159.0 | 206.2 | 161.1          | 7504.9     | 21.0                  | -33.0 |
| 3.000 | 39.   | 100.00         | 300.000           | .009569        | 50.   | 40    | 1.3            | 50.1    | 83.0 | 0     | 210.4 | 176.9          | 15902.7    | 16.1                  | -36.0 |
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|-------|------|--------|---------|---------|-------|------|---------|------|------|-------|-------|-------|-----------|------|-------|
| 3.000 | 26.6 | 5.00   | 15.000  | .000241 | 2079. | 6.   | 260.9   | 30.1 | 90.2 | 127.2 | 150.8 | -37.0 | 433.9     | 32.2 | 2.1   |
| 3.000 | 25.4 | 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  | .000896 | 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 | 25.3 | 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 | 164.4 | -57.7 | 1215.0    | 28.6 | -17.0 |
| 3.000 | 34.4 | 40.00  | 120.000 | .005106 | 90.   | 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 | 36.5 | 70.00  | 210.000 | .007053 | 65.   | 112. | .6      | 53.0 | 95.4 | 162.3 | 208.7 | -71.8 | 7044.9    | 22.4 | -30.6 |
| 3.000 | 30.0 | 100.00 | 300.000 | .009909 | 50.   | 159. | .3      | 56.1 | 81.0 | .0    | 210.4 | -78.8 | L* > 210. |      |       |



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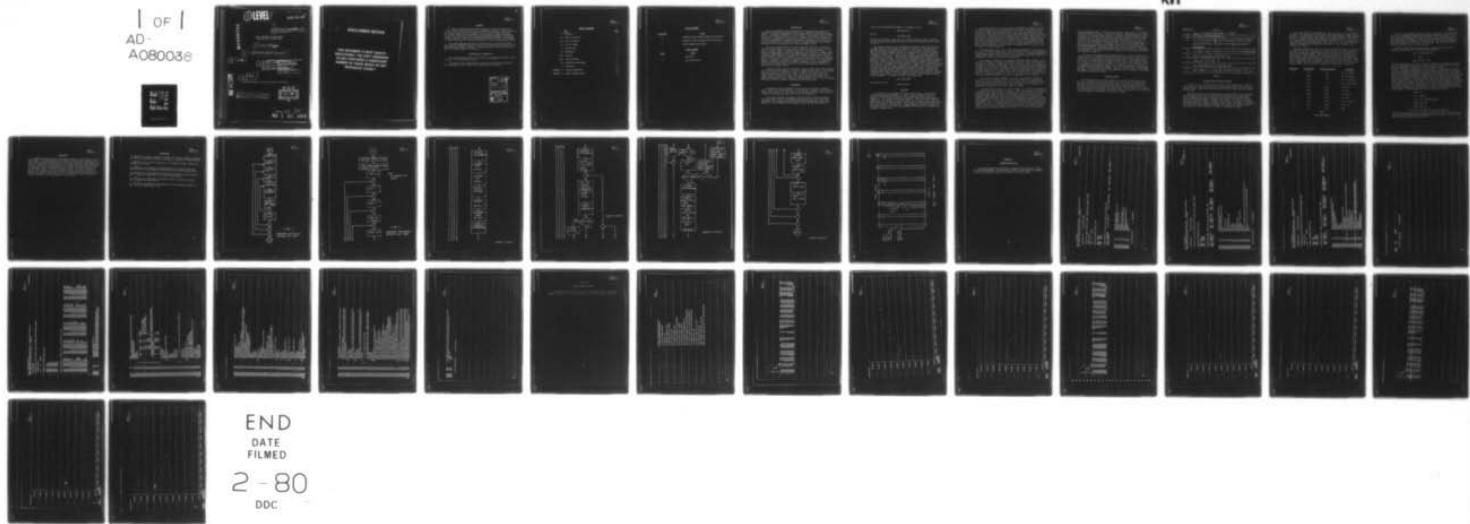
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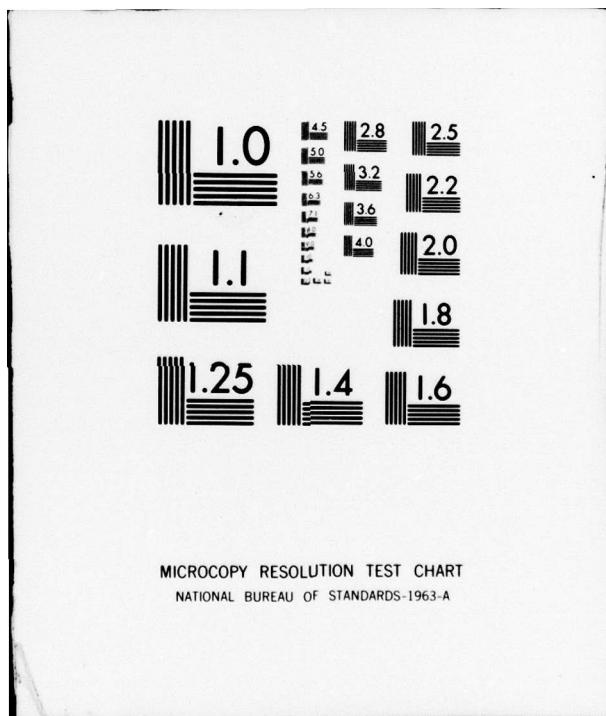
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NAVAL UNDERWATER SYSTEMS CENTER  
Newport, Rhode Island 02840

⑨ Technical Memorandum

⑥ COMPUTER AIDED PARAMETRIC SONAR DESIGN

⑪ 23 May 73

Prepared by, Edmund C. Danner

Edmund C. Gannon,  
Parametric Sonar Group

Robert P./ Pingree

A. J./ Van Wae-Kym

Robert P. Pingree

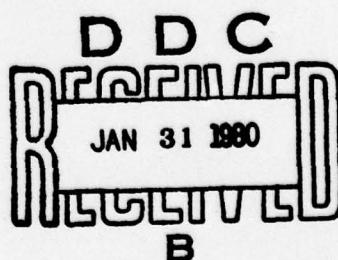
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### ABSTRACT

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.

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## 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<sup>1</sup> 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<sup>2</sup> 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<sup>3</sup> 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<sup>4</sup>. 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

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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 have 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 <sup>5</sup> . | $FT = 21.9 \times 10^6 - (1520/(T+273))$ kHz                                                                                                                                                                                                          |
| 3 <sup>5</sup> . | $AL = (1/8.68)(1/914.4) \left\{ \left[ (1.86 \times 10^{-2})(S)(FT)(FO)^2 / [(FT)^2 + (FO)^2] \right] + \left[ 2.68 \times 10^{-2}(FO)^2 / FT \right] + \left[ 0.1(FO)^2 / (1 + (FO)^2) \right] \right\} (1 - 6.33233 \times 10^5 D)$<br>NEPERS/METER |
| 4 <sup>5</sup> . | $C = 1449.2 + 4.623T - 0.0546(T^2) + 1.391 (S-35) + 0.017D$ METERS/SECOND                                                                                                                                                                             |
| 5 <sup>6</sup> . | $NDIP = 10 \log_{10} (4\pi A (FO)^2 (10^3)^2 / C^2)$ DB                                                                                                                                                                                               |
| 6.               | $PADB = LSP - 70.8 - NDIP$ DB                                                                                                                                                                                                                         |
| 7.               | $PA = \text{ANTILOG} \left[ (1/10)(LSP-70.8-NDIP) \right]$ WATTS                                                                                                                                                                                      |
| 8 <sup>1</sup> . | $NDIS = (NDIP) + 3 - 10 \log_{10} \left[ 1 + ((FO)/F)(2\pi AL)(RO) + X \right]$ 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.

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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 S. 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.

| <u>Card Type</u> | <u>Card Columns</u> | <u>Fortran IV Format</u> | <u>Agreement</u>   |
|------------------|---------------------|--------------------------|--------------------|
| 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

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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 ( $S = 35 \text{ ppt}$ ) and that the system must be capable of operating in the winter ( $T = 7^\circ\text{C}$ ) 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 assume that 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

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4. Goldstein, M., "On A numerical Integration in Parametric Sonar Research," NUSC Tech Memo No. PA4-268-71, 21 Oct 1971, (Unclassified).
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6. "The Design and Construction of Magnetostriction Transducers," NDRC Div 6 Report Vcl. 13, dated 1946, p. 128.

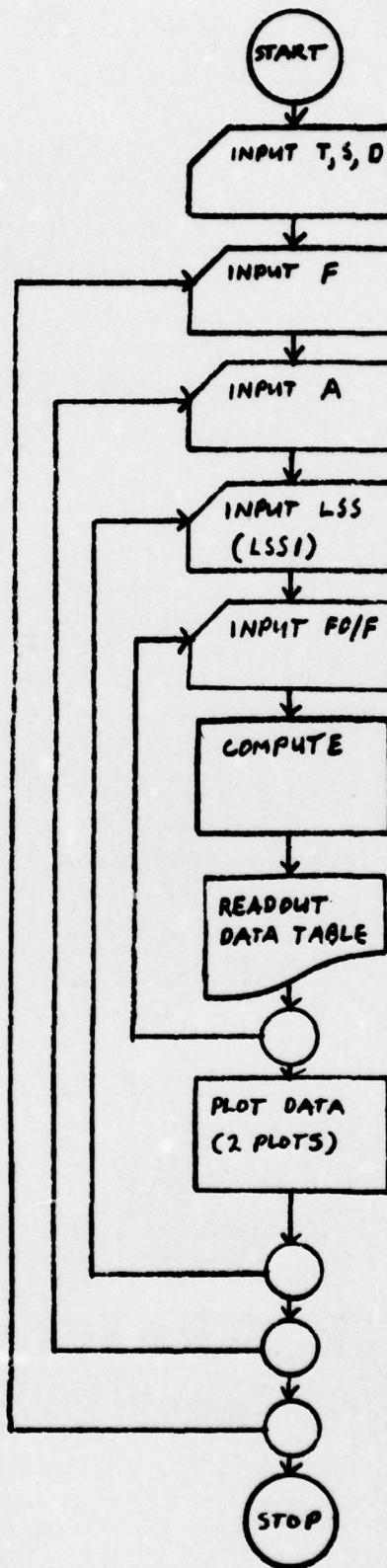


FIGURE 1

PARAMETRIC SONAR DESIGN,  
SIMPLIFIED FLOW CHART

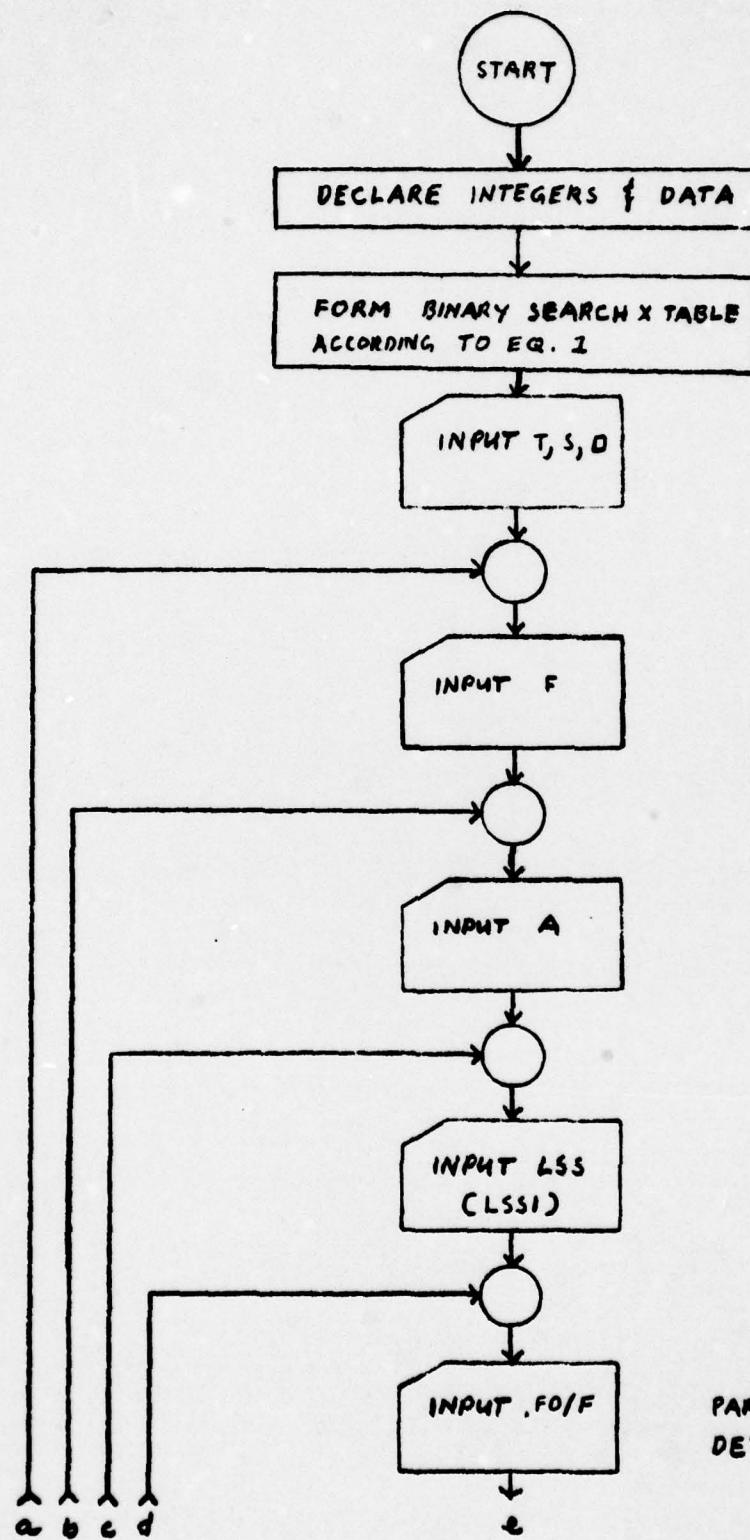


FIGURE 2

PARAMETRIC SONAR DESIGN,  
DETAILED FLOW CHART

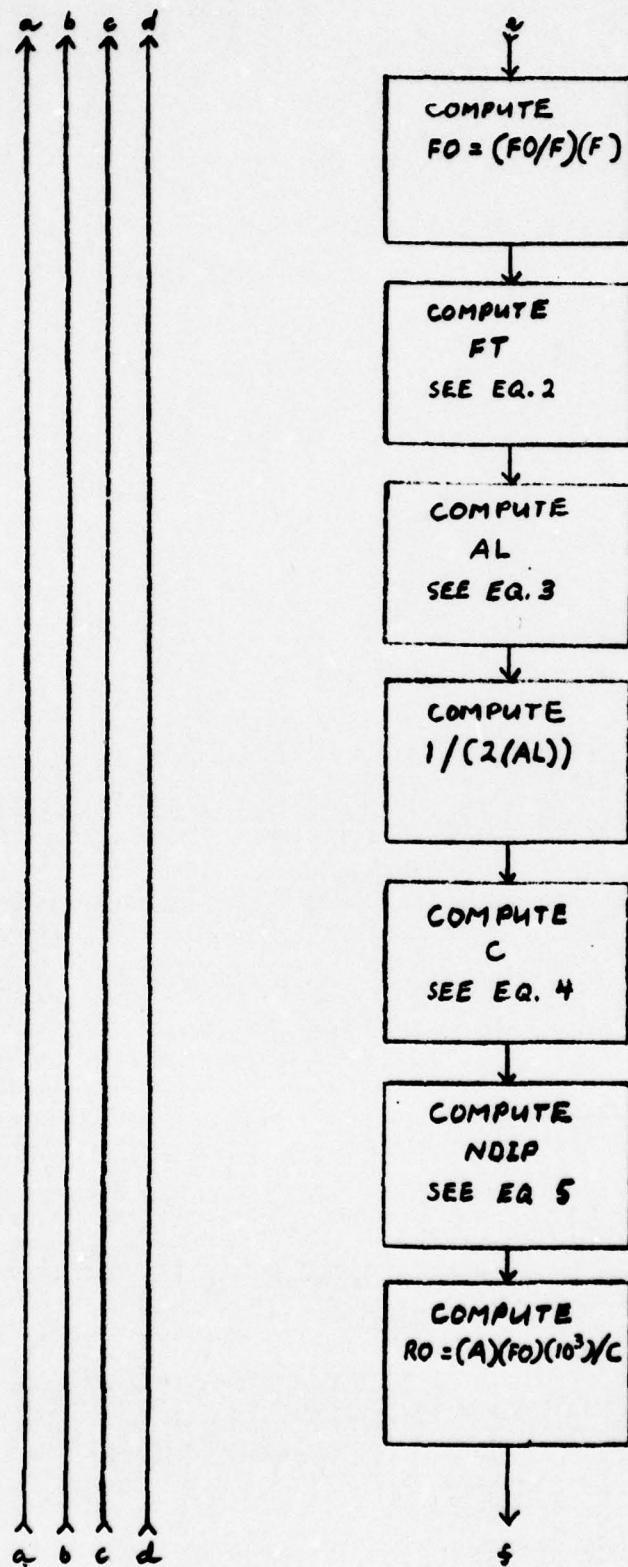


FIGURE 2 (CONT. 1)

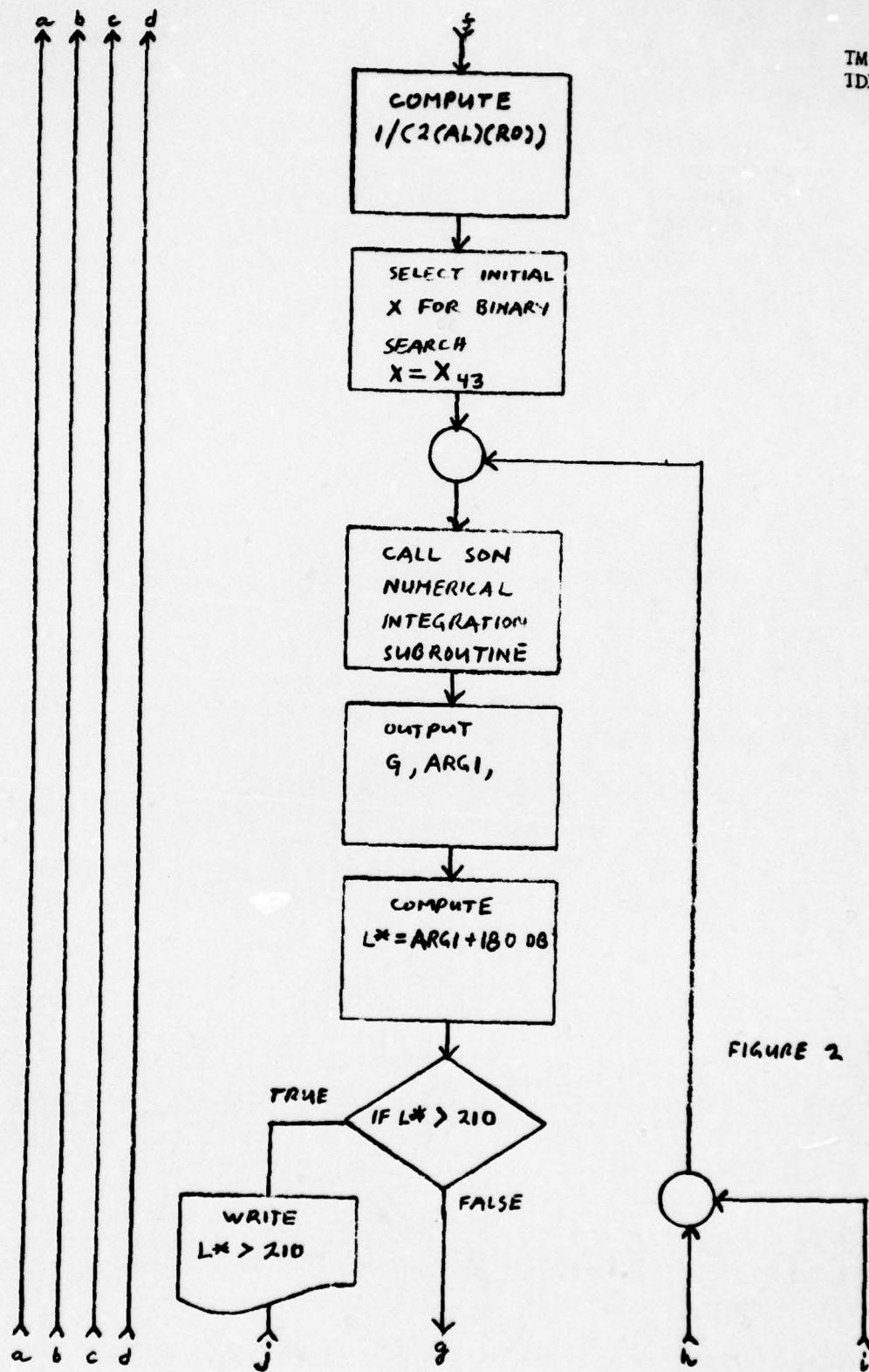


FIGURE 2 (CONT 2)

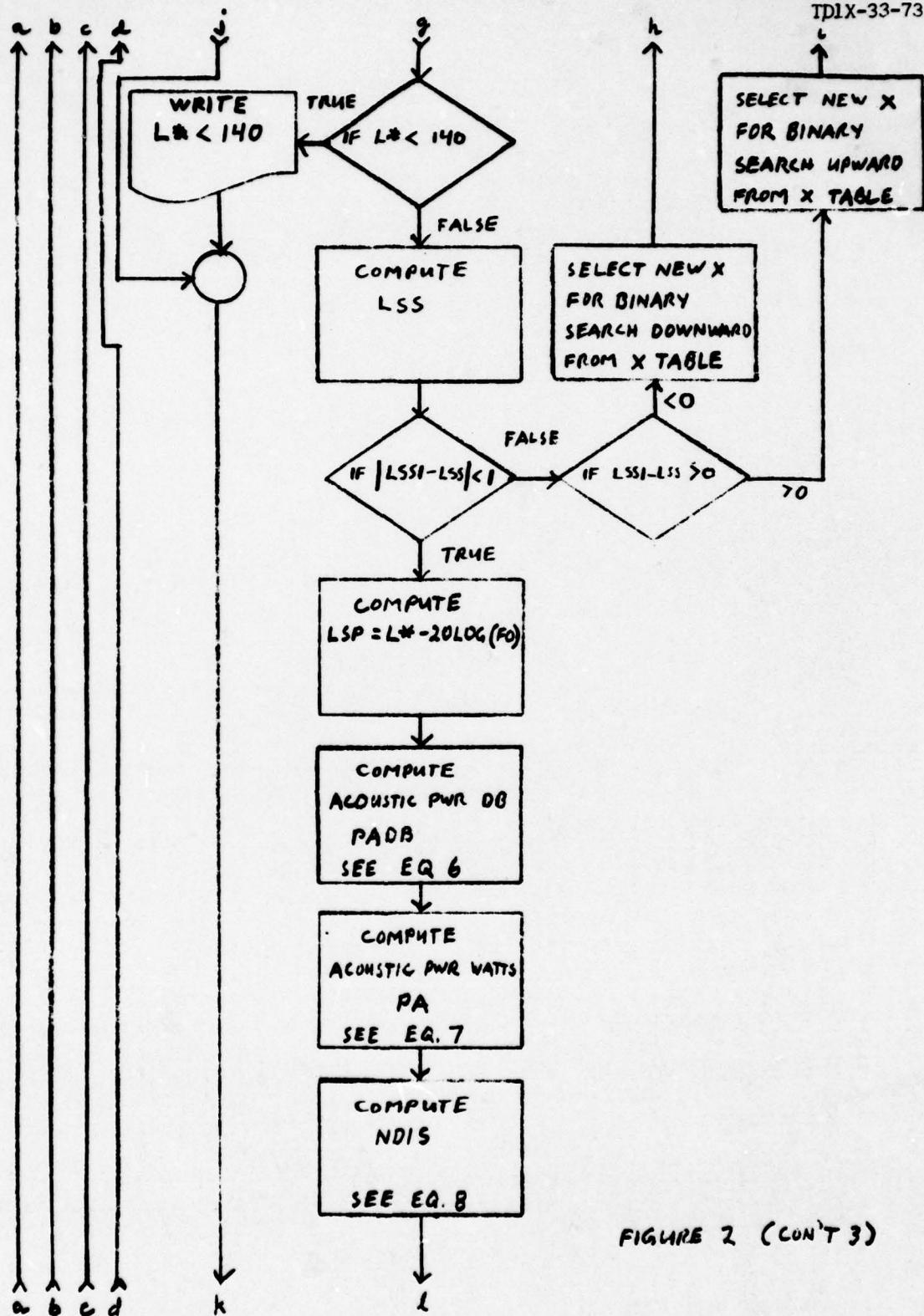


FIGURE 2 (CON'T 3)

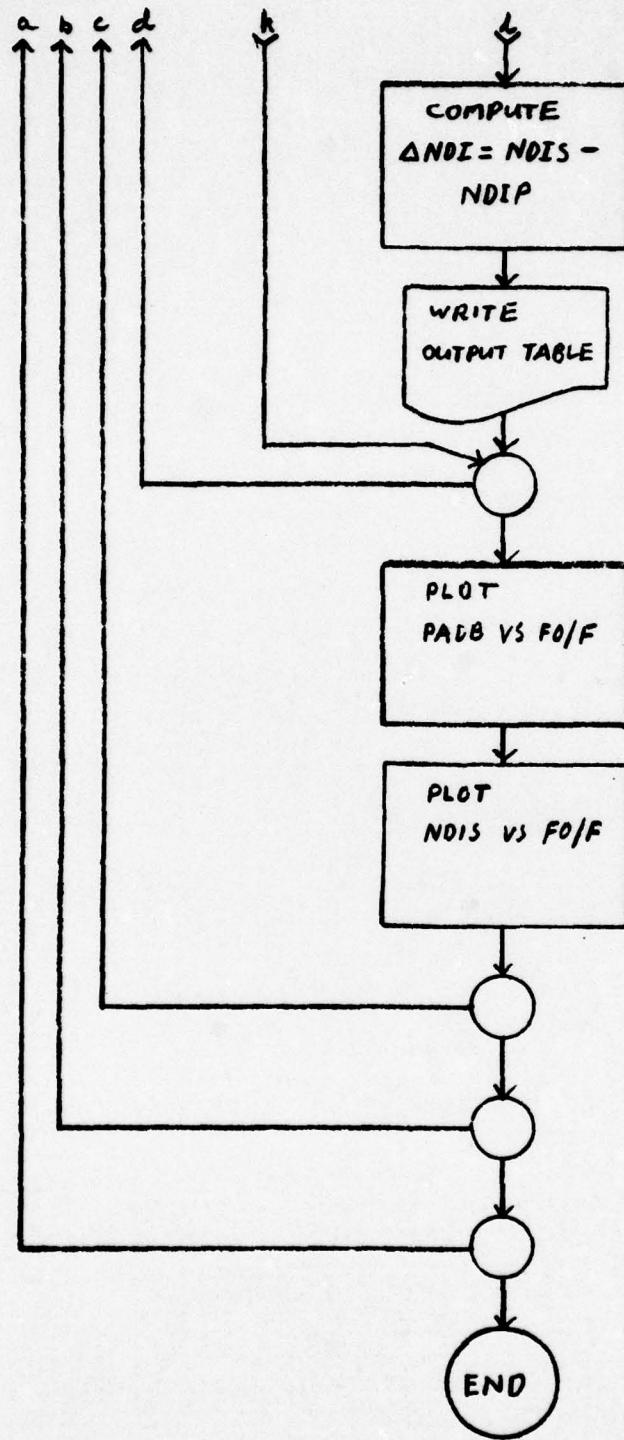


FIGURE 2 (CON'T. 4)

| COLUMN NUMBER |    |
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TM No.  
TDIX-33-73

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.

TM No.  
TDIX-33-73

FOR SUN, SUN  
UNIVAC 1108 FORTRAN V LEVEL 2206 0026 (EXEC8 LEVEL E1201-0011)  
THIS COMPILED AT 14 JUN 73 AT 21:34:46.

21:34:46. 50

SUBROUTINE SUB ENTRY POINT 000067

STORAGE USEU: COUE(1) 0001031 DATA(0) 00000201 BLANK COMMON(2) 000000

COMMON BLOCKS:

0003 BLK 000010

EXTERNAL REFERENCES (BLOCK, NAME)

|            |  |
|------------|--|
| 0004 USINH |  |
| 0005 DEXP  |  |
| 0006 USQRT |  |
| 0007 NERHS |  |

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

|                   |                  |                      |                   |                 |
|-------------------|------------------|----------------------|-------------------|-----------------|
| 0003 D 000000 AHO | 0003 D 0000006 E | 0003 D 0000002 GKDKO | 0000 000012 TNJPS | 0000 D 000000 T |
| 0003 D 0000006 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=USINH(T)                          |
| 00107 6*  | T=1.000+((A*T)*2)/N,000             |
| 00110 7*  | IF(AHO.GT.0.000) E=DEXP(-F*ARO)     |
| 00112 8*  | F=F*E*2                             |
| 00113 9*  | F=(1.000+F)/(1.000+F*GKDKO*E*2)     |
| 00114 10* | FSE=IDSGRT(F)/T                     |
| 00115 11* | RETURN                              |
| 00116 12* | END                                 |

END OF COMPILEATION: NO DIAGNOSTICS.

FOR NOM-NOM  
UNIVAC 1108 FORTRAN V LEVEL 2206 0026 (EXEC6 LEVEL E1201-0011)  
THIS COMPILED IN GAS DUE ON 14 JULY 73 AT 21:34:47

TM No.  
TDIX-33-73  
2134147.40

SUBROUTINE NUM ENTRY POINTI 000246

STORAGE USED: CORE(1) 0002751 DATA(0) 0000601 BLANK COMMON(2) 0000000

EXTERNAL REFERENCES (BLOCK, NAME)

|      |        |
|------|--------|
| 0003 | SUB    |
| 0004 | NEXP1S |
| 0005 | NEXP2S |
| 0006 | NERR3S |

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

|        |             |        |             |        |           |                   |
|--------|-------------|--------|-------------|--------|-----------|-------------------|
| 0001   | 000071 1206 | 0001   | 000120 1306 | 0001   | 000033 4L | 0000 D 000005 FN  |
| 0000 0 | 000000 M    | 0000   | 000031 INPS | 0000 1 | 000015 TU | 0000 I 000013 JI  |
| 0000 1 | 000002 K    | 0000 1 | 000014 L    | 0000 1 | 000011 M  | 0000 D 000007 SIG |

```

C0101      1*      SUBROUTINE ROM(A,B,W,EPS,IV,NMX)
C0103      2*      DIMENSION A(NMX,NMX)
C0104      3*      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
C0105      4*      H=U-A
C0106      5*      K=0
C0107      6*      CALL SUB(A,O,H,F)
C0110      7*      FN=F
C0111      8*      CALL SUB(A,1,H,F)
C0112      9*      N(1,1)=((F+FN)*H)/2.0D0
C0113     10*      4 K=N+1
C0114     11*      H=H/2.0D0
C0115     12*      SIG=0.0D0
C0116     13*      K=2*(K-1)
C0117     14*      DO 1 J=1,M
C0122     15*      J1=2*(J-1)
C0123     16*      CALL SUB(A,J1,H,F)
C0124     17*      1 SIG=SIG+F
C0126     18*      K(K+1,1)=N(K,1)/2.0D0+H*SIG
C0127     19*      DO 2 L=1,K
C0132     20*      2 U=K+1-L
C0133     21*      1 V=L+1
C0134     22*      2 N(JU,IV)=(4.0D0**((V-1)*W(IU+1,IV-1)-W(IU,IV-1))/(4.0D0**((IV-1)-1.
C0134     23*      1U0)
C0136     24*      IF(ABS(W(IU,IV))-W(IU,IV-1)).LT.ABS(W(IU,IV))*EPS) RETURN
C0140     25*      GO TO 4
C0141     26*      END

```

A-3      END OF COMPILATION:      NO DIAGNOSTICS.

TM No.  
TDIX-33-73

FUR SON SUN  
UNIVAC 1108 FORTKAN V LEVEL 2206 0026 (EXEC8 LEVEL E1201-0011)  
THIS CUMPLIMENT GAS DUNE ON 14-JUN-73 AT 2113448

SUBROUTINE SHN ENTRY POINT 000134

PRIVATE LIBRARY COMMISSIONS 191

COMMON BLOCKS:

0003 BLK 00018

## **EXTERNAL REFERENCES (BLOCK NAME)**

| STORAGE ASSIGNMENT (BLOCK, TYPE, RELATIVE LOCATION, NAME) |        |          |              |
|-----------------------------------------------------------|--------|----------|--------------|
| 0004                                                      | KOM    | 00000 D  | 011614 B     |
| 0005                                                      | DLOG   | 00005 1L | 00000 ARO    |
| 0006                                                      | DATAN  | 00000 D  | 00002 GKDQ   |
| 0007                                                      | DLOG0  | 00000 D  | 00000 D      |
| 0010                                                      | NERH35 | 00000 D  | 011616 GKDQS |

TM No.  
TDIX-33-73

00133 246 RETURN  
00134 250 ENU

END OF COMPIRATIONI 2 DIAGNOSTICS.

C-A

21:34:49.464

FOR SONAR'SONAR  
UNIVAC 1108 FORTRESS V LEVEL 2206 0026 (EXEC6 LEVEL E1201-0011)  
THIS COMPILED WAS DONE ON 14 JUN 73 AT 21:34:49

MAIN PROGRAM

STORAGE USED: CODE(11) 0010121 DATA(0) 00455361 BLANK COMMON(2) 0000000

COMMON BLOCKS:

0003 BLK 000000

EXTERNAL REFERENCES (BLOCK, NAME)

|      | SON      | PLOTA  | NKDUS         | N1023       | NEXPoS        | N1013  | N1011         | AL0610 | DLO610        | DLO610 | NSTOP2      |
|------|----------|--------|---------------|-------------|---------------|--------|---------------|--------|---------------|--------|-------------|
| 0004 |          |        |               |             |               |        |               |        |               |        |             |
| 0005 | 006023   | 100F   | 0000          | 004002 101F | 0000          | 004003 | 102F          | 0000   | 004025 103F   | 0000   | 004242 104F |
| 0006 | 004262   | 105F   | 0000          | 004321 106F | 0000          | 004346 | 107F          | 0000   | 004356 112F   | 0000   | 004402 113F |
| 0007 | 006426   | 114F   | 0001          | 000016 1176 | 0001          | 000523 | 13L           | 0001   | 000531 14L    | 0001   | 000561 15L  |
| 0008 | 000149   | 156G   | C001          | 000160 164G | 0001          | 000557 | 17L           | 0001   | 000172 172G   | 0001   | 000204 200G |
| 0009 | 000573   | 200L   | 0001          | 000234 2066 | 0001          | 000671 | 210L          | 0001   | 000237 211G   | 0001   | 000247 214G |
| 0010 | 000117   | 220L   | 0001          | 000312 2366 | 0001          | 000430 | 257G          | 0001   | 000744 4L     | 0001   | 000571 5L   |
| 0011 | R 001130 | A      | 0000 R 002424 | ADUM        | 0000 D 003410 | AIN    | 0000 R 001750 | ALPHA  | 0000 D 003416 | ANS    |             |
| 0012 | R 003244 | ANS1   | 0000 D 003414 | ARG         | 0000 R 003100 | ARG1   | 0003 D 000000 | ARO    | 0000 R 003760 | C      |             |
| 0013 | R 003753 | D      | 0000 R 001274 | WE1ND1      | 0000 R 004000 | DUM    | 0003 D 000006 | E      | 0000 R 000764 | F      |             |
| 0014 | R 001440 | FU     | 0000 R 003764 | FT          | 0003 D 00002  | GDKD0  | 0000 I 003737 | I      | 0000 I 003754 | IA     |             |
| 0015 | I 003755 | I8     | 0000 I 003756 | IC          | 0000 I 003734 | ICARD  | 0000 I 003774 | ICONST | 0000 I 003757 | ID     |             |
| 0016 | I 003776 | IJUM1  | 0000 I 003775 | IJUM2       | 0000 I 003761 | II     | 0000 I 003773 | IIX    | 0000 I 003767 | IMAX   |             |
| 0017 | I 003770 | IM1D   | 0000 I 003766 | IM1N        | 0000 I 003771 | IND    | 0000 I 003772 | IOPT   | 0000 I 003775 | IPRINT |             |
| 0018 | I 003777 | ISAVE  | 0000 I 003762 | J           | 0000 I 003763 | JJ     | 0000 I 003740 | KN     | 0000 I 003741 | KN1    |             |
| 0019 | I 003742 | KM2    | 0000 I 003743 | KNS         | 0000 R 000620 | LSP    | 0000 R 000000 | LSS    | 0000 R 000144 | LSS1   |             |
| 0020 | I 003744 | N      | 0000 R 000454 | NDIP        | 0000 R 000310 | NOIS   | 0000 I 003765 | NLX    | 0000 I 003745 | N1     |             |
| 0021 | I 003746 | N2     | 0000 I 003747 | N3          | 0000 I 003750 | N4     | 0000 R 002114 | PA     | 0000 R 002260 | PADB   |             |
| 0022 | R 003748 | P1     | 0000 R 004001 | PY          | 0000 R 002570 | RARO   | 0000 R 003420 | RARO1  | 0000 R 002734 | RDFD0  |             |
| 0023 | D 003422 | KDFD01 | 0000 R 001604 | RO          | 0000 R 003752 | S      | 0000 R 003751 | T      | 0003 D 000004 | X      |             |
| 0024 | D 003412 | X0     | 0000 D 003424 | XX          |               |        |               |        |               |        |             |

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

|      |        |       |               |        |               |        |               |        |               |        |      |
|------|--------|-------|---------------|--------|---------------|--------|---------------|--------|---------------|--------|------|
| 0000 | 004025 | 103F  | 0000          | 004003 | 102F          | 0000   | 004025        | 103F   | 0000          | 004242 | 104F |
| 0001 | 004356 | 112F  | 0000          | 004346 | 107F          | 0000   | 004356        | 112F   | 0000          | 004402 | 113F |
| 0002 | 000531 | 14L   | 0001          | 000523 | 13L           | 0001   | 000531        | 14L    | 0001          | 000561 | 15L  |
| 0003 | 000172 | 172G  | 0001          | 000557 | 17L           | 0001   | 000172        | 172G   | 0001          | 000204 | 200G |
| 0004 | 000237 | 211G  | 0001          | 000671 | 210L          | 0001   | 000237        | 211G   | 0001          | 000247 | 214G |
| 0005 | 000744 | 4L    | 0001          | 000430 | 257G          | 0001   | 000744        | 4L     | 0001          | 000571 | 5L   |
| 0006 | 001750 | ALPHA | 0000 R 000000 | ARO    | 0003 D 000000 | ARG1   | 0003 D 000000 | ARO    | 0000 R 003760 | C      |      |
| 0007 | 000000 | E     | 0003 D 000006 | DUM    | 0000 R 004000 | DUM    | 0003 D 000006 | E      | 0000 R 000764 | F      |      |
| 0008 | 000002 | GDKD0 | 0003 D 00002  | GDKO   | 0000 R 000620 | LSP    | 0000 R 000000 | LSS    | 0000 R 000144 | LSS1   |      |
| 0009 | 000374 | ICARD | 0000 I 003734 | ICARD  | 0000 I 003774 | ICONST | 0000 I 003774 | ICONST | 0000 I 003757 | ID     |      |
| 0010 | 003761 | II    | 0000 I 003761 | II     | 0000 I 003773 | IIX    | 0000 I 003773 | IIX    | 0000 I 003767 | IMAX   |      |
| 0011 | 003771 | IND   | 0000 I 003771 | IND    | 0000 I 003772 | IOPT   | 0000 I 003772 | IOPT   | 0000 I 003775 | IPRINT |      |
| 0012 | 003763 | JJ    | 0000 I 003763 | JJ     | 0000 I 003740 | KN     | 0000 I 003740 | KN     | 0000 I 003741 | KN1    |      |
| 0013 | 003762 | LSP   | 0000 R 000620 | LSP    | 0000 R 000000 | LSS    | 0000 R 000000 | LSS    | 0000 R 000144 | LSS1   |      |
| 0014 | 003765 | NLX   | 0000 I 003765 | NLX    | 0000 I 003750 | N4     | 0000 I 003750 | N4     | 0000 I 003745 | N1     |      |
| 0015 | 002114 | PA    | 0000 R 002114 | PA     | 0000 R 002260 | PADB   | 0000 R 002260 | PADB   | 0000 R 002734 | RDFD0  |      |
| 0016 | 003420 | RARO1 | 0000 R 003420 | RARO1  | 0000 R 003751 | T      | 0003 D 000004 | X      |               |        |      |

A-6

REAL LSS,LSS1,NOIS,NDIP,LSP  
PARAMETER LM1=100  
DIMENSION LSS(LM1),LSP(LM1),LSS1(LM1),NOIS(LM1),F(LM1),A(LM1)  
DIMENSION LMNDI(LM1),FO(LM1),PRO(LM1),ALPHA(LM1),NDIP(LM1),PA(LM1)  
DIMENSION PARDI(LM1),ADM(LM1),RARDI(LM1),RADO(LM1),RDFO(LM1),ARG1(LM1),ANS1

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```

6*          ALM1)
7*          DOUBLE PRECISION AHO,GRDKO,X,E,AIN,XO,ARG,ANS,RARO1,RFDF01
8*          DOUBLE PRECISION XX(ILMX)
9*          COMMON/BLK/ARG,GRDKO,X,E
10*          ICARD=3
11*          JPRINT=4
12*          PI=3.14159
13*          C
14*          CARU   COLUMNS  FORMAT   ARGUMENT
15*          C       1      1-5    15   KN= NO. OF F VALUES
16*          C       1      6-10   15   KN1= NO. OF A VALUES
17*          C       1      11-15  15   KN2= NO. OF LSS VALUES
18*          C       1      16-20  15   KN3= NO. OF FO/F VALUES +1
19*          C       2      1-10   F10.4
20*          C       2      1-10   F10.4
21*          C       2      1-10   F10.4
22*          C       2      21-30   F10.4
23*          C       2      21-30   F10.4
24*          C       2      21-30   F10.4
25*          C       2      21-30   F10.4
26*          C       3      1-10   F10.5
27*          C       3      1-10   F10.5
28*          C       3      1-10   F10.5
29*          C       3      1-10   F10.5
30*          C       3      1-10   F10.5
31*          X0=.909090910*-2
32*          DO 8  I=1,86
33*          X(I)=I*.1*I*0
34*          & X0=X(1)
35*          HEAD(ICARD,101) KN,KN1,KN2,KN3
36*          101 FOKHAT(145)
37*          NEKI
38*          NI=KNI
39*          N2=K12
40*          N3=K13
41*          N4=N3+1
42*          HFUF(1)=0.0
43*          PALB(1)=0.0
44*          NDIS(1)=0.0
45*          PAUD(1)=50.
46*          NI5(N4)=50.
47*          RFUFO(N4)=0.
48*          HEAD(ICARD,102) T,S,D
49*          102 FOKHAT(3F10,-4)
50*          HEAD(ICARD,100) (F1A),IA=1,N
51*          HEAD(ICARD,100) (A1B),IB=1,N1
52*          HEAD(ICARD,100) (LSS1(F1C),IC=1,N2)
53*          HEAD(ICARD,100) (RFDF01,I0,I0=2,N3)
54*          C=149.2+4.623*1-.0546*(T*2)+1.391*(S-35.1)*.017 *D
55*          DU 1  I=1,KN
56*          DU 2  I=1,KN1
57*          DU 3  I=1,KN2
58*          WRITE(LIPMINT,107)
59*          WRITE(LIPMINT,105)
60*          WRITE(LIPRINT,114)
61*          A-7
62*          63*
64*          65*

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610      WRITE(1PRIN,T,104) T,D,S,C,A(I1)
611      WRITE(1PRIN,T,105)
612      DO 6 J=2,NN3
613      F0(J,J)=RFUF0(J,J)*F(I1)
614      E=(10.*J)*F0(J,J)
615      FT=21.*9*10*(6.-((1520./T+273.))
616      ALPHA(J,J)=(1.-/6.68)*(1.-(.00006332*D))*(1.-/914.*4)*
617      10*(J,J)*E2)/(FT*T2+F0(J,J)*E2)+1.0268*F0(J,J)*E2/FT
618      2*E2/(1.+F0(J,J)*E2))
619      NU1P(J,J)=10.*AL0610((4.*SPLA(I1))*E**2)/C**2
620      RU(J,J)=(A(I1)*E0(J,J)*(10.*E**3))/C
621      HAKO(J,J)=1.0/12.*ALPHA(J,J)*E0(J,J)
622      ADUM(J,J)=1.0/(12.*ALPHA(J,J))
623      R1X=86
624      IM1N=1
625      IMAX=N,X
626      IMID=N,LX/2
627      IMIN=LX/2
628      IOP=T=0
629      20   LU 5 11X=1,91
630      1*X(I,1)
631      RAHO=RAHO(J,J)
632      RFUFO=RFUF0(J,J)
633      CALL SUN1R01,RFUF01,ARG,ANS,AIN,50
634      ANGL(J,J)=AIG6
635      ANS1(J,J)=Ans
636      ARG1(J,J)=AIG1(J,J)+180.
637      IF (ARIG1(J,J),GT,210.) GO TO 210
638      IF (ARIG1(J,J),LT,140.) GO TO 220
639      LS1(J,J)=HKO1(J,J)-20.*AL0610(F0(J,J))+ANS1(J,J)
640      IF (ABS(LSS1(J,J)-LS1(J,J))<LT,1.) GO TO 200
641      IF (LOP1.NE.0) GO TO 15
642      IOP=T=1
643      IF (LSS1(J,J)-LSS1(J,J)) 12,12,13
644      ICUNS=-1
645      IDUM2=MIN
646      IDUM1=IMID
647      10   GO TO 14
648      11   ICUNS=1
649      12   IDUM1=IMAX
650      13   IDUM2=IMID
651      14   IDUM=(IDUM1+IDUM2+ICONST1)/2
652      15   ISAVE=IDUM2
653      16   ICUNS=1
654      17   ISAVE=IDUM2
655      18   IDUM=IDUM1+IDUM2+ICONST1/2
656      19   INUS=(IDUM1+IDUM2+ICONST1)/2
657      20   LSP(J,J)=AR61(J,J)-20.*AL0610(F0(J,J))
658      PHD(J,J)=LSP(J,J)-70.*B4IP(J,J)
659      PUD(J,J)=PABD(J,J)
660      21   INUS=(IDUM1+IDUM2+ICONST1)/2
661      22   CONTINUE
662      23   INUS=(IDUM1+IDUM2+ICONST1)/2
663      24   16   IDUM=IDUM1+IDUM2+ICONST1/2
664      25   17   ICONST1=-1
665      26   18   ISAVE=ISAVE
666      27   19   IDUM=IDUM1+IDUM2+ICONST1/2
667      28   20   LSP(J,J)=AR61(J,J)-20.*AL0610(F0(J,J))
668      29   PHD(J,J)=LSP(J,J)-70.*B4IP(J,J)
669      30   PUD(J,J)=PABD(J,J)
670

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1220
00340      123*          PA(JJ)=10.*90UM
00341      123*          NDIS(JJ)=(NDIP(JJ)+3.)-10.*AL0610(1.+IRFDFO(JJ))*(2.*PI*ALPHA(JJ))*R
00341      124*          1U(JJ)+X(JJ)
00342      125*          UELN(JJ)=NDIS(JJ)-NDIP(JJ)
00342      126*          MINT(IPKINT106) F(1),PAUB(JJJ),RFDF0(JJJ),F0(JJJ),ALPHA(JJJ),ADUM(J
00343      127*          JJJ,RO(JJJ),NARO(JJJ),NDIP(JJJ),LSP(JJJ),LSS(JJJ),ANS1(JJJ),PA(J
00343      128*          2JJ),NDIS(JJJ),DELNDI(JJJ)
00343      129*          GO TO 4
00345      130*          210 LSp(JJJ)=0.0
00346      130*          PAUB(JJJ)=0.0
00347      131*          NDIS(JJJ)=0.0
00347      132*          PAUB(JJJ)=0.0
00348      133*          NDIS(JJJ)=0.0
00348      134*          WHIT(IPRINT112) F(1),PAUB(JJJ),RFDF0(JJJ),F0(JJJ),ALPHA(JJJ),ADUM(J
00349      135*          1JJ,RO(JJJ),NARO(JJJ),NDIP(JJJ),LSS(JJJ),LSP(JJJ),ANS1(JJJ)
00410      136*          220 LSp(JJJ)=0.0
00412      137*          PAUB(JJJ)=0.0
00413      138*          NDIS(JJJ)=0.0
00414      139*          WRITE(IPRINT113) F(1),PAUB(JJJ),RFDF0(JJJ),F0(JJJ),ALPHA(JJJ),ADUM(J
00414      140*          1JJ,RO(JJJ),NARO(JJJ),NDIP(JJJ),LSS(JJJ),LSP(JJJ),ANS1(JJJ)
00433      141*          4 CONTINUE
00433      142*          C THE PLOT ROUTINES ARE ON TAPE U183
00433      143*          C
00433      144*          C
00435      145*          CALL PLOTA(RFDFO,PAOB,PY,N4,1H*,1H+,1, 'PADB VS FO/F',2,IPRINT)
00436      146*          CALL PLOTA(RFDFO,NUTS,PY,N4,1H*,1H+,1, 'NDIS VS FO/F',2,IPRINT)
00437      147*          3 CONTINUE
00441      148*          2 CONTINUE
00441      149*          1 CONTINUE
00443      150*          100 FORMAT(F10.5)
00445      151*          103 FORMAT(50X,'T= WATER TEMPERATURE (DEGREES C)')
00446      152*          1//50X,'D= PROJECTOR DEPTH (METERS)',_
00446      153*          3//50X,'S= SALINITY (PPT)',_
00446      154*          4//50X,'F= SECONDARY FREQUENCY (KHZ)',_
00446      155*          2//50X,'A= PROJECTOR AREA (SQ. METERS)',_
00446      156*          6//50X,'FUR= DOWNSHIFT RATIO',_
00446      157*          7//50X,'FO= PRIMARY FREQUENCY (KHZ)',_
00446      158*          8//50X,'AL= AUSFLECTION COUPSTANT (NEPERS/METER)',_
00446      159*          9//50X,'1/2AL= REACTION LIMIT (METERS)',_
00446      160*          1//50X,'RD= RAYLEIGH DISTANCE (METERS)',_
00446      161*          2//50X,'NDAP= DIRECTIVITY INDEX-PRIMARY (DB)',_
00446      162*          3//50X,'LSS= SECONDARY SOURCE LEVEL (DB/MICROBAR-METER)',_
00446      163*          4//50X,'LSP= PRIMARY SOURCE LEVEL (DB/MICROBAR-METER)',_
00446      164*          5//50X,'L= SCLED SOURCE LEVEL (DB/MICROBAR-METER-KHZ)',_
00446      165*          6//50X,'GZ= PARAMETEN GAIN (DB)',_
00446      166*          7//50X,'P= ACUSTIC POWER PER TONE (WATTS)',_
00446      167*          8//50X,'AND1= DIRECTIVITY GAIN (DB)',_
00446      168*          9//50X,'NU1SE SECONDARY DIRECTIVITY INDEX (DB)',_
00446      169*          1//50X,'PAUD= ACOUSTIC POWER (DB/WATT) PER EACH PRIMARY TONE')
00447      170*          104 FORMAT(//5A,'T= ',F5.0,'/5X,'ID= ',FB,1./5X,'SE ',F4.0,'/5X,'C= ',_
00447      171*          1F0,0.,/5X,'A= ',F9.4)
00450      172*          105 FORMAT(5X,'F= ',BX,'PAOB= ',3X,'FO/F',5X,'AL= ',5X,'/2AL',5X,R
00450      173*          10X,'4X,1/2ALR0,1X,NDIP,3X,L4,5X,PA(2WATS)',1X,NDIS,3X,AND1)
00450      174*          106 FORMAT(F9.4,3X,F5,1,1X,F7,2,1X,F0,3,1X,F9,6,1X,F6,1,1X,F5,1,1X,F7,0,1X,F8,
00451      175*          11,1X,F5,1,1X,F6,1,1X,F6,1,1X,F6,1,1X,F5,1,2X,F5,1)
00451      176*          107 FORMAT(49X,PARAMETRIC SONAR DESIGN AND ANALYSIS)
00452      177*          112 FORMAT(F9,0.3X,F5,1,1X,F7,2,1X,F8,3,X,F9,6,1X,F7,0,1X,F7,0,1X,F8,
00453      178*          113X,F5,1,1X,F6,1,1X,F6,1,1X,F5,1,10X,'L= > 210.')
00453      179*

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|       |      |                                                                       |
|-------|------|-----------------------------------------------------------------------|
| 00454 | 180* | 112 FORMAT(F9.3,X,F5.1,1X,F7.2,1X,F8.3,1X,F9.6,1X,F7.0,1X,F7.0,1X,FB, |
| 00454 | 181* | 111,X,F5.1,1X,F6.1,1X,F6.1,1X,F6.1,1X,F5.1,10X,'L' < 140.,')          |
| 00455 | 182* | 114 FORMAT(1H1)                                                       |
| 00455 | 183* | STOP                                                                  |
| 00456 | 184* | END                                                                   |
| 00457 | 185* |                                                                       |

END OF COMPIILATION: NO DIAGNOSTICS.

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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.

TM No.  
IDIX-33-73

PARAMETRIC SONAR DESIGN AND ANALYSIS

T= WATER TEMPERATURE (DEGREES C)

U= PROJECTOR DEPTH (METERS)

S= SALINITY (PPT)

F= SECONDARY FREQUENCY (KHZ)

A= PROJECTOR AREA (SQ. METERS)

F0/F2= DOWNSHIFT RATIO

F0= PRIMARY FREQUENCY (KHZ)

AL= ABSORPTION CONSTANT (NEPERS/METER)

L/2AL= REACTION LIMIT (METERS)

R0= RAYLEIGH 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-KHZ)

G= PARAMETER GAIN (UB)

PA= ACOUSTIC POWER PER TONE (WATTS)

ANDI= DIRECTIVITY GAIN (UB)

NDIS= SECONDARY DIRECTIVITY INDEX (DB)

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

T3 7.

D3 .0

S3 35.

C3 1479.

| A2    | .1968 | FU/W   | FU/F    | FO      | AL    | 1/2AL | RO     | 1/2AL/HU | MJIP | LSS   | LSP   | L*    | PA(WATTS) | NOTS  | END? |
|-------|-------|--------|---------|---------|-------|-------|--------|----------|------|-------|-------|-------|-----------|-------|------|
| 3.000 | 30.7  | 5.00   | 15.000  | .000241 | 2079. | 20    | 1043.5 | 20.0     | 69.4 | 125.4 | 149.1 | 149.1 | 1165.2    | 26.4  |      |
| 3.000 | 29.5  | 7.50   | 22.500  | .000506 | 989.  | 30    | 330.5  | 27.6     | 91.0 | 127.9 | 150.9 | 150.9 | 689.0     | 26.6  | 1.3  |
| 3.000 | 27.6  | 10.00  | 30.000  | .000646 | 591.  | 40    | 146.3  | 30.1     | 69.8 | 126.7 | 150.2 | 150.2 | 603.0     | 30.0  |      |
| 3.000 | 27.2  | 12.50  | 37.500  | .001237 | 404.  | 50    | 61.1   | 32.0     | 69.7 | 130.0 | 161.5 | 161.5 | 529.4     | 30.3  |      |
| 3.000 | 27.4  | 15.00  | 45.000  | .001657 | 302.  | 60    | 50.5   | 33.6     | 90.2 | 131.0 | 164.8 | 164.8 | 547.3     | 30.0  |      |
| 3.000 | 26.2  | 20.00  | 60.000  | .002510 | 199.  | 60    | 25.0   | 36.1     | 90.5 | 135.1 | 170.6 | 170.6 | 657.6     | 29.0  |      |
| 3.000 | 31.1  | 30.00  | 90.000  | .004021 | 124.  | 120   | 10.4   | 39.6     | 89.2 | 141.5 | 180.6 | 180.6 | 320.3     | 279.5 |      |
| 3.000 | 36.0  | 40.00  | 120.000 | .005166 | 96.   | 160   | 6.1    | 42.1     | 89.5 | 148.9 | 190.5 | 190.5 | 3987.5    | 23.2  |      |
| 3.000 | 36.4  | 50.00  | 150.000 | .006209 | 82.   | 200   | 4.1    | 44.0     | 89.4 | 153.6 | 197.1 | 197.1 | 7504.9    | 21.0  |      |
| 3.000 | 42.0  | 70.00  | 210.000 | .007633 | 65.   | 200   | 2.3    | 47.0     | 89.3 | 159.3 | 206.2 | 206.2 | 18902.7   | 20.1  |      |
| 3.000 | 49.   | 100.00 | 300.000 | .009999 | 50.   | 40    | 1.3    | 50.1     | 89.0 | 163.0 | 210.4 | 210.4 | Le > 210. |       |      |

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

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TDIX-33-73

T= 7.

0= .0

S= 35.

C= 1479.

A= .7654

| F     | μH/L | F <sub>0</sub> /F | AL     | 1/2AL    | KO    | 1/2ALR0 | N0IP  | LSS  | LSP  | L*    | G     | PA(WATTS) | NDIS      | ANDI |
|-------|------|-------------------|--------|----------|-------|---------|-------|------|------|-------|-------|-----------|-----------|------|
| 3.000 | 26.4 | 5.00              | 15.000 | .0010241 | 2079. | 8.      | 260.9 | 30.1 | 90.2 | 127.2 | 150.8 | -37.0     | 433.9     | 32.2 |
| 3.000 | 25.1 | 7.50              | 22.500 | .000506  | 968.  | 12.     | 82.7  | 33.6 | 90.7 | 129.5 | 156.6 | -38.8     | 325.5     | 34.1 |
| 3.000 | 24.3 | 10.00             | 30.000 | .000646  | 591.  | 16.     | 37.1  | 36.1 | 89.9 | 131.2 | 160.7 | -41.2     | 267.1     | 34.4 |
| 3.000 | 24.5 |                   | 37.500 | .001237  | 404.  | 20.     | 20.3  | 38.0 | 90.1 | 133.4 | 166.8 | -43.3     | 283.8     | 33.9 |
| 3.000 | 25.3 | 15.00             | 45.000 | .001957  | 302.  | 24.     | 12.6  | 39.6 | 90.7 | 135.9 | 169.0 | -45.2     | 355.0     | 33.1 |
| 3.000 | 27.1 |                   | 20.00  | .002510  | 199.  | 32.     | 6.3   | 42.1 | 90.2 | 140.0 | 175.6 | -49.9     | 516.1     | 31.5 |
| 3.000 | 30.6 |                   | 30.00  | .004021  | 124.  | 48.     | 2.6   | 45.6 | 89.6 | 147.3 | 186.4 | -57.7     | 1215.0    | 28.6 |
| 3.000 | 34.4 |                   | 40.00  | .005166  | 90.   | 64.     | 1.5   | 48.1 | 90.3 | 153.1 | 194.6 | -92.8     | 2586.3    | 26.4 |
| 3.000 | 35.2 |                   | 50.00  | .0026109 | 82.   | 80.     | 1.0   | 50.1 | 89.5 | 156.1 | 199.6 | -66.6     | 3324.7    | 25.1 |
| 3.000 | 36.5 | 70.00             | 210.00 | .007653  | 65.   | 112.    | .6    | 53.0 | 90.4 | 162.3 | 208.7 | -71.8     | 7044.9    | 22.4 |
| 3.000 | 36.5 |                   | 100.00 | .009969  | 50.   | 159.    | .3    | 56.1 | 81.0 | .0    | 210.4 | -78.8     | L* > 210. |      |

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TDIX-33-73

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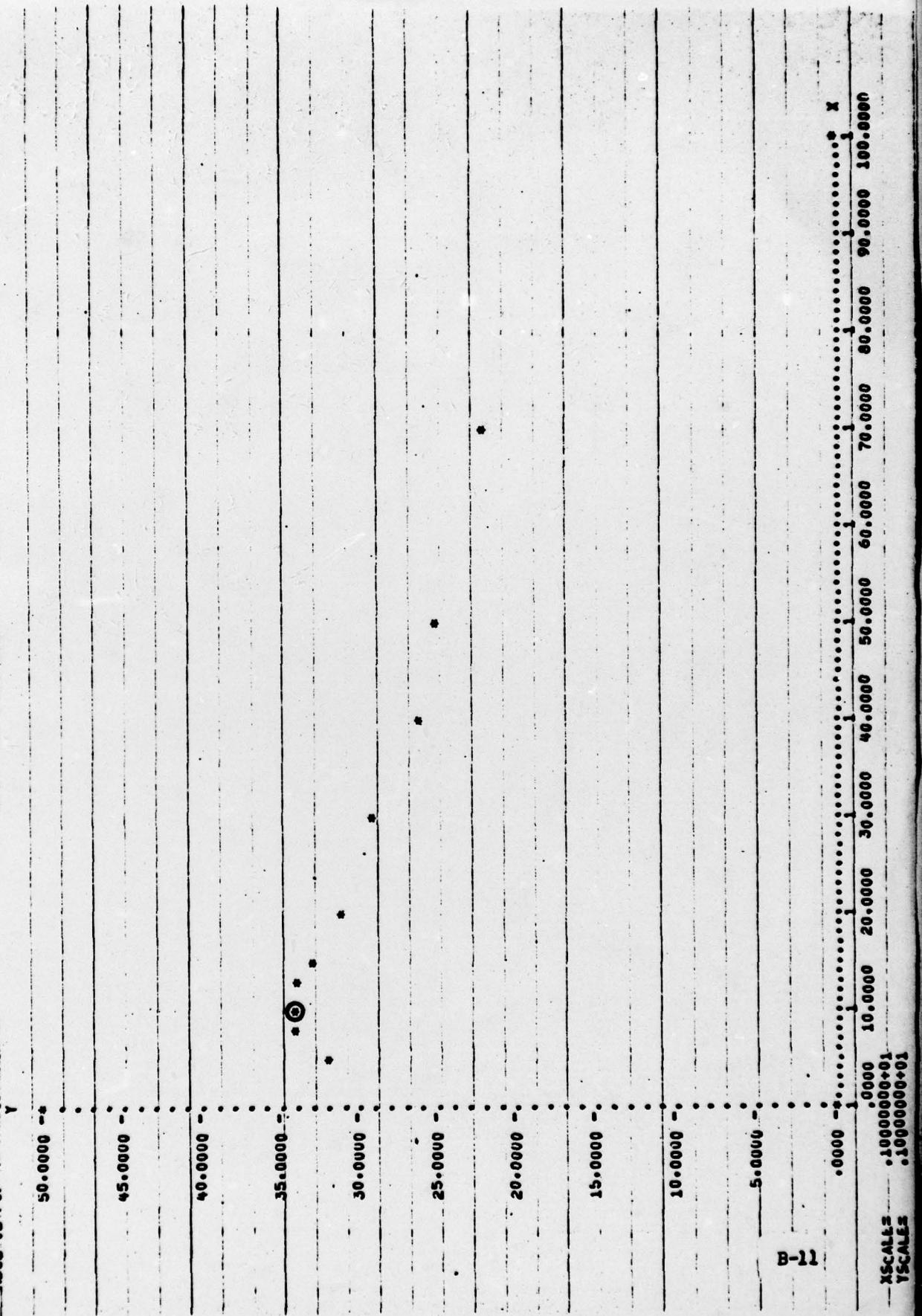
B-10

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YSCALE = .1000000+01

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JNUS VS FU/F



B-11

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YSCALES .1000000+01