A Fortran Program For Calculating The Equivalent Source Strength For The Class I and II Flextensional Underwater Acoustic Transducer Designs

Jack N. Boone
Department of Mechanical and Aerospace Engineering
Center For Acoustical Studies
North Carolina State University
Raleigh, North Carolina

Larry H. Royster
Department of Mechanical and Aerospace Engineering
Center For Acoustical Studies
North Carolina State University
Raleigh, North Carolina

Office of Naval Research
Contract No. Nonr 486(11)
Technical Report No. 3
April 1969

27

TABLE OF CONTENTS

ABSTRACT

A Fortran program is presented which computes a normalized equivalent source strength for the Class I and approximates the Class II Flextentional Underwater Acoustic Transducer Shells. The program utilization, the input data and the output data formats are described in detail.

ACKNOWLEDGEMENT

This work was sponsored by the Office of Naval Research, Acoustics Programs, Contract Nonr 486(11) and by the Naval Underwater Sound Laboratory.

INTRODUCTION

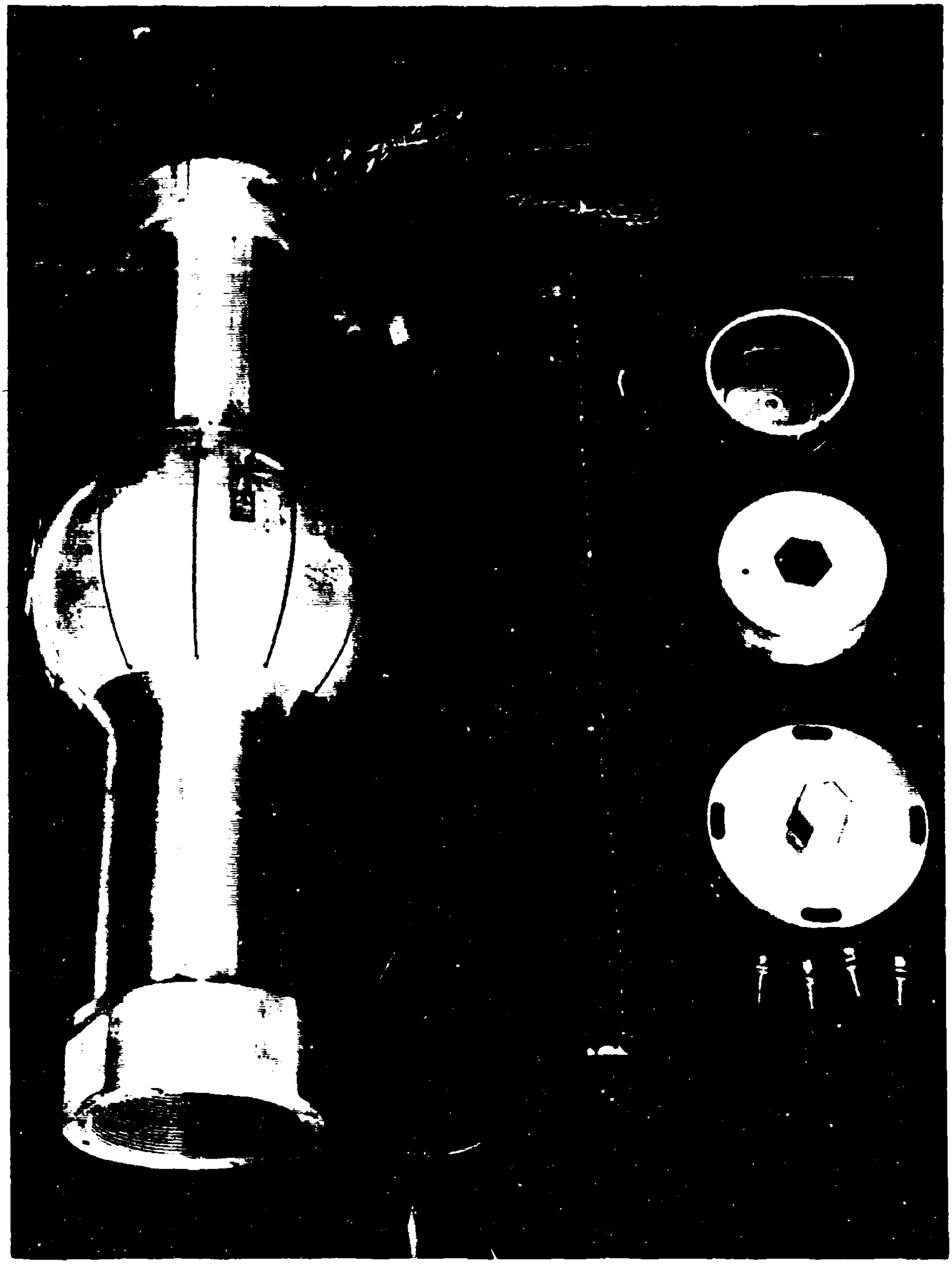
This report describes a Fortran program of an equivalent source strength model for the Class I and II (Reference 1) Flextensional Underwater Acoustic Transducer Shells. Pictures of these two shell configurations are shown in Figures 1 and 2.

An approximate analytical model for the Class I type of shell design has been developed (References 2 and 3. The math model described in References 2 and 3 utilizes a numerical model in order to obtain the near- and far-field acoustic pressures for a specified displacement on the shell and associated frequency of radiation. This model is sufficient for engineering applications up through the fundamental mode of vibration provided that a so-called forbidden frequency is not encountered (Reference 4).

It is not uncommon for the effective ka of a flextensional shell to be less than one thus yielding a relatively omni-directional far-field radiation pattern. If for such design situations an equivalent source strength model was available, an approximation to the far-field pressures at a defined frequency and shell displacement would be possible. In addition, the equivalent source strength model would be more economical to utilize, computer cost, etc., and would yield important preliminary design information.

FIGURE 1

FIGURE 2



PROGRAM UTILIZATION

For a given transducer having the general configuration depicted in Figure 3, all geometric quantities pertinent to the solution of the free vibration eigenvalue problem and the computation of the source strength may be determined by specifying any one of several dimensionless parameters and the opening angle, θ_o. The parameters L/D and θ_o are the independent variables in the accompanying FORTRAN program; L/D being selected since it is also relevant with respect to the size of the piezoelectric stack required to drive the transducer.

The solution of the approximate dynamic model involves computing the first eigenvalue and eigenvector of a 2* NP-2 square matrix, where NP is the number of control points input for generation of the discrete system equations of motion. It is suggested that, for best numerical results, NP should lie in the range $10 \leq NP \leq 15$.

The units used are immaterial since all input - output quantities are dimensionless ratios with the exception of the opening angle which is in degrees.

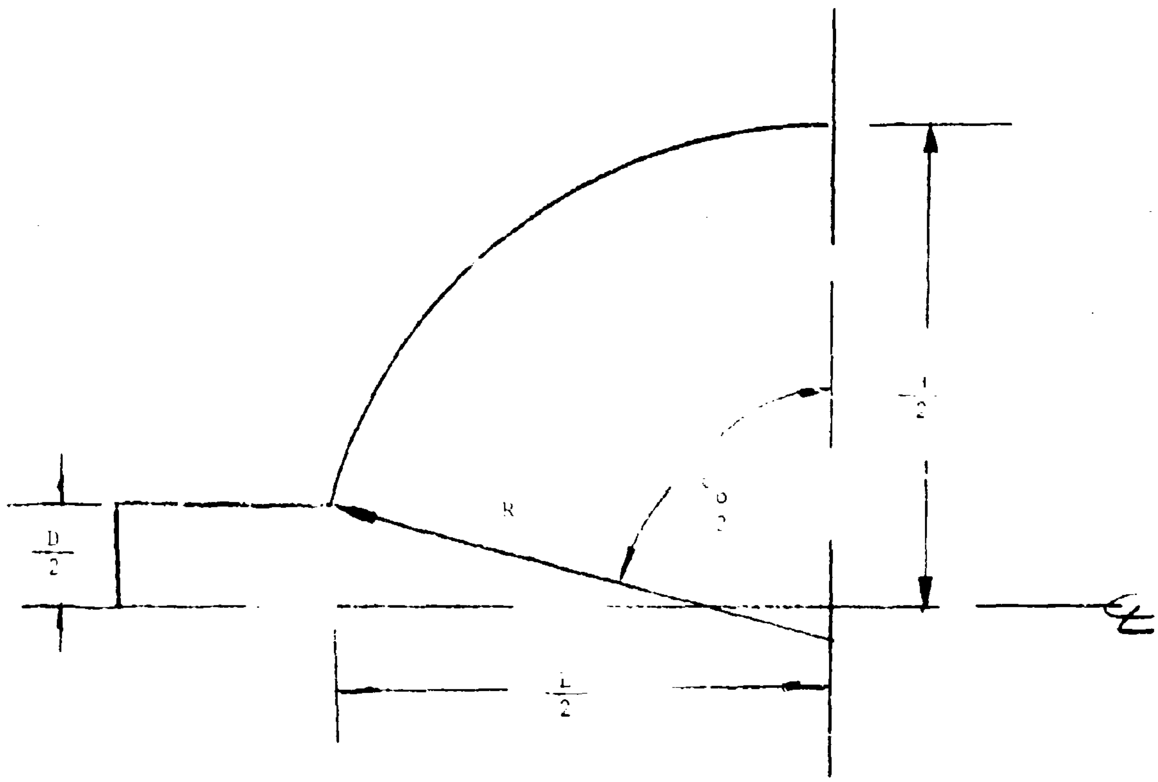


Figure 3 - Transducer Configuration

INPUT DATA

On the first data card enter NN, the number of cases to be run consecutively. NN is input in FORMAT (I2).

On each following card enter the quantities IVC, NP, IAL, IAU, INC, RK, and RATIO in FORMAT (I1, I2, 3I3, 2F4.1).

IVC controls the printout of the components of the eigenvector normal to the surface of the transducer and the normalized radiating areas. These vectors are printed out only if IVC is entered as a non zero positive quantity.

NP is the number of control points to be defined on one half of a typical transducer element for the discrete system dynamic model.

IAL, IAU, and INC correspond to the first opening angle, the last opening angle, and the opening angle increment, respectively, desired in the output for a given RATIO. These quantities have units of degrees.

RK is the ratio of the radius of curvature of a typical transducer element to the radius of gyration of a typical element section as measured at the guided end. The dynamic model is insensitive to this parameter for RK $\geq$ 20. RK is normally input as any large positive number for thin transducer elements. RATIO = L/D.

PRINT-OUT DATA

The input quantities RATIO and NP appear as header information for each case. The output quantities THETA, RADIUS/LENGTH, HEIGHT/LENGTH, DISPL. RATIO, WIDTH RATIO, WIDTH FACTOR, COEFFICIENT AND NORM. SOURCE STR. are printed out for each opening angle where:

THETA = θ_o

RADIUS/LENGTH = R/L

HEIGHT/LENGTH = H/L

DISPL. RATIO is the ratio of the displacement measured at the center of the circular arc formed by a typical transducer element to the corresponding horizontal displacement of the guided end.

WIDTH RATIO is the ratio of the width of a typical element as measured at the center of of circular arc to the width of the element as measured at the guided end.

WIDTH FACTOR = element width at center of arc/(1/2 arc length of element * sin (PI/N)), where N is the number of transducer elements.

COEFFICIENT is the frequency coefficient i.e. that number which, when multiplied by SQRT (E*I/m)/(L*L), yields the natural frequency in rad./sec. where E is the modulus of elasticity, I and m are the area moment of inertia and mass per unit length of a typical element as measured at the guided end, and L is as shown in Figure 3.

NORM. SOURCE STR is the source strength of the transducer normalized with respect to ((PI*D)**2)*F* DELTA where F is the frequency of excitation in cycles/sec., DELTA is the displacement amplitude of the guided end, and D is as in Figure 3. Negative values of this quantity indicate that the net volume displacement is negative when the ends of the transducer are displaced in such a manner that the transducer is elongated.

If IVC > 0, the vectors NORMAL VECTOR and NORMALIZED AREAS are also printed out. NORMAL VECTOR is the vector of eigenvector components normal to the transducer surface normalized with respect to the eigenvector component at the guided end. NORMALIZED AREAS is the vector of radiating areas associated with the discrete system control points normalized with respect to the area of the circular end section.

FINAL REMARKS

The model presented in this report is an approximate model since several simplifying assumptions were necessary. A list of the most important assumptions made and where deemed appropriate the anticipated results of having to make such assumptions are as follows:

a) It is assumed that the external geometry of the shells can be approximated by cylindrical end sections (actual length is not considered since it is assumed that $ka \ll 1$) and circular curved beams exhibiting a varying taper characteristic.

b) The cylindrical end sections do not radiate except on the ends. If the radial thickness of the cylindrical end sections is small compared to the thickness of the curved beams then most likely these end sections will contribute significantly to the overall radiation field.

c) Raidation through the slits between the curved beams is assumed to be insignificant.

d) It is assumed that the boundary condition for the curved beams is clamped-guided. Most Class I shells will approximate this boundary condition as will relatively thick Class II shell designs.

e) The present program does not allow the option of specifying the actual curved beam end mass. If the end masses become large as compared to the total mass of the curved beams, as is quite possible for the Class II shell, then the eigenvector associated with the shells fundamental frequency of vibration approaches the quasi-static solution. This would result in a reduction in the predicted far-field pressures of approximately 25%.

The program described here in has been checked by comparing the predicted and measured far-field pressures for a transducer of known performance. The predicted pressures were approximately +1.5 db above the measured data. In light of the intended use for the model described herein the above variation is acceptable. In addition, since it is entirely possible to design a flextensional transducer (for ka [illegible] 1) with $Q_s < 0$, this program should be utilized early in the design process in order to elimate this type of design error.

REFERENCES

1) Brigham, G. A. and L. H. Royster. Present Status in the Design of Flex-tensional Underwater Acoustic Transducers. Paper presented at the Seventy-Seventh Meeting of the Acoustical Society of America, Philadelphia, Pennsylvania, April, 1969.

2) Royster, L. H. The Flextentional Underwater Acoustic Transducer. J. Acoust. Soc. of America. 45(1): 671-682 (1969).

3) Royster, L. H. Investigation of the Design Principles of the Flextentional Underwater Acoustic Transducer. Contract Nonr 486(11), Part I, Final Report, North Carolina State University, 1967.

4) Hess, J. L. Calculation of Acoustic Fields About Arbitrary Three-Dimensional Bodies by a Method of Surface Source Distributions Based on Certain Wave Number Expansions. Report No. DAC 66901, MCDONNEL DOUGLAS, March 1968.

APPENDIX A

Listing of the Fortran Program

ML

```
C     THIS PROGRAM COMPUTES THE SOURCE STRENGTH, FREQUENCY COEFFICIENT,
C     AND A NUMBER OF GEOMETRIC PARAMETERS FOR A CLASS OF FLEXTENSIONAL
C     ACOUSTIC TRANSDUCERS COMPOSED OF AN ARRAY OF TAPERED CURVED BEAMS
C     (CIRCULAR ARCS) FORMING A SURFACE OF REVOLUTION AND EXHIBITING
C     SHORT CYLINDRICAL END SECTIONS

C     USAGE- THE FOLLOWING PARAMETERS MUST APPEAR ON THE DATA CARD
C     FOR EACH CASE- IVC, NP, IAL, IAU, INC, RK, RATIO

C     DESCRIPTION OF INPUT PARAMETERS

C     NN=NUMBERS OF DATA SETS
C     IVC=1 IF A PRINTOUT OF THE NORMALIZED AREAS AND NORMALIZED NORMAL
C     VECTORS IS DESIRED(THE TANGENTIAL COMPONENTS OF THE EIGENVECTOR ARE
C     DESTROYED IN THE NORMALIZATION), IVC=0 OTHERWISE
C     NP=THE NUMBER OF CONTROL POINTS IN HALF OF THE BEAM
C     IAL=FIRST OPENING ANGLE DESIRED IN THE OUTPUT
C     IAU=LAST OPENING ANGLE DESIRED IN THE OUTPUT
C     INC=OPENING ANGLE INCREMENT
C     RK=BEAM RADIUS/RADIUS OF GYRATION OF A TYPCIAL ELEMENT EVALUATED
C     AT THE GUIDED END
C     RATIO=CHORD SUBTENDED BY THE OPENING ANGLE/DIAMETER OF CYLINDRICAL
C     END SECTION AT THE GUIDED END

C     DESCRIPTION OF OUTPUT PARAMETERS

C     THETA=OPENING ANGLE SUBTENDED BY A TYPICAL ELEMENT OF THE ARRAY
C     RADIUS/LENGTH=BEAM RADIUS/CHORD LENGTH
C     HEIGHT/LENGTH=TRANSDUCER HEIGHT/CHORD LENGTH
C     DISPL. RATIO=RATIO OF NORMAL DISPLACEMENT AT THE BEAM CENTER TO THE
C     DISPLACEMENT OF THE GUIDED END
C     WIDTH RATIO=RATIO OF BEAM WIDTH AT THE CENTER OF THE BEAM TO THE
C     BEAM WIDTH AT THE GUIDED END
C     WIDTH FACTOR=MAXIMUM BEAM WIDTH/(ARC LENGTH OF HALF BEAM*S IN(PI/
C    1N)),N=NUMBER OF BEAMS IN THE ARRAY
C     COEFFICIENT=FREQUENCY COEFFICIENT
C     NORM. SOURCE STR.=SOURCE STRENGTH/(((PI*D)**2)*F*DEL TA), D=END
C     DIAMETER, F=FREQUENCY IN CY./SEC., DELTA=DISPLACEMENT OF GUIDED END
C     NORMAL VECTOR=NORMAL EIGENVECTOR COMPONENTS NORMALIZED ON THE
C     DISPLACEMENT OF THE GUIDED END
C     NORMALIZED AREAS=RADIATING AREAS ASSOCIATED WITH EACH DISCRETE CONTROL
C     POINT NORMALIZED WITH RESPECT TO THE AREA OF THE CYLINDRICAL END
```

```
      DIMENSION A(60,60),VU(60),RM(60),RI(30),RN(30),RS(30)
      COMMON N,M, MODE,A,VU
      PI=3.1415927
      M=1
      MODE=1
      READ(1,102)NN
  102 FORMAT(I2)
      DO 1 KK=1,NN


      READ(1,103)IVC,NP,IAL,IAU,INC,RK,RATIO
  103 FORMAT(I1,I2,3I3,2F4.1)
      N=2*NP-2
      WRITE(3,100)RATIO,NP
  100 FORMAT('1'//////47X,'LENGTH/END DIA.-'F7.4/47X,'NO. OF CONTROL PTS
     1. IN HALF BEAM='I2////8X,'THETA',3X,'RADIUS/LENGTH',3X,'HEIGHT/LEN
     2GTH',3X,'DISPL. RATIO',3X,'WIDTH RATIO',3X,'WIDTH FACTOR',3X,'COEF
     3FICIENT',3X,"NORM. SOURCE STR.')
      DO 1 LA=IAL,IAU,INC
      OA=LA*PI/180.
      RR=SIN(OA/2.)/RATIO
      CALL COEFF(N,NP,OA,RR,SI,PHI,RM,RI,RN,RS)
      CALL STIFF(N,NP,RK,SI,PHI,A,RM,RI,RN)
      CALL GIVENS
      VU(1)=SQRT(VU(1))*COS(PHI/2.)*(S IN(OA/2.)**2)/(SIN(PHI/2.)**2)
      DO 2 I=1,N
      A(I,1)=A(I,1)/SQRT(RM(I))
    2 CONTINUE
      QSN=A(1,1)/ABS(A(1,1))
      DO 3 I=2,N,2
      K=I/2+1
      QSN-QSN+A(I,1)*RS(K)/ABS(A(1,1))
    3 CONTINUE
      IF(A(1,1))4,4,5
    4 QSN=-QSN
    5 RL=1./(2.*SIN(OA/2.))
      THL=(RR+1.-COS(OA/2.))/SIN(OA/2.)
      DR=A(N,1)/A(1,1)
      WR=RI(NP)
      WF=4.*(1.-COS(OA/2.)+SIN(OA/2.)/RATIO)/OA
      OA=OA*180./PI
      WRITE(3,101)OA,RL,THL,DR,WR,WF,VU(1),QSN
  101 FORMAT(//F13.1,2E16.6,E15.5,E14.5,E15.5,E14.5,E18.6)
      IF(IVC)1,1,6
    6 IF(A(1,1))7,7,8
    7 A(1,1)=-A(1,1)
      DO 9 I=2,N,2
      A(I,1)=-A(I,1)
```

```
    9 CONTINUE
    8 DO 10 I=2,N,2
      K=I/2+1
      A(K,1)=A(I,1)/A(1,1)
   10 CONTINUE
      A(1,1)=1.
      WRITE(3,104)
  104 FORMAT(//34X,'NORMAL VECTOR',34X,'NORMALIZED AREAS'//)
      WRITE(3,105)(A(I,1),RS(I),I=1,NP)
  105 FORMAT(35X,E12.5,36X,E12.5)
    1 CONTINUE
      END
```

```
      SUBROUTINE COEFF(N,NP,OA,RR,SI,PHI,RM,RI,RN,RS)
      DIMENSION RM(60),RI(30),RN(30),RS(30)
      PI=3.1415927
      S1=(PI-OA)/2.
      PHI=OA/(2.*(NP-1.))
      OA2=OA/2.
      PHI2=PHI/2.
      D=COS(OA/2.)-RR
      RI(1)=1.
      RN(1)=1.          RS(1)=1
      DO 1 J=2,NP
      RI(J)=(COS(OA2-(J-1.)*PHI)-D)/RR
      RN(J)=2.*RI(J)*RI(J-1)/(RI(J)+RI(J-1))
      RS(J)=2.*(2.*SIN(PHI2)*COS(OA2-(J-1.)*PHI)-D*PHI)/(RR*RR)
    1 CONTINUE
      RS(2)=2.*(2.*SIN(3.*PHI/4.)*COS(OA/2.-3.*PHI/4.)-D*3.*PHI/2.)/(RR*
     1RR)
      RS(NP)=2.*(SIN(PHI2)-D*PHI2)/(RR*RR)
      RM(1)=1.
      RM(N)=RI(NP)/2.
      M=N-2
      DO 2 J=2,M,2
      RM(J)=RI(J/2+1)
      RM(J+1)=RM(J)
    2 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE STIFF(N,NP,RK,SI,PHI,A,RM,RI,RN)
      DIMENSION A(60,60),RM(60),RN(30),RI(30)
      C=SIN(PHI/2.)/COS(PHI/2.)
      C2=SIN(SI)/COS(SI)
      P=(2.*RK*SIN(PHI/2.))**2
      DO  1 I=1,N
      DO  1 J=1,N
      A(I,J)=0.0
    1 CONTINUE
      A(1,1)=((C*(C+C2)*RN(2)*P-(2.+RI(2))*(C*C2-1.))*COS(SI)+((C+C2*RN
     1(2)*P+(2.+RI(2))*C*(C*C2-1.))*SIN(SI))*COS(SI)
      A(1,2)=(C*(C+C2)*RN(2)*P+2.*(1.+RI(2))*(C*C2-1.))*COS(SI)
      A(1,3)=((C+C2)*RN(2)*P-2.*C*(C*C2-1.))*COS(SI)
      A(1,4)=-RI(2)*(C*C2-1.)*COS(SI)
      A(1,5)=RI(2)*C*(C*C2-1.)*COS(SI)
      A(2,2)=(RN(2)+RN(3))*P*C*C+2.+4.*RI(2)+RI(3)
      A(2,3)=C*((RN(2)-RN(3))*P-2.+RI(3))
      A(2,4)=RN(3)*P*C*C-2.*(RI(2)+RI(3))
      A(2,5)=C*(RN(3)*P+2.*RI(2))
      A(2,6)=RI(3)
      A(2,7)=-RI(3)*C
      A(3,3)=(RN(2)+RN(3))*P+(2.+RI(3))*C*C
      A(3,4)=-C*(RN(3)*P+2.*RI(3))
      A(3,5)=-RN(3)*P
      A(3,6)=RI(3)*C
      A(3,7)=-RI(3)*C*C
      K1=N-4
      K2=N-3
      K3=N-2
      K4=N-1
      J1=NP-3
      J2=NP-2
      J3=NP-1
      A(K1,K1)=(RN(J2)+RN(J3))*P*C*C+RI(J1)+4.*RI(J2)+RI(J3)
      A(K1,K2)=C*((RN(J2)-RN(J3))*P-RI(J1)+RI(J3))
      A(K1,K3)=RN(J3)*P*C*C-2.*(RI(J2)+RI(J3))
      A(K1,K4)=C*(RN(J3)*P+2.*RI(J2))
      A(K1,N)=RI(J3)
      A(K2,K2)=(RN(J2)+RN(J3))*P+(RI(J1)+RI(J3))*C*C
      A(K2,K3)=-C*(RN(J3)*P+2.*RI(J3))
      A(K2,K4)=-RN(J3)*P
      A(K2,N)=RI(J3)*C
      A(K3,K3)=(RN(J3)+RN(NP))*P*C*C+RI(J2)+4.*RI(J3)+2.*RI(NP)
      A(K3,K4)=C*((RN(J3)-RN(NP))*P-RI(J2)+2.*RI(NP))
      A(K3,N)=RN(NP)*P*C*C-2.*RI(J3)+RI(NP))
      A(K4,K4)=(RN(J3)+RN(NP))*P+(RI(J2)+2.*RI(NP))*C*C
      A(N,N)=RN(NP)*P*C*C+RI(J3)+2.*RI(NP)
      A(K4,N)=-C*(RN(NP)*P+2.*RI(NP))
      JM=N-6
      DO 2 I=4,JM,2
      DO 2 J=4,JM,2
      IF(I-J)2,3,2
```

```
3 K=I/2+1
  A(I,J)=(RN(K)+RN(K+1))*P*C*C+RI(K-1)+4.*RI(K)+RI(K+1)
  A(I,J+1)=C*((RN(K)-RN(K+1))*P-RI(K-1)+RI(K+1))
  A(I,J+2)=RN(K+1)*P*C*C-2.*(RI(K)+RI(K+1))
  A(I,J+3)=C*(RN(K+1)*P+2.*RI(K))
  A(I,J+4)=RI(K+1)
  A(I,J+5)=-RI(K+1)*C
  M=I+1
  L=J+1
  A(M,L)=(RN(K)+RN(K+1))*P+(RI(K-1)+RI(K+1))*C*C
  A(M,L+1)=-C*(RN(K+1)*P+2.*RI(K+1))
  A(M,L+2)=-RN(K+1)*P
  A(M,L+3)=RI(K+1)*C
  A(M,L+4)=-RI(K+1)*C*C
2 CONTINUE
  DO 4 I=1,N
  DO 4 J=1,N
  A(J,I)=A(I,J)
4 CONTINUE
  DO 5 I=1,N
  DO 5 J=1,N
  A(I,J)=A(I,J)/SQRT(RM(I)*RM(J))
5 CONTINUE
  RETURN
  END
```

```
      SUBROUTINE GIVENS
      DIMENSION A(60,60),B(60,60),DIAG(60),VU(60),VL(60),SD(60),
     1Q(60),S(60),C(60),D(60),IND(60),U(60)
      COMMON N,M,MODE,A,VU
      EQUIVALENCE (P,PRODS),(TAU,BETA),(T,SMALLD),(II,MATCH),(VL(1),D(1)
     1),(Q(1),S(1))

C     CALCULATE NORM OF MATRIX

      ANORM=0.
      DO 1 I=1,N
      SD(I)=0.
      DO 1 J=1,N
    1 ANORM=ANORM+A(I,J)*A(I,J)
      ANORM=SQRT(ANORM)

C     GENERATE IDENTITY MATRIX

      IF(M)1000,11,1000
 1000 DO 7 I=1,N
      DO 7 J=1,N
      IF(I-J)6,1001,6
 1001 B(I,J)=1.
      GO TO 7
    6 B(I,J)=0.
    7 CONTINUE

C     PERFORM ROTATIONS TO REDUCE MATRIX TO JACOBI FORM

   11 NN=N-2
      IF(NN)100,21,1003
 1003 DO 15 I=1,NN
      II=I+2
      DO 15 J=II,N
      T1=A(I,I+1)
      T2=A(I,J)
      IF(T2)1004,15,1004
 1004 CALL ROTATE(T1,T2,SN,CSN)
      DO 12 K=1,N
      T2=CSN*A(K,I+1)+SN*A(K,J)
      A(K,J)=CSN*A(K,J)-SN*A(K,I+1)
   12 A(K,I+1)=T2
      DO 13 K=I,N
      T2=CSN*A(I+1,K)+SN*A(J,K)
      A(J,K)=CSN*A(J,K)-SN*A(I+1,K)
   13 A(I+1,K)=T2
      IF(M)1005,15,1005
 1005 DO 14 K=1,N
      T2=CSN*B(K,I+1)+SN*B(K,J)
```

```
      B(K,J)=CSN*B(K,J)-SN*B(K,I+1)
   14 B(K,I+1)=T2
   15 CONTINUE

C     MOVE JACOBI ELEMENTS AND INITIALIZE EIGENVALUE BOUNDS

   21 DO 22 I=1,N
      DIAG(I)=A(I,I)
      VU(I)=ANORM
   22 VL(I)=-ANORM
      DO 23 I=2,N
      SD(I-1)=A(I-1,I)
   23 Q(I-1)=SD(I-1)*SD(I-1)

C     DETERMINE SIGNS OF PRINCIPAL MINORS

      TAU=0.
      I=1
   35 MATCH=0
      T2=0.
      T1=1.
      DO 26 J=1,N
      P=DIAG(J)-TAU
      IF(T2)1007,27,1007
 1007 IF(T1)1008,28,1008
 1008 T=P*T1-Q(J-1)*T2
      GO TO 29
   27 IF(T1)1009,30,30
 1009 T1=-1.
      T=-P
      GO TO 29
   30 T1=1.
      T=P
      GO TO 29
   28 IF(Q(J-1))1010,30,1010
 1010 IF(T2)31,1011,1011
 1011 T=-1.
      GO TO 29
   31 T=1.

C     COUNT AGREEMENTS IN SIGN

   29 IF(T1)32,1012,1012
 1012 IF(T)34,33,33
   32 IF(T)33,34,34
   33 MATCH=MATCH+1
   34 T2=T1/ABS(T1)
   26 T1=T/ABS(T1)
```

```
C     ESTABLISH TIGHTER BOUNDS ON EIGENVALUES
      DO 41 K=I,MODE
      IF(K-N+MATCH)1014,1014,42
 1014 IF(VU(K)-TAU)41,41,1015
 1015 VU(K)=TAU
      GO TO 41
   42 IF(VL(K)-TAU)1018,41,41
 1018 VL(K)=TAU
   41 CONTINUE
   45 IF(VU(I)-VL(I)-5.E-6)43,43,1016
 1016 IF(VU(I))1017,44,1017
 1017 IF(ABS(VL(I)/VU(I)-1.)-5.E-6)43,43,44
   43 I=I+1
      IF(I-MODE)1019,1019,51
 1019 GO TO 45
   44 TAU=(VL(I)+VU(I))/2.
      GO TO 35
   51 IF(M)100,100,1020
 1020 IF(M-MODE)1021,1021,1022
 1022 M=MODE
 1021 DO 52 I=1,N
      DO 52 J=1,N
   52 A(I,J)=0.
      DO 53 I=1,M
      IF(I-1)1029,54,1029
 1029 IF(VU(I)-VU(I-1)-5.E-6)55,55,1023
 1023 IF(VU(I))1024,54,1024
 1024 IF(ABS(VU(I-1)/VU(I)-1.)-5.E-6)55,55,54
   54 CSN=1.
      SN=0.
      DO 56 J=1,N
      IF(J-1)1025,57,1025
 1025 CALL ROTATE(T1,T2,SN,CSN)
      S(J-1)=SN
      C(J-1)=CSN
      D(J-1)=T1*CSN+T2*SN
   57 T1=(DIAG(J)-VU(I))*CSN-BETA*SN
      T2=SD(J)
   56 BETA=SD(J)*CSN
      D(N)=T1
      DO 58 J=1,N
   58 IND(J)=0
   55 SMALLD=ANORM
      DO 60 J=1,N
      IF(IND(J)-1 )1026,60,60
 1026 IF(ABS(SMALLD)-ABS(D(J)))60,60,1027
 1027 SMALLD=D(J)
```

```
      NN=J
   60 CONTINUE
      IND(NN)=1
      [illegible]
      IF(NN-1)1028,53,1028
 1028 DO 61 K=2,NN
      II=NN+1-K
      A(II+1,1)=C(II)*PRODS
   61 PRODS=-PRODS*S(II)
   53 A(1,1)=PRODS
C      FORM MATRIX PRODUCT OF ROTATION MATRIX WITH JACOBI VECTOR MATRIX
      DO 66 J=1,M
      DO 67 K=1,N
   67 U(K)=A(K,J)
      DO 66 I=1,N
      A(I,J)=0.
      DO 66 K=1,N
   66 A(I,J)=B(I,K)*U(K)+A(I,J)
  100 RETURN
      END

      SUBROUTINE ROTATE(A,B,C,D)
      E=SQRT(A*A+B*B)
      D=A/E
      C=B/E
      RETURN
      END
```

APPENDIX B

Listing of a Typical Output Data Set

TYPICAL OUTPUT

LENGTH/END DIA.= 1.2600
NO. OF CONTROL PTS. IN HALF BEAM=15

THETA	RADIUS/LENGTH	HEIGHT/LENGTH	DISPL. RATIO	WIDTH RATIO	WIDTH FACTOR	COEFFICIENT	NORM. SOURCE STR.
102.0	0.643380E 00	0.127063E 01	-0.19610E 01	0.16010E 01	0.22187E 01	0.16698E 02	-0.234460E 01

NORMAL VECTOR	NORMALIZED AREAS
0.10000E 01	0.10000E 01
0.69187E 00	0.32734E 00
0.53385E 00	0.23737E 00
0.31990E 00	0.25156E 00
0.65892E-01	0.26471E 00
-0.21328E 00	0.27677E 00
-0.50371E 00	0.28771E 00
-0.79261E 00	0.29746E 00
-0.10684E 01	0.30599E 00
-0.13207E 01	0.31327E 00
-0.15403E 01	0.31926E 00
-0.17195E 01	0.32395E 00
-0.18521E 01	0.32731E 00
-0.19335E 01	0.32934E 00
-0.19610E 01	0.16501E 00

TYPICAL OUTPUT (continued)

108.0	0.618035E 00	0.130317E 01	-0.18372E 01	0.16420E 01	0.22373E 01	0.16727E 02	-0.212407E 01

NORMAL VECTOR	NORMALIZED AREAS
0.10000E 01	0.10000E 01
0.72579E 00	0.33404E 00
0.57543E 00	0.24338E 00
0.37029E 00	0.25874E 00
0.12604E 00	0.27302E 00
-0.14329E 00	0.28613E 00
-0.42432E 00	0.29804E 00
-0.70451E 00	0.30867E 00
-0.97226E 00	0.31798E 00
-0.12172E 01	0.32593E 00
-0.14302E 01	0.33249E 00
-0.16038E 01	0.33762E 00
-0.17320E 01	0.34130E 00
-0.18107E 01	0.34352E 00
-0.18372E 01	0.17213E 00

Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Center for Acoustical Studies Dept. of Mechanical and Aerospace Engineering North Carolina State University Raleigh, North Carolina 27607	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP

3. REPORT TITLE

A Fortran Program For Calculating The Equivalent Source Stength For The Class I and II Flextensional Underwater Acoustic Transducer Designs

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Technical Report, 1968-69

5. AUTHOR(S) (Last name, first name, initial)

Boone, Jack N. and Royster, Larry H.

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
April 1969	(25)	(4)

8a. CONTRACT OR GRANT NO. NONR 486(11) b. PROJECT NO. NR 185-551 c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) Technical Report No. 3 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) CAS - 38

10. AVAILABILITY/LIMITATION NOTICES

Distribution of this document is unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Office of Naval Research, Acoustics Programs and the Naval Underwater Sound Laboratory

13. ABSTRACT

A Fortran program is presented which computes a normalized equivalent source strength for the Class I and approximates the Class II Flextensional Underwater Acoustic Transducer Shells. The program utilization, the input data and the output data formats are described in detail.

DD FORM 1 JAN 64 1473

UNCLASSIFIED

Security Classification

Security Classification

14. KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
Flextensional						
Underwater						
Acoustic						
Transducer						
Source Strength						
Curved Beams						
Radiation						

INSTRUCTIONS

1. **ORIGINATING ACTIVITY:** Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization *(corporate author)* issuing the report.

2a. **REPORT SECURITY CLASSIFICATION:** Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2b. **GROUP:** Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. **REPORT TITLE:** Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. **DESCRIPTIVE NOTES:** If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. **AUTHOR(S):** Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. **REPORT DATE:** Enter the date of the report as day, month, year; or month, year. If more than one date appears on the report, use date of publication.

7a. **TOTAL NUMBER OF PAGES:** The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7b. **NUMBER OF REFERENCES:** Enter the total number of references cited in the report.

8a. **CONTRACT OR GRANT NUMBER:** If appropriate, enter the applicable number of the contract or grant under which the report was written.

8b, 8c, & 8d. **PROJECT NUMBER:** Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9a. **ORIGINATOR'S REPORT NUMBER(S):** Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9b. **OTHER REPORT NUMBER(S):** If the report has been assigned any other report numbers *(either by the originator or by the sponsor)*, also enter this number(s).

10. **AVAILABILITY/LIMITATION NOTICES:** Enter any limitations on further dissemination of the report, other than those imposed by security classification, using standard statements such as:

(1) "Qualified requesters may obtain copies of this report from DDC."

(2) "Foreign announcement and dissemination of this report by DDC is not authorized."

(3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through ______________."

(4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through ______________."

(5) "All distribution of this report is controlled. Qualified DDC users shall request through ______________."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. **SUPPLEMENTARY NOTES:** Use for additional explanatory notes.

12. **SPONSORING MILITARY ACTIVITY:** Enter the name of the departmental project office or laboratory sponsoring *(paying for)* the research and development. Include address.

13. **ABSTRACT:** Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as *(TS)*, *(S)*, *(C)*, *or (U)*.

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. **KEY WORDS:** Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, rules, and weights is optional.