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DITT: A Computer Program for Data Interpretation for Torsional Tests

by

Albert T. F. Chen

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INTRODUCTION

Recent advances in testing technology have allowed soil samples to be loaded in the torsional mode to the nonlinear strain range of most soils. However, the effect of this nonlinearity on data interpretation from these tests has been given only limited attention. In an effort to investigate systematically this problem, the U. S. Geological Survey undertook a study in which the torque-twist curves from various stress-strain relations for soils were computed and the effective shear modulus and hysteretic damping based on these torque-twist curves were examined. Results and recommendations concerning data interpretation from that study were presented in an earlier report (Chen and Stokoe, 1979). The computer program, DITT, that was used to generate torque-twist curves and associated results is the subject of this report.

DITT can be used for two purposes. It can be used to compute torque-twist relations for torsional vibration analysis of cylindrical test specimens of materials not restricted only to soils. DITT can also be used to estimate correction factors of shear modulus and hysteretic damping for interpreting torsional testing data. In the following sections, a general description, the input requirements, and the listing of the computer program are presented. In addition, results from a sample computer run are shown.

GENERAL DESCRIPTION

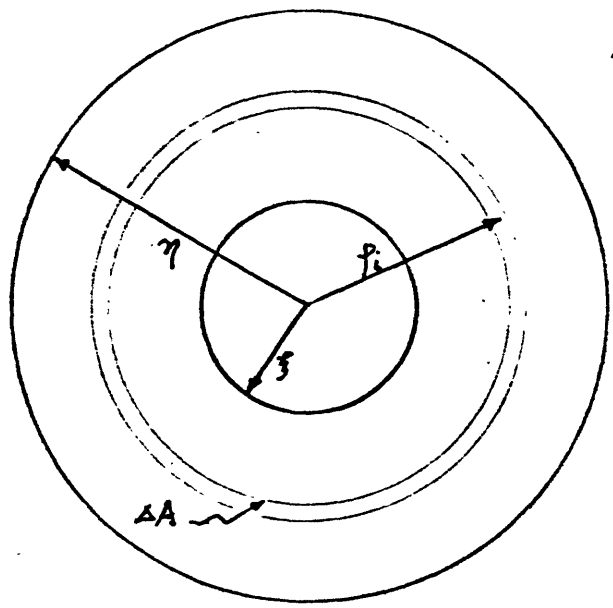
The program accepts any type of input stress-strain relation assigned to the soil under consideration and considers both solid and hollow cylindrical soil samples of circular cross-section. If the input stress-strain relation is not the modified Hardin and Drnevich (H&D) type with parameters a and b (Hardin and Drnevich, 1972) or the Ramberg-Osgood (R&O) type with parameters α, R and C1 (Richart, 1975), the stress-strain relation is input in a piecewise-linear manner (the multi-linear case, Chen and Joyner, 1974).

To compute the torque, T, on a given circular cross-section due to a given twist per unit length, Ø, DITT divides the cross-section into a specified number of concentric rings of equal areas, computes the average strain and stress on each ring, and determines the sum of the torque on each ring by using:

$$T = \sum_{i=1}^{N} (\tau_i \cdot \Delta A) \cdot \rho_i \qquad (1)$$

where T is the torque on the total cross-section, N is the number of subdivisions, τ_i is the average shear stress in the i^{th} ring, and ΔA and ρ_i are the area and the average radius of the i^{th} ring, respectively, as shown in Fig. 1. Note that τ_i is specified by the input stress-strain relation for an average shear strain of γ_i which is

$$\gamma_i = \rho_i \cdot \phi \qquad (2)$$



No. OF SUBDIVISIONS : N

TOTAL AREA : $A = \pi(\eta^2 - \xi^2)$

AREA OF EACH SUBDIVISION : $\Delta A = \frac{A}{N}$

Figure 1. — Definition of terms used with a circular cross-section.

For comparison purposes, shear stress and shear strain at the periphery (the outermost ring from the center), τ_η and γ_η, are chosen as reference values. Shear modulus, $G(\gamma_\eta)$, and damping ratio, $\lambda(\gamma_\eta)$, are then computed with respect to these reference values. The use of these reference values enables the investigator to relate quantities determined from the τ-γ plane with those determined from the T-Ø plane through Eq.(2).

Normalized quantities associated with the τ-γ plane are defined as:

$$\tau' = \tau/\tau_{max} \qquad \text{(normalized stress)}$$

$$G' = G/G_{max} \qquad \text{(normalized modulus)} \tag{3}$$

$$\gamma' = \gamma/\gamma_{max} \qquad \text{(normalized strain)}$$

where τ_{max} and G_{max} are, respectively, the maximum shear stress and the maximum shear modulus, and γ_{ref}, the reference strain, is defined as:

$$\gamma_{ref} = \tau_{max}/G_{max} \tag{4}$$

On the T-Ø plane, effective shear modulus, G_{eff}, is defined as:

$$G_{eff} = T/(J*Ø) \tag{5}$$

where

$$J = \int_A \rho^2 \cdot dA \tag{6}$$

is the polar moment of inertia of the cross section.

Normalized quantities associated with the T-Ø plane are:

$$T' = T/T_{ref} \qquad \text{(normalized torque)}$$

$$\phi' = \phi/\phi_{ref} \qquad \text{(normalized twist)} \tag{7}$$

$$G'_{eff} = G_{eff}/G_{max} \qquad \text{(normalized effective modulus)}$$

where, taking η as the outside radius of the specimen,

$$\phi_{ref} = \gamma_{ref}/\eta \tag{8}$$

is the reference twist, and

$$T_{ref} = J \cdot G_{max} \cdot \phi_{ref} \tag{9}$$

is the reference torque.

Damping ratios are determined on the basis of the energy lost per strain (twist) cycle as a result of the hysteresis loop generated on the τ-γ (or T-Ø) plane. The damping ratio, $\lambda(\gamma_\eta)$ (or λ_{eff} as in the case of T-Ø plane), is computed according to:

$$\lambda = A_L/(4\pi \cdot A_T) \tag{10}$$

where A_L and A_T are, respectively, areas of the loop and the triangle as

shown in Fig. 2. The shape of the loop is assumed to follow Masing's criterion (Masing, 1926). It should be noted that, for small strains, most input stress-strain relations are essentially linear and the value of A_L in Eq.(10) becomes very small or zero. Any computation involving the damping in this small strain range may thus become unreliable. When this situation occurs, the program replaces these unreliable values by 9.99 or 9.9999 to alert the user.

The equivalent radius for modulus or damping is defined as the radius at which the shear strain corresponds to a shear modulus or damping ratio on the τ-γ plane which is equal to G_{eff} or λ_{eff}. Equivalent radii are determined by iteration in DITT and their use is presented elsewhere together with the advantages of using normalized quantities (Chen and Stokoe, 1979).

Quantities defined so far are all dependent on the variable Ø. To assure that the proper range of interest in Ø is covered while computing, Ø is assigned such that its normalized value has 20 equal increments per logarithmic cycle that ranges from $Ø'=10^{-3}$ to $Ø'=10^{+3}$. The results are stored in a 16x121 matrix which is used for printer output or plotting.

DITT is coded in FORTRAN IV for the IBM 370 system. The program contains 281 source statements and requires a storage allocation of 50K bytes. Execution time for each run is less than 6 seconds. Without the addition of subroutines, the program can be easily modified to suit special individual needs or other computing devices.

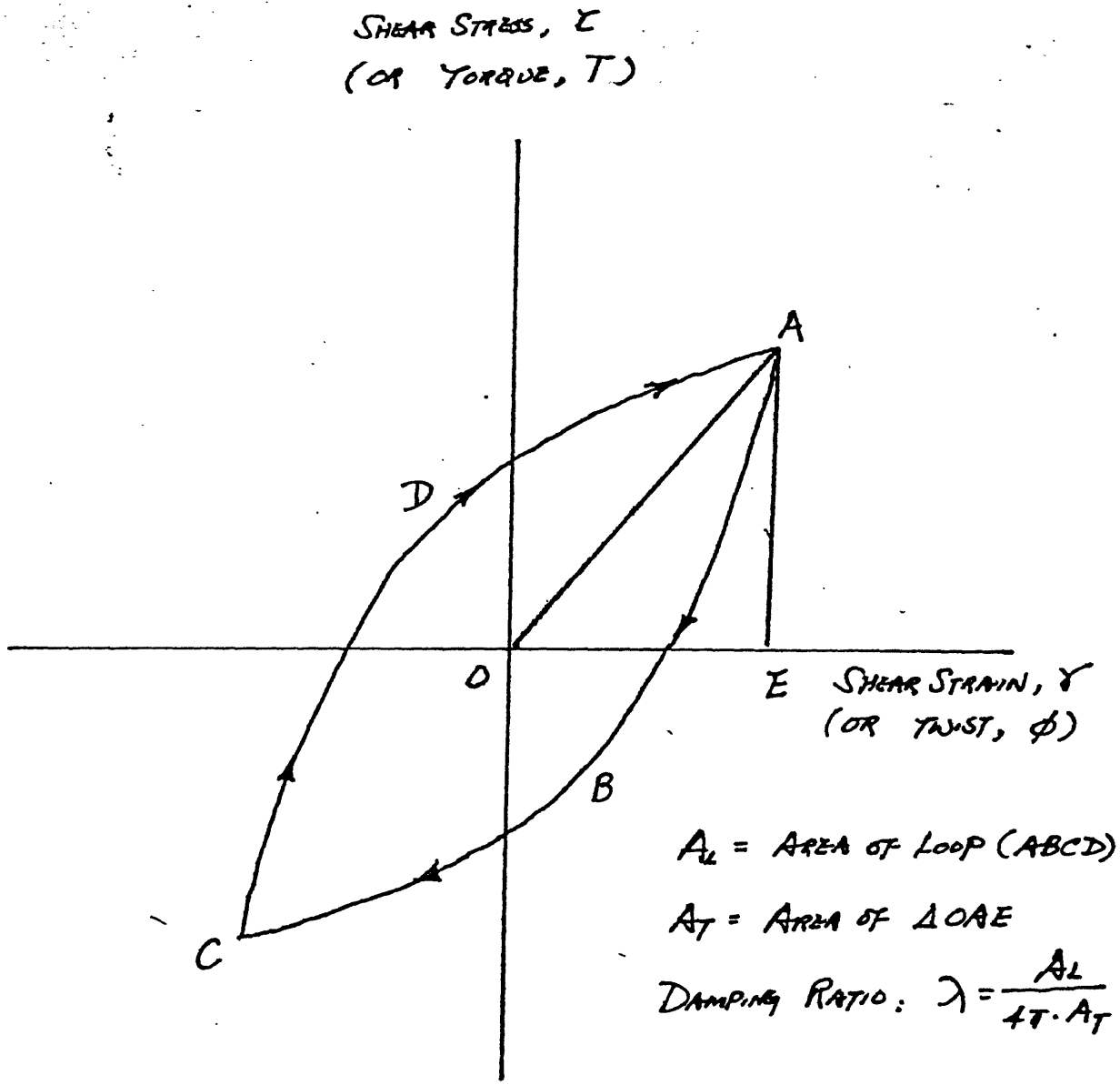


Figure 2. -- Definition of hysteretic damping.

INPUT REQUIREMENTS

In most cases, DITT requires three input data cards. In the multi-linear case, however, the third input data card is replaced by M cards where M is the number of linear segments in the input multi-linear stress-strain relation.

Card 1 FORMAT(18A4)

col 1-72 Title of computation for identification.

Card 2 FORMAT(4F12.0,2I6)

col 1-12 Outside sample radius in cm.
col 13-24 Inside sample radius in cm (=0.0, for solid samples).
col 25-36 Gmax in KPa.
col 37-48 Tmax in KPa.
col 49-54 KTYPE $\geq$ 0, an index to specify type of stress-strain input.
col 58-60 N $\geq$ 101, the number of subdivisions needed (see Eq. 1).

If KTYPE=0, the use of modified H&D relation is specified and the program reads:

Card 3 FORMAT(2F12.0)

col 1-12 Parameter a of the modified H&D relation.
col 13-24 Parameter b of the modified H&D relation.

If KTYPE=1, the use of the R&O relation is specified and the program reads:

Card 3 FORMAT(3F12.0)

col 1-12 Parameter α of the R&O relation.
col 13-24 Parameter R of the R&O relation.
col 25-36 Parameter C1 of the R&O relation.

If KTYPE=M, and M is greater than 1, the multi-linear relation is specified and the program reads M pairs of non-zero, normalized strain, γ', and normalized stress, τ', in the order of increasing strain:

Cards 3(I) I=1,M FORMAT(2F12.0)

col 1-12 The I^{th} normalized strain value.
col 13-24 The I^{th} normalized stress value.

REFERENCES CITED

Chen, A. T. F., and Stokoe, K. H., II, 1979, Interpretation of strain-dependent modulus and damping from torsional soil tests: Report No. USGS-GS-79-002, NTIS, Clearinghouse, Springfield, VA 22151, 45 pages.

Chen, A. T. F., and Joyner, W. B., 1974, Multi-linear analysis for ground motion studies of layered systems: Report No. USGS-GD-74-020, NTIS No. PB232-704/AS, Clearinghouse, Springfield, VA 22151, 48 pages.

Hardin, B. O., and Drnevich, V. P., 1972, Shear modulus and damping in soils -- design equations and curves: Journal of the Soil Mechanics and Foundations Division, ASCE, vol. 98, no. SM7, Proc. Paper 9006, July, pp. 667-692.

Masing, G., 1926, Eigenspannugen und verfestigung beim messing: Proceedings of the Second International Congress of Applied Mechanics, pp. 160-195

Richart F. E., Jr., 1975, Some effects of dynamic properties on soil-structure interaction: Journal of the Geotechnical Engineering Division, ASCE, vol. 101, no. GT12, Proc. Paper 11764, December, pp. 1193-1240.

SOURCE LISTING

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C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C*                                                                        *
C*  DITT: DATA INTERPRETATION FOR TORSIONAL TESTS                         *
C*                                                                        *
C*        6/79, BY ALBERT T. F. CHEN,  U. S. GEOLOGICAL SURVEY, MS74      *
C*                                     345 MIDDLEFIELD ROAD               *
C*                                     MENLO PARK, CA 94025               *
C*                                                                        *
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C
C
C  REQUIRED UNITS FOR I-O PARAMETERS:
C
C                   RADIUS, AREAS -- CM, CM*CM
C                   ALL G'S, ALL TAU'S -- KPA (1 PA = 10 DYNES/CM/CM)
C                   PHY, ANGLE OF TWIST/UNIT LENGTH -- RAD/CM
C                   TORQUE -- NEWTONS-CM
C
      REAL*8 YINT, RO
      DIMENSION R(201), RB(101), RC(101), XQ(16,126), TITLE(18),
     &ICOUNT(101), SIGY(103), EM(103), XX(127), YY(127)
C
    2 FORMAT('1'///5X,'TORQUE, TWIST AND RELATED CALCULATIONS * * *'//)
    4 FORMAT(18A4)
    6 FORMAT(4F12.0, 2I6)
    8 FORMAT(3F12.0)
   10 FORMAT(2F12.0)
   12 FORMAT(5X,18A4)
   14 FORMAT(//10X,'            OUTSIDE SAMPLE RADIUS, RO=',F7.3,' CM.'
     &/10X,'          INSIDE SAMPLE RADIUS, RI=',F7.3,' CM.'
     &/10X, '            NUMBER OF DIVISIONS, N =',I4
     &/10X, '          OUTER MOST RADIUS, RC(N) =',F8.5,' CM'
     &//10X,'TOTAL CROSS-SECTIONAL AREA, ATOTAL =',F9.3,' SQ.CM.'
     &/10X, '      POLAR MOMENT OF INERTIA, PMI =',F9.3,' CM**4.'
     &//10X,'   INPUT MAX. SHEAR MODULUS, GMAX =',E11.4,' KPA'
     &/10X, '   INPUT MAX. SHEAR STRESS, TAUMAX =',E11.4,' KPA'
     &//10X,'          REFERENCE STRAIN, GMAREF =',E11.4,' ABSOLUTE'
     &/10X, '    REFERENCE TWIST/LENGTH, PHYREF =',E11.4,' RAD/CM'
     &/10X, '          REFERENCE TORQUE, TRQREF =',E11.4,' NEWTONS-CM')
   16 FORMAT(/5X,'HARDIN-DRNEVICH RELATION, A=',F10.6,'  B=',F9.6)
   18 FORMAT(/5X,'RAMBERG-OSGOOD PARAMETERS ARE (A,R,C1):',3F8.3//)
   20 FORMAT(' INPUT FOR N-LINEAR RELATION:  I    YIELD STRAIN      ',
     & 'YIELD STRESS'/(30X,I3,2E14.5))
   22 FORMAT(12X,'1',13X,'2',13X,'3',13X,'4',13X,'5',13X,'6',13X,'7',
     & 13X,'8')
   24 FORMAT(8X,'STRAIN AT',5X,'STRESS AT',4X,'SECANT SHEAR',4X
     & 'HYSTERETIC',4X,'TWIST PER',18X,'EFFECTIVE',5X,'EFFECTIVE'/8X
     & 'PERIPHERY',5X,'PERIPHERY',6X,'MODULUS',5X,'DAMPING RATIO',2X
     & 'UNIT LENGTH',5X,'TORQUE',7X,'MODULUS',7X,'DAMPING'/'  I',5X,
     & '(ABSOLUTE)',6X,'(KPA)',9X,'(KPA)',7X,'(ABSOLUTE)',5X,
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     & '(RAD/CM)',4X,'(NEWTONS-CM)',5X,'(KPA)',7X,'(ABSOLUTE)  I'/)      DITT051
  26 FORMAT(8X,'NORMALIZED',4X,'NORMALIZED',4X,'NORMALIZED',4X,          DITT052
     & 'NORMALIZED',5X,'EFFECTIVE',4X,'EQUIVALENT',5X,'RATIO IN',5X,     DITT053
     & 'EQUIVALENT'/9X,'STRAIN',9X,'STRESS',8X,'TWIST',8X,'TORQUE',6X,   DITT054
     & 'MODULUS RATIO',' RADIUS RATIO',5X,'DAMPING',4X,'RADIUS RATIO'/   DITT055
     & '  I  (1)/REF.STRAIN',3X,'(2)/TAUMAX',3X,'(5)/REF.TWIST',         DITT056
     & ' (6)/REF.TORQ',5X,'(3)/(7)',6X,'(MODULUS)',6X,'(4)/(8)',5X,     DITT057
     & '(DAMPING)',3X,'I'/)                                             DITT058
  28 FORMAT(13X,'9',12X,'10',12X,'11',12X,'12',12X,'13',12X,'14',12X,   DITT059
     & '15',12X,'16')                                                   DITT060
  30 FORMAT(I4,8E14.5,I4)                                               DITT061
  42 FORMAT('1    ')                                                    DITT062
  44 FORMAT('      ')                                                   DITT063
C                                                                       DITT064
C         READ ALL INPUT DATA                                           DITT065
C                                                                       DITT066
  50 READ(5,4,END=2000) TITLE                                           DITT067
     READ(5,6) RADOU, RADIN, GMAX, TAUMAX, KTYPE, N                     DITT068
     IF(KTYPE .EQ. 0) READ(5,8) AHD, BHD                                DITT069
     IF(KTYPE .EQ. 1) READ(5,8) AAA, BBB, CCC                           DITT070
     IF(KTYPE .GT. 1) READ(5,10) (EM(I), SIGY(I), I=1,KTYPE)            DITT071
C                                                                       DITT072
     WRITE(6,2)                                                         DITT073
     WRITE(6,12) TITLE                                                  DITT074
C                                                                       DITT075
     PI = 3.1415927                                                     DITT076
     ISTOP = 121                                                        DITT077
     B1 = BBB - 1.0                                                     DITT078
     ATOTAL = PI*(RADOU**2-RADIN**2)                                    DITT079
     PMI = 0.5*PI*(RADOU**4-RADIN**4)                                   DITT080
     AREAIN = PI*RADIN*RADIN                                            DITT081
     N2 = 2 * N                                                         DITT082
     DA = ATOTAL/N                                                      DITT083
     DO 100 I=1,N2                                                      DITT084
     ATEMP = AREAIN + 0.50*DA*I                                         DITT085
     R(I) = SQRT(ATEMP/PI)                                              DITT086
 100 CONTINUE                                                           DITT087
     RB(1) = RADIN                                                      DITT088
     RADIUS = RADOU                                                     DITT089
     DO 200 I=1,N                                                       DITT090
     J = 2*I - 1                                                        DITT091
     K = 2*I                                                            DITT092
     RC(I) = R(J) * 1.                                                  DITT093
     RB(I+1) = R(K)*1.                                                  DITT094
     ICOUNT(I) = 1                                                      DITT095
 200 CONTINUE                                                           DITT096
     GMAREF = TAUMAX/GMAX                                               DITT097
     PHYREF = GMAREF/RADIUS                                             DITT098
     TRQREF = GMAX*PMI*PHYREF/10.                                       DITT099
     PHYSTR = 0.001*PHYREF                                              DITT100
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      PHYSTP = 10000.*PHYREF                                            DITT101
C                                                                       DITT102
      WRITE(6,14) RADOU,RADIN,N,RC(N),ATOTAL,PMI,GMAX,TAUMAX,GMAREF,    DITT103
     & PHYREF,TRQREF                                                    DITT104
      WRITE(6,44)                                                       DITT105
      IF(KTYPE .EQ. 0) WRITE(6,16) AHD, BHD                             DITT106
      IF(KTYPE .EQ. 1) WRITE(6,18) AAA, BBB, CCC                        DITT107
      IF(KTYPE .GT. 1) WRITE(6,20) (EM(I), SIGY(I), I=1,KTYPE)          DITT108
C                                                                       DITT109
      IF(KTYPE .NE. 0) GO TO 450                                        DITT110
C                                                                       DITT111
C          KTYPE = 0, CASE OF H&D                                       DITT112
      DO 420 I=1,ISTOP                                                  DITT113
      PHYEXP = 0.05*(I-1)                                               DITT114
      PHYO = PHYSTR*10.0**PHYEXP                                        DITT115
      SUM = 0.0                                                         DITT116
      DO 400 J=1,N                                                      DITT117
      GMA = PHYO * RC(J)                                                DITT118
      ARG = BHD*GMA/GMAREF                                              DITT119
      IF(ARG .GT. 88.0) GO TO 380                                       DITT120
      HYGMA = GMA*(1.+AHD*EXP(-ARG))/GMAREF                             DITT121
      GO TO 390                                                         DITT122
  380 HYGMA = GMA/GMAREF                                                DITT123
  390 TAU = GMAX*GMA/(1.+HYGMA)                                         DITT124
      DM = TAU*DA*RC(J)/10.                                             DITT125
  400 SUM = SUM + DM                                                    DITT126
C                                                                       DITT127
      XQ(1,I) = GMA                                                     DITT128
      XQ(2,I) = TAU                                                     DITT129
      XQ(3,I) = TAU/GMA                                                 DITT130
      XQ(5,I) = PHYO                                                    DITT131
      XQ(6,I) = SUM                                                     DITT132
      XQ(7,I) = 10.*SUM/PHYO/PMI                                        DITT133
      XQ(9,I) = GMA/GMAREF                                              DITT134
      XQ(10,I) = TAU/TAUMAX                                             DITT135
      XQ(11,I) = PHYO/PHYREF                                            DITT136
      XQ(12,I) = SUM/TRQREF                                             DITT137
      XQ(13,I) = XQ(3,I)/XQ(7,I)                                        DITT138
  420 CONTINUE                                                          DITT139
      GO TO 600                                                         DITT140
C                                                                       DITT141
C          FOR R&O, OR MULTI-LINEAR CASES                               DITT142
  450 IF(KTYPE .GT. 1) GO TO 465                                        DITT143
      SIGY(1) = 0.0                                                     DITT144
      EM(1) = 0.0                                                       DITT145
      DO 460 J=2,102                                                    DITT146
      RAEXP = 0.02*(J-2)                                                DITT147
      RATIO = 0.01*10.0**RAEXP                                          DITT148
      ARG = RATIO/CCC                                                   DITT149
      SIGY(J) = RATIO*TAUMAX                                            DITT150
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      EM(J) = CCC*GMAREF*ARG*(1.+AAA*ARG**B1)                                  DITT151
  460 CONTINUE                                                                 DITT152
      IMAX = 102                                                               DITT153
      GO TO 475                                                                DITT154
  465 IMAX = KTYPE                                                             DITT155
      EM(1) = 0.0                                                              DITT156
      SIGY(1) = 0.0                                                            DITT157
      DO 470 I=2, IMAX                                                         DITT158
      SIGY(I) = SIGY(I)*TAUMAX                                                 DITT159
      EM(I) = EM(I)*GMAREF                                                     DITT160
  470 CONTINUE                                                                 DITT161
  475 CONTINUE                                                                 DITT162
      DO 580 I=1,ISTOP                                                         DITT163
      PHYEXP = 0.05*(I-1)                                                      DITT164
      PHYO = PHYSTR*10.0**PHYEXP                                               DITT165
      SUM = 0.0                                                                DITT166
      DO 560 J=1,N                                                             DITT167
      GMA = PHYO * RC(J)                                                       DITT168
  510 JC = ICOUNT(J)                                                           DITT169
      IF(JC .GE. IMAX) GO TO 530                                               DITT170
      IF(GMA .LE. EM(JC+1)) GO TO 520                                          DITT171
      ICOUNT(J) = JC+1                                                         DITT172
      GO TO 510                                                                DITT173
  520 TAU=SIGY(JC)+(GMA-EM(JC))*(SIGY(JC+1)-SIGY(JC))/(EM(JC+1)-EM(JC))        DITT174
      GO TO 540                                                                DITT175
  530 TAU = TAUMAX                                                             DITT176
  540 DM = TAU*DA*RC(J)/10.                                                    DITT177
  560 SUM = SUM + DM                                                           DITT178
C        DM IS THE TORQUE TAKEN BY ITH RING, IN NEWTONS-CM                     DITT179
C                                                                              DITT180
      XQ(1,I) = GMA                                                            DITT181
      XQ(2,I) = TAU                                                            DITT182
      XQ(3,I) = TAU/GMA                                                        DITT183
      XQ(5,I) = PHYO                                                           DITT184
      XQ(6,I) = SUM                                                            DITT185
      XQ(7,I) = 10.*SUM/PHYO/PMI                                               DITT186
      XQ(9,I) = GMA/GMAREF                                                     DITT187
      XQ(10,I) = TAU/TAUMAX                                                    DITT188
      XQ(11,I) = PHYO/PHYREF                                                   DITT189
      XQ(12,I) = SUM/TRQREF                                                    DITT190
      XQ(13,I) = XQ(3,I)/XQ(7,I)                                               DITT191
  580 CONTINUE                                                                 DITT192
C                                                                              DITT193
  600 CONTINUE                                                                 DITT194
      DO 850 I=1,ISTOP                                                         DITT195
      GPK = XQ(7,I)                                                            DITT196
      DO 650 LOOP=1,I                                                          DITT197
      JM = I-LOOP                                                              DITT198
      IF(GPK .LE. XQ(3,JM)) GO TO 700                                          DITT199
  650 CONTINUE                                                                 DITT200
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  700 JSET = JM                                                          DITT201
      IF(JSET .EQ. 0) GO TO 750                                          DITT202
      DENO = XQ(3,JSET+1)-XQ(3,JSET)                                     DITT203
      IF(DENO .GE. 0.0) GO TO 750                                        DITT204
      DGRT = (GPK-XQ(3,JSET))/DENO                                       DITT205
      RHS = ALOG(XQ(1,JSET)) + 0.05*DGRT*2.302585                        DITT206
      GMAEQ = EXP(RHS)                                                   DITT207
      XQ(14,I) = GMAEQ/XQ(1,I)                                           DITT208
      GO TO 800                                                          DITT209
  750 XQ(14,I) = 1.0                                                     DITT210
  800 CONTINUE                                                           DITT211
  850 CONTINUE                                                           DITT212
C                                                                        DITT213
C      FOR DAMPING COMPUTATION                                           DITT214
C                                                                        DITT215
      DO 1200 II=1,2                                                     DITT216
      I=2                                                                DITT217
      I1=1                                                               DITT218
      IF(II .EQ. 2) I=6                                                  DITT219
      IF(II .EQ. 2) I1=5                                                 DITT220
      DO 1000 JLOOP=2,ISTOP                                              DITT221
      XX(1) = -XQ(I1,JLOOP)                                              DITT222
      X0 = XX(1)                                                         DITT223
      Y0 = -XQ(I,JLOOP)                                                  DITT224
      YY(1) = 0.0                                                        DITT225
      R0 = Y0/X0                                                         DITT226
      DO 900 J=1,JLOOP                                                   DITT227
      XX(J+1) = X0 + 2.*XQ(I1,J)                                         DITT228
      YINT = R0*XX(J+1)                                                  DITT229
      YY(J+1) = Y0 + 2.*XQ(I,J) - YINT                                   DITT230
  900 CONTINUE                                                           DITT231
      SUM = 0.0                                                          DITT232
      DO 950 J=1,JLOOP                                                   DITT233
      DSUM = 0.5*(YY(J)+YY(J+1))*(XX(J+1)-XX(J))                         DITT234
      SUM = SUM + DSUM                                                   DITT235
  950 CONTINUE                                                           DITT236
      JJJ=JLOOP+1                                                        DITT237
      XQ(II*4,JLOOP) = SUM/(1.*PI*X0*Y0)                                 DITT238
 1000 CONTINUE                                                           DITT239
      XQ(II*4,1) = 0.0                                                   DITT240
 1200 CONTINUE                                                           DITT241
C                                                                        DITT242
      XQ(15,1) = 9.9999                                                  DITT243
      XQ(16,1) = 9.99                                                    DITT244
      DO 1600 J=2,ISTOP                                                  DITT245
      IF(XQ(8,J) .EQ. 0.0) GO TO 1300                                    DITT246
      XQ(15,J) = XQ(4,J)/XQ(8,J)                                         DITT247
      GO TO 1350                                                         DITT248
 1300 XQ(15,J) = 9.9999                                                  DITT249
 1350 DPK = XQ(8,J)                                                      DITT250
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      IF(DPK .LE. 0.0) GO TO 1500                                          DITT251
      DO 1400 LOOP = 1,J                                                   DITT252
      JM = J - LOOP                                                        DITT253
      IF(DPK .LE. 0.0) GO TO 1500                                          DITT254
      IF(DPK .GE. XQ(4,JM)) GO TO 1450                                     DITT255
 1400 CONTINUE                                                             DITT256
 1450 JSET = JM                                                            DITT257
      IF(XQ(4,JSET) .LE. 0.0) GO TO 1500                                   DITT258
      DDRT = (DPK-XQ(4,JSET))/(XQ(4,JSET+1)-XQ(4,JSET))                    DITT259
      RHS = ALOG(XQ(1,JSET)) + 0.05*DDRT*2.302585                          DITT260
      GMAEQ = EXP(RHS)                                                     DITT261
      XQ(16,J) = GMAEQ/XQ(1,J)                                             DITT262
      GO TO 1550                                                           DITT263
 1500 XQ(16,J) = 9.99                                                      DITT264
 1550 CONTINUE                                                             DITT265
 1600 CONTINUE                                                             DITT266
C                                                                          DITT267
      WRITE(6,42)                                                          DITT268
      WRITE(6,22)                                                          DITT269
      WRITE(6,24)                                                          DITT270
      DO 1700 I=1,ISTOP                                                    DITT271
      WRITE(6,30) I,(XQ(JK,I),JK=1,8),I                                    DITT272
 1700 CONTINUE                                                             DITT273
      WRITE(6,42)                                                          DITT274
      WRITE(6,28)                                                          DITT275
      WRITE(6,26)                                                          DITT276
      DO 1800 I =1,ISTOP                                                   DITT277
      WRITE(6,30) I,(XQ(JK,I),JK=9,16),I                                   DITT278
 1800 CONTINUE                                                             DITT279
      GO TO 50                                                             DITT280
 2000 STOP                                                                 DITT281
      END                                                                  DITT282
```

SAMPLE PROBLEM

To illustrate the use of DITT, a sample problem is prepared and presented in this section. The problem considers a solid cylindrical soil specimen with an outside radius of 4.0 cm. The soil has a maximum shear modulus of 50000 KPa, a maximum shear stress of 100KPa, and is described by the H&D hyperbolic relation (KTYPE=0 with both parameters, a and b, equal to 0.0). The number of subdivisions, N, is set at 50. Input data cards for this problem thus are:

```
Column   1         2         3         4         5         6         7
12345678901234567890123456789012345678901234567890123456789012345678901234567890

 DITT: SAMPLE RUN, 7/07/79                                          (Card 1)

     4.0         0.0      50000.0         100.0         0    50    (Card 2)

     0.0         0.0                                               (Card 3)
```

The computer output for this problem is included next. Since the output is quite self-explanatory, no further remarks are necessary.

TORQUE, TWIST AND RELATED CALCULATIONS * * *

DITT: SAMPLE RUN, 7/07/79

OUTSIDE SAMPLE RADIUS, RO= 4.000 CM.
INSIDE SAMPLE RADIUS, RI= 0.0 CM.
NUMBER OF DIVISIONS, N = 50
OUTER MOST RADIUS, RC(N) = 3.97995 CM

TOTAL CROSS-SECTIONAL AREA, ATOTAL = 50.265 SQ.CM.
POLAR MOMENT OF INERTIA, PMI = 402.124 CM**4.

INPUT MAX. SHEAR MODULUS, GMAX = 0.5000E 05 KPA
INPUT MAX. SHEAR STRESS, TAUMAX = 0.1000E 03 KPA

REFERENCE STRAIN, GMAREF = 0.2000E-02 ABSOLUTE
REFERENCE TWIST/LENGTH, PHYREF = 0.5000E-03 RAD/CM
REFERENCE TORQUE, TRQREF = 0.1005E 04 NEWTONS-CM

HARDIN-DRNEVICH RELATION, A= 0.0 B= 0.0

I	1 STRAIN AT PERIPHERY (ABSOLUTE)	2 STRESS AT PERIPHERY (KPA)	3 SECANT SHEAR MODULUS (KPA)	4 HYSTERETIC DAMPING RATIO (ABSOLUTE)	5 TWIST PER UNIT LENGTH (RAD/CM)	6 TORQUE (NEWTONS-CM)	7 EFFECTIVE MODULUS (KPA)	8 EFFECTIVE DAMPING (ABSOLUTE)	I
1	0.19900E-05	0.99400E-01	0.49950E 05	0.0	0.50000E-06	0.10045E 01	0.49960E 05	0.0	1
2	0.22328E-05	0.11151E 00	0.49944E 05	0.68475E-04	0.56101E-06	0.11270E 01	0.49955E 05	0.55816E-04	2
3	0.25052E-05	0.12510E 00	0.49937E 05	0.13177E-03	0.62946E-06	0.12643E 01	0.49949E 05	0.10701E-03	3
4	0.28109E-05	0.14035E 00	0.49930E 05	0.19106E-03	0.70627E-06	0.14184E 01	0.49943E 05	0.15464E-03	4
5	0.31539E-05	0.15745E 00	0.49921E 05	0.24924E-03	0.79245E-06	0.15913E 01	0.49936E 05	0.20168E-03	5
6	0.35387E-05	0.17662E 00	0.49912E 05	0.30705E-03	0.88914E-06	0.17852E 01	0.49929E 05	0.24796E-03	6
7	0.39705E-05	0.19813E 00	0.49901E 05	0.36604E-03	0.99763E-06	0.20026E 01	0.49920E 05	0.29480E-03	7
8	0.44550E-05	0.22225E 00	0.49889E 05	0.42782E-03	0.11194E-05	0.22466E 01	0.49910E 05	0.34468E-03	8
9	0.49986E-05	0.24931E 00	0.49875E 05	0.49381E-03	0.12559E-05	0.25201E 01	0.49899E 05	0.39771E-03	9
10	0.56085E-05	0.27964E 00	0.49860E 05	0.56512E-03	0.14092E-05	0.28270E 01	0.49887E 05	0.45442E-03	10
11	0.62928E-05	0.31366E 00	0.49843E 05	0.64266E-03	0.15811E-05	0.31710E 01	0.49874E 05	0.51669E-03	11
12	0.70607E-05	0.35179E 00	0.49824E 05	0.72750E-03	0.17741E-05	0.35569E 01	0.49858E 05	0.58510E-03	12
13	0.79222E-05	0.39455E 00	0.49803E 05	0.82187E-03	0.19905E-05	0.39895E 01	0.49841E 05	0.66107E-03	13
14	0.88889E-05	0.44248E 00	0.49779E 05	0.92657E-03	0.22334E-05	0.44745E 01	0.49822E 05	0.74479E-03	14
15	0.99735E-05	0.49620E 00	0.49752E 05	0.10424E-02	0.25059E-05	0.50183E 01	0.49800E 05	0.83789E-03	15
16	0.11190E-04	0.55641E 00	0.49722E 05	0.11726E-02	0.28117E-05	0.56279E 01	0.49776E 05	0.94204E-03	16
17	0.12556E-04	0.62388E 00	0.49688E 05	0.13167E-02	0.31548E-05	0.63112E 01	0.49749E 05	0.10586E-02	17
18	0.14088E-04	0.69947E 00	0.49650E 05	0.14790E-02	0.35397E-05	0.70769E 01	0.49718E 05	0.11888E-02	18
19	0.15807E-04	0.78415E 00	0.49608E 05	0.16599E-02	0.39716E-05	0.79350E 01	0.49684E 05	0.13346E-02	19
20	0.17736E-04	0.87899E 00	0.49561E 05	0.18625E-02	0.44562E-05	0.88964E 01	0.49646E 05	0.14975E-02	20
21	0.19900E-04	0.98518E 00	0.49507E 05	0.20897E-02	0.50000E-05	0.99733E 01	0.49603E 05	0.16805E-02	21
22	0.22328E-04	0.11041E 01	0.49448E 05	0.23444E-02	0.56101E-05	0.11179E 02	0.49555E 05	0.18851E-02	22
23	0.25052E-04	0.12371E 01	0.49381E 05	0.26290E-02	0.62946E-05	0.12530E 02	0.49502E 05	0.21145E-02	23
24	0.28109E-04	0.13860E 01	0.49307E 05	0.29480E-02	0.70627E-05	0.14042E 02	0.49441E 05	0.23715E-02	24
25	0.31539E-04	0.15525E 01	0.49224E 05	0.33046E-02	0.79245E-05	0.15734E 02	0.49374E 05	0.26588E-02	25
26	0.35387E-04	0.17386E 01	0.49131E 05	0.37053E-02	0.88914E-05	0.17626E 02	0.49299E 05	0.29814E-02	26
27	0.39705E-04	0.19466E 01	0.49027E 05	0.41527E-02	0.99763E-05	0.19743E 02	0.49215E 05	0.33430E-02	27
28	0.44550E-04	0.21790E 01	0.48911E 05	0.46538E-02	0.11194E-04	0.22110E 02	0.49121E 05	0.37468E-02	28
29	0.49986E-04	0.24383E 01	0.48781E 05	0.52152E-02	0.12559E-04	0.24755E 02	0.49016E 05	0.41988E-02	29
30	0.56085E-04	0.27278E 01	0.48636E 05	0.58430E-02	0.14092E-04	0.27709E 02	0.48898E 05	0.47048E-02	30
31	0.62928E-04	0.30504E 01	0.48475E 05	0.65451E-02	0.15811E-04	0.31007E 02	0.48767E 05	0.52713E-02	31
32	0.70607E-04	0.34100E 01	0.48295E 05	0.73304E-02	0.17741E-04	0.34686E 02	0.48621E 05	0.59037E-02	32
33	0.79222E-04	0.38102E 01	0.48095E 05	0.82079E-02	0.19905E-04	0.38788E 02	0.48459E 05	0.66111E-02	33
34	0.88889E-04	0.42553E 01	0.47872E 05	0.91877E-02	0.22334E-04	0.43358E 02	0.48277E 05	0.74013E-02	34
35	0.99735E-04	0.47499E 01	0.47625E 05	0.10282E-01	0.25059E-04	0.48445E 02	0.48075E 05	0.82859E-02	35
36	0.11190E-03	0.52987E 01	0.47351E 05	0.11503E-01	0.28117E-04	0.54103E 02	0.47851E 05	0.92720E-02	36
37	0.12556E-03	0.59071E 01	0.47046E 05	0.12865E-01	0.31548E-04	0.60388E 02	0.47602E 05	0.10373E-01	37
38	0.14088E-03	0.65804E 01	0.46710E 05	0.14382E-01	0.35397E-04	0.67364E 02	0.47326E 05	0.11600E-01	38
39	0.15807E-03	0.73246E 01	0.46338E 05	0.16071E-01	0.39716E-04	0.75094E 02	0.47020E 05	0.12968E-01	39
40	0.17736E-03	0.81455E 01	0.45927E 05	0.17951E-01	0.44562E-04	0.83651E 02	0.46681E 05	0.14491E-01	40
41	0.19900E-03	0.90494E 01	0.45475E 05	0.20040E-01	0.50000E-04	0.93106E 02	0.46307E 05	0.16185E-01	41
42	0.22328E-03	0.10043E 02	0.44979E 05	0.22359E-01	0.56101E-04	0.10354E 03	0.45895E 05	0.18068E-01	42
43	0.25052E-03	0.11132E 02	0.44434E 05	0.24931E-01	0.62946E-04	0.11502E 03	0.45441E 05	0.20158E-01	43
44	0.28109E-03	0.12323E 02	0.43839E 05	0.27779E-01	0.70627E-04	0.12764E 03	0.44943E 05	0.22476E-01	44
45	0.31539E-03	0.13621E 02	0.43189E 05	0.30929E-01	0.79244E-04	0.14148E 03	0.44398E 05	0.25043E-01	45
46	0.35387E-03	0.15034E 02	0.42483E 05	0.34406E-01	0.88914E-04	0.15661E 03	0.43802E 05	0.27881E-01	46
47	0.39705E-03	0.16564E 02	0.41718E 05	0.38239E-01	0.99763E-04	0.17312E 03	0.43153E 05	0.31016E-01	47
48	0.44550E-03	0.18217E 02	0.40891E 05	0.42456E-01	0.11194E-03	0.19107E 03	0.42448E 05	0.34470E-01	48
49	0.49986E-03	0.19995E 02	0.40002E 05	0.47086E-01	0.12559E-03	0.21053E 03	0.41685E 05	0.38272E-01	49
50	0.56085E-03	0.21901E 02	0.39050E 05	0.52157E-01	0.14092E-03	0.23155E 03	0.40861E 05	0.42466E-01	50
51	0.62928E-03	0.23934E 02	0.38033E 05	0.57700E-01	0.15811E-03	0.25417E 03	0.39976E 05	0.47020E-01	51
52	0.70607E-03	0.26092E 02	0.36954E 05	0.63740E-01	0.17741E-03	0.27843E 03	0.39030E 05	0.52020E-01	52
53	0.79222E-03	0.28372E 02	0.35814E 05	0.70307E-01	0.19905E-03	0.30433E 03	0.38021E 05	0.57473E-01	53
54	0.88889E-03	0.30769E 02	0.34615E 05	0.77423E-01	0.22334E-03	0.33186E 03	0.36951E 05	0.63404E-01	54
55	0.99735E-03	0.33274E 02	0.33363E 05	0.85110E-01	0.25059E-03	0.36097E 03	0.35822E 05	0.69836E-01	55

56	0.11190E-02	0.35878E 02	0.32061E 05	0.93386E-01	0.28117E-03	0.39162E 03	0.34636E 05	0.76787E-01	56
57	0.12556E-02	0.38567E 02	0.30716E 05	0.10727E 00	0.31548E-03	0.42370E 03	0.33399E 05	0.84280E-01	57
58	0.14088E-02	0.41328E 02	0.29336E 05	0.11176E 00	0.35397E-03	0.45711E 03	0.32114E 05	0.92331E-01	58
59	0.15807E-02	0.44145E 02	0.27928E 05	0.12186E 00	0.39716E-03	0.49170E 03	0.30787E 05	0.10095E 00	59
60	0.17736E-02	0.47000E 02	0.26500E 05	0.13257E 00	0.44562E-03	0.52730E 03	0.29426E 05	0.11014E 00	60
61	0.19900E-02	0.49874E 02	0.25063E 05	0.14388E 00	0.50000E-03	0.56374E 03	0.28038E 05	0.11990E 00	61
62	0.22328E-02	0.52750E 02	0.23625E 05	0.15578E 00	0.56101E-03	0.60079E 03	0.26632E 05	0.13024E 00	62
63	0.25052E-02	0.55607E 02	0.22196E 05	0.16822E 00	0.62946E-03	0.63825E 03	0.25215E 05	0.14113E 00	63
64	0.28109E-02	0.58428E 02	0.20786E 05	0.18119E 00	0.70627E-03	0.67588E 03	0.23798E 05	0.15257E 00	64
65	0.31539E-02	0.61194E 02	0.19403E 05	0.19463E 00	0.79244E-03	0.71345E 03	0.22389E 05	0.16453E 00	65
66	0.35387E-02	0.63891E 02	0.18055E 05	0.20851E 00	0.88914E-03	0.75072E 03	0.20997E 05	0.17696E 00	66
67	0.39705E-02	0.66502E 02	0.16749E 05	0.22277E 00	0.99763E-03	0.78748E 03	0.19630E 05	0.18988E 00	67
68	0.44550E-02	0.69016E 02	0.15492E 05	0.23735E 00	0.11194E-02	0.82351E 03	0.18295E 05	0.20320E 00	68
69	0.49986E-02	0.71423E 02	0.14289E 05	0.25219E 00	0.12559E-02	0.85863E 03	0.17001E 05	0.21689E 00	69
70	0.56085E-02	0.73714E 02	0.13143E 05	0.26723E 00	0.14092E-02	0.89266E 03	0.15753E 05	0.23090E 00	70
71	0.62928E-02	0.75883E 02	0.12059E 05	0.28239E 00	0.15811E-02	0.92545E 03	0.14555E 05	0.24518E 00	71
72	0.70607E-02	0.77927E 02	0.11037E 05	0.29762E 00	0.17741E-02	0.95687E 03	0.13413E 05	0.25966E 00	72
73	0.79222E-02	0.79843E 02	0.10078E 05	0.31284E 00	0.19905E-02	0.98684E 03	0.12329E 05	0.27429E 00	73
74	0.88889E-02	0.81633E 02	0.91837E 04	0.32798E 00	0.22334E-02	0.10153E 04	0.11305E 05	0.28902E 00	74
75	0.99734E-02	0.83296E 02	0.83518E 04	0.34299E 00	0.25059E-02	0.10421E 04	0.10342E 05	0.30377E 00	75
76	0.11190E-01	0.84837E 02	0.75813E 04	0.35780E 00	0.28117E-02	0.10674E 04	0.94405E 04	0.31850E 00	76
77	0.12556E-01	0.86260E 02	0.68701E 04	0.37237E 00	0.31548E-02	0.10910E 04	0.86003E 04	0.33315E 00	77
78	0.14088E-01	0.87568E 02	0.62159E 04	0.38663E 00	0.35397E-02	0.11131E 04	0.78200E 04	0.34765E 00	78
79	0.15807E-01	0.88768E 02	0.56158E 04	0.40055E 00	0.39716E-02	0.11336E 04	0.70979E 04	0.36196E 00	79
80	0.17736E-01	0.89866E 02	0.50670E 04	0.41409E 00	0.44562E-02	0.11526E 04	0.64319E 04	0.37603E 00	80
81	0.19900E-01	0.90867E 02	0.45663E 04	0.42721E 00	0.50000E-02	0.11701E 04	0.58196E 04	0.38982E 00	81
82	0.22328E-01	0.91779E 02	0.41105E 04	0.43988E 00	0.56101E-02	0.11862E 04	0.52582E 04	0.40329E 00	82
83	0.25052E-01	0.92607E 02	0.36966E 04	0.45207E 00	0.62946E-02	0.12010E 04	0.47448E 04	0.41639E 00	83
84	0.28109E-01	0.93357E 02	0.33213E 04	0.46379E 00	0.70627E-02	0.12146E 04	0.42765E 04	0.42910E 00	84
85	0.31539E-01	0.94037E 02	0.29816E 04	0.47500E 00	0.79244E-02	0.12269E 04	0.38503E 04	0.44140E 00	85
86	0.35387E-01	0.94651E 02	0.26747E 04	0.48570E 00	0.88914E-02	0.12382E 04	0.34631E 04	0.45325E 00	86
87	0.39705E-01	0.95204E 02	0.23978E 04	0.49589E 00	0.99763E-02	0.12484E 04	0.31120E 04	0.46465E 00	87
88	0.44550E-01	0.95704E 02	0.21482E 04	0.50557E 00	0.11194E-01	0.12577E 04	0.27942E 04	0.47558E 00	88
89	0.49986E-01	0.96153E 02	0.19236E 04	0.51474E 00	0.12559E-01	0.12662E 04	0.25071E 04	0.48604E 00	89
90	0.56085E-01	0.96557E 02	0.17216E 04	0.52341E 00	0.14092E-01	0.12738E 04	0.22479E 04	0.49601E 00	90
91	0.62928E-01	0.96920E 02	0.15402E 04	0.53159E 00	0.15811E-01	0.12807E 04	0.20143E 04	0.50550E 00	91
92	0.70607E-01	0.97245E 02	0.13773E 04	0.53929E 00	0.17741E-01	0.12869E 04	0.18039E 04	0.51451E 00	92
93	0.79222E-01	0.97538E 02	0.12312E 04	0.54653E 00	0.19905E-01	0.12925E 04	0.16147E 04	0.52305E 00	93
94	0.88888E-01	0.97799E 02	0.11002E 04	0.55332E 00	0.22334E-01	0.12975E 04	0.14447E 04	0.53111E 00	94
95	0.99734E-01	0.98034E 02	0.98295E 03	0.55967E 00	0.25059E-01	0.13021E 04	0.12921E 04	0.53872E 00	95
96	0.11190E 00	0.98244E 02	0.87793E 03	0.56561E 00	0.28117E-01	0.13061E 04	0.11552E 04	0.54589E 00	96
97	0.12556E 00	0.98432E 02	0.78396E 03	0.57116E 00	0.31548E-01	0.13098E 04	0.10325E 04	0.55262E 00	97
98	0.14088E 00	0.98600E 02	0.69989E 03	0.57632E 00	0.35397E-01	0.13131E 04	0.92249E 03	0.55893E 00	98
99	0.15807E 00	0.98750E 02	0.62473E 03	0.58113E 00	0.39716E-01	0.13160E 04	0.82401E 03	0.56485E 00	99
100	0.17736E 00	0.98885E 02	0.55755E 03	0.58559E 00	0.44562E-01	0.13186E 04	0.73587E 03	0.57038E 00	100
101	0.19900E 00	0.99005E 02	0.49752E 03	0.58974E 00	0.50000E-01	0.13210E 04	0.65702E 03	0.57554E 00	101
102	0.22328E 00	0.99112E 02	0.44390E 03	0.59358E 00	0.56101E-01	0.13231E 04	0.58650E 03	0.58035E 00	102
103	0.25052E 00	0.99208E 02	0.39601E 03	0.59713E 00	0.62946E-01	0.13250E 04	0.52347E 03	0.58482E 00	103
104	0.28109E 00	0.99293E 02	0.35324E 03	0.60042E 00	0.70627E-01	0.13267E 04	0.46713E 03	0.58889E 00	104
105	0.31539E 00	0.99370E 02	0.31507E 03	0.60346E 00	0.79244E-01	0.13282E 04	0.41681E 03	0.59264E 00	105
106	0.35387E 00	0.99438E 02	0.28100E 03	0.60626E 00	0.88913E-01	0.13296E 04	0.37186E 03	0.59642E 00	106
107	0.39705E 00	0.99499E 02	0.25060E 03	0.60884E 00	0.99763E-01	0.13308E 04	0.33172E 03	0.59973E 00	107
108	0.44550E 00	0.99553E 02	0.22346E 03	0.61122E 00	0.11194E 00	0.13318E 04	0.29588E 03	0.60280E 00	108
109	0.49986E 00	0.99601E 02	0.19926E 03	0.61341E 00	0.12559E 00	0.13328E 04	0.26390E 03	0.60563E 00	109
110	0.56085E 00	0.99644E 02	0.17767E 03	0.61542E 00	0.14092E 00	0.13337E 04	0.23535E 03	0.60824E 00	110
111	0.62928E 00	0.99683E 02	0.15841E 03	0.61727E 00	0.15811E 00	0.13344E 04	0.20988E 03	0.61065E 00	111
112	0.70607E 00	0.99718E 02	0.14123E 03	0.61896E 00	0.17741E 00	0.13351E 04	0.18715E 03	0.61287E 00	112
113	0.79222E 00	0.99748E 02	0.12591E 03	0.62052E 00	0.19905E 00	0.13357E 04	0.16687E 03	0.61491E 00	113
114	0.88888E 00	0.99774E 02	0.11225E 03	0.62194E 00	0.22334E 00	0.13363E 04	0.14879E 03	0.61679E 00	114
115	0.99734E 00	0.99800E 02	0.10007E 03	0.62325E 00	0.25059E 00	0.13367E 04	0.13265E 03	0.61852E 00	115
116	0.11190E 01	0.99822E 02	0.89203E 02	0.62444E 00	0.28117E 00	0.13372E 04	0.11827E 03	0.62010E 00	116

117	0.12556E 01	0.99841E 02	0.79518E 02	0.62554E 00	0.31548E 00	0.13376E 04	0.10544E 03	0.62155E 00	117
118	0.14088E 01	0.99858E 02	0.70882E 02	0.62653E 00	0.35197E 00	0.13379E 04	0.93993E 02	0.62289E 00	118
119	0.15807E 01	0.99874E 02	0.63184E 02	0.62745E 00	0.39716E 00	0.13382E 04	0.83791E 02	0.62410E 00	119
120	0.17734E 01	0.99897E 02	0.56320E 02	0.62824E 00	0.44562E 00	0.13385E 04	0.74694E 02	0.62522E 00	120
121	0.19900E 01	0.99900E 02	0.50202E 02	0.62904E 00	0.50000E 00	0.13387E 04	0.66583E 02	0.62624E 00	121

I	9 NORMALIZED STRAIN (1)/REF.STRAIN	10 NORMALIZED STRESS (2)/TAUMAX	11 NORMALIZED TWIST (5)/REF.TWIST	12 NORMALIZED TORQUE (6)/REF.TORQ	13 EFFECTIVE MODULUS RATIO (3)/(7)	14 EQUIVALENT RADIUS RATIO (MODULUS)	15 RATIO IN DAMPING (4)/(8)	16 EQUIVALENT RADIUS RATIO (DAMPING)	I
1	0.99499E-03	0.99400E-03	0.10000E-02	0.99920E-03	0.99981E 00	0.10000E 01	0.99999E 01	0.99900E 01	1
2	0.11164E-02	0.11151E-02	0.11220E-02	0.11210E-02	0.99979E 00	0.10000E 01	0.12268E 01	0.99900E 01	2
3	0.12526E-02	0.12510E-02	0.12589E-02	0.12577E-02	0.99976E 00	0.80723E 00	0.12314E 01	0.95596E 00	3
4	0.14055E-02	0.14035E-02	0.14125E-02	0.14109E-02	0.99973E 00	0.80713E 00	0.12355E 01	0.93173E 00	4
5	0.15769E-02	0.15745E-02	0.15849E-02	0.15829E-02	0.99970E 00	0.80717E 00	0.12358E 01	0.91018E 00	5
6	0.17694E-02	0.17662E-02	0.17783E-02	0.17757E-02	0.99966E 00	0.80697E 00	0.12383E 01	0.88901E 00	6
7	0.19853E-02	0.19813E-02	0.19953E-02	0.19921E-02	0.99962E 00	0.80619E 00	0.12416E 01	0.86978E 00	7
8	0.22275E-02	0.22225E-02	0.22387E-02	0.22347E-02	0.99957E 00	0.80558E 00	0.12412E 01	0.85486E 00	8
9	0.24993E-02	0.24931E-02	0.25119E-02	0.25068E-02	0.99952E 00	0.80595E 00	0.12416E 01	0.84261E 00	9
10	0.28042E-02	0.27964E-02	0.28184E-02	0.28120E-02	0.99946E 00	0.80526E 00	0.12436E 01	0.83206E 00	10
11	0.31454E-02	0.31366E-02	0.31623E-02	0.31543E-02	0.99939E 00	0.80504E 00	0.12438E 01	0.82421E 00	11
12	0.35303E-02	0.35179E-02	0.35481E-02	0.35381E-02	0.99932E 00	0.80464E 00	0.12434E 01	0.81824E 00	12
13	0.39611E-02	0.39455E-02	0.39811E-02	0.39684E-02	0.99923E 00	0.80460E 00	0.12432E 01	0.81442E 00	13
14	0.44444E-02	0.44248E-02	0.44668E-02	0.44509E-02	0.99914E 00	0.80458E 00	0.12441E 01	0.81126E 00	14
15	0.49867E-02	0.49620E-02	0.50119E-02	0.49918E-02	0.99903E 00	0.80414E 00	0.12441E 01	0.80845E 00	15
16	0.55952E-02	0.55641E-02	0.56234E-02	0.55982E-02	0.99891E 00	0.80395E 00	0.12448E 01	0.80663E 00	16
17	0.62779E-02	0.62388E-02	0.63096E-02	0.62779E-02	0.99878E 00	0.80395E 00	0.12438E 01	0.80578E 00	17
18	0.70440E-02	0.69947E-02	0.70794E-02	0.70396E-02	0.99863E 00	0.80374E 00	0.12442E 01	0.80465E 00	18
19	0.79034E-02	0.78415E-02	0.79433E-02	0.78931E-02	0.99846E 00	0.80381E 00	0.12438E 01	0.80447E 00	19
20	0.88678E-02	0.87899E-02	0.89125E-02	0.88494E-02	0.99828E 00	0.80359E 00	0.12437E 01	0.80373E 00	20
21	0.99498E-02	0.98518E-02	0.10000E-01	0.99206E-02	0.99807E 00	0.80361E 00	0.12435E 01	0.80367E 00	21
22	0.11164E-01	0.11041E-01	0.11220E-01	0.11120E-01	0.99784E 00	0.80354E 00	0.12437E 01	0.80348E 00	22
23	0.12526E-01	0.12371E-01	0.12589E-01	0.12464E-01	0.99757E 00	0.80342E 00	0.12433E 01	0.80328E 00	23
24	0.14055E-01	0.13860E-01	0.14125E-01	0.13968E-01	0.99728E 00	0.80334E 00	0.12431E 01	0.80307E 00	24
25	0.15769E-01	0.15525E-01	0.15849E-01	0.15651E-01	0.99695E 00	0.80329E 00	0.12429E 01	0.80293E 00	25
26	0.17694E-01	0.17386E-01	0.17783E-01	0.17533E-01	0.99659E 00	0.80323E 00	0.12428E 01	0.80294E 00	26
27	0.19853E-01	0.19446E-01	0.19953E-01	0.19639E-01	0.99618E 00	0.80327E 00	0.12422E 01	0.80314E 00	27
28	0.22275E-01	0.21790E-01	0.22387E-01	0.21993E-01	0.99572E 00	0.80317E 00	0.12421E 01	0.80286E 00	28
29	0.24993E-01	0.24383E-01	0.25119E-01	0.24624E-01	0.99521E 00	0.80309E 00	0.12421E 01	0.80279E 00	29
30	0.28042E-01	0.27278E-01	0.28184E-01	0.27563E-01	0.99464E 00	0.80304E 00	0.12419E 01	0.80268E 00	30
31	0.31454E-01	0.30504E-01	0.31623E-01	0.30843E-01	0.99400E 00	0.80295E 00	0.12416E 01	0.80255E 00	31
32	0.35303E-01	0.34100E-01	0.35481E-01	0.34503E-01	0.99329E 00	0.80279E 00	0.12417E 01	0.80227E 00	32
33	0.39611E-01	0.38102E-01	0.39811E-01	0.38583E-01	0.99250E 00	0.80266E 00	0.12415E 01	0.80204E 00	33
34	0.44444E-01	0.42553E-01	0.44668E-01	0.43129E-01	0.99161E 00	0.80250E 00	0.12414E 01	0.80175E 00	34
35	0.49867E-01	0.47499E-01	0.50119E-01	0.48190E-01	0.99063E 00	0.80239E 00	0.12409E 01	0.80164E 00	35
36	0.55952E-01	0.52987E-01	0.56234E-01	0.53817E-01	0.98954E 00	0.80223E 00	0.12406E 01	0.80141E 00	36
37	0.62779E-01	0.59071E-01	0.63096E-01	0.60070E-01	0.98833E 00	0.80207E 00	0.12402E 01	0.80119E 00	37
38	0.70439E-01	0.65804E-01	0.70794E-01	0.67008E-01	0.98699E 00	0.80187E 00	0.12398E 01	0.80091E 00	38
39	0.79034E-01	0.73245E-01	0.79433E-01	0.74698E-01	0.98550E 00	0.80167E 00	0.12393E 01	0.80058E 00	39
40	0.88678E-01	0.81455E-01	0.89125E-01	0.83209E-01	0.98385E 00	0.80143E 00	0.12388E 01	0.80022E 00	40
41	0.99498E-01	0.90494E-01	0.10000E 00	0.92614E-01	0.98204E 00	0.80119E 00	0.12382E 01	0.79986E 00	41
42	0.11164E 00	0.10043E 00	0.11220E 00	0.10299E 00	0.98004E 00	0.80091E 00	0.12375E 01	0.79945E 00	42
43	0.12526E 00	0.11132E 00	0.12589E 00	0.11441E 00	0.97784E 00	0.80061E 00	0.12368E 01	0.79899E 00	43
44	0.14055E 00	0.12323E 00	0.14125E 00	0.12697E 00	0.97542E 00	0.80027E 00	0.12360E 01	0.79849E 00	44
45	0.15769E 00	0.13621E 00	0.15849E 00	0.14073E 00	0.97278E 00	0.79990E 00	0.12350E 01	0.79792E 00	45
46	0.17694E 00	0.15034E 00	0.17783E 00	0.15578E 00	0.96989E 00	0.79950E 00	0.12340E 01	0.79730E 00	46
47	0.19853E 00	0.16564E 00	0.19953E 00	0.17220E 00	0.96675E 00	0.79906E 00	0.12329E 01	0.79662E 00	47
48	0.22275E 00	0.18217E 00	0.22387E 00	0.19006E 00	0.96333E 00	0.79857E 00	0.12317E 01	0.79586E 00	48
49	0.24993E 00	0.19995E 00	0.25119E 00	0.20941E 00	0.95964E 00	0.79803E 00	0.12303E 01	0.79504E 00	49
50	0.28042E 00	0.21901E 00	0.28184E 00	0.23032E 00	0.95566E 00	0.79745E 00	0.12288E 01	0.79411E 00	50
51	0.31454E 00	0.23934E 00	0.31623E 00	0.25283E 00	0.95139E 00	0.79682E 00	0.12271E 01	0.79303E 00	51
52	0.35303E 00	0.26072E 00	0.35481E 00	0.27696E 00	0.94682E 00	0.79613E 00	0.12253E 01	0.79187E 00	52
53	0.39611E 00	0.28372E 00	0.39811E 00	0.30273E 00	0.94196E 00	0.79539E 00	0.12233E 01	0.79060E 00	53
54	0.44444E 00	0.30769E 00	0.44668E 00	0.33011E 00	0.93680E 00	0.79459E 00	0.12211E 01	0.78924E 00	54
55	0.49867E 00	0.33274E 00	0.50119E 00	0.35907E 00	0.93136E 00	0.79370E 00	0.12187E 01	0.78778E 00	55

56	0.55952E 00	0.35878E 00	0.56234E 00	0.38955E 00	0.92565E 00	0.79273E 00	0.12162E 01	0.78620E 00	56
57	0.62779E 00	0.38567E 00	0.63095E 00	0.42146E 00	0.91969E 00	0.79172E 00	0.12134E 01	0.78452E 00	57
58	0.70439E 00	0.41328E 00	0.70794E 00	0.45469E 00	0.91351E 00	0.79066E 00	0.12104E 01	0.78275E 00	58
59	0.79034E 00	0.44145E 00	0.79433E 00	0.48910E 00	0.90712E 00	0.78954E 00	0.12072E 01	0.78087E 00	59
60	0.88678E 00	0.47000E 00	0.89125E 00	0.52452E 00	0.90057E 00	0.78839E 00	0.12037E 01	0.77890E 00	60
61	0.99498E 00	0.49874E 00	0.10000E 01	0.56076E 00	0.89389E 00	0.78719E 00	0.12000E 01	0.77680E 00	61
62	0.11164E 01	0.52750E 00	0.11220E 01	0.59762E 00	0.88711E 00	0.78596E 00	0.11961E 01	0.77465E 00	62
63	0.12526E 01	0.55607E 00	0.12589E 01	0.63488E 00	0.88028E 00	0.78470E 00	0.11919E 01	0.77240E 00	63
64	0.14055E 01	0.58428E 00	0.14125E 01	0.67231E 00	0.87344E 00	0.78341E 00	0.11876E 01	0.77006E 00	64
65	0.15769E 01	0.61194E 00	0.15849E 01	0.70968E 00	0.86663E 00	0.78211E 00	0.11830E 01	0.76767E 00	65
66	0.17694E 01	0.63891E 00	0.17783E 01	0.74675E 00	0.85989E 00	0.78080E 00	0.11782E 01	0.76521E 00	66
67	0.19852E 01	0.66502E 00	0.19953E 01	0.78332E 00	0.85325E 00	0.77948E 00	0.11732E 01	0.76268E 00	67
68	0.22275E 01	0.69016E 00	0.22387E 01	0.81917E 00	0.84676E 00	0.77817E 00	0.11681E 01	0.76011E 00	68
69	0.24993E 01	0.71423E 00	0.25119E 01	0.85410E 00	0.84045E 00	0.77686E 00	0.11628E 01	0.75752E 00	69
70	0.28042E 01	0.73714E 00	0.28184E 01	0.88794E 00	0.83434E 00	0.77555E 00	0.11573E 01	0.75489E 00	70
71	0.31464E 01	0.75883E 00	0.31623E 01	0.92056E 00	0.82846E 00	0.77431E 00	0.11518E 01	0.75224E 00	71
72	0.35303E 01	0.77927E 00	0.35481E 01	0.95182E 00	0.82283E 00	0.77308E 00	0.11462E 01	0.74959E 00	72
73	0.39611E 01	0.79843E 00	0.39811E 01	0.98163E 00	0.81747E 00	0.77187E 00	0.11405E 01	0.74693E 00	73
74	0.44444E 01	0.81633E 00	0.44668E 01	0.10099E 01	0.81238E 00	0.77071E 00	0.11348E 01	0.74431E 00	74
75	0.49867E 01	0.83296E 00	0.50118E 01	0.10366E 01	0.80758E 00	0.76958E 00	0.11291E 01	0.74169E 00	75
76	0.55952E 01	0.84837E 00	0.56234E 01	0.10618E 01	0.80306E 00	0.76851E 00	0.11234E 01	0.73911E 00	76
77	0.62779E 01	0.86260E 00	0.63095E 01	0.10853E 01	0.79882E 00	0.76748E 00	0.11177E 01	0.73656E 00	77
78	0.70439E 01	0.87568E 00	0.70794E 01	0.11072E 01	0.79487E 00	0.76650E 00	0.11121E 01	0.73406E 00	78
79	0.79034E 01	0.88768E 00	0.79433E 01	0.11276E 01	0.79119E 00	0.76557E 00	0.11066E 01	0.73160E 00	79
80	0.88678E 01	0.89866E 00	0.89125E 01	0.11465E 01	0.78779E 00	0.76469E 00	0.11012E 01	0.72920E 00	80
81	0.99498E 01	0.90867E 00	0.99999E 01	0.11639E 01	0.78464E 00	0.76387E 00	0.10959E 01	0.72687E 00	81
82	0.11164E 02	0.91779E 00	0.11220E 02	0.11800E 01	0.78174E 00	0.76310E 00	0.10907E 01	0.72459E 00	82
83	0.12526E 02	0.92607E 00	0.12589E 02	0.11947E 01	0.77907E 00	0.76238E 00	0.10857E 01	0.72238E 00	83
84	0.14055E 02	0.93357E 00	0.14125E 02	0.12081E 01	0.77663E 00	0.76171E 00	0.10808E 01	0.72024E 00	84
85	0.15769E 02	0.94037E 00	0.15849E 02	0.12204E 01	0.77439E 00	0.76109E 00	0.10761E 01	0.71817E 00	85
86	0.17694E 02	0.94651E 00	0.17783E 02	0.12317E 01	0.77235E 00	0.76052E 00	0.10716E 01	0.71618E 00	86
87	0.19852E 02	0.95204E 00	0.19953E 02	0.12419E 01	0.77050E 00	0.75999E 00	0.10672E 01	0.71426E 00	87
88	0.22275E 02	0.95704E 00	0.22387E 02	0.12511E 01	0.76881E 00	0.75950E 00	0.10631E 01	0.71241E 00	88
89	0.24993E 02	0.96153E 00	0.25119E 02	0.12595E 01	0.76728E 00	0.75905E 00	0.10591E 01	0.71064E 00	89
90	0.28042E 02	0.96557E 00	0.28184E 02	0.12671E 01	0.76589E 00	0.75864E 00	0.10552E 01	0.70895E 00	90
91	0.31464E 02	0.96920E 00	0.31623E 02	0.12739E 01	0.76463E 00	0.75827E 00	0.10516E 01	0.70736E 00	91
92	0.35303E 02	0.97245E 00	0.35481E 02	0.12801E 01	0.76350E 00	0.75793E 00	0.10482E 01	0.70589E 00	92
93	0.39611E 02	0.97538E 00	0.39811E 02	0.12857E 01	0.76248E 00	0.75762E 00	0.10449E 01	0.70451E 00	93
94	0.44444E 02	0.97799E 00	0.44668E 02	0.12907E 01	0.76155E 00	0.75734E 00	0.10418E 01	0.70318E 00	94
95	0.49867E 02	0.98034E 00	0.50118E 02	0.12952E 01	0.76072E 00	0.75709E 00	0.10389E 01	0.70192E 00	95
96	0.55952E 02	0.98244E 00	0.56234E 02	0.12992E 01	0.75998E 00	0.75686E 00	0.10361E 01	0.70072E 00	96
97	0.62779E 02	0.98432E 00	0.63095E 02	0.13029E 01	0.75930E 00	0.75665E 00	0.10335E 01	0.69959E 00	97
98	0.70439E 02	0.98600E 00	0.70794E 02	0.13061E 01	0.75870E 00	0.75646E 00	0.10311E 01	0.69853E 00	98
99	0.79034E 02	0.98750E 00	0.79433E 02	0.13091E 01	0.75816E 00	0.75629E 00	0.10288E 01	0.69751E 00	99
100	0.88678E 02	0.98885E 00	0.89125E 02	0.13117E 01	0.75768E 00	0.75614E 00	0.10267E 01	0.69655E 00	100
101	0.99498E 02	0.99005E 00	0.99999E 02	0.13140E 01	0.75724E 00	0.75600E 00	0.10247E 01	0.69565E 00	101
102	0.11164E 03	0.99112E 00	0.11220E 03	0.13161E 01	0.75685E 00	0.75588E 00	0.10228E 01	0.69479E 00	102
103	0.12526E 03	0.99208E 00	0.12589E 03	0.13180E 01	0.75651E 00	0.75577E 00	0.10211E 01	0.69398E 00	103
104	0.14055E 03	0.99293E 00	0.14125E 03	0.13197E 01	0.75619E 00	0.75567E 00	0.10194E 01	0.69321E 00	104
105	0.15769E 03	0.99370E 00	0.15849E 03	0.13212E 01	0.75592E 00	0.75558E 00	0.10179E 01	0.69245E 00	105
106	0.17694E 03	0.99438E 00	0.17783E 03	0.13225E 01	0.75567E 00	0.75550E 00	0.10165E 01	0.69176E 00	106
107	0.19852E 03	0.99499E 00	0.19953E 03	0.13237E 01	0.75544E 00	0.75543E 00	0.10152E 01	0.69112E 00	107
108	0.22275E 03	0.99553E 00	0.22387E 03	0.13248E 01	0.75525E 00	0.75537E 00	0.10140E 01	0.69045E 00	108
109	0.24993E 03	0.99601E 00	0.25119E 03	0.13258E 01	0.75507E 00	0.75531E 00	0.10128E 01	0.68983E 00	109
110	0.28042E 03	0.99645E 00	0.28184E 03	0.13266E 01	0.75491E 00	0.75526E 00	0.10118E 01	0.68928E 00	110
111	0.31464E 03	0.99683E 00	0.31623E 03	0.13274E 01	0.75477E 00	0.75521E 00	0.10108E 01	0.68871E 00	111
112	0.35303E 03	0.99718E 00	0.35481E 03	0.13281E 01	0.75464E 00	0.75517E 00	0.10099E 01	0.68818E 00	112
113	0.39611E 03	0.99748E 00	0.39811E 03	0.13287E 01	0.75453E 00	0.75514E 00	0.10091E 01	0.68770E 00	113
114	0.44444E 03	0.99776E 00	0.44668E 03	0.13292E 01	0.75443E 00	0.75510E 00	0.10084E 01	0.68725E 00	114
115	0.49867E 03	0.99800E 00	0.50118E 03	0.13297E 01	0.75434E 00	0.75507E 00	0.10077E 01	0.68681E 00	115
116	0.55952E 03	0.99822E 00	0.56234E 03	0.13301E 01	0.75426E 00	0.75505E 00	0.10070E 01	0.68642E 00	116

117	0.62779E 03	0.99841E 00	0.63095E 03	0.13305E 01	0.75419E 00	0.75503E 00	0.10064E 01	0.68597E 00	117
118	0.70439E 03	0.99858E 00	0.70794E 03	0.13308E 01	0.75412E 00	0.75501E 00	0.10059E 01	0.68563E 00	118
119	0.79034E 03	0.99874E 00	0.79432E 03	0.13311E 01	0.75406E 00	0.75499E 00	0.10054E 01	0.68524E 00	119
120	0.88678E 03	0.99887E 00	0.89125E 03	0.13314E 01	0.75401E 00	0.75497E 00	0.10049E 01	0.68491E 00	120
121	0.99498E 03	0.99900E 00	0.99999E 03	0.13317E 01	0.75397E 00	0.75496E 00	0.10045E 01	0.68459E 00	121